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Women in science:
Aging and public health
2022

Edited by
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Women in science: Aging and public health 2022

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Editorial: Women in science: aging and public health 2022

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Editorial on the Research Topic
Women in science: aging and public health 2022

Introduction

As noted in our inaugural *Women in science: aging and public health 2021* Research Topic, globally there is a recognition that women are under-represented both as scientists and as participants in health research but have much to contribute to advancing public health knowledge and practice (1).

This Year's Research Topic includes 22 papers led by senior and early career women from across the world covering a range of geographies, topic areas, methodologies, and data collection sites. We highlight research studies conducted in Asia, Australia, Europe, the United Kingdom, and the United States of America, as well as reviews which are not country specific. This year's papers explore timely topical themes such as social determinants of health including gender effects, and conditions where women experience significant disease burden (breast cancer, cardiovascular disease, falls, and osteoarthritis). Many of the papers report findings from large-scale longitudinal studies on aging including the Chinese Longitudinal Healthy Longevity Survey (CLHLS), the China Health and Retirement Study (CHARLS), the China Health and Nutrition Survey (CHNS), the China Family Panel Study (CFPS), and the English Longitudinal Study of Aging (ELSA). While others are smaller, focussed studies in under-researched or difficult to reach populations. The papers in this Research Topic include systematic reviews, and studies that identify risk factors for disease and disability that can enhance the effectiveness of public health and aging interventions. Specific areas covered include functional and health capacity, physical activity and sedentary behavior, social isolation and social support, age -related diseases, and health and aged care. The career trajectories of three women scientists who have made salient contributions to aging and public health are envisioned through their colleagues. These three thought leaders in aging and public health research (Adepoju; Pachana; Vollmer Dahlke) represent women scientists who have established stellar careers while mentoring others. A common theme is their passion for their research and recognition of the importance of community.

Functional and health capacity in various roles

At a population level, as people age, functional capacity and health status declines and disability increases. However, decline is not inevitable for all groups nor individuals, and appropriate interventions that address personal as well as social and environmental impacts can mitigate these trajectories (2, 3).

While disability is often associated with depression in older people, Tian et al. examined the potential moderating effect of social support on that relationship. Using data from the CLHLS of adults aged 65 years and over, 26.8% of the sample exhibited depressive symptoms, 31% showed limited activities of daily living and social support reduced the impact of disability on depressive symptoms. As with other research stressing the nuances of different types and amounts of social support (4), the effect of social support measured according to who provided the support potentially reflects the importance of the closeness of the source of support rather than simply frequency of contact. This finding has implications for recent COVID-19 social interaction restrictions.

Examining trajectories of aging outcomes using longitudinal methods has increased over the last decade. Such approaches provide stronger evidence about the predictors of healthy aging and the opportunities for interventions to address modifiable risk factors. Using data from the CLHLS, Zhao et al. identified four trajectories of physical functioning over 16 years as measured by ADL and IADL in adults aged 64 years and over: stable (35.4%), slow decline (33.0%), rapid decline (23.5%), poor function, and moderate decline (8.1%). Predictors of the trajectories included older age and male sex as well as potential modifiable risk factors such as poorer vision status, more chronic illnesses, poorer cognitive function, lack of exercise and decreased leisure activity, and depressive symptoms. It is important to address potentially modifiable risk factors associated with increased rates of decline in physical functioning.

Population aging has resulted in more pressure for older people to continue in the workforce beyond "normal" retirement age. In China, the retirement age for men is between 55 and 60 years and for women between 50 and 55 years depending upon occupation. "Early" legislated retirement in China and the impact of COVID-19 on early retirement in other countries such as the US have put pressure on labor availability and pension systems. Cheng et al. propose that there is an untapped work capacity in older Chinese women. Using data from CHARLS they examined the health capacity of Chinese women aged 45–74 years to support a delay in retirement. They concluded that urban women, particularly those with higher education, have higher "excess" capacity to work than less healthy, under-educated rural women who in contrast show higher labor participation rates. The reluctance of urban women to continue working may be related to caring for grandchildren, and incentives to keep women in the workforce need to recognize the disproportionate burden that women face as carers (5).

In many countries continuing to drive is seen as a marker of independence and facilitator of social and work connections. One study in this Research Topic (Mielenz et al.) investigated driving cessation prevalence and the relationships with self-care health behaviors. This US study of active drivers aged 65–79 years found that driving cessation prevalence at a 6-year follow up was low (0.63 per 100 person years). However, the ability to participate in and derive satisfaction with social roles and activities was protective for driving cessation. The relationship between loss of community engagement and loss of independence through driving cessation reflects unintended consequences that may be experienced by older adults in response to restrictive emergency management guidelines.

Physical activity/sedentary behavior

It is well-established that physical activity is a protective factor for health and wellbeing as we age, and sedentary behavior is a risk factor for many chronic conditions (6, 7). The papers in this section focussed on physical activity and/or sedentary behavior in different countries and cultures, including literature reviews linking physical activity/sedentary behaviors to key geriatric conditions, observational studies examining prevalence rates and interactions, and small intervention efforts.

A major public health question is the type and amount of physical activity needed to show positive health outcomes. In a systematic review, Alzar-Teruel et al. examine the impact of different intensity levels on key healthy aging indicators such as body composition and muscle strength. While they find positive outcomes associated with high-intensity interval training, they could not demonstrate a benefit over moderate-intensity continuous training for physical functioning. More research is needed to better explicate what exercise regimens are best in different populations and settings, and guide public health recommendations.

Baseline data from the European (Austria, France, Germany, Portugal, and Switzerland) Do-Health clinical trial (Mattle et al.) was used to investigate the prevalence of physical activity (PA) and sedentary behavior (SB) in community dwelling adults aged 70 years and over. While almost two-thirds (62.2%) met physical activity recommendations, over a third (37.1%) spent at least 5.5 h per day sedentary. Physical activity prevalence but not sedentary behavior varied across the country sites, and older age, female sex, and higher BMI groups were less likely to meet the PA recommendations. These initial variations in prevalence warrant a consideration of individualized public health interventions for those at greater risk.

Luo et al. investigated the mediating role of physical activity on the role of income inequality, as measured by different types of health insurance, in life satisfaction. The data source was older participants aged 60 years and over from the last 4 data collection waves (2006, 2009, 2011, 2015) of the CHNS. In China people have access to different types of health insurance depending on their geographical location (urban vs. rural) and employment status. Having any type of health insurance and physical activity were both positively associated with life satisfaction, and physical activity mediated the impact of health insurance on life satisfaction.

Two small studies are especially promising for guiding future public health actions for older adults as well as sedentary workers. Improving adherence to exercise programs, particularly post-hospital rehabilitation programs for older people, was the focus of an Australian video intervention (Vaz et al.) to facilitate home exercises. Functional mobility, gait speed, balance and physical activity participation improved at follow-up. Tailored self-modeled videos and other digital health modalities show promise in reaching those in home settings where continued exercise adherence is important for recovery process.

The impact of sedentary behavior on metabolic health has been well-established (8). Silva et al. investigated the effects of a 16-week exercise program on middle aged sedentary workers during the 2020 COVID-19 lockdown in Portugal. The intervention

group had reduced waist and hip measures and fasting glucose and lipid profiles remained stable in the intervention group. The intervention group showed less perceived stress and better quality of life. Adopting and adhering to an exercise program in middle age has the potential to favorably impact healthy aging.

Social isolation/social support

Social isolation and the impacts on older people, especially during the height of the COVID-19 pandemic, have received considerable attention in the recent research literature (9). Several studies have found that vulnerable and disadvantaged groups had worst outcomes during the pandemic (10–12).

A French study (Silberzan et al.) surveying adults aged 65 year and over during and after the COVID-19 lockdown in France found that women were more likely to be socially isolated than men. Older age, perceived financial difficulties, and belonging to an ethnic minority were also associated with social isolation. Identification of such health inequities can inform preventive policies aimed at helping the most socially isolated stay socially connected and informed about the latest health information.

Shen et al. using data from the CFPS investigated the impact of formal social support and informal social support on quality of life in China. Different patterns of impacts on quality of life were evident depending on the quality of life measure and gender status. While both formal and informal social support enhanced older adult's quality of life, informal support had the greatest impact, consistent with findings by Tian on the importance of close informal relationships.

Age-related diseases

Cancer, cardiovascular disease, and suicide are increasingly more prevalent in later life and warrant continued attention. Deaths from cardiovascular disease following chemotherapy for breast cancer are a significant issue for breast cancer survivors. Huang et al. constructed a nomogram from the US SEER cancer database, consisting of older female patients aged 65 years and over who underwent chemotherapy between 2010 and 2015 to predict long term survival. The nomogram, based on six factors (age, race, tumor stage, surgery, and radiotherapy), was able to classify patients at different risk levels to assist with targeted management. This is an important tool in identifying breast cancer patients who will need further management to address heart disease risk.

Knee osteoarthritis (OA) is a significant contributor to disability as we age, impacting mobility and quality of life. Obesity and socioeconomic position are risk factors in OA. To study the longitudinal relationships in England, Witkam et al. used data from nine waves of ELSA. Lower socioeconomic position increased the chances of functional limitations. Yet, participants with lower income, wealth and higher deprivation were less likely to have joint replacements. These data indicate that even in a health system where medical treatment is free, unmet need is related to health inequality.

Suicide risk is an under-developed area in older populations often related to stigma, ageist attitudes and simplistic understandings of suicide prevention in older people (13). An Australian survey (Klein et al.) on suicidality in older people aged 65 years and over found that suicidality was associated with dissatisfaction with social interaction and community engagement. While social relationships can buffer the negative effects of aging and has potential as a preventive measure in suicide prevention, addressing broader social determinants of suicide (14) such as poverty, elder abuse and discrimination are important in preventing suicide in old age.

Health and aged care

The WHO Decade of Healthy Aging highlights the importance of integrated care and high quality long-term care (2). Polypharmacy where older adults are prescribed multiple medicines to treat different conditions can have adverse effects on health, such as falls, overdoses and cognitive problems, due to medication interactions (15). A systematic review (Oktora et al.) of patients' attitudes to deprescribing found that in low-middle income countries such as Nepal and Malaysia <70% of patients were willing to stop medications compared to patients in high-income countries such as Australia, USA and Europe where >85% of patients were willing to stop medications. Future research calls for understanding how the health care system and setting factors interact with sociodemographic factors and cultural predispositions to influence deprescribing behaviors.

Polypharmacy also increases the risk of poor medication adherence, particularly in older patients living with dementia. A study (Muñoz-Contreras et al.) located in Spain found that caregivers improved medication adherence for care recipients living with Alzheimer's disease. Female sex and first-degree relative status of the caregiver were associated with greater adherence. Training caregivers in disease management and medication adherence can help support optimum treatment for their underlying chronic illnesses.

There is a global focus on research in residential aged care settings (nursing homes) and particularly with patients living with dementia and their carers. Aging in place promotes supporting people to live in their own homes with social and health care support. However, little is known about this significant group of older people in terms of their experiences and service needs. An Australian study (Hobden et al.) of older people receiving care services in their own home investigated their experiences of patient-centered care from health professionals. Many participants responded that they had experienced many of the elements of patient centered care. However, only just over half of participants were involved in goal setting or involvement in treatment decisions. The incomplete delivery of patient centered care to older people is linked to deficiencies in the training and accreditation of health care professionals who work with older people (16).

Older people, especially those living in nursing homes were particularly vulnerable during the COVID-19 pandemic. Using health and demographic data from a Spanish cohort undergoing COVID-19 testing between 2020 and 2021, Aguilar-Palacio et al. found that 38.3% of COVID-19 confirmed patients aged 65 years and over were hospitalized. Risk of hospitalization was higher in men, older people, those with a diagnosed chronic illness and those

on higher pensions. The death rate within 90 days of COVID-19 diagnosis was 31.5% and the risk of death was higher in men and older patients. Knowing patient specific risk factors will be valuable for preparing for future health threats for the most vulnerable long-term care populations.

Conclusion

While there were many more articles to highlight in this year's 2022 collection, we still lament the relative lack of research that is theory driven and methodologically rigorous asking critical questions about women's issues or gender differences in lifestyle behaviors, access to health care and social service supports, activity friendly communities, or disease/disability states. A final article in the Research Topic emphasizes this concern. While the role of technology in supporting aging well has been highlighted elsewhere in this journal (17), Heine and Feldman review the role of technology in the quality of life of older women. Their focus was on the context of COVID-19 where many became socially isolated and needed to rely on technology for social interactions. They concluded that gender specific models were lacking in the literature and highlighted the need to consider dignity, ageism, autonomy and privacy in the design and implementation of technologies for older women. We would broaden this sentiment to highlight all these factors in aging and public health research.

On a positive note, this Research Topic shines a light on contributions that women scientists are making to further our knowledge about functional and health capacity, lifestyle behaviors associated with health risks, social isolation and social supports as major risk or protective factors, age related diseases, and health and aged care. We hope that the worst of the COVID-19 world-wide pandemic is behind us, but that we carry forth lessons learned about Research Topics of interest and the conduct of research to prepare us for future research and practice challenges that established and emerging women in science can address effectively.

Author contributions

CB and MO conceptualized the editorial. CB led the writing of the editorial. MO provided expert feedback on the editorial. 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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MINI REVIEW
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Differences in Older Patients' Attitudes Toward Deprescribing at Contextual and Individual Level

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Background: Deprescribing requires patients' involvement and taking patients' attitudes toward deprescribing into account. To understand the observed variation in these attitudes, the influence of contextual-level factors, such as country or healthcare setting, should be taken into account.

Methods: We conducted a systematic review of studies using the revised Patients' Attitudes Towards Deprescribing (rPATD) questionnaire among older adults. We searched articles in Medline and Embase up to 30 June 2021. PRISMA guideline was used for the search process and reporting. We summarized the outcomes from the rPATD and compared attitudes at study population level between high or low-middle-income countries, global regions, and healthcare settings using ANOVA testing. Correlations of the rPATD outcomes with the mean age of the study populations were tested. Associations with the rPATD outcomes at individual patient level extracted from the included studies were summarized.

Results: Sixteen articles were included. Percentages of patients willing to stop medication were significantly lower in low-middle-income countries (<70% in Nepal and Malaysia) compared to high-income countries (>85% in USA, Australia, European countries). No significant differences were observed when results were compared by global region or by healthcare setting but a high willingness (>95%) was seen in the two studies conducted in an inpatient population. A higher mean age at study level was associated with a higher willingness to stop medication. At individual level, associations between patient characteristics, including demographics and education, and attitudes toward deprescribing showed inconsistent results.

Conclusion: Findings about attitudes toward deprescribing are influenced by contextual factors. Future research should pay more attention to the influence of the healthcare system and setting as well as the culture on patients' attitudes.

Keywords: deprescribing, older adults, polypharmacy, patient attitude, rPATD

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INTRODUCTION

Medication optimization is important for older people using multiple medicines. This includes deprescribing, which is the process of withdrawing or reducing a patient's medication in order to prevent or mitigate negative effects and improve patient outcomes (1). Deprescribing requires a patient-centered approach and involvement of the patients (2). The patients' attitudes toward their medication and deprescribing should be integrated into a shared decision-making process (3). These attitudes vary between patients and different deprescribing typologies have been described for older people with polypharmacy (4, 5). Recently, some studies have looked at individual-level factors that may explain differences in the attitudes toward deprescribing (6–8). Patient demographics, like age or sex, and a number of medications used were inconsistently associated with the patients' willingness to stop medication. Most of these studies, however, are limited by restricting the included population to certain age groups or healthcare settings. The influence of contextual-level factors, such as the healthcare system or country, was not addressed. We present a review of studies assessing patients' attitudes toward deprescribing introducing an ecological perspective to identify contextual-level next to individual-level factors that may explain differences in these attitudes, and discuss implications for future research.

METHODS

We conducted a systematic review including English-language articles published up to 30 June 2021, using the search terms "rPATD," "attitudes toward deprescribing," or "attitudes towards deprescribing." The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline and checklist was used for the search process and to guide reporting. We included articles using the same instrument to prevent variation caused by the questionnaire, and chose the revised Patients' Attitudes Towards Deprescribing (rPATD) questionnaire, which has been validated and translated in several languages (9).

Two researchers independently reviewed the articles to include original studies among older adults (≥60 years) using this questionnaire. Studies adapting the rPATD questions to a specific drug or drug class were excluded. We extracted data on country, healthcare setting, study period, in/exclusion criteria, response rate, and patient characteristics. Countries were grouped in global regions. Healthcare settings were classified as [1] primary care or home dwelling, [2] outpatient care provided by hospital, [3] secondary or inpatient hospital care, [4] nursing homes, and [5] mixed. Next, we extracted the outcomes from the rPATD. In particular, we extracted percentages of patients willing to stop medication, and satisfied with their medication. Furthermore, we extracted results regarding the four factors covered by the rPATD: "burden of medication," "appropriateness of medication," "concerns about stopping," and "involvement in decision making." Means with standard deviations or median with interquartile ranges were summarized. One study presented factor scores on a scale up to 100 (10), which we divided by 20 to represent the original scale up to 5. For one study that presented "inappropriateness" without carrying out the inverse scoring (11), we reversed the scores and reported associations. We tested for differences at study level in (a) willingness to stop medication, (b) satisfaction with medication, and (c) the four rPATD factors using ANOVA, comparing global regions (USA, Europe, Australia, Asia, Africa), high-income versus low-middle-income countries (OECD classification), and healthcare settings (primary care, outpatient, inpatient, nursing home). For studies reporting outcomes among subpopulations from different healthcare settings, the data were tested at this level. We also tested for associations of the rPATD outcomes with the mean or median age of the study (sub)population using Pearson Correlation. Expecting sample sizes >25, the median was considered as the best estimator for the mean (12). All tests were 2-sided and conducted with SPSS Statistics v23.0 for Windows. Finally, we extracted and summarized data from the studies testing for associations with the rPATD outcomes at individual level regarding the patients' age, sex, educational level, number of drugs used, and healthcare setting.

RESULTS

We identified 198 titles and abstracts and excluded 182 for not meeting our inclusion criteria, resulting in 16 included articles referring to 14 data collections. The included studies were conducted in 11 different countries and recruited patients from all possible healthcare settings. The median number of drugs taken by the patients ranged from three to 10.

Differences in Attitudes at Contextual Level

In 13 studies reporting on willingness, the majority of older adults were willing to have one or more of their regular medications stopped if their physician said it is possible, with percentages ranging from 57 to 97% (**Figure 1A**). Of note, the populations with the lowest percentages of 57 and 68% had high percentages of 19 and 24% of patients being unsure about their willingness (6, 13). In other studies, these percentages of being unsure were <10% (10, 14–18). A higher willingness was observed in high-income countries as compared to low-middle-income countries ($n = 12$, ANOVA, F 15.426, p-value 0.002), with highest percentages in the USA (average 91%) (16, 19), followed by Australia (88%) (18), and European countries (average 87%) (8, 10, 14, 15, 17, 20, 21). Intermediate precentages were seen in Singapore (83%) and Ethiopia (82%) (11, 22), whereas the lowest percentages were observed in Nepal and Malaysia (57%, 68%) (6, 13). There was no significant difference in willingness between healthcare settings, although the highest willingness percentages (>95%) were seen in the two studies conducted in inpatient care (**Figure 1A**) (10, 20). The willingness was not significantly different between global regions. Finally, a higher average age of the study (sub)population was associated with a higher willingness (n = 16, Pearson Correlation, 0.685, p-value 0.003).

In 11 studies reporting on satisfaction, the majority of older adults were satisfied with their medication, with percentages

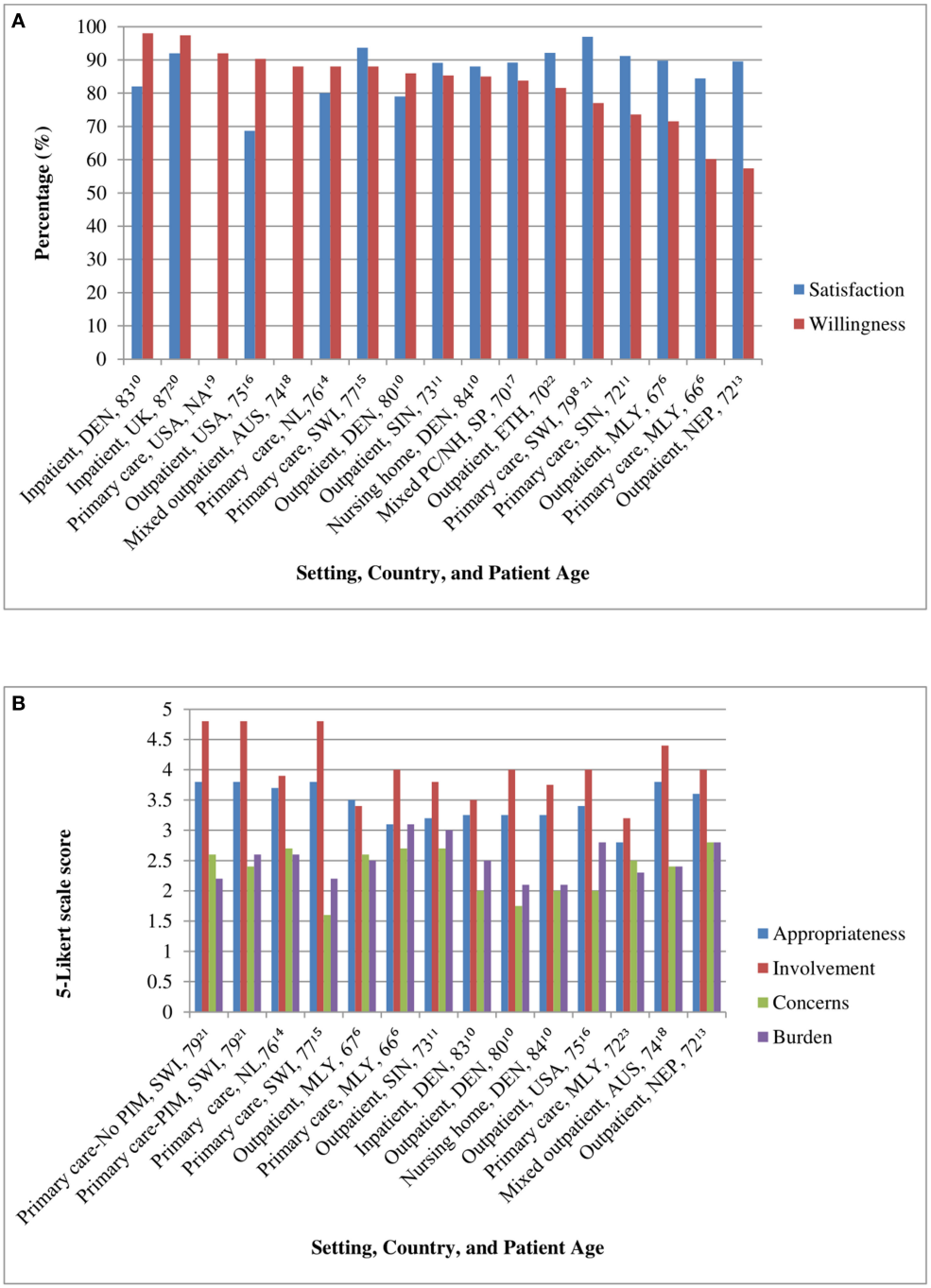

FIGURE 1 | (A) Satisfaction and willingness scores across study (sub)populations. Bars are presented with setting, country, and mean age of study (sub)population in the labels, including the reference number in superscript. DEN, Denmark; UK, United Kingdom; USA, United States of America; AUS, Australia; NL, Netherlands; SWI, Switzerland; SIN, Singapore; SP, Spain; ETH, Ethiopia; MLY, Malaysia; NEP, Nepal; NA, not assessed; PC/NH, primary care/nursing home. **(B)** rPATD factor scores across study (sub)populations. Bars are presented with setting, country and mean age of study (sub)population in the labels, including the reference number in superscript. rPATD, revised Patients' Attitudes Towards Deprescribing; No PIM/PIM, subgroups without or with potentially inappropriate medication subgroups; SWI, Switzerland; NL, Netherlands; MLY, Malaysia; SIN, Singapore; DEN, Denmark; USA, United States of America; NEP, Nepal.

ranging from 69 to 97% (**Figure 1A**). These percentages did not significantly differ between healthcare settings, economic level of the countries, and was also not associated with the mean age of the study population. There was a difference in satisfaction between the global regions ($n = 10$, ANOVA, F 4.639, p-value 0.043). The highest percentages of satisfaction were seen in Africa

TABLE 1 | Characteristics associated with the two global questions and four factors outcomes from the revised Patients' Attitudes Towards Deprescribing (rPATD) questionnaire.

References	Analysis	Outcomes rPATD	Non-significant characteristics	Significant characteristics
Crutzen et al. (14)	Linear and ordinal logistic regression	Satisfaction	Age; sex; number of drugs (≤5, 5–10, >10)	–
		Willingness	Age; sex; number of drugs (≤5, 5–10, >10)	–
		Appropriateness	Age; sex; number of drugs (≤5, 5–10, >10)	–
		Concerns	Age; sex; number of drugs (≤5, 5–10, >10)	–
		Burden	Age; sex	Number of drugs (>10), beta-coefficient 0.41
		Involvement	Age; sex; number of drugs	–
Kua et al. (6)	Spearman's correlations (univariate)	Willingness	Sex; number of drugs	Age (60–74 or ≥75), correlation 0.131 Education (primary, secondary, higher), correlation −0.158
		Appropriateness	Age (60–74 or ≥75); sex; education (primary, secondary, higher)	Number of drugs, correlation −0.219
		Concerns	Age (60-74 or ≥75); sex	Education (primary, secondary, higher), correlation 0.118 Number of drugs, correlation −0.191
		Burden	Age (60–74 or ≥75); sex; education (primary, secondary, higher)	Number of drugs, correlation −0.344
		Involvement	Sex; number of drugs	Age (60–74 or ≥75), correlation 0.267 Education (primary, secondary, higher), correlation −0.211
Kua et al. (11)	Mann-Whitney U; Kruskal-Wallis test (univariate)	Satisfaction	Age (<80 vs. 80+); education; setting (outpatient vs. primary care)	Sex, male > female Number of drugs, ≤5 > more than 10
		Willingness	Age (<80 vs. 80+); sex; education	Setting, outpatient > primary care Number of drugs, more > less (≤5, 5–10, >10)
		Appropriateness	Age (<80 vs. 80+); education	Sex, female > male Number of drugs, less > more (≤5, 5–10, >10) Setting, community hospital < other hospital and community pharmacy
		Concerns	Age (<80 vs. 80+); sex; number of drugs (≤5, 5–10, >10); setting (outpatient vs. primary care)	Education, direction not clear
		Burden	Age (<80 vs. 80+); sex; education; setting (outpatient vs. primary care)	Number of drugs, more > less (≤5, 5–10, >10)
		Involvement	Age (<80 vs. 80+); number of drugs (≤5, 5–10, >10)	Sex, male > female Education, higher > lower Setting, outpatient > primary care
Lundby et al. (10)	Quantile regression (univariate)	Appropriateness	Age (<80 vs. 80+); sex; setting (inpatient, outpatient, nursing home)	Number of drugs, less > more (≤5, 5–9, ≥10)
		Concerns	Age (<80 vs. 80+); sex; setting (inpatient, outpatient, nursing home)	Number of drugs, more > less (≤5, 5–9, ≥10)
		Burden	Age (<80 vs. 80+); sex; setting (inpatient, outpatient, nursing home)	Number of drugs, more > less (≤5, 5-9, ≥10)
		Involvement	Age (<80 vs. 80+); sex; number of drugs (≤5, 5–9, ≥10)	Setting, outpatient > nursing home and inpatient
Omar et al. (23)	Spearman correlations (univariate)	Appropriateness	Sex	Age, correlation −0.174 Number of drugs, correlation −0.176
		Concerns	Age; sex; number of drugs	–

(Continued)

TABLE 1 | Continued

References	Analysis	Outcomes rPATD	Non-significant characteristics	Significant characteristics
		Burden	Sex	Age, correlation 0.183 Number of drugs, correlation 0.271
		Involvement	Age; sex; number of drugs	–
Reeve et al. (19)	Logistic regression	Willingness	Age (65–74, 75–84, ≥85); sex; education (low, medium, high)	Number of drugs (≥6 drugs), aOR 2.90 (adjusted also for race, health, number of chronic medical conditions)
Reeve et al. (18)	Logistic regression	Willingness	Age (65–74 vs. ≥75); sex, number of drugs (≥6 drugs)	Education (English as first language), aOR 3.78 (adjusted also for burden, appropriateness, concerns, autonomy, health, goal of care, insurance)
Rozsnyai et al. (8)	Logistic regression	Willingness	Age; sex; number of drugs	Education, high > low, OR 3.28 (adjusted also for living alone, self-management of medication)
Serrano Gimenez et al. (17)	Odds ratio (univariate)	Satisfaction	Age (<70 vs. ≥70); sex; education (low vs. other)	Polypharmacy, >6 drugs, OR 1.33
Shrestha et al. (13)	Logistic regression	Willingness	Sex; education (up to high school), number of drugs (≥5 drugs)	Age, OR 0.95 (adjusted for concern about stopping)

(92%) and Europe (average 89%) and the lowest in the USA (69%) (8, 10, 14–17, 20, 22).

In 10 studies presenting the mean or median rPATD factor scores, "appropriateness" ranged from 2.8 to 3.8, "concerns" from 1.6 to 2.8, "burden" from 2.1 to 3.1, and "involvement" from 3.2 to 4.8 (**Figure 1B**). These factors were not significantly associated with the economic level of the country, healthcare setting, nor global region. A higher aged study population was associated with less concerns ($n = 10$, Pearson Correlation, −0.696, p-value 0.025) and less burden ($n = 10$, Pearson Correlation, −0.677, p-value 0.031).

Differences in Attitudes at Individual Patient Level

In seven studies, age was not significantly associated with any of the rPATD outcomes (8, 10, 11, 14, 17–19), whereas inconsistent findings were observed in three studies (6, 13, 23) (**Table 1**). A higher age was associated with less willingness in one study (13) but more willingness in another study (6). Sex was not associated with any of the rPATD outcomes in nine studies (6, 8, 10, 13, 14, 17–19, 23). In one study, males showed lower appropriateness but higher satisfaction and involvement scores (11). A higher number of drugs was associated with more willingness in two studies (11, 19), but not associated with willingness in four studies (6, 8, 14, 18). Furthermore, a higher number of drugs was associated with higher burden scores in four studies (10, 11, 14, 23), whereas an opposite association was seen in one study (6). For educational level, a positive association was found with willingness in two studies (8, 18), a negative association in one study (6) and no association in another study (19). Only two studies tested for the influence of setting, indicating that patients recruited in outpatient setting may have higher willingness as compared to a primary care setting (11), but inconsistent results were observed for involvement scores (10, 11).

DISCUSSION

Principal Findings

Looking at contextual level, we observed that populations from low-middle-income countries were less willing to stop medication than those from high-income countries. The highest average willingness scores were seen in inpatient settings. At population level, a higher average age was associated with a higher willingness but usually no associations with age were observed at individual level. At individual level, a higher number of drugs was sometimes associated with more willingness and higher burden scores. In general, the patients' sex or education were not associated with their attitudes toward deprescribing.

Recent meta-analyses showed pooled proportions of willingness to stop medication between 84 and 88% (24, 25). We observed no differences when studies were compared by global region, confirming previous results (24). Possibly such regions are too heterogeneous to identify differences related to the healthcare system or culture. In our review, the lowest percentages of willingness were seen in Malaysia and Nepal (6, 13), whereas patients from high-income countries showed a higher willingness. So far, there have been few studies from low-middle-income countries and more studies are needed to strengthen our finding and identify underlying mechanisms. We noticed that both studies with low percentages of willingness showed high percentages of patients being unsure about this. It could be that in these countries there are less initiatives to optimize medication and involve patients in such processes (26, 27). Previously, it was found that the Southeast-Asian hierarchical culture and one-way communication style of healthcare professionals inhibits patients to ask questions (28).

Although we did not see any significant associations between the healthcare setting and attitudes toward deprescribing, high willingness scores were seen in both studies conducted in a geriatric ward setting (10, 20). A *post-hoc* analysis showed a significant difference in willingness between this setting as compared to the combined other settings ($n = 13$, ANOVA, F 4.896, p-value 0.045). This suggests that when patients are admitted to a geriatric ward this can be a good opportunity to initiate deprescribing. Of note, combining patients recruited at hospital wards with those recruited at outpatient clinics as "hospital setting" or "secondary/tertiary care," as done previously (24, 25), may lead to loss of relevant information. One study in our review observed that patients in a primary care setting were less willing to stop medication as compared to an outpatient hospital setting (11). More studies are needed comparing patients recruited from different healthcare settings to ascertain which settings require more effort when involving patients to initiate deprescribing.

When looking at individual patient characteristics, it is still not clear which factors should be taken into account when implementing deprescribing. Patients' sex appears to be irrelevant but findings regarding associations with age, number of drugs and education are inconsistent, in line with findings from previous reviews (24, 25). To gain better insight, more attention should be paid to the influence of the selected study population. For example, we observed a positive association between age and willingness at study level, and this was also observed within one study that included relatively young patients, comparing the group from 60–74 to ≥75 years (6). Most studies observing no association compared older age groups (8, 10, 11, 14, 17–19), indicating that differences among patients of ≥65 years are less relevant. Regarding number of drugs and education, the context should be taken into account. There was a wide range in the median number of drugs taken by patients, possibly related to the healthcare setting where patients were recruited. Testing for associations with the number of drugs within a population using on average three drugs (6) is likely to give different results then in populations using on average five drugs (11). Regarding educational level, a higher education was related to more willingness to stop medication in the USA and Switzerland and less willingness in Malaysia (6, 8, 18). Differences in overall educational level of the included population might explain such contradictory findings.

Strengths and Limitations

All review steps were conducted by two people, following rules for conducting systematic reviews. We included studies using the same questionnaire to assess attitudes toward deprescribing, thereby reducing the chance that observed differences might be caused by the questionnaire used. As a consequence, studies using the older PATD were not included. We grouped healthcare settings in four groups but the information about the setting was sometimes limited or difficult to interpret. Particularly related to the outpatient care, quite different outpatient clinics and acute care facilities were grouped together. Furthermore, the number of studies we could include in the analysis at contextual level was rather small, which limits the power for significant findings. Finally, our analysis on mean age should be interpreted in the light of its ecological fallacy.

CONCLUSION

Research findings about attitudes toward deprescribing are influenced by contextual factors partly inherent to the inclusion criteria of the study population. Future research should pay more attention to the influence of context, such as the healthcare system and setting as well as the communication culture on patients' attitudes toward deprescribing. More cross-cultural, and cross-setting studies are needed that allow for direct comparisons.

AUTHOR CONTRIBUTIONS

MO, AE, and PD designed the study concept and search strategy. MO and AE conducted the literature search, screened the identified articles, extracted data from eligible articles, and drafted the manuscript. PD checked eligibility, data extractions, supervised the research, and edited the manuscript. MO and PD analyzed and interpreted data. All authors read the final version and approved submission and agreed to be accountable for all aspects of the work.

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BRIEF RESEARCH REPORT
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Associations of Self-Care Health Behaviors With Driving Cessation Among Older Drivers

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Older adults are at risk of driving cessation as they age, which can result in negative health outcomes including loss of independence. This study aimed to investigate the associations of self-care health behaviors with the risk of driving cessation. Demographics, health and driving characteristics were captured from healthcare systems in Denver, CO, San Diego, CA, Ann Arbor, MI, Baltimore, MD and Cooperstown, NY for 2,990 adults at baseline then followed from July 2015 to January 2021 *via* in-person assessments and questionnaires. The follow-up accumulated a total of 7,348 person-years and 46 driving cessations, yielding an incidence rate of 0.63 per 100 person-years. Multivariable Cox proportional hazards regression was used to evaluate the relationship between self-care behaviors and driving cessation, stratified by gender, and accounting for multiple failure events and clustering by study site. Ability to participate in social roles and activities was associated with an 8% reduction in the risk of driving cessation [adjusted hazard ratio (HR): 0.92; 95% CI: 0.89, 0.94]. Increased participation in social activities and relationships is associated with driving longevity in older adults and should be targeted for interventions to maintain driving mobility.

Keywords: health behavior, older adult, self-care, driving cessation, physical activity, sleep, community engagement

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INTRODUCTION

The majority of older adults start on a downward spiral toward driving cessation due to physical and cognitive declines (1). Self-care behaviors identified to slow these physical and cognitive declines, include: physical exercise, sleep hygiene, financial fitness, social interaction, and healthy relationships (2, 3). Low levels of physical activity and exercise are related to driving cessation (4). Sleep disturbances are associated with a decrease in annual mileage driven (5). Low levels of community engagement have been associated with driving cessation, yet the directionality of this relationship remains unclear (4). Self-care behaviors are modifiable by behavior change thus are important to investigate further for their effects on driving cessation. Using longitudinal data from a multisite prospective cohort of 2,990 older drivers, we assessed the associations of baseline self-care behaviors (physical activity, community engagement, and sleep) with driving cessation. We hypothesized that healthy self-care behaviors can contribute to driving longevity over time and that there is a differential risk decrease depending on the self-care behavior. More specifically, we anticipated that physical activity would have the strongest effect, followed by community engagement and sleep health.

METHODS

Study Design

The study design and methods for the LongROAD study are described in detail elsewhere (6). LongROAD consists of five US clinical sites with each site enrolling roughly 600 participants, with a total enrollment of 2,990 active drivers aged 65–79 at baseline. Enrollment began on July 6, 2015 and it was completed March 31, 2017. This study involved an analysis of data from baseline through the second anniversary. Driving cessation data were current as of 1/20/2021.

Measures

Self-Care Behaviors

Three self-care behaviors were included: (1) social roles and activities to capture community engagement, (2) physical activity, and (3) sleep disturbance to capture sleep hygiene.

Social Health

We used the PROMIS® v2.0—Ability to Participate in Social Roles and Activities Short-Form (SF) 4a (a higher *T*-score reflects better and a lower *T*-score reflects worse) as the measure of community engagement.

Sleep Disturbance

We measured sleep disturbance using the PROMIS® v1.0—Sleep Disturbance SF 4a measure which, when compared with two legacy measures, Epworth Sleepiness Scale and the Pittsburgh Sleep Quality Index, was found to be precise and efficient (7).

Physical Activity

Our assessment of physical activity was adapted from the Modified Minnesota Leisure Time Activities Questionnaire (MLTA) (8). If subjects were in the lowest quintile by gender for kilocalorie expenditure per week as reported by six questions on the Minnesota Leisure Time Activities (MLTA) Questionnaire, then they were considered low physical activity (8).

Driving Cessation

Information regarding driving cessation were collected during follow-up telephone interviews 1–3 months after GPS data transmission from the DataLogger has ceased. The Driving Habits Questionnaire (DHQ), Oregon Older Driver survey, Candrive, and Advanced Driving Decisions and Patterns of Travel (ADDAPT) Questionnaire were adapted for our driving cessation survey (9). If a specific date of cessation was not available, date of cessation was considered the date on which the interview was conducted.

Demographics and Covariates

Besides considering demographics, two important potentially modifiable factors that are known to be associated with driving cessation, vision and cognition, were included. Self-reported vision was categorized as poor to good, very good, and excellent. Episodic and working memory was determined by Immediate and Delayed Word Recall (10). Correct word recall scores of 0–10 were considered impaired cognitive performance, and scores of 11–20 were considered unimpaired.

TABLE 1 | Adjusted hazard ratio of self-care behaviors with time to driving cessation with 95% confidence interval.

	Adjusted*
Physical activity	1.20 (0.67, 2.15)
Sleep disturbance	0.99 (0.95, 1.02)
Ability to participate in social roles and activities	0.92 (0.89, 0.94)

**Adjusted for baseline age, marital status, vision, and cognitive health, stratified by gender, and clustered by site. Total N = 2,744 and 6,736.27 person-years.*

Statistical Analysis

The primary goal of this analysis was a time-to-event analysis of the three self-care health behaviors on driving cessation. We assessed the proportional hazards (PH) assumption and if it was violated, then we conducted a stratified Cox model. We used the Efron method for tied events. Because it is possible for subjects to cease driving, then resume driving, and cease again, we first checked the failure data to see if this occurred. For this study, the self-care behaviors and covariate measures were assessed only at baseline as time-invariant predictors.

All statistical investigations and analyses were conducted using Stata SE version 16.1 (StataCorp. 2019. College Station, Texas: StataCorp LLC).

RESULTS

The mean scores for self-reported participation in social roles and sleep disturbance were 57.5, and 45.5, respectively, and 29% of respondents were considered low physical activity. As of January 20, 2021, the most recent date for which data were available, 46 subjects had ceased driving. Examination of cessation data showed that all subjects ceased and did not resume driving except for one, who ceased driving temporarily then resumed, but did not have a subsequent cessation event. The analysis accounted for the potential for multiple failures and subsequent resumption of at-risk person-time. The follow-up ($N = 2{,}774$) accumulated a total of 7,348 person-years, yielding an incidence rate of 0.63 per 100 person-years.

We conducted stratified Cox models to account for non-proportionality by gender. Education was dropped using the change-in-estimate method. The final stratified Cox model ($N = 2{,}687$) contained physical activity, participation in social activities, and sleep disturbance adjusted for our baseline demographics and covariates including age, marital status, cognition, and vision, accounting for error clustering by study site (**Table 1**).

The adjusted hazard ratios (HRs) of driving cessation were 1.20 (95% CI: 0.67, 2.15) for physical activity, 0.99 (95% CI: 0.95, 1.02) for sleep disturbance, and 0.92 (95% CI: 0.89, 0.94) for the PROMIS® measure Ability to Participate in Social Roles and Activities (a higher score on the scale represents greater social participation ability). Therefore, every 1-unit increase (or 1/10th of a standard deviation on a *T*-score metric) in self-rated ability to participate in social roles and activities was associated with an 8% reduction in the risk of driving cessation.

DISCUSSION

Initially, it had been hypothesized that of the three self-care behaviors measured, physical activity would be the main effect driving the association (4). However, participation in social roles and activities suggested a modest protective effect on driving cessation after adjusting for other self-care health behaviors and covariates. In other words, greater community engagement can result in better health driving outcomes for aging drivers. This finding is particularly salient in light of the ongoing COVID-19 pandemic. Among older adults in the US, considered one of the most vulnerable groups to the new disease, loss of community engagement due to public health containment measures may be associated with a subsequent loss of independence through driving (11).

Others in the literature report on the role that social participation plays on driving cessation. Prior to driving and after cessation social engagement declines (12). Older drivers who are socially active and provide rides to activities to family and friends avoid driving cessation longer (13–15). A strength of this study is measuring social roles and activities with a precise PROMIS measure compared to Pachana et al. (16) who measured social engagement as a dichotomous variable (17).

The number of participants who stopped driving over the 3-year period may be low at 46 of the 2,687 included in the final analysis. Self-reported reasons for driving cessation were not taken into account. Self-care health behaviors and all other covariates were assessed only at baseline. It is possible that self-care behaviors may be time-variant. We limited the number of modifiable and other covariates we controlled for to focus on the self-care behaviors and non-modifiable demographics.

The chosen behaviors were selected because they are modifiable on the individual level, at least to a certain extent. If the evidence presented here is confirmed, interventions may include targeted outreach campaigns for older adults to keep them engaged in the community in meaningful ways.

PUBLIC HEALTH IMPLICATIONS

An increased ability to participate in social roles and activities was moderately associated with a reduction in cessation risk adjusting for other self-care health behaviors and covariates. Further research is needed in this area to better understand these associations, and how interventions can be applied to support aging drivers and reduce the negative effects of driving cessation.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The research was approved and monitored by the Institutional Review Board of the Columbia University Medical Center [IRB-AAAN9950]. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TM: conceptualization and supervision. TM, AW, Q-LX, HA, LM, DE, and GL: methodology. AW and TM: formal analysis and writing—original draft preparation. TM, HA, LM, DE, and GL: data curation. AW, DE, LM, GL, HA, Q-LX, and TM: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.794639/full#supplementary-material

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Prevalence of Physical Activity and Sedentary Behavior Patterns in Generally Healthy European Adults Aged 70 Years and Older—Baseline Results From the DO-HEALTH Clinical Trial

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Background: Physical activity (PA) is important for healthy aging and disease prevention whereas sedentary behavior (SB) accelerates health deterioration.

Aim: To investigate activity profiles regarding PA and SB among generally healthy European older adults.

Methods: Meeting PA recommendations was defined as ≥150 min/week of moderate and/or ≥75 min/week of vigorous PA. A cut-off of ≥5.5 h/day was used to define time spent with SB. We present prevalence of PA and SB overall and by sex, age, BMI, and country. We examined correlates with multivariate logistic regression models.

Results: Two thousand one hundred and fifty-five DO-HEALTH participants completed baseline information on activity profiles [mean age 74.9 years (SD 4.5), 61.8% women]. Overall, 62.2% met PA recommendations and overall, 37.1% spent ≥5.5 h/day with SB. Younger participants (70–74 years), men, and those with BMI <25 kg/m^2 met PA recommendations more often. Per country, prevalence of meeting PA recommendations were: Austria 74.4%, France 51.0%, Germany 65.6%, Portugal 46.5%, and Switzerland 66.7%. Regarding SB, prevalence did not differ in all subgroups. In multivariate logistic regression analyses, being male, younger age, lower MoCA scores, and higher SPPB score were associated with greater odds, whereas higher BMI, more years of education, higher GDS score, and residing in Portugal were associated with lower odds of meeting PA recommendations. High BMI and higher MoCA scores were associated with greater odds of high SB.

Conclusion: Individualized public health efforts may be warranted even in active older adults, as profiles were less favorable in subgroups of older age, female sex and higher BMI.

Keywords: sedentary behavior, physical activity, older adults, lifestyle, prevalence, healthy aging, active aging

INTRODUCTION

In Europe, the share of the population being older than 65 years is expected to rise from 20% in 2020 up to 30% in 2050 (1). Age-related chronic diseases such as cardiovascular diseases, diabetes, cancer, and dementia represent a considerable burden to the affected individual, the society, the economy, and the health care system (2).

Physical activity (PA) plays a key role in the prevention of chronic diseases and reduces mortality (3). Likewise, engaging in PA reduces loss of autonomy by prevention of frailty (4), as well as through high effectiveness to prevent falls (5). Consequently, sufficient PA strongly influences an older person's trajectories of "active and healthy aging" (6). Currently, the World Health Organization (WHO) recommends ≥150 min of moderate or ≥75 min of vigorous PA per week for all adults, with a specification for older adults to engage in multicomponent PA of at least moderate intensity on 3 or more days a week (7). However, about 55–83% of women and 47–74% of men do not meet these recommendations (8).

Spending high amounts of time with sedentary behavior (SB) has been associated with aggravated decline of physical function (9), decreased muscle health (10), and subsequently increased risk of falling (11). Furthermore, a dose-response relationship between the amount of SB and mortality risk has been reported in community-dwelling older adults (12).

Higher PA levels and limited time spent with SB are proposed to be independently related to better health outcomes (13). As it is challenging to meet PA recommendations for many older adults, especially in presence of multimorbidity (14–16), replacing SB with light PA may be the stepping-stone toward eventually spending more time with moderate or vigorous PA (17).

Consequently, the WHO emphasizes the importance of decreasing SB in addition to meeting PA recommendations (7). Nonetheless, the Eurobarometer surveys show that overall, the total time spent with SB/day increased between 2002 and 2017 (18). Importantly, a review of large cohort studies found that older adults spent between 5 and 9 h/day with SB (19).

Aging research increasingly investigates conditions leading to increased SB and insufficient PA. Nevertheless, a consistent operational definition of a phenotype of older adults living active vs. inactive, and sedentary vs. non-sedentary lifestyles is still missing today. Further, as the definition of SB was only introduced in 2012, limited research is available about prevalence of SB among older adults, especially within subgroups of oldest age, sex, or geographical origin (19). To establish a risk profile in clinical care and foster suitable interventions, knowledge about living circumstances and behavioral patterns is essential.

The DO-HEALTH clinical trial offers a unique data set from extensively phenotyped community-dwelling generally healthy older adults aged 70+ from five European countries (20). The first aim of this secondary analysis of baseline data from DO-HEALTH is to describe the prevalence of PA, SB, and the combination of these two behavioral patterns in a generally healthy community-dwelling older adult population. Secondly, this study aims to characterize participants meeting PA recommendations and/or engaging in high amounts of SB regarding socio-demographic characteristics, as well as physical and cognitive function.

METHODS

Study Design and Participants

The DO-HEALTH clinical trial randomized 2,157 community-dwelling healthy older adults aged 70 and older to vitamin D, omega-3 fatty acids, and simple home exercise program, according to the 2 × 2 × 2 factorial design. Participants were recruited at seven study centers in five European countries. The design variables used for randomization stratification in the DO-HEALTH trial were age, sex, experience of a fall in the year prior to study inclusion, and study site. Participants were recruited from the community trough mailing lists of, i.e., retirement authorities and community services, and trough advertisements in newspapers and other media. The study design and the main results have been published elsewhere (20, 21).

Assessment of PA and SB

Participants reported the types and average time spent with PA and SB per week within the past year with an excerpt of the Nurses' Health Study questionnaire (NHS PAQ) (22). The NHS PAQ is a validated self-reporting questionnaire covering the time spent with different leisure-time PA, time spent standing or walking, time spent with SB, number of days exercised per week, number of stair flights climbed per week, and rating of usual gait speed outdoors (22). Participants filled out the NHS PAQ independently on a tablet. Answers given as intervals of time were coded as means of the intervals (**Supplement 1**).

We classified the intensity of activities reported with the NHS PAQ following the physical activities compendium using metabolic equivalents of tasks (METs) as light (<3 METs), moderate (3–6 METs) and vigorous (≥6 METs) (23). Then, we calculated the reported time per week spent with moderate and vigorous activities (23). To account for over-reporting of amounts of activities (outlier data), we capped the sum of moderate PA at 35 h/week and the sum of vigorous PA at 21 h/week. We defined participants meeting PA recommendations if they engaged in either ≥150 min/week of moderate, and/or ≥75 min/week of vigorous PA (**Supplement 2**) (7).

We calculated the reported hours/day of SB based on questions q4.3–q4.5 of the NHS PAQ (**Supplement 1**). There is no established definition of "high SB" or a cut-off available to account for time spent with SB considered as health threatening (19). In compliance with a special report by the Swiss Federal Office for Public Health (FOPH), we set the cut-off for the binary variable SB (0.1) at 5.5 h/day (24). We capped the sum of SB at 24 h/day.

Assessment of Participant Characteristics

All DO-HEALTH study participants completed a comprehensive baseline assessment including questionnaires and standardized assessments of physical and cognitive function. Physical function was assessed with the Short Physical Performance Battery (SPPB) (25), and handgrip strength measured using a Martin Vigorimeter (26). Cognitive function was assessed with the Montreal Cognitive Assessment (MoCA) (27), and the Mini-Mental State Examination (MMSE) (28). The number of comorbidities was assessed with a self-administered questionnaire (Sangha's score) (29). Health-related quality of life was assessed with the EuroQol 5 Dimensions 3 Levels (EQ-5D-3L) and self-rated health was assessed by the EQ-5D-3L vertical visual analog scale (VAS) (30). Depression was assessed with the 15 items Geriatric Depression scale (GDS) (31).

Statistical Analyses

Descriptive statistics are presented with frequency counts and percentages for categorical variables and mean ± standard deviation (SD) or median with interquartile range (IQR) for continuous variables depending on the normality of their distribution. In a first step, bivariate associations were examined using the Chi-square test between two categorical variables (pre-specified subgroup analyses regarding categories of age (70–74 years/≥75), sex (female/male), body mass index (BMI, ≥25/<25), and country of residence (reference = Switzerland).

Secondly, dichotomous outcomes of meeting PA recommendations (yes/no, model 1) and spending ≥5.5 h/day with SB (yes/no, model 2) were analyzed using separate multivariable logistic regression models. The following variables simultaneously entered both models: age, sex, experiencing a fall prior to inclusion, country of residence, BMI, current smoking, living alone, years of education, being depressed (GDS), cognitive function (MoCA score), multimorbidity (≥2 comorbidities), polypharmacy (taking ≥5 medications), and physical function (Grip Strength and SPPB score).

Additional analyses were conducted by including SB (spending ≥5.5 h/day: yes/no) in the multivariable logistic regression model of the odds of meeting PA recommendations; Similarly, the covariate meeting PA recommendations (yes/no) was added in the multivariable logistic regression model of the odds of spending ≥5.5 h/day with SB.

All analyses were performed using SAS® software, Version 9.4 of the SAS System for Windows and RStudio Version 4.0.3. The significance level was fixed at 0.05.

RESULTS

Baseline Characteristics of Study Population

We included 2,155 of all 2,157 DO-HEALTH participants with complete baseline NHS PAQ profiles. Mean age was 74.9 years (SD 4.5), and 61.8% were women (**Table 1**). As per design of the clinical trial, 41.9% of participants reported having experienced a fall 12 months prior to study inclusion. Overall, 5.8% reported current smoking. The mean number of comorbidities was 3.3 (SD 3.0) and the mean number of medications taken 3.2 (SD 2.8).

Overall, participants reported a median of 18.5 (IQR: 9.5, 38.7) h/week spent with light PA, 2.6 (IQR: 0.7, 7.3) h/week spent with moderate PA, 0.2 (IQR: 0.5, 1.4) h/week spent with vigorous PA, and a median sum of 3.9 (IQR: 2.1, 6.7) h/day spent with SB (**Supplement 3**). Interestingly, participants reporting to spend ≥ 5.5 h/day with SB at the same time reported overall more time spent with PA.

Walking was the most common PA, followed by gymnastics (including Yoga, stretching, figure training) and "other activities (e.g., lawn mowing)". Regarding SB, median reported time spent watching TV and median time "sitting at home" were both 1.1 h/day (IQR: 0.5, 2.2, for both).

Prevalence of PA

Overall, 62.2% of participants met PA recommendations (shown in **Figure 1**).

Men, participants in the younger age category (70–74 years), and those in the lower BMI category (<25 kg/m^2) met PA recommendations more often (all $p < 0.001$ in univariate chi-square tests). Specifically, 71.6% of men met PA recommendations whereas only 56.4% of women did. The proportion of participants meeting PA recommendations decreased from 67.8% at ages 70–74 years to 54.7% for ages 75+. Of the participants with BMI ≥ 25 kg/m^2, 58.0% reported to meet PA recommendations, while in the <25 kg/m^2 category, 68.5% met PA.

With regard to country, prevalence of meeting PA recommendations was as follows: Austria 74.4% (148/199), France 51.0% (153/300), Germany 65.6% (229/349), Portugal 46.5% (140/301), and Switzerland 66.7% (671/1,006).

Prevalence of SB

Overall, 37.1% of participants classified as being sedentary (spent ≥ 5.5 h/day with SB; shown in **Figure 1**).

There was no significant univariate differences due to age, sex and country with regard to SB with a consistent proportion of about one third of participants spending ≥5.5 h/day with SB.

Prevalence for the Combination of Both Behavioral Patterns

We grouped participants into four categories based on combined patterns of PA and SB (shown in **Figure 2**): 24.0% met PA recommendations and at the same time classified as being sedentary (spent ≥5.5 h/day with SB); 38.2% met PA recommendations and at the same time spent <5.5 h/day with SB; 24.6% did not met PA recommendations and spent <5.5

TABLE 1 | Baseline characteristics of the study population, a) by meeting or not meeting PA recommendations, b) by reporting ≥5.5 hours/day of SB or not.

		a)		b)	
	Overall	**Meeting PA recommendations**	**Not meeting PA recommendations**	**≥5.5 hours/ day of SB**	**<5.5 hours/ day of SB**
n* (%)	2,155	1,341 (62.2)	814 (37.8)	800 (37.1)	1,355 (62.9)
Age, (yrs)					
Mean (SD)	74.9 (4.5)	74.3 (3.9)	76.0 (5.0)	75.0 (4.4)	74.9 (4.5)
70–74, *n* (%)	1,236 (57.4)	838 (67.8)	398 (32.2)	447 (36.2)	789 (63.8)
>75, *n* (%)	919 (42.6)	503 (54.7)	416 (45.3)	353 (38.4)	566 (61.6)
Sex, *n* (%)					
Female	1,331 (61.8)	751 (56.4)	580 (43.6)	473 (35.5)	858 (64.5)
Male	824 (38.2)	590 (71.6)	234 (28.4)	327 (39.7)	497 (60.3)
Prior fall, *n* (%)					
Yes	902 (41.9)	541 (60.0)	361 (40.0)	348 (38.6)	554 (61.4)
No	1,253 (58.1)	800 (63.8)	453 (36.2)	452 (36.1)	801 (63.9)
BMI, (kg/m^2)					
Mean (SD)	26.3 (4.3); (*n* = 2,154)	25.8 (4.0)	27.2 (4.6)	26.6 (4.4)	26.2 (4.2)
≥25	1,286 (59.7)	746 (58.0)	540 (42.0)	498 (38.7)	788 (61.3)
<25	868 (40.3)	595 (68.5)	273 (31.5)	302 (34.8)	567 (65.2)
Current smoking, *n* (%)					
Yes	126 (5.8)	48 (38.1)	78 (61.9)	55 (43.7)	71 (56.3)
No	2,029 (94.2)	1,293 (63.7)	736 (36.3)	745 (36.7)	1,284 (63.3)
Years of education, mean (SD)	12.6 (4.3); (*n* = 2,153)	12.8 (4.1)	12.3 (4.6)	12.9 (4.4)	12.5 (4.3)
MoCA score, mean (SD)	25.7 (3.4); (*n* = 2,151)	25.7 (3.1)	25.5 (3.6)	26.0 (3.2)	25.5 (3.5)
MMSE score, mean (SD)	28.5 (1.5)	28.4 (1.6)	28.6 (1.5)	28.5 (1.5)	28.5 (1.5)
Number of comorbidities, mean (SD)	3.3 (3.0); (*n* = 2,154)	4.0 (3.2)	2.9 (2.9)	3.5 (3.2)	3.2 (2.9)
Number of medications/polypharmacy					
Mean (SD)	3.2 (2.8)	3.7 (3.0)	2.9 (2.6)	3.3 (2.9)	3.1 (2.7)
<5, *n* (%)	1,571 (72.9)	1,026 (65.3)	545 (34.7)	575 (36.6)	996 (63.4)
≥5, *n* (%)	584 (27.1)	315 (53.9)	269 (46.1)	225 (38.5)	359 (61.5)
Health-related quality of life (EQ-5D-3L) score, mean (SD)	0.901 (0.139); (*n* = 2,152)	0.918 (0.128)	0.873 (0.151)	0.891 (0.146)	0.907 (0.134)
Self-rated health (EQ-5D-3L VAS) score, mean (SD)	81.2 (14.9); (*n* = 2,152)	83.4 (13.7)	77.8 (16.2)	81.6 (14.8)	81.0 (15.0)
Geriatric depression scale (GDS) score, mean (SD)	1.8 (2.3); (*n* = 2,127)	1.4 (2.0)	2.4 (2.7)	1.8 (2.4)	1.7 (2.3)
Living alone, *n* (%)					
Yes	900 (41.8)	522 (58.0)	378 (42.0)	339 (37.7)	561 (62.3)
No	1,255 (58.2)	819 (65.3)	436 (34.7)	461 (36.7)	794 (63.3)
Physical function					
mean (SD)					
SPPB (score)	10.9 (1.5); (*n* = 2,151)	11.15 (1.2)	10.4 (1.8)	10.8 (1.5)	10.9 (1.5)
Grip Strength dominant hand (kPa)	60.2 (18.6); (*n* = 2,150)	62.6 (18.5)	56.2 (18.1)	61.3 (18.6)	59.5 (18.5)
Country, *n* (%)					
Austria	199 (9.2)	148 (74.4)	51 (25.6)	76 (38.2)	123 (61.8)
France	300 (13.9)	153 (51.0)	147 (49.0)	124 (41.3)	176 (58.7)
Germany	349 (16.2)	229 (65.6)	120 (34.4)	119 (34.1)	230 (65.9)
Portugal	301 (14.0)	140 (46.5)	161 (53.5)	101 (33.6)	200 (66.4)
Switzerland	1,006 (46.7)	671 (66.7)	335 (33.3)	380 (37.8)	626 (62.2)

**DO-HEALTH included total 2,157 participants. Two participants had missing values for the NHS PAQ and therefore were excluded.*

For the overall, % sum up to 100 in columns, within sections a) and b), % sum up to 100 in rows.

Prior fall: reporting of a fall in the 1-year period before study start. BMI: Body mass index, calculated as weight in kilograms divided by height in meters squared (kg/m^2). BMI values ≥25 reflect overweight and values ≥30 obesity. MoCA, Montreal Cognitive Assessment: screening test for mild cognitive dysfunction with a range of 0 to 30 points, in which higher scores are better and scores >26 suggest normal cognitive function. MMSE: Mini-Mental State Examination, measures cognitive impairment with a range of 0 to 30 points, in which higher scores are better and scores >24 suggest normal cognitive function. MMSE of ≥24 was one of the inclusion criteria for the DO-HEALTH clinical trial. Comorbidities were assessed with a self-administered questionnaire to assess comorbidities (Sangha's Score). Health-related quality of life: assessed by the EuroQol 5 Dimensions 3 Levels (EQ-5D-3L). Scores range from <0 to a maximum of 1 point, in which 0 means a health state equivalent to death, negative values are equivalent to a health state worse than death, and 1 is equivalent to perfect health. Self-rated health: assessed by the EQ-5D-3L vertical visual analog scale (VAS), which ranges from 0 to 100 points, in which higher scores are better. GDS: Geriatric Depression scale, Questionnaire to assesses depression. Scores range from 0 to 15, 0–5 points are considered normal, 5–10 points translate to light to moderate depression, 11–15 to severe depression. SPPB: Short Physical Performance Battery, standardized assessment battery to test lower extremity function. Scores range from 0 to 12, in which higher scores are better. Grip Strength of the dominant hand was measured with a Martin Vigorimeter (in kilopascal, kPa).

TABLE 2 | Multivariate logistic regression models, a) odds of meeting PA recommendations at baseline, b) odds of spending ≥5.5 hours/day with SB at baseline.

	a) odds of meeting PA recommendations (n = 2,111)			b) odds to spend ≥5.5 hours/day with SB (n = 2,111)		
	OR	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Age (yrs)	0.93	0.90, 0.95	<0.0001	1.01	0.98, 1.03	0.6409
Female	0.53	0.40, 0.71	<0.0001	0.87	0.66, 1.14	0.3029
Prior Fall	1.09	0.89, 1.32	0.4051	1.07	0.89, 1.29	0.4776
BMI (kg/m^2)	0.93	0.91, 0.95	<0.0001	1.03	1.00, 1.05	0.0317
Current smoker	0.79	0.52, 1.19	0.2632	1.35	0.92, 1.96	0.1219
Years of education (years)	0.96	0.94, 0.99	0.0044	1.02	0.99, 1.04	0.1582
MoCA score (continuous)	0.93	0.90, 0.96	<0.0001	1.04	1.01, 1.08	0.0119
Comorbidities (continuous)	0.86	0.69, 1.05	0.1408	1.14	0.93, 1.39	0.2070
Polypharmacy (≥5 medications)	1.12	0.88, 1.43	0.3484	1.00	0.80, 1.27	0.9523
Geriatric depression Scale score (GDS, continuous)	0.91	0.87, 0.96	0.0001	1.03	0.99, 1.08	0.1424
Living alone	0.99	0.81, 1.22	0.9172	1.08	0.89, 1.31	0.4441
SPPB score (continuous)	1.23	1.14, 1.34	<0.0001	0.97	0.90, 1.05	0.4261
Grip Strength dominant hand (continuous)	1.00	1.00, 1.01	0.4365	1.00	1.00, 1.01	0.4851
Country						
Austria	1.17	0.81, 1.70	0.4079	1.00	0.72, 1.38	0.9893
France	0.74	0.54, 0.99	0.0459	1.04	0.78, 1.39	0.7912
Germany	0.83	0.62, 1.10	0.1955	0.88	0.67, 1.15	0.3456
Portugal	0.58	0.40, 0.84	0.0034	0.89	0.63, 1.26	0.5110
Switzerland	*Reference*			*Reference*		

Prior fall: reporting of a fall in the 1-year period before study start. BMI: Body mass index, calculated as weight in kilograms divided by height in meters squared (kg/m^2). BMI values ≥25 reflect overweight and values ≥30 obesity. MoCA: Montreal Cognitive Assessment, screening test for mild cognitive dysfunction with a range of 0 to 30 points, in which higher scores are better and scores >26 suggest normal cognitive function. MMSE: Mini-Mental State Examination, measures cognitive impairment with a range of 0 to 30 points, in which higher scores are better and scores >24 suggest normal cognitive function. MMSE of ≥24 was one of the inclusion criteria for the DO-HEALTH clinical trial. Multimorbidity was defined as ≥2 comorbidities. Comorbidities were assessed with a self-administered questionnaire to assess comorbidities (Sangha's Scores). GDS: Geriatric Depression scale, Questionnaire to assesses depression. Scores range from 0 to 15, 0–5 points are considered normal, 5–10 points translate to light to moderate depression, 11–15 to severe depression. SPPB: Short Physical Performance Battery, standardized assessment battery to test lower extremity function. Scores range from 0 to 12, in which higher scores are better. Grip Strength of the dominant hand was measured with a Martin Vigorimeter (in kilopascal, kPa). Multivariate logistic regression models: design variables of the DO-HEALTH study were age, sex, experience of a fall prior to inclusion, and country of residence. Additional covariates were: BMI, current smoking, having a dog, taking care of a person, living alone, years of education, being depressed (GDS score), cognitive function (MoCA score), multimorbidity (presence of ≥2 comorbidities), polypharmacy (taking ≥5 medications), and physical function (SPPB score, Grip Strength of the dominant hand).

h/day with SB; 13.1% did not meet PA recommendations and were sedentary.

For Portugal, the highest prevalence rate was in the category "not meeting PA recommendations/low SB", while for all other countries the highest prevalence rate was in the "meeting PA recommendations/low SB" group (**Supplement 4**).

Multivariable Logistic Regression Model for Odds of Meeting PA Recommendations

Participants had greater odds of meeting PA recommendations with each additional point on the SPPB score (OR= 1.23; 95%CI: 1.14, 1.34; **Table 2**).

Participants had lower odds of meeting PA recommendations if being female (OR = 0.53; 95%CI: 0.40, 0.71), for each additional year of age (OR = 0.93; 95%CI: 0.90, 0.95), for each 1 kg/m^2 increase in BMI (OR = 0.93; 95%CI: 0.91, 0.95), for each additional year of education (OR = 0.96; 95%CI: 0.94, 0.99), for each additional point on the MoCA score (OR = 0.93; 95%CI: 0.99, 0.96), and for each additional point on the GDS score (OR = 0.91; 95%CI: 0.87, 0.96).

Regarding country of residence, participants residing in Portugal had lower odds of meeting PA recommendations compared to Switzerland (OR = 0.58; 95%CI: 0.40, 0.84). Additional analysis revealed that participants who spent ≥5.5 h/day with SB had greater odds of meeting PA recommendations compared to participants who spent <5.5 h/day with SB (OR = 1.33; 95%CI: 1.09, 1.63; **Supplement 5**).

Multivariable Logistic Regression Model for Odds of Spending ≥5.5 h/day With SB

Participants had greater odds of spending ≥5.5 h/day with SB for each 1 kg/m^2 increase in BMI (OR = 1.03; 95%CI: 1.00, 1.05; **Table 2**) and for each additional point in the MoCA score (OR = 1.04; 95%CI: 1.01, 1.08). Additional analysis revealed that participants who met PA recommendations had greater odds of spending ≥5.5 h/day with SB (OR = 1.33; 95%CI: 1.09, 1.62; **Supplement 6**). Variance inflation factors (VIFs) ranged between 1.0 and 2.2, indicating little evidence of multi-collinearity.

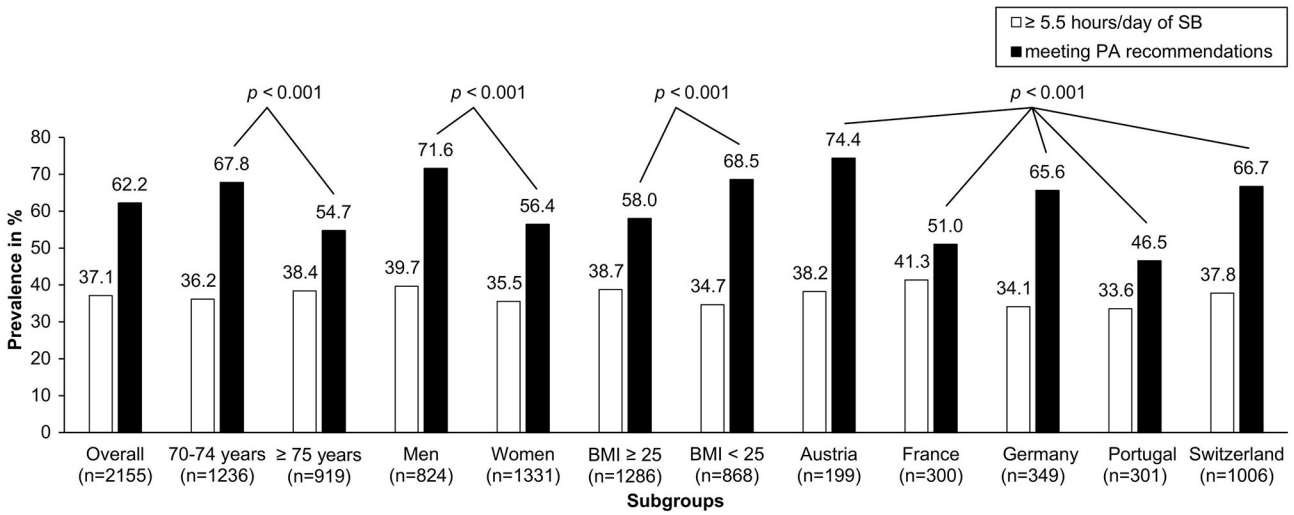

FIGURE 1 | Prevalence of participants meeting PA recommendations and prevalence of participants spending ≥ 5.5 hours/day with SB; in %, per subgroup. For BMI, data of 2,154 participants was available. *P*-values for comparisons within subgroups are from Chi-Square Tests meeting PA. For SB, none of the comparison within subgroups were significant.

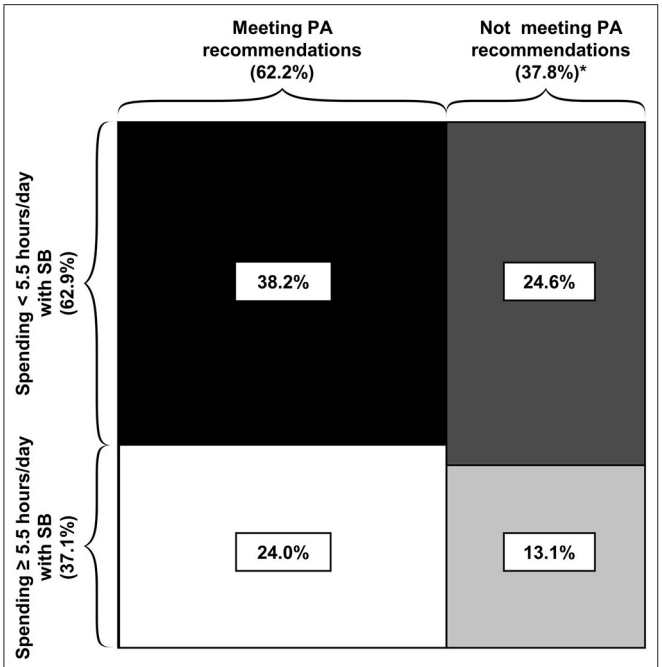

FIGURE 2 | Prevalence within the four groups of combined physical activity and sedentary behavior patterns. *Differences in the sum are due to rounding. Areas reflect the number of participants in corresponding group.

DISCUSSION

In this cross-sectional study of relatively healthy adults aged 70 years and older recruited from the community in 5 European countries, at baseline 62.2% reported to meet PA recommendations and 37.1% classified as sedentary (reported to spend ≥5.5 h/day of SB).

There was an overlap between these groups, with 24.0% of those meeting PA recommendations also reaching the threshold of being sedentary. Notably, 38.2% of those meeting PA recommendations also were below the sedentary threshold.

Meeting PA recommendations correlated positively with better physical function, and negatively with older age, being female, higher BMI, better education, better cognition, worse mental health, and residing in Portugal. Spending ≥5.5 h/day with SB was associated with higher BMI and better cognition.

Consistent with our findings, Bauman et al. (32) reported a lower prevalence of meeting PA with higher age within the World Health and SAGE Surveys: While less than a quarter of participants in the age group 60–69 years reported not meeting PA recommendations, this number rose to 30–40% among ages 70–79 years and to almost half of the population for ages 80+. Also, our findings are consistent with prior reports stating that men meet PA recommendations more often than women (33).

Regarding country-specific reports, our findings corroborate the SHARE study data on the variability of meeting PA recommendations between countries for older adults in Europe, which varied between 55 and 83% in SHARE (within 10 European countries at wave four, including cohort data of Switzerland, Austria, and France), and 46.5–74.4% in DO-HEALTH (8). Notably, compared to the European data, within three national surveys among older adults aged 65 and older residing in the USA (NHANES, BRFSS, and NHIS), prevalence of meeting PA recommendations has been reported to be lower: between 27 and 44% (34).

Our findings are also in line with prior studies suggesting that a higher BMI, decreased physical function, and lower mental health is associated with less engagement in PA (8, 35, 36).

In contrast to our findings, previous research reported a higher likelihood for meeting PA recommendations for participants with a higher education level (8). In DO-HEALTH, we found that for each additional year of education, the odds to meet PA recommendations decreased. This may in part be explained by the results of a systematic review among studies including cognitively healthy adults aged 60 years and older, which suggested that the association of better education with higher PA levels depends on the type of PA and may be more pronounced for PA behaviors that presuppose knowledge about associated health-benefits and accessibility (37).

Previously, exercise has been shown to improve cognitive function in healthy as well as in cognitively impaired older adults (38). In DO-HEALTH, better MoCA scores were associated with less favorable PA behaviors. As DO-HEALTH was not a population based study and had an inclusion criteria of MMSE $\geq$ 24, a cut-point generally considered to indicate normal cognitive function, our findings need to be interpreted with caution.

DO-HEALTH participants reported spending most PA time with light PA, such as walking—followed by gymnastics (yoga, stretching, figure training) and "other activities". Notably, recent findings suggest that already engaging in light PA is reducing pre-mature mortality (3).

Pooling data from six countries, Harvey et al. (39) reported that on average 59% of older adults reported >4 h/day of SB, which is somewhat higher as reported in DO-HEALTH (37% overall) and likely reflective of the target population of relatively healthy adults age 70 and older in DO-HEALTH. However, similar to an European study investigating nationally representative samples aged 15 years and older, DO-HEALTH found that the prevalence rates of SB varied between European countries with high amounts of SB being more prevalent in Mediterranean countries than in more Northern countries (40).

Regarding correlates of SB, DO-HEALTH confirms prior studies among older adults that having a higher BMI is associated with greater levels of subjectively and objectively measured SB (35, 41).

In DO-HEALTH, we found that better cognition was associated with higher odds for spending $\geq$5.5 h/day with SB. The association of SB with cognitive function has not been studied extensively among healthy older adults and findings remain inconclusive as most studies did not adjust for PA (42). Further, the association of SB with cognitive function has been found to depend on the type of SB, e.g., whether the activity is passively watching TV, or to actively use a computer or reading (43). In DO-HEALTH, participants reported an overall median of 1.5 h/day of watching TV, which is less than half of the time that has previously been reported to be associated with tremendous health effects independently from PA in older adults (44).

Previous research including objective assessment of SB indicated that high amounts of SB may be associated with unfavorable health-related outcomes independent of engagement in PA (44). Thus, the assessment of both, PA and SB, appears to be relevant to health at older age.

The two latest population-based health surveys conducted in Switzerland considering PA and SB also reported similar prevalence around 50% of meeting PA recommendations and at the same time low SB behavior for adults aged 65–74 years as we found in DO-HEALTH (24).

For subgroups, we found that men more often met PA recommendations while at the same time reporting high amounts of SB, but women reported more often not meeting PA recommendations while spending <5.5 h/day with SB. This gender difference was also reported among a Dutch cohort (35). It has been speculated that this may be linked to traditional roles, such as women being less sedentary due to their household tasks and men having a more sedentary working history (18, 35).

Possibly reflecting such trade-offs in an overall very active older population, DO-HEALTH participants who met PA recommendations had a significantly greater odds to spend $\geq$5.5 h/day with SB.

Further research using longitudinal data is needed to clarify the impact of PA and PA intensity in relation to SB on health outcomes within this well characterized European population.

In DO-HEALTH, PA and SB was measured by self-report, but not by objective measures of PA such as accelerometer. Thus, we cannot exclude over- or underreporting of PA and SB. However, we used a highly validated assessment (NHS PAQ) (22), which was applied in a standardized way in all 5 recruitment countries. Another limitation is that participants were selected to be relatively healthy and active to be enrolled in DO-HEALTH. Therefore, they may not reflect the community-dwelling population aged 70 and older at a population-based level, and our findings need to be interpreted with caution.

Finally, as no established cut-off for SB exists (19), our findings related to SB need further validation.

In conclusion, the study population of DO-HEALTH represents a generally very active older adult population with a majority of participants meeting PA recommendations and spending <5.5 h/day with SB. However, PA profiles were less favorable in subgroups of older age, female sex and higher BMI. In addition, regarding the combined behavioral patterns of PA and SB, about half of the participants were either meeting PA recommendations or reporting <5.5 h/day of SB. Therefore, our findings support that individualized public health efforts may be warranted even in active older adults with similar characteristics as the DO-HEALTH participants.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because in a first step, no data will be made available to researchers external to DO-HEALTH Research Group to allow primary researchers to fully exploit the dataset. The data will be shared in a second step according to a controlled access system. Requests to access the datasets should be directed to HB-F, heike.bischoff@usz.ch.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Kantonale Ethikkommission Zurich, Switzerland.

The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MM: substantial contribution to the design of the study, substantial contribution to the analysis and interpretation of data, writing of the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. UM: substantial contribution to the design of the study, the interpretation of data, critically revising of the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. WL and NM: substantial contribution to data analysis, critically revising the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. MG and RK: substantial contribution to the interpretation of the results, critically revising the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. RM and AE: substantial contribution to acquisition of data, critically revising the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. EO: substantial contribution to the interpretation of the results, advising expert for data analysis, critically revising the manuscript and presentation of data, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. HB-F: PI of the DO-HEALTH clinical trial, PI and leading supervisor of the study, conception and design of the study and substantial contribution to the interpretation of the results, critically revising the manuscript, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.810725/full#supplementary-material

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Social Isolation Among Older Adults in the Time of COVID-19: A Gender Perspective

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We aimed to analyze inequalities in social isolation among older adults in a time of COVID-19 social restrictions, using a gender perspective. A random population-based survey, including 21,543 older adults (65+) was conducted during and post COVID-19 lockdown in France. Our main outcome was a three-dimension indicator of social isolation based on living conditions, i.e., living alone (i) and not having gone out in the past week (ii), completed by an indicator measuring Internet use i.e., never using the Internet (iii). Logistic regressions were used to identify factors associated with isolation for women and men. Women were more likely to live alone (aOR = 2.72 [2.53; 2.92]), not to have gone out in the past week (aOR = 1.53 [1.39; 1.68]), and not to use the Internet (aOR = 1.30 [1.20; 1.44]). In addition to gender effects, being older, at the bottom of the social hierarchy, and from an ethno-racial minority was also associated with social isolation. Preventive policies should take into account these inequalities when addressing the issue of social isolation among older women and men, so as to enable all social groups to maintain social contacts, and access health information.

Keywords: social inequalities, social contacts, COVID-19, gender, older adults

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INTRODUCTION

Since the beginning of the COVID-19 pandemic, older adults, over-represented among COVID-19 infected people and deaths all around the world (1), have been portrayed as a vulnerable group (2, 3). The epidemiological reality and the biological factors underlying higher mortality among older adults have led to consider them as a homogeneous category. However, studies have shown that aging is a gendered and socially constructed process (4, 5) and that health problems and treatments strongly differ according to social characteristics.

In France, care to older adults was traditionally characterized by a familist approach and has now shifted to a mixed model relying on family and public care (6). As a matter of fact, France now has among the highest shares of older adults living in institutions among developed countries (7). However, as "community care" is scarce in France, people living at home rely before all on informal help (family, neighbors, friends) on a daily basis. During the first lockdown, formal and informal help became limited (8), raising the issue of social isolation among older adults. It reminded the country of the thousands of excess deaths during the August-2003-heatwave in France (9), namely among older adults who did not have access to social contacts during the crisis, because living in places affected by the loss of services and social infrastructure (10).

Social relations have been particularly impacted during the Covid-19 pandemic. Mobility restrictions, as it pertains to lockdown policies, have been put in place in many countries around the world to limit the spread of the epidemic (11, 12). In France, during lockdown (from March 17th

up to May 11th 2020), people could only leave their place of residence with an exemption certificate to conduct necessary activities, limiting in-person contacts outside the household to activities such as running necessary errands, imperative family reasons, assisting vulnerable persons, consults and provision of care, medication purchase, individual outdoor exercise within 1 km of one's place of residence and for 1 h. Even after the strict lockdown phase, the government and scientists still appealed to the responsibility of older adults to stay safe and limit in-person contacts. These measures impacted both physical contacts, inside or outside the household, and digital contacts (13, 14), contributing to the 25% increase in older adults feeling isolated in their home or neighborhood compared to the pre-lockdown situation (15), and potentially leading to gender (16), and social (17–19) inequalities in social isolation. Those who maintained high levels of social contacts showed better coping mechanisms during lockdown periods (20), as well as lower risks of depression (21, 22), and frailty (23). In this paper we aim to study social inequalities in social isolation, as defined by Berg and Cassel (24), i.e., the absence of social interactions, contacts, and relationships with family and friends, with neighbors on an individual level, and with "society at large" on a broader level.

Based on a random national population-based survey, we aim to analyze gender and social inequalities in social isolation of adults over 65 years old in France from May 2nd to June 2nd 2020, which included 10 days of strict lockdown, considering access to physical and to digital social contacts. In this study, living alone, having gone outside in the past week and the use of the Internet will be considered as proxies for social contacts.

MATERIALS AND METHODS

Study Design and Participants

The cohort was set-up in April 2020, with the general aim of understanding the main epidemiological, social and behavioral issues related to the COVID-19 epidemic in France (25). The data collection period ran from May 2nd to June 2nd, 2020. In France, strict lockdown expanded from March 17th to May 10th.

Survey

A random sample of 350,000 people aged 15 and over was drawn from the tax database of the National Institute of Statistics and Economic Studies (INSEE), which covers 96% of the population living in France but excludes people living in institutional settings, and in particular older people living in collectivities. People who belonged to the lowest decile of income were over-represented. All those selected were sent a letter to participate in the survey. A total of 134,391 (38.4%) participated in the survey. Individuals were invited to answer the questionnaire online, or by phone for those who did not have Internet access. Furthermore, a random sample of 10% of people with Internet access was interviewed by phone in order to take into account a method collection effect.

Data collected included socio-demographic characteristics, household size and composition, ethno-racial status, health characteristics and the frequency of Internet use. A total of 25,927 individuals over 65, not living in a residential care facility, responded to the survey. Older adults who carry out an occupational activity were excluded from this study. Indeed, they represented a very specific group when it comes to social isolation, as they might be more likely to have social contacts (namely with colleagues or clients). When restricting the sample to individuals not carrying out an occupational activity and residing in Metropolitan France, the size sample was reduced to 21,543.

We used reweighting and marginal calibrations in the survey and sampling design to correct for non-participation bias among those invited. Weights were calculated using socio-demographics characteristics as covariates to estimate participation probability: sex, age group, employment status (active, inactive), and department, that were available in the original sampling frame.

Measures

Social Variables

We considered the following six variables: age, sex, ethno-racial status (based on migration history), socio-professional category combined with level of formal education (based on current or most recent occupation and education) (*Farmers, self-employed and entrepreneurs/Senior executive professionals/Middle executive professionals/Skilled employees and skilled manual workers/Unskilled employees and unskilled manual workers/Never worked and others*), perceived financial situation (*Very good/Good/Fair/Bad to very bad*) and formal education (defined according to the hierarchical grid of diplomas in France) (*No diploma/Primary education/Vocational secondary/Highschool/Highschool + 2 to 4 years/Highschool +5 or more years*). The ethno-racial status distinguished mainstream population, i.e., persons residing in metropolitan France who are neither immigrants nor native to French Overseas Departments (DOM, i.e., Martinique, Guadeloupe, Reunion Island), nor descendants of immigrant(s) or of DOM native. For the minority population, a distinction was made according to the first (immigrants) and second (descendants of immigrants) generations of immigration, and the country of origin. The term racialized refers to immigrants or descendants of immigrants from the Maghreb, Turkey, Asia and Africa (26).

Living Condition Variables

We took into account two variables: that of the household composition (*Living alone/With a partner and with or without children/Other compositions*) and that of the population size of the municipality (*Rural area/<50,000 inhabitants/[50,000 – 200,000[inhabitants/>200,000 inhabitants/Paris area*).

Health Variables

Health variables included drinking habits *(Everyday/Once or several times a week/Once or several times a month/Less often/Never*), perceived health status (*Very good/Good/Fair/Bad/Very bad*) and declared chronic anxiety or depression.

Outcomes

The main outcome of the study was a three-dimension indicator of social isolation, relying on living conditions and lifestyle (*ie.*

respondents who lived alone and respondents who did not go out in the past week), and Internet use (*ie.* respondents who do not use the Internet).

To determine their household composition, participants were asked "Who are the people in this dwelling ie: people who lived in the same dwelling as the respondent at the time of lockdown, including the respondent and the children in shared custody?)": *Your partner/Your 18 and under children/Your 19 and over children/Your 18 and under grandchildren/Your 19 and over grandchildren/Your 18 and under siblings/Your 19 and over sibling/Your parents/Other members of the family/Other persons (friends, hosts, etc…)*. Results were grouped as follows: *Living alone/With a partner and with or without children/Other compositions.*

To measure how many times respondents had gone out in the past week, they were asked "How many times have you left your home in the last 7 days?": *Never/Only once/2 to 5 times/6 to 10 times/More than 10 times* Results were grouped as follows: *6 times and over//2 to 5 times/Only once/Never*.

In addition to the living conditions and lifestyle of the respondents, and with the goal of accessing Internet use, the frequency of Internet use was analyzed. To assess the use of the Internet, participants were asked "In the past 3 months, on average, you used the Internet…": *Almost every day/Not every day, but at least once a week/Less than once a week/Never/I do not have access to the Internet.* Results were grouped as follows: *Regularly* (Almost every day/Not every day, but at least once a week), *Occasionally* (Less than once a week), *No use of the Internet* (Never, I do not have access to the Internet).

Statistical Analysis

We first described the distribution of living arrangements and lifestyle by gender and age. Then we studied the social distributions of the main social isolation factors, which are (*i*) living alone and (*ii*) not having gone out in the past week, and never using the Internet (*iii)*. We used logistic regressions by gender and for the whole population to measure relations between socio-demographic characteristics and each of these social isolation items adjusted for socio-demographic indicators, living arrangements and lifestyle and health characteristics. Not having gone out in the past week (ii) was also adjusted for the date of the questionnaire, as the survey was carried out during a period of hard lockdown (02/05–10/05) and a period of easing of lockdown (11/05 and onwards). In addition, we performed the same logistic regressions by household compositoin (*ie.* living alone yes/no), factor which may impact going out and using the Internet.

All analyses were performed with the R software (1.3.959). A $P < 0.05$ was considered statistically significant. All figures shown are gross figures and percentages are weighted. Given the sample size, the observed differences were consistently statistically significant. Therefore, no tests are presented for univariable analyses.

RESULTS

The higher proportion of women in the sample (56.3% of women, 43.7% of men) reflected the demographic structure of the French population. Half of older adults lived in municipalities with <50,000 inhabitants (50.8%, including 23.2% in rural areas). About one in eight women (12.6%) never worked (vs. 2.5% for men), and 12.3% used to be senior executives (vs. 27.9% for men) (**Supplementary Table 1**), reflecting the gendered division of the workforce in France. Women were over-represented in primary education levels (33.6 vs. 21.1% for men) and under-represented in the highest education level (3.2 vs. 9.4% for men).

Older women were in poorer perceived health: 57.8% reported being in a "good" or "very good" general health (vs. 60.1% of men), with a stronger difference at age 85 and over (35.9 vs. 45.7%). They also reported chronic anxiety or depression more often (10.1 vs. 3.8%) and a lower alcohol consumption (9.4% of women declared drinking alcohol everyday vs. 28.1% of men).

Gender differences were found regarding social connectedness in the time of COVID-19 (**Table 1**). Women were more exposed to social isolation than men, whether it be for the fact of living alone (38.5% of women vs. 17.9% of men) or not having gone out in the past week (18.9% of women vs. 11.9% of men). Compared to me, they were also more exposed to not using the Internet (32.1% of women vs. 21.4% of men). These differences were found at all ages (**Table 1**).

All things being equal, women were more likely to live alone than men (aOR = 2.72 [2.53; 2.92]) (**Supplementary Table 3**). An age gradient was found for women (up to aOR = 5.17 [4.38; 6.11] for 85+ compared to 65–69 years old) but not for men (**Table 2**). Women with a less comfortable perceived financial situation were more likely to live alone than those in a "comfortable" situation (aOR = 3.85 [3.12; 4.76]). The difference was less marked for men (aOR = 2.24 [1.72; 2.93]). Women with no diploma were less likely to live alone (aOR = 0.74 [0.62; 0.88]), compared to those with a high school level. A similar result was found for men. For women, ethno-racial differences were found as the "racialized 1st or 2nd generation immigrants" group was less likely to live alone than the mainstream population (aOR = 0.70 [0.54; 0.90]). Similar results were found for men.

As regard to having gone out in the past week, data showed that women were more likely than men not to have gone out in the past week than men (aOR = 1.53 [1.39; 1.67]) (**Supplementary Table 3**). A strong age gradient was found for women (up to aOR = 7.86 [6.41; 9.64] for 85+) (**Table 2**). A similar age gradient was found for men. A gradient for level of education was noted for women with education levels under the high school level (up to aOR = 2.58 [2.07; 3.23] for women without any diploma). A similar gradient was found for men, although it was less pronounced than for women. Women who belonged to the racialized immigrants group were more likely not to have gone out in the past week than women from the mainstream population (aOR = 1.96 [1.46; 2.64]) (**Table 2**). A similar result was found for men.

When it comes to not using the Internet in the past 3 months, women were more likely not to use the Internet compared to men (1.30 [1.20; 1.44]) (**Supplementary Table 3**). Furthermore, an age gradient was found for women and men, but was stronger for women [up to aOR = 16.33 [13.21; 20.18] for 85+ vs. aOR = 10.47 [8.25; 13.28] for men (**Table 2**)]. Women with lower education levels were more likely not to use the Internet: up to aOR = 9.84 [7.85; 12.34] for respondents without any diploma

TABLE 1 | Characteristics of isolation indicators by gender.

	Lives alone (%)		Did not go out in the last 7 days (%)		Does not use the Internet (%)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Variable						
Age						
65–69	27.7	17.6	9.1	6	13.3	9.9
70–74	30.3	16.2	10.9	8.8	18.6	15
75–79	38.9	14.8	16.4	12.1	32.5	22.3
80–84	47.4	16.9	24	15.6	49.1	33.1
85 +	63.4	30.3	48.1	32.6	71.8	55.5
Formal education						
No diploma	39.6	16.8	33.2	18.9	63.5	51.9
Primary education	42	19.6	21.7	15.8	41.1	28.6
Vocational secondary	33.8	16.8	14	11	19.6	18.8
High school	38.1	19	11	8	13.5	9.5
High school + 2–4 years	37.7	18.3	10.1	6.9	11	6.4
High school + 5 or more years	31.2	16.7	8.5	8.1	4.5	5.6
Perceived financial situation						
Comfortable	31.8	19.6	15.4	9.2	22.6	14.4
Decent	35.6	15.8	17.7	11.5	28.9	18.8
Just enough	43	18.5	20.9	13.5	37.8	28.1
Difficult to impossible without going into debt	50.4	26.8	23.8	14.5	44.4	27.9
Population size of municipality						
Rural area	31.7	16.5	21.9	12	34.5	24.4
<50,000 inhabitants	37.8	18.6	18.2	11.3	33.9	22.2
[50,000–200,000] inhabitants	43	15.6	17.6	10.3	30	18.5
>200,000 inhabitants	42.2	19.6	19.4	12.1	31.6	19.8
Paris	41.4	18.3	14.7	14.4	26.5	18.9
Household composition						
Living alone	100	100	21.7	11.8	41	28.4
With a partner and with or without children			13.9	11.2	22.8	19
Other compositions			32.4	19.5	44.2	29
Ethno-racial status						
Mainstream population	39	17.9	18.2	11.1	31	19.9
Racialized first or second-generation immigrants and DOM descendants	30.7	13.8	28.5	18.6	43.4	35.2
Non-racialized first or second-generation immigrants	38.1	20.1	20.2	13.8	35.9	25.1
Perceived health status						
Very good	35.2	15.7	9.1	6.3	18.6	10
Good	35.8	16.9	12.5	8	23.8	18.5
Fair	42.6	19.1	24.9	14.2	42	25.6
Bad to very bad	41.7	22.6	45.2	35.1	59	42.4
Declared chronic disease or physical limitation						
Declared at least one	40.2	18.1	23.7	14.5	36.4	23.2
Did not declare any	35.5	17.5	10.1	6.8	24.3	18
Declared chronic anxiety or depression						
Declared chronic anxiety or depression	45.6	23.1	28.7	21.9	48.2	33.9
Did not declare chronic anxiety or depression	37.8	17.7	17.8	11.5	30.3	20.9
Date of questionnaire						
02/05-10/05	37.7	15.3	22.7	12.9	30.1	17.5
11/05-17/05	38.3	18.6	18.3	12.5	30.5	21.5
18/05-01/06	40	21.1	14	9.7	36.4	27.3
	Total *n* (%)		**Total *n* (%)**		**Total *n* (%)**	
	3,507 (38.6)	1,469 (17.9)	1,531 (18.9)	951 (11.9)	2,114 (32.1)	1,298 (21.4)

Notes: N = 21.543.
50.4% of women in a "difficult to impossible without going into debt" perceived financial situation lived alone; 6% of men aged 65 to 69 did not go out in the past 7 days; 32.1% of women and 21.4% of men do not use the Internet.

TABLE 2 | Logistic regressions of living alone, not having gone out in the past week and never using the internet, by gender.

	Lives alone		Did not go out in the last 7 days		Does not use the internet	
	Women aOR [95% CI]	**Men aOR [95% CI]**	**Women aOR [95% CI]**	**Men aOR [95% CI]**	**Women aOR [95% CI]**	**Men aOR [95% CI]**
Age						
65–69 (ref)	1	1	1	1	1	1
70–74	**1.16 [1.04; 1.29]**	0.87 [0.76; 1.00]	1.18 [1.00; 1.39]	**1.49 [1.22; 1.81]**	**1.59 [1.35; 1.87]**	**1.49 [1.24; 1.79]**
75–79	**1.70 [1.50; 1.93]**	0.90 [0.75; 1.07]	**1.91 [1.59; 2.29]**	**2.11 [1.70; 2.63]**	**3.33 [2.80; 3.97]**	**2.52 [2.06; 3.08]**
80–84	**2.54 [2.19; 2.95]**	1.08 [0.89; 1.32]	**2.59 [2.12; 3.17]**	**3.08 [2.43; 3.90]**	**6.80 [5.64; 8.21]**	**4.66 [3.76; 5.77]**
85 +	**5.17 [4.38; 6.11]**	**2.38 [1.93; 2.93]**	**7.86 [6.41; 9.64]**	**7.29 [5.70; 9.31]**	**16.33 [13.21; 20.18]**	**10.47 [8.25; 13.28]**
Formal education						
No diploma	**0.74 [0.62; 0.88]**	**0.69 [0.53; 0.88]**	**2.58 [2.07; 3.23]**	**1.64 [1.24; 2.17]**	**9.84 [7.85; 12.34]**	**11.99 [9.09; 15.82]**
Primary education	0.87 [0.76; 1.00]	0.92 [0.76; 1.12]	**1.61 [1.32; 1.96]**	**1.69 [1.32; 2.16]**	**3.83 [3.13; 4.69]**	**3.93 [3.02; 5.11]**
Vocational secondary	**0.78 [0.68; 0.90]**	**0.78 [0.66; 0.93]**	**1.41 [1.15; 1.74]**	**1.27 [1.00; 1.60]**	**1.88 [1.51; 2.34]**	**3.26 [2.53; 4.19]**
High school (ref)	1	1	1	1	1	1
High school + 2–4 years	1.07 [0.93; 1.23]	0.94 [0.78; 1.13]	0.91 [0.72; 1.15]	0.83 [0.63; 1.10]	0.90 [0.70; 1.16]	0.95 [0.68; 1.32]
High school + 5 or more years	1.03 [0.83; 1.26]	0.91 [0.74; 1.12]	0.86 [0.60; 1.23]	1.02 [0.76; 1.36]	**0.37 [0.22; 0.63]**	**0.63 [0.43; 0.94]**
Perceived financial situation						
Comfortable (ref)	1	1	1	1	1	1
Decent	**1.45 [1.28; 1.65]**	0.86 [0.73; 1.00]	0.96 [0.81; 1.15]	1.21 [0.98; 1.49]	1.03 [0.85; 1.24]	1.21 [0.98; 1.50]
Just enough	**2.21 [1.92; 2.54]**	1.18 [0.99; 1.40]	1.06 [0.87; 1.29]	**1.38 [1.10; 1.74]**	**1.35 [1.11; 1.65]**	**1.68 [1.34; 2.11]**
Difficult to impossible without going into debt	**3.85 [3.12; 4.76]**	**2.24 [1.72; 2.93]**	1.04 [0.77; 1.40]	1.41 [0.97; 2.03]	**1.53 [1.15; 2.04]**	**1.51 [1.08; 2.12]**
Population size of municipality						
Rural area	**0.61 [0.53; 0.70]**	1.05 [0.86; 1.28]	**1.60 [1.30; 1.96]**	**1.46 [1.14; 1.88]**	**1.34 [1.11; 1.64]**	**1.56 [1.24; 1.97]**
<50,000 inhabitants	**0.81 [0.71; 0.93]**	1.02 [0.84; 1.24]	1.19 [0.97; 1.46]	1.14 [0.88; 1.47]	**1.24 [1.02; 1.50]**	**1.30 [1.03; 1.64]**
[50,000–200,000] inhabitants (ref)	1	1	1	1	1	1
>200,000 inhabitants	0.98 [0.85; 1.12]	1.12 [0.92; 1.37]	1.11 [0.90; 1.37]	1.27 [0.98; 1.65]	1.04 [0.85; 1.27]	1.11 [0.87; 1.42]
Paris	1.02 [0.87; 1.21]	1.15 [0.91; 1.46]	0.82 [0.63; 1.07]	1.19 [0.88; 1.62]	0.89 [0.70; 1.14]	0.89 [0.66; 1.21]
Household composition						
Living alone (ref)			1	1	1	1
With a partner and with or without children			1.12 [0.97; 1.29]	1.14 [0.93; 1.41]	**0.78 [0.69; 0.89]**	**0.64 [0.54; 0.77]**
Other compositions			**1.72 [1.41; 2.10]**	**1.81 [1.33; 2.47]**	1.05 [0.86; 1.28]	0.97 [0.73; 1.30]
Ethno-racial status						
Mainstream population (ref)	1	1	1	1	1	1
Racialized first or second-generation immigrants and DOM descendants	**0.70 [0.54; 0.90]**	**0.72 [0.53; 0.98]**	**1.96 [1.46; 2.64]**	**1.77 [1.30; 2.41]**	**1.40 [1.04; 1.89]**	**1.49 [1.11; 2.01]**
Non-racialized first or second-generation immigrants	0.95 [0.84; 1.09]	1.11 [0.93; 1.32]	0.95 [0.79; 1.14]	1.21 [0.98; 1.49]	1.05 [0.88; 1.25]	1.13 [0.92; 1.38]
Perceived health status						
Very good (ref)	1	1	1	1	1	1
Good	0.90 [0.80; 1.01]	1.13 [0.96; 1.33]	1.17 [0.95; 1.43]	1.08 [0.85; 1.37]	1.15 [0.95; 1.39]	**1.65 [1.30; 2.09]**
Fair	0.96 [0.84; 1.09]	1.17 [0.98; 1.40]	**1.82 [1.48; 2.23]**	**1.67 [1.31; 2.12]**	**1.78 [1.46; 2.16]**	**2.16 [1.70; 2.75]**
Bad to very bad	0.81 [0.66; 1.00]	**1.63 [1.28; 2.09]**	**4.66 [3.60; 6.02]**	**5.53 [4.18; 7.31]**	**2.65 [2.04; 3.45]**	**3.62 [2.70; 4.87]**
Date of questionnaire						
02/05-10/05			1	1		
11/05-17/05			**0.79 [0.69; 0.90]**	0.88 [0.74; 1.03]		
18/05-01/06			**0.39 [0.33; 0.46]**	**0.45 [0.37; 0.55]**		

Notes: N = 21.543, aOR = adjusted odd ratio, significant associations are indicated in bold.

compared to those with a high school degree (**Table 2**). A similar trend was found regarding financial situations: aOR = 1.53 [1.15; 2.04] for those in a "difficult to impossible without going into debt" compared to those in a "comfortable" perceived financial situation. Similar trends for education level and perceived financial situation were found for men. Results also showed that the racialized immigrant women were more likely to not use the Internet than women from the mainstream population (aOR = 1.40 [1.04; 1.89]) (**Table 2**). A similar result was found for men. Women living in a municipality with <50,000 inhabitants were more likely not to use the Internet than those living in a municipality with 50,000–200,000 inhabitants (aOR = 1.34 [1.11; 1.64] and aOR = 1.24 [1.02; 1.50]). Those living with a partner were less likely not to use the Internet (aOR = 0.78 [0.69; 0.89]). These results were also found for men.

Finally, it is worth noting that the relation between the perceived financial situation and not having gone out and not using the Internet, was no longer significant when considering those living alone (**Supplementary Table 4**). Furthermore, the relation between belonging to the racialized immigrant group was not associated with not having gone out, when considering those living alone.

DISCUSSION

Our findings provide contextual information on social isolation of older adults during the first national lockdown in France based on a population-based random survey. To question the so-called vulnerability of this population (27), we focused on social variations of specific living arrangements and practices, *ie.*, living alone, not having gone outside the home, and not using the Internet. In a Covid-19 context of limited in-person contacts, we found that women were more likely to live alone, not having gone out in the past week and not using the Internet. In addition to gender effects, being older, less educated, in economic precariousness, and belonging to racialized minorities were associated with living alone and not using the Internet.

Among the three indicators that we used to describe and characterize social isolation, living alone was not a consequence of the pandemic, as 97.5% of older adults stayed in their regular place of residence during lockdown (15). The pandemic, and the associated period of strict limited-contacts might have, however, put a dire strain on individuals living alone.

Our results confirmed the importance of demographic and social issues in accounting for the characteristics of older people in France. To begin with, older women lived more often alone as they got older, compared to men of the same age, which refers to the excess male mortality rate, but also to age differences between spouses (28, 29). Secondly, a larger proportion of women than men did not have any diploma and never worked, which reflects the gendered socialization and division of the workforce in France. This accounts for the stronger economic precariousness of older women whether they live alone or not.

Our analysis opened new points of discussion on gender inequalities. Perceived financial status, closely related to the income level, was associated with living alone, especially among those in poorer financial situations. Living alone, as a result of widowhood or divorce has strong financial consequences (30), especially for women. Compared to men, women, living alone or not, were also less likely to have physical contact outside the household by going out. They may be more likely to perceive the pandemic as a serious health issue and therefore to fully agree to comply with restrictive measures, such as limiting contacts outside the household (31, 32). This result may also reflect the long-term socialization process that assigns domestic responsibilities in the household to women. The relation between low education level and lower likelihood to have gone out was stronger among women than among men, possibly referring to the double effect of higher risk perception in low-educated groups and higher protective behaviors, such as limiting social contacts, of women regarding Covid-19 (33). Moreover, women were found to be less likely to use the Internet than men, especially at older ages. A similar result was found in a US study on the Internet use of older adults at the time of COVID-19 (13). This gender gap is likely to refer to a gendered socialization process as women have gained less experience and skills before retirement and therefore have higher barriers toward adopting and using innovative technology in later life (34).

In addition to gender effects, we found marked social differences. The odds of not going out were lower for those living alone, which could relate to the higher frequency of the necessity of going out to conduct necessary activities, such as running errands, when living alone. Moreover, lower levels of education were associated with not having gone out in the past week. Research is scarce on the topic, although we could hypothesize a lower health literacy level (35) and therefore an increased fear of going out. Regarding the use of the Internet, participants with lower levels of education and perceived difficult financial situation were less likely to use it, which is consistent with other studies in the UK on the use of the Internet in later life (36). The Internet was also less likely to be used by participants living in low-populated areas, which are more often lagging behind when it comes to digital infrastructures (37). Finally, the association between lower perceived financial situation and not having gone out and not using the Internet, was significant only for people who do not live alone. As people in lower economic groups are more likely to live in an intergenerational household (38), they might have relied on others to run necessary errands and use the Internet.

Findings also highlight the specific effects added from the geographic origin. Indeed, regardless of gender or social class, racialized 1st or 2nd generation immigrants lived less often alone than the mainstream population. This could be partly explained by late family reunification procedures and by the fundamental supporting role of the family in network ties of immigrants, especially that of the first generation, that lead to intergenerational cohabitation (39). When considering only those who do not live alone, our study found that they went out significantly less than the mainstream population, which could also be partly explained by the fact that their children play an essential part in helping them in their daily lives (39), possibly preventing them from going out. They also had lower levels of Internet use, a possible consequence of a later access to new

technologies than the mainstream population (40), and possible barriers to accessing digital health information (41).

This study enabled us to identify categories of older adults who cumulate strong exposure to several social isolation indicators. Women with lower incomes and level of qualification, racialized 1st or 2nd generation immigrants, and people living in rural areas were less likely to go out in the last 7 days and more likely not to use the Internet. Furthermore, a cumulative effect of gender, age and perceived financial situation was observed. Thus, older adults in a precarious financial situation, and before all older women, were more concerned by social isolation, in the sense that they accumulated the likelihood of living alone, not going out, and not using the Internet. We could assume that these groups suffered a "double lockdown" during the first wave of Covid-19 in France (18), suffering the consequences of enforced self-isolation, and the loss of services and social infrastructure.

Our analyses presented some limitations. People in retirement homes were not included in this inquiry, which prevented us from being fully representative of the French population over 65 years old. The indicators used in the study would have benefited from further development. For example, the fact that participants did not go out in the past week does not mean that they were totally deprived of physical contacts from the outside, such as visits from relatives or help from remunerated assistance. Moreover, details on how many contacts the person had when going out would have provided information on the person's social network, even though at the time of the survey, it was strictly recommended by Public Health authorities not to have contacts with older adults.

Finally, our results highlight gender and social inequalities in social isolation, women and especially older women, but also women living in low-populated areas (half of older adults in France), living alone, from low-educated or low-economic groups, or from racialized minorities being more likely cumulate isolation factors. In particular, these groups were less likely to have access to the Internet, and therefore not only to online services and health information, but also to social networks and opportunity to develop them. As women are socially considered the pillar of social contacts and family relationships, this networking capacity may be considered as crucial, in a context where collective togetherness was mainly organized through Internet-based communication networks.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Data of the study are protected under the protection of health data regulation set by the French National Commission on Informatics and Liberty (Commission Nationale de l'Informatique et des Libertés, CNIL) in line with the European regulations and the Data Protection Act. The data can be available upon reasonable request to the co-principal investigator of the study (nathalie.bajos@inserm.fr). The French law forbids us to provide free access to EPICOV data; access could however be given by the EPICOV steering committee after legal verification of the use of the data. Please, feel free to come back to us should you have any additional questions.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the CNIL (French independent administrative authority responsible for data protection), the Comité de protection des personnes (French equivalent of the Research Ethics Committee), and the Comité du Label de la statistique publique. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

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AUTHOR CONTRIBUTIONS

LS: conceptualization, software, formal analysis, and writing-original draft. CM: conceptualization and writing-review & editing. NB: conceptualization, writing-original draft, and supervision. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.840940/full#supplementary-material

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Experiences of Patient-Centered Care Among Older Community-Dwelling Australians

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Background: Older adults represent the largest consumers of health care. It is, therefore, important that they receive adequate patient-centered care to empower them to be proactive in managing their health.

Aims: This study examined the proportion of older community-dwelling individuals who report receiving patient-centered care during healthcare consultations.

Methods: A cross-sectional study was conducted with 117 clients of an Australian aged care provider. Clients completed a survey examining their perceptions of whether they received patient-centered care (11-items) from healthcare professionals.

Results: The mean number of patient-centered care items reported was 8.7 (±3.1). Speaking to the patient with respect was the item most often reported to be patient-centered (94%). Asking patients about treatment goals or expectations (62%) and how involved they would like to be in treatment (67%) were the items least reported to be patient-centered.

Conclusion: Older adults perceived some important aspects of care were not provided with a patient-centered approach. There is a need to improve healthcare providers' elicitation of older patients' care preferences, enabling patients to determine their level of involvement in their health management.

Keywords: patient care, patient-centered care, community-dwelling, older adults, aged care, perceptions, healthcare, consultation

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INTRODUCTION

Older adults represent the largest consumers of health care (1, 2). This is due to increased rates of chronic conditions among older adults, including higher rates of multi-morbidity (1). Managing one or more chronic conditions, as well as the physical effects of aging (e.g., frailty), often result in complex health care management for older adults. As the aging populations continues to grow, there is a need to ensure that the healthcare needs of older people are met and that they feel confident in their ability to manage their health.

Patient-centered care is widely accepted as a pillar of high quality medical care (3). Patient centered care places responsiveness to the patients' needs, values and preferences at the

forefront of medical care (3). It has been associated with increased medication adherence (4), decreased healthcare utilization (5), and improved health outcomes (6, 7). The importance of patient-centered care for vulnerable population groups, such as the older population and people with dementia (8), patients with multi-morbidity (6) and chronic heart failure (7) has been highlighted in the literature.

While patient-centered care is considered a key component of high-quality health care (3), the move from a paternalistic healthcare model to a more patient-centered shared care approach continues to be difficult to implement in to practice (9). The paternalistic model of healthcare positions the provider as the expert in patient care and therefore the key decision-maker (10). This model has been the traditional approach up until the last few decades and does not enable the patients' individual needs or preferences to be accounted for in the decision-making process. Studies have consistently demonstrated gaps in patient-centered care delivery across a range of chronic disease groups (11–13) and health care settings (9, 14, 15). For instance, a study examining receipt of patient-centered follow-up care for 239 patients who completed cancer treatment demonstrated only 49% received all of the examined care aspects (13). Another study conducted among more than 1,400 general practice patients demonstrated higher rates of patient-centered care, with 83% reporting receipt of all the examined care aspects (15). While these studies demonstrate variation in self-reported receipt of patient-centered care, they highlight a need for improvement in this area.

Internationally, policies and initiatives are being developed to help older adults remain community-dwelling for as long as possible (16). High quality healthcare, which includes a patient-centered approach, is an integral part to ensuring older adults are able to manage their health at home. Nevertheless, there are several challenges to implementing patient-centered care for older community-dwelling adults. Negative attitudes, ageist stereotypes, prejudice and discrimination toward older adults in the healthcare system have been reported (2). These views may, in turn, impact healthcare providers' preconceptions about older adults' desires and abilities to be involved in decision making for their care. There may also be difficulties in engaging older adults in person-centered care processes, particularly for those with cognitive impairment (17), hearing loss and communication difficulties (18). Limited research has explored patient-centered care among community-dwelling older adults (19–21). To the authors' knowledge, no quantitative descriptive studies have been conducted to explore community-dwelling older adults' perceptions of patient-centered care during interactions with a healthcare professional. Increased understanding of patient-centered care can better inform policies and initiatives to support older adults to remain community-dwelling.

AIMS

To examine the proportion of older community-dwelling individuals who report receiving patient-centered care during consultations with healthcare professionals.

METHODS

Design and Setting

This cross-sectional descriptive survey study was conducted with clients receiving care from one not-for-profit, Australian government-funded aged care provider. In Australia, community-based aged care providers deliver services such as personal care, domestic assistance and support with medications. The participating aged care provider delivers services to over 8,000 older Australians living in the community in rural, regional, and remote areas. Participants for this study were recruited from three Australian states. Ethics approval was granted by the University of Newcastle Human Research Ethics Committee. Participants provided written informed consent.

Sample

Eligible clients were those who were: receiving home care services from the participating aged care provider; considered by their Case Manager to be physically and cognitively capable of providing informed consent; and able to complete an English language survey. Clients who were too ill to complete the survey, overseas, were recently bereaved, or were on a waiting list for a permanent place in a residential aged care facility were ineligible.

Participant Recruitment

Case Managers ($n = 30$) working with the Aged Care Provider performed recruitment and data collection for the study. The Case Managers role involves providing assessments, developing care plans, managing budgets and liaising with health professionals on behalf of their clients. Case Managers were identified *via* staff lists and invited *via* email to participate. They participated in a 1-h training session that detailed the study and the survey's administration that was led by a member of the research team (BH). All invited Case Managers consented to undertaking the study. Potentially eligible clients of participating Case Managers were identified by a staff member at the aged care provider. Case Managers further reviewed the client list to ensure the included patients were considered cognitively able and were not on a waiting list for an aged care facility. Of the remaining sample, a random computer generator was used to select 400 clients to participate in the study. Identified clients were mailed a recruitment package by the aged care provider, including an information statement and consent form. Case Managers followed up with the identified clients either by telephone or at the next scheduled appointment to confirm the client's eligibility and obtain informed consent.

Data Collection

During a scheduled home visit, Case Managers administered a web-based survey with consenting clients *via* a computer tablet, with pen-and-paper surveys available in case of technical difficulties. To reduce participant burden, the survey questions were administered across two sessions conducted 3 months apart.

Measures

The data reported in this study were collected as part of a larger research study. Only measures pertaining to the current research question are provided here.

Demographic Variables

In survey 1, patients self-reported their age, gender, highest level of education, Aboriginal or Torres Strait Islander status, marital status, living arrangements, private health insurance status, and home postcode.

Previous Experience With Healthcare Professionals

In survey 2, participants were asked to self-report their experiences of receiving patient-centered care in general during appointments with healthcare professionals (seven items), and when discussing possible treatments with their healthcare professionals (four items). The items were developed by the research team, following a review of the literature on principles of patient-centered care for older adults (3, 18, 22) and refined in consultation with consumers. Participants were asked to respond using a four-point response scale ("Yes, and I wanted this;" "Yes, but I didn't want this;" "No, but I wanted this;" "No, but I didn't want this"). This response scale allowed for an examination of whether or not care received was consistent with clients' preferences. The reading age for the survey was under an 8th grade level according the Flesch Kincaid Reading Ease test and items were piloted with five participants prior to data collection.

TABLE 1 | Participant demographics ($n = 101$).

Characteristic	Categories	*N* (%)
Age	Mean (SD)	78.0 (8.5)
Gender	Male	34 (33.7)
	Female	66 (65.3)
	Other	1 (1.0)
Education	High School or below	73 (72.3)
	Trade or vocational education	21 (20.8)
	University or postgraduate degree	7 (6.9)
Aboriginal or Torres Strait Islander	Yes, Aboriginal	4 (4.0)
Marital status	Married or living with partner	33 (32.7)
	Divorced or separated	15 (14.9)
	Widowed	43 (42.6)
	Never married	10 (9.9)
Living arrangements	Lives alone	59 (58.4)
Private health insurance	Yes	37 (36.6)
Remoteness	Inner/Outer Regional	73 (74.5)
	Major Cities	25 (25.5)

ANALYSIS

Counts and percentages of non-missing observations for categorical variables and mean with standard deviation (SD) for continuous variables were calculated. A "received patient-centered care" variable was created and was defined as receiving care consistent with preferences (i.e., Yes, and I wanted this or No, but I didn't want this). A "did not receive patient-centered care" variable was created and was defined as receiving care inconsistent with preferences (i.e., Yes, but I didn't want this or No, but I wanted this). The number of "received patient-centered" items was calculated for each participant, with a maximum score of 11. Postcode was used to categorize remoteness using the Accessibility/Remoteness Index of Australia (ARIA). Statistical analyses were undertaken using R version 4.0.3 (2020-10-10; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Of the 400 randomly selected clients, 357 were approached to participate in the study and 295 were eligible. Consent was provided by 158 participants (54% consent rate) and 117 participants were retained at the 3-month follow-up (74% retention rate) and were included in the current analysis. Sixteen participants had missing demographic data (14%). Most participants were female (65.3%), with an average age of 78 years (SD = ±8.5) and had a high school education or below (72.3%; see **Table 1** for full characteristics).

Table 2 presents the participant responses for the 11 patient-centered care items. Speaking to the patient with respect was the aspect of care most commonly reported to be patient-centered (94%, $n = 108$). Items with the lowest proportion of participants indicating that they received patient-centered care included whether health care professionals generally: asked the patient about goals or expectations of treatment (61.7%, $n = 71$); asked how involved the patient would like to be in treatment (67%, $n = 77$); encouraged the patient to ask questions (69%, $n = 80$); and helped to weigh up the pros and cons of different treatment options (75%, $n = 87$). The majority of these responses consisted of patients reporting, "No, but I wanted this" (21–37%). The total patient-centered care score was calculated for 106 participants who answered all 11 items of care. Of these participants, 42% ($n = 44$) received all 11 care aspects in agreement with their wishes, while 3.8% ($n = 4$) did not receive any of the care items in agreement with their wishes. The mean number of items for which participants perceived receiving patient-centered care was 8.7 (±3.1) out of 11.

DISCUSSION

This study sought to explore of the perceptions of older community dwelling adults regarding whether they had received patient-centered care from their care providers. The majority of older adults perceived that they had received care in alignment with their preferences across a range of care aspects. Nevertheless, the findings do highlight that a substantial proportion of older people perceive that some aspects of care are not delivered in alignment with their preferences. Only, 42% of participants reported receiving all 11 aspects of care in alignment with their wishes. This finding aligns with previous research examining patient-centered care aspects in oncology (13).

The only care aspect where patients reported more than 90% patient-centered care was for healthcare professionals speaking to the patient with respect. However, even for this widely endorsed care item, six patients (5%) indicated they received this but did not want it. Although on face value this seems counter intuitive, it may be that a more paternalistic healthcare approach

TABLE 2 | Self-reported patient-centered care for community-dwelling older persons ($N = 117$).

	Patient-centered		Not patient-centered	
In general, during your appointments with health care professional do they:	**Yes and I wanted this**	**No, but I didn't want this**	**Yes, but I didn't want this**	**No, but I wanted this**
Listen to what you have to say?	91 (78%)	3 (3%)	7 (6%)	15 (13%)
Encourage you to ask them questions?	71 (61%)	9 (8%)	7 (7%)	29 (25%)
Give you enough time to explain your health concerns?	87 (75%)	1 (1%)	6 (5%)	22 (19%)
Do whatever they can to address your health concerns?	93 (82%)	2 (2%)	5 (4%)	13 (11%)
Explain things in a way you can understand?	94 (81%)	2 (2%)	5 (4%)	15 (13%)
Mainly speak to you, rather than the person/s accompanying you (e.g., Family member or friend)	86 (78%)	4 (4%)	6 (5%)	15 (14%)
Speak to you with respect	108 (94%)	0 (0%)	6 (5%)	1 (1%)
When discussing treatments do your health care professionals:				
Ask you about your goals or expectations of treatment?	60 (52%)	11 (10%)	2 (2%)	42 (37%)
Ask you how involved you would like to be in making decisions about treatment?	67 (58%)	10 (9%)	5 (4%)	33 (29%)
Give you sufficient information about each treatment option?	87 (75%)	2 (2%)	6 (5%)	21 (18%)
Help you weigh up the pros and cons of different treatment options?	83 (72%)	4 (3%)	5 (4%)	24 (21%)

N varied from 111 to 116 due to missing data.

is preferred by some patients. This may also be the case for the small proportion of participants who indicated they did not want to be listened to. These patients may also require assistance in increasing their health literacy to inform their expectations surrounding patient-doctor interactions. These findings highlight the need for health professional to elicit older patients' care preferences to enable patients to be engaged in their health management at a level that the patient wants.

Being asked about treatment goals and involvement in treatment decision-making were the aspects of care least frequently perceived as being patient-centered, with 37 and 29% (respectively) of community-dwelling older adults indicating that they did not receive these aspects, despite wanting them. This finding aligns with previous research suggesting a lack of patient engagement in treatment decision-making, particularly for older adults (9, 23). Healthcare providers have reported a perception that older adults prefer to defer their decision-making to their provider (24), which has been previously suggested in literature that could now be considered outdated (25). However, the current study indicates a strong preference for being asked about involvement in treatment decision-making by older adults, with 87% indicating they wanted this. There is a clear need to increase older patient's involvement in decision-making by healthcare professionals.

A quarter of the older adults in this study reported not being encouraged to ask questions. Encouraging patients to ask questions enables the provider to gain an understanding of the patients' health literacy and increase the probability for information retention (26). It may also reduce the likelihood of medical errors, such as medication non-adherence, and the need for follow-up calls or consultations. A previous systematic review demonstrated that interventions to increase questions by patients had small benefits and indicated a need for more extensive and targeted training for providers in addressing patient concerns (27). The findings of this study support the need for providers to consider their role in patients' asking questions and that older adults wish to have greater encouragement to do so.

LIMITATIONS

The findings of this study should be considered in light of its limitations. The small sample size may impact on the representativeness of the study findings. While the survey was examined for general acceptability, it has not undergone rigorous psychometrics testing to determine the validity and reliability of the administered items. Further, no data was collected regarding the nature of the healthcare appointments older adults were attending, so it is not clear from the current study the healthcare settings for which these findings are applicable. However, the general nature of study questions were intended to provide an overall picture of healthcare interactions for community-dwelling older adults rather than targeting a specific interaction. It is also important to consider the participants' risk of bias in the current study. In the healthcare system, patients may feel an unequal power balance in the patient-provider relationship and, in turn, report higher levels of satisfaction with care. Understanding the health literacy of patients in this study could have further informed whether patients felt sufficiently knowledgeable on the health care they are entitled to receive.

IMPLICATIONS AND FUTURE RESEARCH

The findings from this study indicate gaps in patient-centered care for community-dwelling older adults. The majority of the gap was attributed to patients not receiving an aspect of care that they wanted. This may indicate that healthcare professionals are adopting a paternalistic approach for some aspects of care. Future research should examine strategies

that increase healthcare provider delivery of patient-centered care, particularly in aspects such as treatment decision making and goal setting. Research should also investigate the health literacy of patients reporting patient-centered care to inform strategies to empower older people to stipulate their expectations regarding patient-centered care. Consideration of population strategies to address healthcare culture, health literacy and health behavior represent a significant area for future consideration in working toward a true patient-centered care model in healthcare.

CONCLUSION

Older people are the most frequent users of the health care system and experience a high burden of disease. This study indicated that important aspects of care are not being provided with a patient-centered approach by health care professionals. There is a need to improve healthcare providers' elicitation of older patients' preferences for care to ensure patients are able to be proactive in managing their health and hence increase the likelihood of their healthcare needs being met.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethics approval was granted by the University of Newcastle Human Research Ethics Committee (H-2017-0356). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RS-F designed the study. BH undertook the study. MC completed the statistical analysis. All authors contributed to manuscript writing. All authors contributed to the article and approved the submitted version.

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Technology and Older Women: Considerations Regarding Their Use and Misuse

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Health and wellbeing are inextricably linked to an individual's capacity for continued meaningful engagement and connection with the world around them. Technological innovations designed to maximize the quality of life for older women range from sophisticated bio-medical interventions to ordinary day-to-day communication devices. Many innovations can ensure a higher quality of life for older women and support and care as required.

In this article, we consider: (1) The range of appropriate technologies currently available for older women, their families and communities. (2) The way technology contributes to the maintenance of optimum physical health and wellbeing for older women. (3) The significant challenges and considerations associated with the incorporation of technologies into their daily lives.

Keywords: technologies, older women, challenges, ethics, dignity, ageism, self-determination, privacy

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INTRODUCTION

Estimates are that the world's population of people aged 60 years and over will increase to nearly 1.5 billion by 2050 (1). As of June 2020, more than half of older Australians were aged 65–74 years (56%), 3 in 10 were aged 75–84 years (31%) and around 1 in 8 were aged 85 years and over (13%) (2). The increase in longevity globally is reflected in Australian population trends with women currently outliving their male counterparts by up to 4.1 years in 2018–2020 (2, 3).

Living a long time can be a challenge for any individual, especially those who strive to achieve a healthy older age. Thus, it is useful to draw upon concepts of successful or healthy aging which specifically acknowledges aging as a dynamic process across the life span (4). Increasingly, older Australian women face the challenge of divorce, separation or widowhood. Many women choose to continue living in their own homes and outside of institutional care arrangements for as long as is possible, despite the physical, cognitive or mental health changes that may accompany growing older (5).

CONTEXT

In line with both international and Australian policies to provide support and care for individuals to "age in place" (6–8), significant numbers of older women continue to live independently (5, 9).

The weeks and months of "lockdown" isolation and separation during the global COVID-19 pandemic were, for many older women, confronting, particularly for individuals living alone. It was a time of disruption of supportive and reciprocal relationships with family, community, and peers (10). For some older women, communication devices and social media platforms may have facilitated

a certain level of connection and positive exchanges with family, friends, informal networks, and activities (11, 12). In the short term, technology might have eased the sense of dislocation and loneliness that can disrupt a person's sense of inclusion, their psychosocial health and wellbeing (13).

ENABLING AND ASSISTIVE TECHNOLOGIES

Daly et al. (14) describe technology in the broadest sense, as encompassing devices which "range from simple tools such as glasses for weak eyesight, to large technological systems that govern our hospitals and health care systems" (pxxi). "Enabling and assistive technologies" describe the range of devices and tools that promote and assist with the maintenance of optimum health and wellbeing and are pertinent at an individual, family, community and societal level regardless of gender, age or health status (15). These range from voice activated devices and home systems (e.g., Automatic lighting, stove-top monitors), mobile telephones, computers (e.g., Screen readers and speech and voice recognition), email, social media to face-to-face communication platforms, including telehealth (16). These applications can contribute to the overall social connectedness and thus quality of life, of older women, especially those who live alone or with minimal support (13).

We scanned the peer-review literature to review appropriate models that comprehensively illustrate the application of technology in a wide range of domains. This search indicated that there is a dearth of information presenting gender specific models of technology and in particular relating to older women see **Table 1**. These innovative medical technologies, that have a critical life-saving role include personalized health monitoring devices, robotics and mechanical protheses, especially in the surging field of regenerative medicine (19). Technologies for personal safety and peace of mind for both individuals and their family members, extend to the installation of home and personal devices that detect and alert and vehicle safety devices. These may be related to falls prevention, smoke alarms and temperature controls, wandering management and door locking systems and vehicle safety devices such as automatic brake engagement and lane detection technology (20). Medication compliance technologies and cognition assessment tool, video monitoring, and mobile phones are not only used for communicating but for tracking and locating individuals.

As can be seen from **Table 1**, increasingly technological enhancements have a significant role in maximizing the mobility, safety and independence of older women, especially when moving out and about in the community (20).

CHALLENGES

Community acceptance and uptake of innovative technologies might not be unproblematic and without criticism, particularly from those individuals and communities who hold specific philosophical, cultural or religious beliefs. Consideration must also be given to the confidence or willingness of older women and their carers to engage with new technological developments (8, 21, 22). Furthermore, women living beyond urban areas face the challenges associated with limited access to technology either through issues of affordability, unreliable connections, or in some instances especially in regional and rural areas, lack of internet services altogether.

ILLUSTRATIVE VIGNETTES

The following vignettes illustrate the role of ever evolving technology in optimizing health, encouraging independent living and promoting a sense of autonomy and control for older women who continue to "age in place" at home (7, 8).

Scenario 1 – "a Visit to the GP"

Edie is aged 86 years and lives alone in her own home. Following heart surgery, she attends a post-operative appointment with her General Practitioner (GP). Edie is also diabetic. Her family are concerned about her ability to drive and live alone. Prior to the consultation, and with Edie's consent, the GP's practice manager downloaded and collated electronically all of Edie's tests and interventions, current medications, ECG and EEG results via e-record sharing between laboratories, pharmacy and GP. Alford and Johnston (19) remind us that telehealth relies on health services that have access to reliable electronic patient record systems with permission to share patient records across the health service network. Edie's case illustrates technological innovations that assisted her GP to access the Australian national e-health networking systems (My HealthRecord) via a National Highspeed Broadband Network (NBN). The GP recommends that Edie: consults an audiologist for fitting of a digital hearing aid with state-of-art technology such as speech enhancement and directional microphone to improve her declining hearing due to presbycusis; considers using a personal button necklace security alarm, a video camera system at home as well as a blood pressure monitoring system including a wrist-watch to alert to irregular breathing or pulse rates, and vehicle mats to reassure Edie and her family about her driving safety.

Scenario 2 – "Safe and Sound at Home"

Rose is aged 97 years, recipient of a part government Pension and despite changes of aging, lives alone in her own home with limited help. "Meals on wheels" delivers food once a week, supplemented by supermarket deliveries and food prepared by family. Rose's home has access to NBN and she is "iPad savvy," which enables online shopping once the refrigerator system has alerted her to the need for replenishment. Keeping in regular contact with family is via email, text and Skype. Technologies enable her TV to be set at a predetermined volume, and food be heated safely on a pre-set stove. Rose feels quite safe and secure in her home where she spends time in her small garden which is fitted with an automatic watering system. Rose also enjoys walking and meeting up with neighbors (using GPS).

Technologies have assisted Rose in retaining her sense of security, independence and autonomy. Other innovations include automated home security, electronic warning devices that monitor and shut down heating and cooking equipment

TABLE 1 | Selected technological frameworks relevant to maintaining the health and wellbeing of older Women's lives.

	Alwan et al. (17); Resnick et al. (18)	**Roco et al. (26)**	**Coughlin et al. (20)**
Safety	• Fall detection and prevention • Stove use detectors • Smoke/temperature detectors • Door locks • Wander management systems		"Monitor" - monitoring of health and safety using intelligent devices, appliances, robotics internet (e.g., Status of the vehicle driver) enabled services and predictive behavior models. e.g., Corrected vehicle positioning to prevent off-road excursions
Health and wellbeing	• Telemedicine and tele-health technologies, (e.g., Ambulatory and wearable monitors, video phones and two-way video stations) • Medication compliance • Cognitive assessment (stimulation and entertainment systems and assessment and reminder systems)	• Self-delivered nano-medical intervention • Self-monitoring of physiological wellbeing and dysfunction using nano implant devices (e.g., metabolic and anatomical monitoring to track energy balance) • Nanobiotechnologies for adjusting organ performance and to aid localized drug or metabolite delivery to artificial organs	"Manage" – vehicle software including adaptive cruise control (ACC), blind-spot detection, parking assistance, rumble strips, lane markings, lane departure prevention, and smart airbags
Social connectedness/ communication	• Senior friendly email and web portal systems • Video phones and two way video conferencing	• Multi modalities for living and hearing impaired (e.g., different modes of communication including talking environments and 3-D touch screens to enable access to the Internet • Information systems designed to present medical data in ways intelligible to laypersons	• "Motivate" – creating a more comprehensive and cohesive connection between the driver-vehicle unit and developing IntelliDrive and intelligent transportation system (ITS) applications. • Information supports the display of important feedback to the driver and can trigger appropriate alerting or calming features aimed at refreshing and reducing stress, and thus improving safety • Feedback systems that communicate without startling the driver
Mobility	Mobility aids traditionally used to enhance balance and/or help in weight support adapted and enhanced to allow seniors to navigate their environments safely	• Nanobiotechnology (e.g., improved joint replacement) • Driving: computers and sensors driven by nanotechnology combined with on-board artificial intelligence helping the driver plan routes and avoid hazards • Nanobiotechnology: on-board biosensors to monitor driver stress and physiological condition, to be fed back to the car's computer • Implanted devices to improve cognizance and keep driver alert	Driving (e.g., improved accessibility through design and information services)

when danger is detected, and automatic climate control. In addition, Rose communicates with family and friends with local government sponsored tele and phone links and high-speed internet systems. Importantly, both Edie and Rose were assured that protecting their privacy was of tantamount importance regardless of the array of technological devices introduced into their homes.

In summary, each vignette has illustrated those technological innovations and devices that can enhance an older woman's health and wellbeing. This is particularly so through active participation in family, community and social life. The two examples have also included examples of technologies and devices that can assist an older woman to achieve a sense of autonomy and control over their own life, despite their changing health or physical capacities.

Figure 1 is an illustration of the overarching and inextricably linked key elements essential to any older woman's health and wellbeing. While they are distinct one from the other, they are also inextricably interrelated one to the other with one impacting the other in different ways and at different times in a woman's life span.

DISCUSSION

The universal uptake of any technological innovation, particularly those which relate to health must be tempered

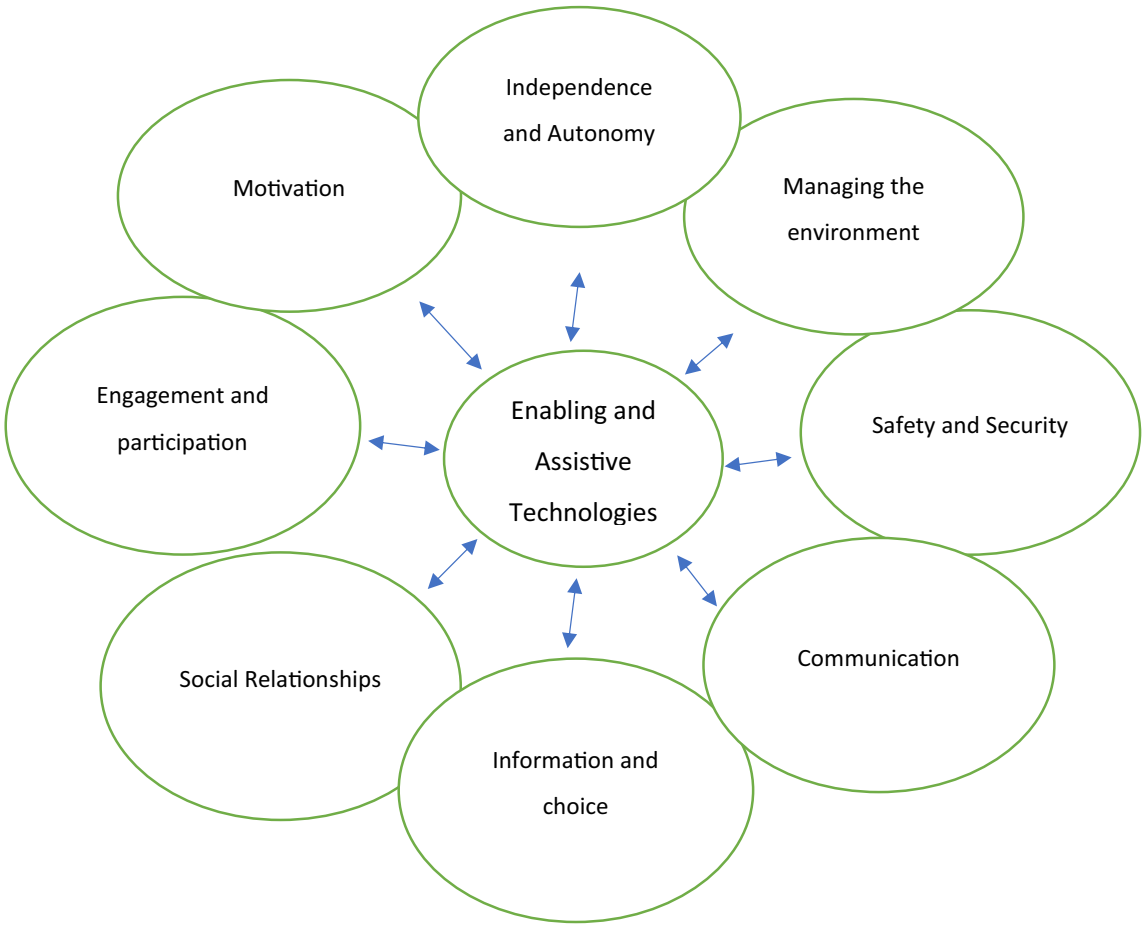

FIGURE 1 | Technology in the promotion of health and wellbeing in older women.

with ongoing critical analysis and evaluation of the proposed health benefits as well as the potential for negative consequences or risks.

Ethical Considerations

Any discussion regarding the role of technologies should consider whether there may be a conflict between prevailing community standards and moral rules, or principles related to their use. We assert that any discussions about the potential role of technology in the lives of older women must reflect contemporary ethical standards. In addition, ethical considerations should not only apply to clinical, medical or social settings, but equally transcend into the policy, planning and practice arenas (23). Charlesworth (24) suggests that the issues and problems related to medical ethics or bioethics are both diffuse and complex.

Dignity

The right of any individual for self-determination and choice underpins the idea of the protection of human dignity and the respect of older people is central to the WHO-UN policy framework of Healthy Aging (25). Contemporary medical diagnosis and treatment is aided by the latest laboratory testing of human functioning, along with a range of readily available and relatively affordable physical interventions and life-changing procedures such as hip and knee replacements or repair and replacement of heart vessels and valves. The value of these technological interventions, however, must always be measured against individual circumstances and wishes. Questions must be raised about whether the outcomes of any procedures are necessarily positive for the dignity of the individual (23). By way of example, the use of a hearing aid may be perceived by some individuals as an indicator of aging and accompanying loss of dignity, no matter how advanced the technology.

The convergence of technologies not only brings the possibility to improve every dimension of human life, but also a warning about the problematic nature of striving to improve human performance or an unreasonable effort to extend life (26). For example, it is possible that an older woman who has outlived her partner may not wish to have the latest technology such as a pacemaker to improve or extend her quality of life. Such procedures alone cannot resolve her experience of loneliness, loss and grief.

Ageism

It is the case that ageist attitudes continue to abound (25, 27, 28). Older women and men are very often viewed as vulnerable, dependent and a potential burden on community resources without the capacity to represent themselves in specific negotiations, particularly around management of their health and wellbeing. The consequence of stereotyping older people and their ability to make important decisions has the potential for "technological paternalism where the healthcare system acts to control people in their perceived best interests, perhaps without their consent" [(15), p. 38] and highlights further questions about the damage to individuals with the presumption of incompetence and decrepitude. Unfortunately, there is still a common and incorrect view that as women transition to older age they are automatically dependent and passive recipients of services and care (25, 29).

Of central concern to many older women is being able to maintain their relevance, influence and inclusion as active participants in their own lives. This they indicate, can only be achieved through proactive engagement in making informed choices about the direction of their own lives (29, 30).

Self-Determination and Autonomy

Moody (31) suggests that "few principles of contemporary bioethics are as honored as the ideal of autonomy" (p. 134). Decisions about the choice and uptake of aids and devices that enable an individual woman to continue living in her own home can be complex, especially since the individual must be involved in a process of "negotiated consent" (p. 136). As much as is practicable, older women must be provided with relevant and up to date information so that they are involved in all decision-making process about whether the proposed technologies are appropriate for them. The inclusion of older women in this process is also central to ensuring that the uptake is successful, thus, maintaining a sense of self determination and autonomy in the face of increasing reliance on assistance from others often presents a challenge, especially so for older women.

Privacy

All individuals value the concept of privacy and older women are no exception. A fine balance however must be struck between privacy, personal risk, and the integration within a home setting of a range of monitoring technologies. Unfortunately, home surveillance devices can also be intrusive and compromise older women's privacy and sense of self-determination. In addition, regardless of the good intent, we must be wary of how, even with consent, these devices can lead to the invasion of an individual's home, their personal space (13, 31). Consideration must be given to whether the social and ethical impacts of enabling technologies reflect contemporary community standards and expectations regarding the protection of an individual's privacy (32). Consequently, it is vital to consider how the access to and control of medical and health information might be compromised especially, within the context of the development of sophisticated technology and information sharing systems across the health and service system.

CONCLUSION

It is only by thinking about technologies as constantly changing and evolving entities that we can vigorously and critically examine their increasing power and potential to enhance the quality of life of women as they enter their older years. An array of technologies will enable women to participate in the social world around them, and as best as possible to maximize the independent and autonomous lifestyle of their choice. We therefore envisage that new and emerging technologies will continue to play a key role in ensuring the provision of high-quality support and care as deemed appropriate by older women themselves. It is important to ask ourselves what are the ultimate goals when introducing technology into an older woman's life?

We emphasize that the promotion of any technologies into daily life must ensure that there is as little compromise as is possible in an individual's needs or wishes for privacy regardless of their gender, language, socio-economic status, culture, geographic region, and of course age.

There is no doubt that technologies play a vital role in the enhancement of the psycho-social health, and well-being of older women right now and in the future. We must query: What kind of technological advancement will there be in the future as we grow old? Finally, we question whether the increased dependence on technological devices in the place of personal interaction will lead to a greater proportion of older women without regular human contact and we ask ourselves what are the implications if we follow this precarious path?

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

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

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Understanding the COVID-19 Pandemic in Nursing Homes (Aragón, Spain): Sociodemographic and Clinical Factors Associated With Hospitalization and Mortality

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Old people residing in nursing homes have been a vulnerable group to the coronavirus disease 2019 (COVID-19) pandemic, with high rates of infection and death. Our objective was to describe the profile of institutionalized patients with a confirmed COVID-19 infection and the socioeconomic and morbidity factors associated with hospitalization and death. We conducted a retrospective cohort study including data from subjects aged 65 years or older residing in a nursing home with a confirmed COVID-19 infection from March 2020 to March 2021 (4,632 individuals) in Aragón (Spain). We analyzed their sociodemographic and clinical profiles and factors related to hospitalization and mortality at 7, 30, and 90 days of COVID-19 diagnosis using logistic regression analyses. We found that the risk of hospitalization and mortality varied according to sociodemographic and morbidity profile. There were inequalities in hospitalization by socioeconomic status and gender. Patients with low contributory pensions and women had a lower risk of hospitalization. Diabetes mellitus, heart failure, and chronic kidney disease were associated with a higher risk of hospitalization. On the contrary, people with dementia showed the highest risk of mortality with no hospitalization. Patient-specific factors must be considered to develop equitable and effective measures in nursing homes to be prepared for future health threats.

Keywords: COVID-19, inequalities, hospitalization, mortality, nursing home

INTRODUCTION

In March 2020, the coronavirus disease 2019 (COVID-19) outbreak in China was declared a global pandemic (1). From that day, and according to the World Health Organization COVID-19 Dashboard (2), by January 2022, more than 315 million confirmed cases have been diagnosed worldwide. In Spain, almost 8 million cases have been declared and more than 90,000 people have died (3) in an unprecedented public health crisis.

One of the facts that the pandemic has brought to light is its greater impact on vulnerable groups. Inequalities have been observed in the risk of COVID-19 disease, with a higher risk of infection in groups with worse socioeconomic conditions. COVID-19 infection has shown a socioeconomic gradient, which has been linked to the type of job, the existence of lower health literacy or higher exposure rates, among others (4–7). This vulnerability has also been associated with the area of residence, due to household crowding and the existence of chronic stressors (8, 9), and both, individual and area vulnerability, mutually potentiate each other (10). These differences are not only limited to the risk of infection but also to the diagnosis of the disease and the medical attention received by these patients. Access to diagnostic tests (11) and to healthcare attention (12) seems to be worse for those people living in deprived areas, even in the universal healthcare systems. This may result in poorer care for the most vulnerable groups, amplifying existing inequalities.

The elderly population has been the most affected by the COVID-19 pandemic, especially in terms of mortality. Among the elderly, institutionalized people residing in nursing homes have been a particularly vulnerable group, showing high rates of infection and death in the 1 month of the pandemic and before the appearance of vaccines (13). The greatest impact of the COVID-19 pandemic on this group has been associated with both physical and psychological vulnerability, as well as with the living conditions related to the fact of residing in an institution (14, 15). In Spain, this fact has been particularly serious, as it is an aging country, with an aging index in 2020 of 125.75% (125 people aged over 64 years for every 100 aged under 16 years) (16). In addition, more than 300,000 elderly people live in nursing homes (17), where the effect of the pandemic was devastating: it is estimated that, only during the first wave, around 20,000 institutionalized people died, and the mortality rate for elderly people living in long-term care (LTC) facilities was 6% (18). These high mortality rates have been associated with high levels of community transmission and deficient nursing homes-related policy responses (19).

When analyzing COVID-19 mortality in nursing homes, factors, such as the patient's complex chronic conditions, the location, or the capacity of the center, have been analyzed (20, 21). Nonetheless, other aspects, such as the determinants of hospital admission or the existence of socioeconomic inequalities, are still unknown. Therefore, gaining a broad view of the factors involved in mortality and the healthcare received by these patients is an unavoidable task to prevent its recurrence. To this end, the objective of this study was to describe the profile of institutionalized patients with a confirmed COVID-19 infection in Aragón (Spain) and the socioeconomic and morbidity factors associated with hospitalization and death.

MATERIALS AND METHODS

Design, Information Sources, and Study Population

Retrospective cohort study data were obtained from the Aragón-COVID-19 cohort. This is a health data collection of all individuals undergoing COVID-19 testing in the Spanish region of Aragón, an Autonomous Community in the northeastern Spain with a high aging rate 21.7% of people over 64 years of age (22).

The Aragón-COVID-19 cohort includes information gathered from administrative health data sources as well as electronic health records of the Aragón Health Service. The people included in the cohort were tested either when they presented symptoms compatible with COVID-19 or when they had close contact with a confirmed subject. All COVID-19 cases were confirmed by polymerase chain reaction (PCR) or COVID antigen testing. Individuals in the cohort were included from 9, March, 2020, the first epidemiological week with COVID-19 cases reported in Aragón, to 14, March, 2021, the end of the fourth wave in Aragón. On this date, 103,281 people were COVID-19 confirmed cases.

For this study, we selected subjects aged 65 years or older residing in a nursing home with a confirmed COVID-19 infection. This information was obtained from the Aragón health service user database (BDU) (**Figure 1**).

The research protocol of this study was approved by The Clinical Research Ethics Committee of Aragón (CEICA) (PI20/184).

Variables of the Study

We considered the sociodemographic and clinical information of all the institutionalized individuals in the Aragón-COVID-19 cohort with a COVID-19 confirmed infection.

Regarding sociodemographic characteristics, we considered sex, age (65–79 years; ≥80 years of age), and socioeconomic level. The socioeconomic level was calculated on the basis of pharmacy copayment levels and social security benefits received, according to the type of user of the Aragón health service. From the combination of these two variables, 5 mutually exclusive categories were obtained for institutionalized patients as follows: individuals with a contributory pension < 18,000€ per year; individuals with a contributory pension ≥ 18,000€ per year; individuals affiliated with the mutual insurance system for civil servants; individuals receiving free medicines (people with minimum integration income or who no longer receive the unemployment allowance); and other situations not previously considered.

Information related to the patient's clinical status was obtained from the morbidity-adjusted groups (GMA) (23). This source of information considers all medical diagnoses available in primary healthcare and hospitalization (hospital discharge records (CMBD) and emergency service). We considered GMA information from January 2020 in order to know the health status prior to the COVID-19 diagnosis of the individuals. The variables analyzed from GMA were weight complexity (obtained from the aggregation of the patient's different diagnoses); number of chronic morbidities; and existence of a medical diagnosis of diabetes mellitus, obesity, hypertension, stroke, ischemic heart disease, heart failure, chronic obstructive pulmonary disease (COPD), chronic kidney disease, depression, or dementia. These medical diagnoses were selected due to their high prevalence in this group of age.

The outcomes evaluated in patients with a COVID-19 confirmed infection were hospitalization and mortality by all causes. Only hospitalizations occurring within 14 days before

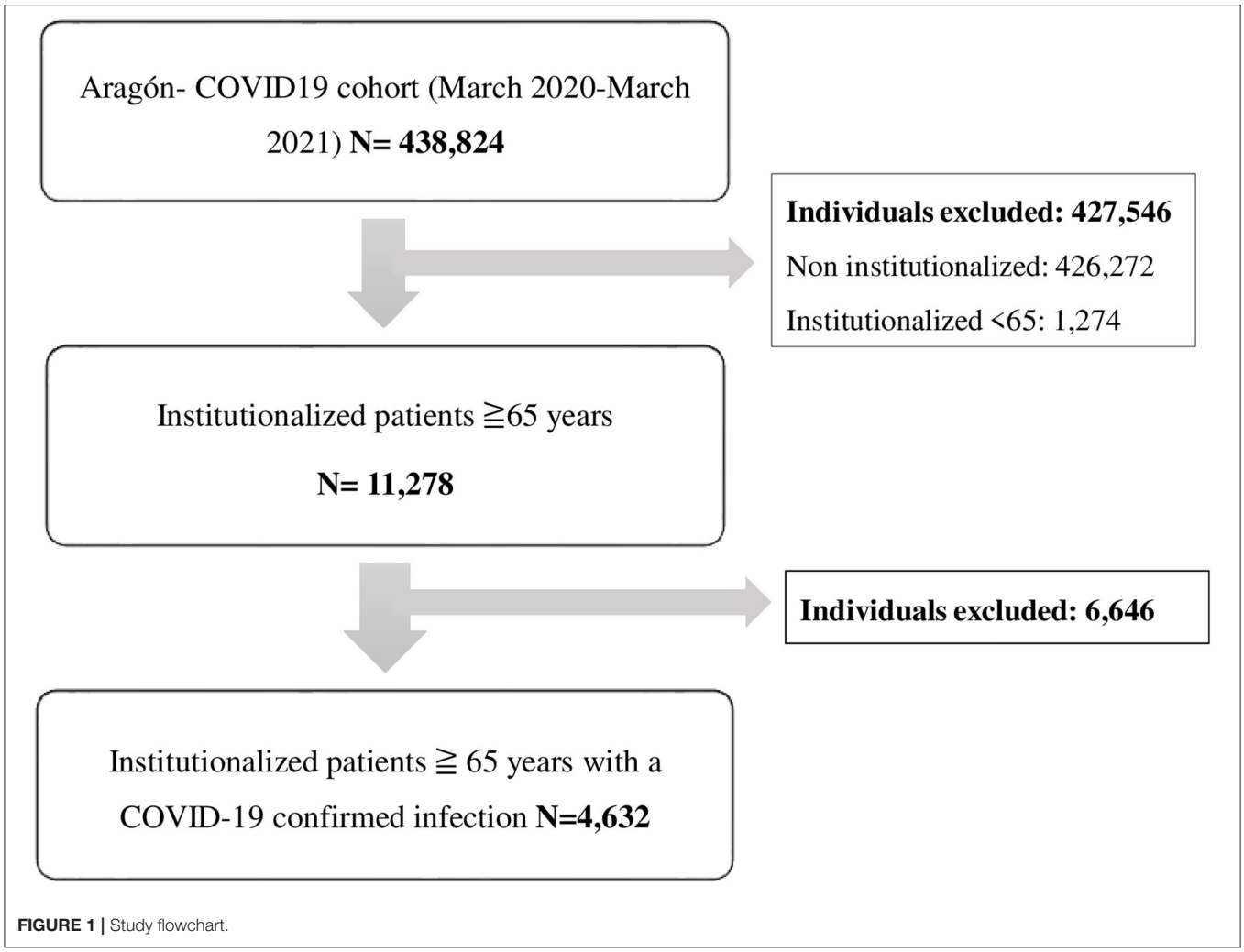

FIGURE 1 | Study flowchart.

and after COVID-19 diagnosis were considered in the study. In addition, since the cause of death was not available, we considered mortality from 3 days before diagnosis (as some patients died before the results of the test were obtained) to 90 days after. Both variables were obtained from the basic minimum dataset of hospital discharge (CMBDH) of Aragón.

Analyses

First, we described the sociodemographic and clinical characteristics of all the individuals, over 64 years of age, living in a nursing home in Aragón with a confirmed diagnosis of COVID-19. In addition, a description of the sociodemographic and clinical profiles of the patients according to their hospitalization and mortality was conducted. To evaluate possible differences in the factors associated with mortality, this outcome was categorized into three different categories, namely, mortality at 7, 30, and 90 days after diagnosis. Categorical variables were described by percentages. Weight complexity and number of diagnoses had a non-normal distribution, so median and interquartile ranges were used to describe these variables. Statistical differences between categories were assessed using chi-square and Mann–Whitney *U*–tests.

To find out which sociodemographic and clinical characteristics were associated with the risk of hospitalization and death in institutionalized patients, univariate and multivariate logistic regression analyses were conducted. We performed explanatory logistic regression models. These models were adjusted by those available variables that were associated with hospitalization and death in the literature.

All analyses were performed using the R Statistical Software (the R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

We identified 4,632 people aged 65 years or older residing in a nursing home with a COVID-19 confirmed infection in Aragón from March 2020 to March 2021. The description of the subjects included in the study according to their socioeconomic and clinical conditions, and their differences by sex, can be consulted online in **Supplementary Table S1**. They were mainly over 80

TABLE 1 | Hospitalization in COVID-19 confirmed institutionalized patients over 64 years of age.

	Global (*N* = 4,632)	No hospitalization (*N* = 2,860)	Hospitalization (*N* = 1,772)	*p*
Sex				<0.001*
Male	1,621 (35.00%)	865 (30.24%)	756 (42.66%)	
Female	3,011 (65.00%)	1,995 (69.76%)	1,016 (57.34%)	
Age				0.058
65–79	760 (16.41%)	493 (17.24%)	267 (15.07%)	
≥80	3,872 (83.59%)	2,367 (82.76%)	1,505 (84.93%)	
Socioeconomic level				<0.001*
Mutualist	160 (3.45%)	121 (4.23%)	39 (2.20%)	
Pensioner <18,000€/year	3,639 (78.56%)	2,260 (79.02%)	1,379 (77.82%)	
Pensioner ≥ 18,000€/year	611 (13.19%)	337 (11.78%)	274 (15.46%)	
Free medicines	184 (3.97%)	114 (3.99%)	70 (3.95%)	
Other	38 (0.82%)	28 (0.98%)	10 (0.56%)	
Number of diseases (a)	6.00 (4.00; 8.00)	6.00 (4.00; 8.00)	6.00 (5.00; 8.00)	<0.001*
Complexity (a)	3.00 (2.00; 4.00)	3.00 (2.00; 4.00)	3.00 (2.00; 4.00)	0.003*
Diagnosis				
Diabetes mellitus	1,166 (25.99%)	668 (24.31%)	498 (28.64%)	0.001*
Obesity	440 (9.50%)	343 (12.48%)	229 (13.17%)	0.531
Hypertension	3,237 (72.14%)	1,966 (71.54%)	1,271 (73.09%)	0.275
Stroke	654 (14.58%)	382 (13.90%)	272 (15.64%)	0.117
Ischemic heart disease	460 (10.25%)	254 (9.24%)	206 (11.85%)	0.006*
Heart failure	578 (12.88%)	321 (11.68%)	257 (14.78%)	0.003*
COPD	453 (10.10%)	243 (8.84%)	210 (12.08%)	0.001*
Chronic kidney disease	1,258 (28.04%)	716 (26.06%)	542 (31.17%)	<0.001*
Depression	1,269 (28.28%)	771 (28.06%)	498 (28.64%)	0.699
Dementia	1,494 (33.30%)	928 (33.77%)	566 (32.55%)	0.416

Sociodemographic and clinical characteristics.

N, number; p, statistical significance; a, results expressed as median and interquartile range; COPD, chronic obstructive pulmonary disease.

**Statistically significant results.*

years of age, were pensioners with <18,000€ per year, and presented a high number of diseases. Hypertension (72.14%) and dementia (33.30%) were the most frequent diagnoses. Differences were observed between men and women for all the characteristics evaluated, with the only exception of the frequency of chronic kidney disease.

A total of 1,772 COVID-19 confirmed cases were hospitalized (38.3%) within 14 days of COVID-19 diagnosis. Results are summarized in **Table 1**. Hospitalization was slightly more frequent in men than in women ($p < 0.001$) and in people with a contributory pension of 18,000€ per year or more ($p < 0.001$). Regarding clinical diagnoses, people residing in a nursing home with a diagnosis of DM, ischemic heart disease, heart failure, COPD, or chronic kidney disease showed a higher frequency of hospitalization. No statistical differences were observed by age groups and a diagnosis of obesity, stroke, hypertension, depression, or dementia. In 145 individuals (109 women and 36 men), no previous morbidity was recorded.

We evaluated mortality within 7, 30, and 90 days after COVID-19 diagnosis. In **Table 2**, results related to the socioeconomic and clinical profiles of both dead and alive patients for each cutoff point are available.

A total of 1,458 people aged 65 years or older residing in a nursing home with a confirmed COVID-19 infection in Aragón died within 90 days of COVID-19 diagnosis from all causes (31.5%). Mortality in men and in people aged 80 years or older was higher for the three time intervals considered. Differences in socioeconomic status were observed at 30 and 90 days.

Regarding morbidity, mortality increased in people with a high number of diseases and with high complexity for all the time intervals evaluated. Mortality was higher for the three moments evaluated for heart failure and chronic kidney disease. A higher risk of death at 30 and 90 days of COVID-19 diagnosis was also observed in people with ischemic heart disease, COPD, and dementia. In contrast, people with obesity showed a lower mortality at 90 days ($p = 0.045$).

We analyzed those COVID-19 confirmed institutionalized patients who died within 90 days after diagnosis and their probability of having been hospitalized by COVID-19 (**Table 3**). Of the 1,458 patients who died, 523 (35.8%) patients were not hospitalized by COVID-19. Differences in hospitalization were observed according to sex. Those women who died showed a lower prevalence of hospitalization than men ($p < 0.001$). People who died with a high number of chronic diseases, diabetes mellitus and heart failure were more frequently hospitalized.

TABLE 2 | Mortality in COVID-19 confirmed institutionalized patients over 64 years of age.

		Mortality at 7 days			Mortality at 30 days			Mortality at 90 days		
		Alive (*N* = 4,292)	**Death (*N* = 340)**	***p***	**Alive (*N* = 3,504)**	**Death (*N* = 1,128)**	***P***	**Alive (*N* = 3,174)**	**Death (*N* = 1,458)**	***p***
Sex:	Male	1,478 (34.44%)	143 (42.06%)	0.005*	1,162 (33.16%)	459 (40.69%)	<0.001*	1,034 (32.58%)	587 (40.26%)	<0.001*
	Female	2,814 (65.56%)	197 (57.94%)		2,342 (66.84%)	669 (59.31%)		2,140 (67.42%)	871 (59.74%)	
Age:	65–79	726 (16.92%)	34 (10.00%)	0.001*	657 (18.75%)	103 (9.13%)	<0.001*	620 (19.53%)	140 (9.60%)	<0.001*
	≥80	3,566 (83.08%)	306 (90.00%)		2,847 (81.25%)	1,025 (90.87%)		2,554 (80.47%)	1,318 (90.40%)	
SE level:	Mutualist	153 (3.56%)	7 (2.06%)	0.328	138 (3.94%)	22 (1.95%)	0.003*	130 (4.11%)	30 (2.05%)	0.001*
	Pensioner <18,000€/year	3,359 (78.26%)	280 (82.35%)		2,748 (78.42%)	891 (78.99%)		2,468 (77.76%)	1,171 (80.32%)	
	Pensioner ≥18,000€/year	573 (13.35%)	38 (11.18%)		448 (12.79%)	163 (14.45%)		415 (13.07%)	196 (13.44%)	
	Free medicines	170 (3.96%)	14 (4.12%)		136 (3.88%)	48 (4.26%)		128 (4.04%)	56 (3.82%)	
	Other	37 (0.86%)	1 (0.29%)		34 (0.97%)	4 (0.35%)		33 (1.04%)	5 (0.34%)	
Number of diseases (a)		6.00 (4.00;8.00)	6.00 (5.00;8.00)	0.012*	6.00 (4.00;8.00)	6.00 (5.00;8.00)	0.003*	6.00 (4.00;8.00)	6.00 (5.00;8.00)	0.004*
Complexity (a)		3.00 (2.00;4.00)	3.00 (2.00;4.00)	0.015*	3.00 (2.00;4.00)	3.00 (2.00;4.00)	<0.001*	3.00 (2.00;4.00)	3.00 (2.00;4.00)	0.003*
Diagnosis:	Diabetes mellitus	1,068 (25.72%)	98 (29.25%)	0.176	850 (25.20%)	316 (28.37%)	0.040*	771 (25.30%)	395 (27.45%)	0.134
	Obesity	535 (12.89%)	37 (11.04%)	0.375	448 (13.28%)	124 (11.13%)	0.070	410 (13.45%)	162 (11.26%)	0.045*
	Hypertension	3,001 (72.28%)	236 (70.45%)	0.512	2,453 (72.72%)	784 (70.38%)	0.140	2,216 (72.70%)	1,021 (70.95%)	0.236
	Stroke	599 (14.43%)	55 (16.42%)	0.361	475 (14.08%)	179 (16.07%)	0.114	427 (14.01%)	227 (15.77%)	0.129
	Ischemic heart disease	419 (10.09%)	41 (12.24%)	0.249	315 (9.34%)	145 (13.02%)	0.001*	293 (9.61%)	167 (11.61%)	0.045*
	Heart failure	514 (12.38%)	64 (19.10%)	0.001*	399 (11.83%)	179 (16.07%)	<0.001*	359 (11.78%)	219 (15.22%)	0.002*
	COPD	412 (9.92%)	41 (12.24%)	0.208	321 (9.52%)	132 (11.85%)	0.029*	281 (9.22%)	172 (11.95%)	0.005*
	Chronic kidney disease	1,147 (27.63%)	111 (33.13%)	0.036*	894 (26.50%)	364 (32.68%)	<0.001*	797 (26.15%)	461 (32.04%)	<0.001*
	Depression	1,167 (28.11%)	102 (30.45%)	0.394	949 (28.14%)	320 (28.73%)	0.733	867 (28.44%)	402 (27.94%)	0.751
	Dementia	1,372 (33.04%)	122 (36.42%)	0.230	1,086 (32.20%)	408 (36.62%)	0.007*	968 (31.76%)	526 (36.55%)	0.002*

Sociodemographic and clinical characteristics.

N, number; SE socioeconomic; p, statistical significance; a, results expressed as median and interquartile range; COPD, chronic obstructive pulmonary disease.

**Statistically significant results.*

TABLE 3 | Hospitalization in COVID-19 confirmed institutionalized patients over 64 years of age who died.

	Mortality at 90 days (*N* = 1,458)	No hospitalization (*N* = 523)	Hospitalization (*N* = 935)	*p*
Sex				0.001*
Male	587 (40.26%)	181 (34.61%)	406 (43.42%)	
Female	871 (59.74%)	342 (65.39%)	529 (56.58%)	
Age				0.072
65–79	140 (9.60%)	40 (7.65%)	100 (10.70%)	
≥80	1,318 (90.40%)	483 (92.35%)	835 (89.30%)	
Socioeconomic level				0.247
Mutualist	30 (2.06%)	11 (2.10%)	19 (2.03%)	
Pensioner <18,000€/year	1,171 (80.32%)	435 (83.17%)	736 (78.72%)	
Pensioner ≥ 18,000€/year	196 (13.44%)	57 (10.90%)	139 (14.87%)	
Free medicines	56 (3.84%)	18 (3.44%)	38 (4.06%)	
Other	5 (0.34%)	2 (0.38%)	3 (0.32%)	
Number of diseases (a)	6.00 [5.00;8.00]	6.00 [4.00;8.00]	6.00 [5.00;8.00]	0.022 *
Complexity (a)	3.00 [2.00;4.00]	3.00 [2.00;4.00]	3.00 [2.00;4.00]	0.774
Diagnosis				
Diabetes mellitus	395 (27.45%)	116 (22.66%)	279 (30.10%)	0.003*
Obesity	162 (11.26%)	46 (8.98%)	116 (12.51%)	0.052
Hypertension	1,021 (70.95%)	357 (69.73%)	664 (71.63%)	0.484
Stroke	227 (15.77%)	76 (14.84%)	151 (16.29%)	0.519
Ischemic heart disease	167 (11.61%)	50 (9.77%)	117 (12.62%)	0.125
Heart failure	219 (15.22%)	60 (11.72%)	159 (17.15%)	0.008*
COPD	172 (11.95%)	57 (11.13%)	115 (12.41%)	0.530
Chronic kidney disease	461 (32.04%)	157 (30.66%)	304 (32.79%)	0.441
Depression	402 (27.94%)	142 (27.73%)	260 (28.05%)	0.948
Dementia	526 (36.55%)	224 (43.75%)	302 (32.58%)	<0.001*

Sociodemographic and clinical characteristics.

N, number; p, statistical significance; a, results expressed as median and interquartile range; COPD, chronic obstructive pulmonary disease.

**Statistically significant results.*

However, people who died with dementia showed a lower probability of hospitalization ($p < 0.001$).

We conducted multivariate models to analyze those factors associated with the risk of hospitalization by COVID-19 and death at 7, 30, and 90 days in our population (**Table 4**). Women showed a lower risk of hospitalization and death than men. The risk of hospitalization and death was also higher in people aged 80 years or older than in those aged 65–79 years. Regarding socioeconomic status, people with a contributory pension of €18,000 or more showed a higher risk of hospitalization than those with low contributory pensions [odds ratio (OR): 1.24; 95% CI 1.04–1.48]. No differences were observed according to death. Finally, the number of chronic diagnoses was associated with a higher risk of hospitalization and death at 7 and 90 days. High complexity was only associated with a higher risk of death at 30 days ($p = 0.004$).

We observed differences in the risk of hospitalization and mortality risk according to chronic morbidity. The existence of DM, heart failure, and chronic kidney insufficiency was associated with a higher risk of hospitalization (**Figure 2**). Regarding mortality, heart failure was associated with a higher risk of mortality for all the cutoff points considered (OR: 1.62; 95% CI 1.20–2.15 at 7 days). Other diagnoses associated with a higher risk of mortality at 90 days were chronic kidney disease (OR: 1.24; 95% CI 1.08–1.42) and dementia (OR: 1.28; 95% CI 1.12–1.46) (**Figure 3**).

When we analyzed the risk of hospitalization in those who died of any cause at 90 days, multivariate analyses showed that the risk of hospitalization was lower in women than in men (OR: 0.67; 95% CI 0.53–0.84). An increasing number of diseases were associated with a high risk of hospitalization (OR: 1.07; 95% CI 1.03–1.11). No differences were observed by age, complexity, or socioeconomic position. We also observed differences in hospitalization in patients who died according to chronic morbidity. The diagnoses of DM, obesity, and heart failure were associated with a higher risk of hospitalization. On the contrary, a diagnosis of dementia was associated with a lower risk of hospitalization (OR: 0.64; 95% CI 0.51–0.80) (**Figure 4**).

DISCUSSION

In Aragón, 38.3% of COVID-19 confirmed patients over 64 years of age residing in a nursing home were hospitalized. The risk of hospitalization varied according to sociodemographic and morbidity profiles. Therefore, the risk of hospitalization was higher in men and in older people. Those with a contributory pension equal to or > 18,000€ per year showed a slightly higher risk of hospitalization than those with lower pensions. People

TABLE 4 | Sociodemographic and clinical factors associated with hospitalization and mortality in COVID-19 confirmed institutionalized patients over 64 years of age.

		Hospitalization		Mortality at 7 days		Mortality at 30 days		Mortality at 90 days	
		OR (95%CI)	***P***	**OR (95%CI)**	***P***	**OR (95%CI)**	***p***	**OR (95%CI)**	***p***
Sex:	Male	*Reference*		*Reference*		*Reference*		*Reference*	
	Female	0.57 (0.50–0.64)	<0.001*	0.69 (0.54–0.87)	0.002*	0.68 (0.59–0.79)	<0.001*	0.66 (0.57–0.75)	<0.001*
Age:	65–79	*Reference*		Reference		Reference		Reference	
	≥ 80	1.27 (1.07–1.51)	0.006*	*1.90 (1.33–2.81)*	*0.001**	*2.43 (1.95–3.06)*	*<0.001**	*2.39 (1.96–2.93)*	*<0.001**
Socioeconomic level:	Pensioner <18,000€	Reference		Reference		Reference		Reference	
	Mutualist	0.91 (0.50–1.62)	0.754	1.73 (0.65–3.82)	0.219	1.24 (0.64–2.29)	0.498	1.23 (0.67–2.19)	0.495
	Pensioner ≥ 18,000€	1.24 (1.04–1.48)	0.019*	0.77 (0.53–1.08)	0.143	1.09 (0.89–1.33)	0.376	0.97 (0.80–1.17)	0.729
	Free medicines	1.14 (0.83–1.55)	0.414	1.18 (0.64–2.00)	0.574	1.33 (0.93–1.87)	0.106	1.13 (0.81–1.56)	0.475
	Other	0.72 (0.31–1.49)	0.394	0.48 (0.03–2.25)	0.471	0.54 (0.16–1.38)	0.249	0.46 (0.16–1.10)	0.113
Number of diseases		1.05 (1.03–1.08)	<0.001*	1.05 (1.01–1.09)	0.010*	1.02 (1.00–1.05)	0.051	1.03 (1.00–1.05)	0.027*
Complexity		1.01 (0.96–1.07)	0.682	1.07 (0.96–1.18)	0.231	1.10 (1.03–1.17)	0.004*	1.05 (0.99–1.11)	0.116

Adjusted results.
OR, Odds ratios; 95%CI, 95% Confidence interval; p, statistical significance.
**Statistically significant results.*
Odds ratios adjusted by sex, age, socioeconomic level, number of diseases and complexity.

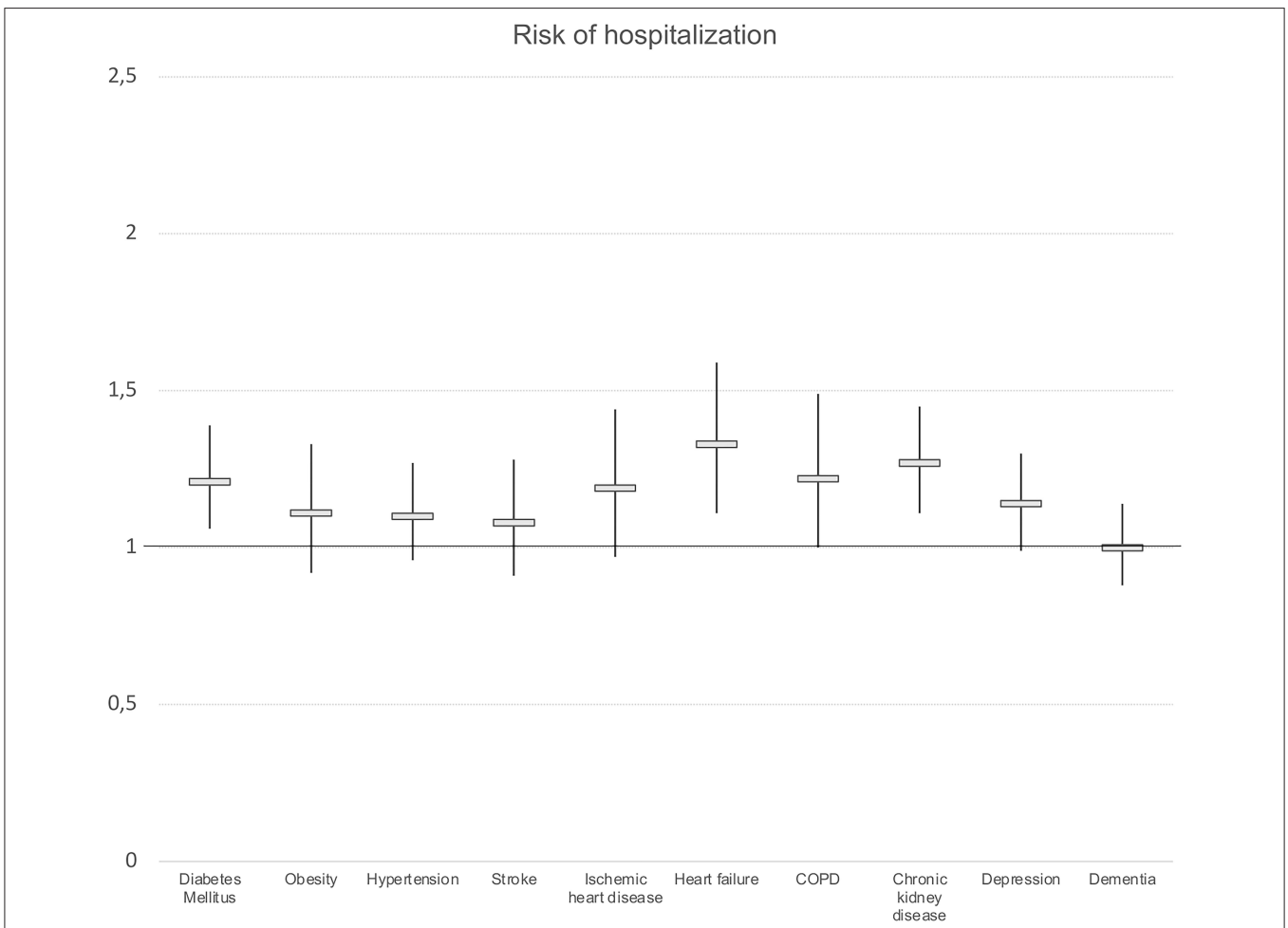

FIGURE 2 | Presence of chronic morbidity and risk of hospitalization. Logistic regression models. Odds ratios and 95%Confidence intervals. Results adjusted by sex, age and socioeconomic level. COPD, chronic obstructive pulmonary disease.

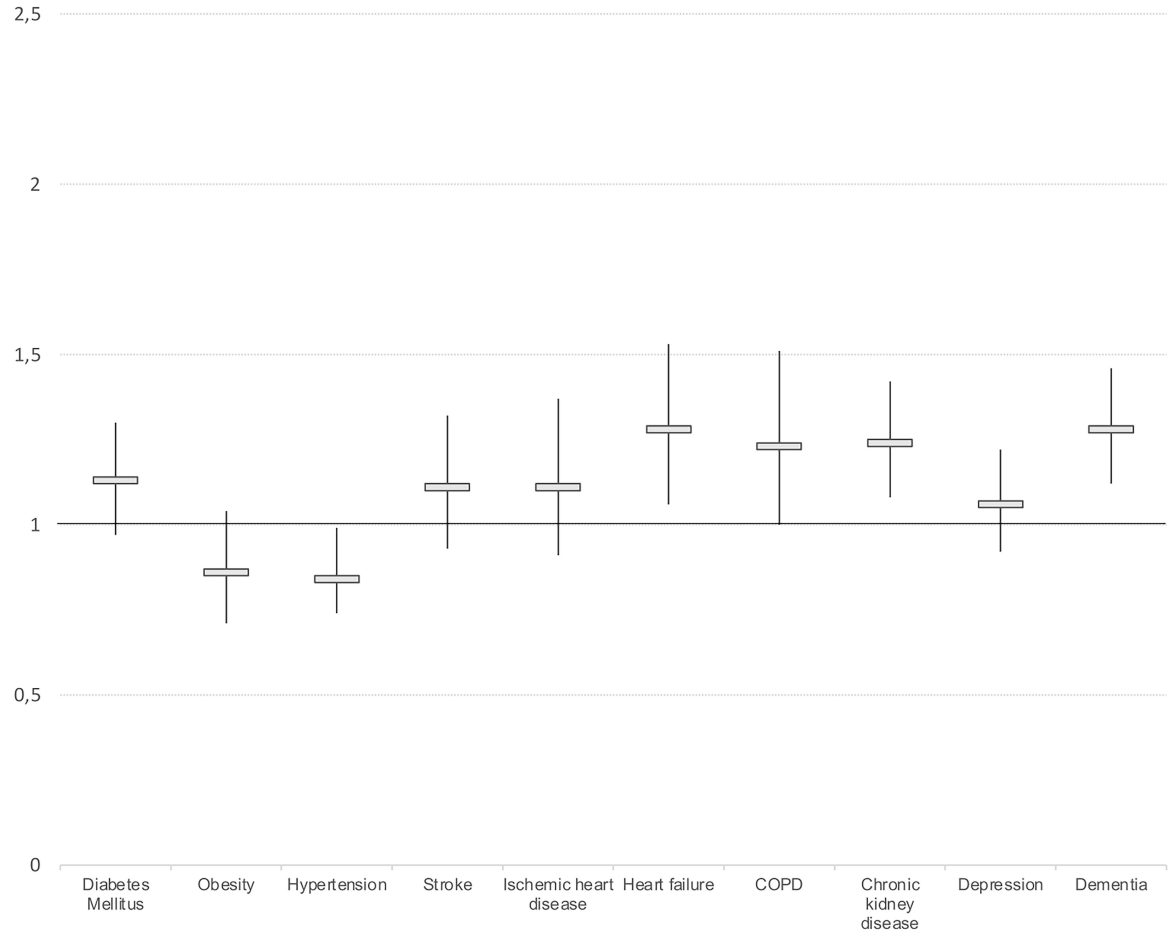

FIGURE 3 | Presence of chronic morbidity and risk of mortality at 90 days. Logistic regression models. Odds ratios and 95%Confidence intervals. Results adjusted by sex, age and socioeconomic level. COPD, chronic obstructive pulmonary disease.

with a diagnosis of DM, heart failure, or chronic kidney disease also showed a higher risk of hospitalization.

Of all COVID-19 confirmed patients residing in a nursing home, 31.5% died at 90 days of COVID-19 diagnosis. Mortality was higher in men and in older patients. Heart failure was the diagnosis showing a stronger association with the risk of death. Finally, 35.8% of the residents with a COVID-19 confirmed diagnosis who died had not been hospitalized. Hospitalization in those patients who died was positively associated with being men and a diagnosis of DM, obesity, or heart failure. On the contrary, patients with dementia showed a higher risk of mortality without hospitalization.

COVID-19 has had a devastating impact on old people residing in nursing homes. In Aragón, almost 40% of the patients required hospitalization and one of three patients died. Some personal factors have been associated with the vulnerability of these subjects as follows: the existence of frailty patients (24), low Barthel index, or the high prevalence of comorbidities (25, 26). In addition, organizational factors have been involved in this equation. A large number of beds in many LTC facilities, the very low staffing ratios, shortage of qualified professionals, or the deficient coordination between social and health services (27) are some of the factors that can explain the high impact of the COVID-19 pandemic in Spanish nursing homes.

There is a relationship between the sociodemographic characteristics of the patients with a COVID-19 confirmed diagnosis living in a nursing home and their risk of hospitalization and death. Men showed a higher risk of hospitalization than women, as well as a higher risk of death, after adjusting by age, socioeconomic position, number of chronic diseases, and complexity. This fact has already been described widely in the literature (28, 29) and has been related to biological, psychosocial, and behavioral factors (30). However, it is striking that among those patients who died, women also had a lower risk of being hospitalized. Another study conducted in Spain on the general population (31) found that women presented different symptoms at disease onset, clinical outcomes, and treatment patterns, with differences in hospitalization and intensive care unit admission. Further research is required to explore the factors that could have conditioned this gender bias.

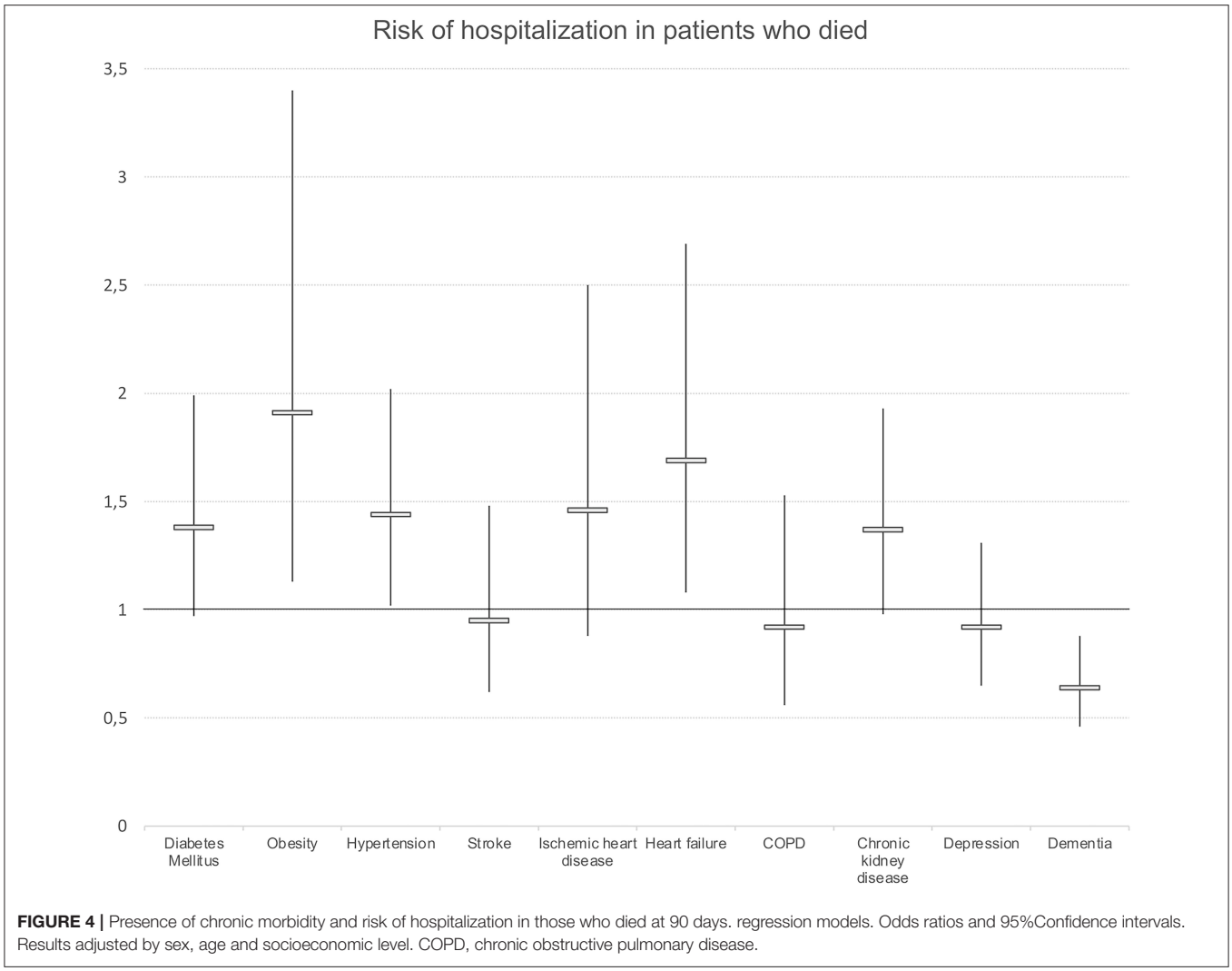

FIGURE 4 | Presence of chronic morbidity and risk of hospitalization in those who died at 90 days. regression models. Odds ratios and 95%Confidence intervals. Results adjusted by sex, age and socioeconomic level. COPD, chronic obstructive pulmonary disease.

We also found differences in hospitalization according to socioeconomic level but not for mortality risk. Those old patients living in a nursing home with a contributory pension equal to or higher than 18,000€ per year had a higher risk of hospitalization than those with lower pensions, after taking into account age, sex, and morbidities. When we selected those people who died at 90 days of diagnosis, there were no differences in hospitalization by socioeconomic status, but differences existed when considering mortality at 7 days (OR: 4.5; 95% CI 1.9–12.6). Nonetheless, when analyzing the profile of those patients who survived, people with a contributory pension of 18,000€ per year or higher had a high risk of hospitalization ($p = 0.046$). It has been described the association between low socioeconomic status and a higher risk of hospitalization and death by COVID-19 in the general population (12, 32) but, to the best of our knowledge, this is the first study to assess the influence of individual socioeconomic status on the risk of hospitalization and death from COVID-19 in institutionalized patients. A poor individual socioeconomic level may reflect deficient conditions of the nursing homes, which could result in poorer care for these patients, but also the existence of few social and support networks.

The suffering of some chronic diseases was associated with hospitalization and death. In this sense, patients with heart failure had the highest risk of hospitalization and death, after controlling by sex, age, and socioeconomic position. Our results are consistent with other studies, in which patients with underlying cardiovascular disease have an increased risk of mechanical ventilation and death by COVID-19 (33, 34). In the case of COVID-19 infection in patients with this illness, it seems to be associated with a significant risk of developing acute decompensation (35). Patients with heart failure have also shown an increased risk of COVID-19 infection due to reduced immunity, frailty, and low hemodynamic ability to cope with severe infections (36). In contrast, people with dementia had the highest risk of mortality with no hospitalization. Lockdown and quarantine have had a high impact on patients with dementia living in nursing homes. Changes in their routines and physical inactivity lead to a worsening of their functional and cognitive status (37) and an increased stress in an already vulnerable population (38), resulting in a high risk of mortality by COVID-19 (39, 40). Some of the reasons proposed to explain this fact were the advanced age of these patients and the existence of

comorbidities. Nonetheless, in our study, a high risk of mortality at 90 days in people with dementia was observed even after adjusting by the presence of other comorbidities. Other authors have pointed out the presence of atypical symptoms of infection (41), namely, the onset of hypoactive delirium and worsening functional status (42), as the cause of an increased mortality in this group. This atypical presentation could explain the lower risk of hospitalization observed in patients with dementia and COVID-19 who died.

This study has several strengths. We analyzed all the individuals residing in a nursing home with a confirmed COVID-19 infection from the population of Aragón, including data from administrative health data sources and electronic health records. Clinical diagnoses were obtained from GMA. This source of information combines diagnoses from primary healthcare and from hospital admissions, which makes this a high-sensitivity classification. Finally, we used a combination of two different socioeconomic indicators (pharmacy copayment levels and the type of user of the Aragón Health Service) to categorize the socioeconomic level of the individuals. The combination of these two variables has already been used in other analyses of health inequities at a population level (10, 43) and provides a good knowledge of the individual socioeconomic position.

Nevertheless, this study has some limitations. There are limitations inherent to observational studies, such as quality of data and cases with incomplete data. Second, neither the cause of death nor the cause of hospitalization was available. The cause of death was not identified because the information from the Aragón-COVID-19 cohort could not be matched with the information available in the mortality registry. To address this issue, only deaths occurring up to 90 days after COVID-19 diagnosis were considered. A total of 481 institutionalized patients over 64 years of age died after 90 days of COVID-19 diagnosis, with a median of 207 days. In addition, we only considered hospital admissions within 14 days, both before and after COVID-19, as the hospital discharge records (CMBD), where hospital cause is codified, were not available in the Aragón-COVID-19 cohort. In this case, 218 patients were hospitalized but did not fulfill our criteria, with a median of −21 days. Instead of the possible bias, we considered that the established criteria allow us to define plausible ranges for identifying both death and hospitalization due to COVID-19. Finally, some of the patients who were not hospitalized could have been treated in one of the "COVID centers" set up in Aragón in the first waves of the pandemic. This information was not available for its consideration.

CONCLUSION

Many challenges have been faced by nursing homes in this COVID-19 pandemic. The characteristics of its residents and the delay of the measures taken have had a devastating effect in terms of morbidity and mortality. In this study, we found gender and socioeconomic inequalities in the risk of hospitalization of these patients, as well as an increased risk of hospitalization and death for some diagnostic groups.

The LTC facilities must be prepared for future health threats, and this requires an appropriate implementation of geriatric interventions (44) and taking into account patient-specific factors, in order to develop equitable and effective measures. As we have observed in our analyses, patients with underlying cardiac pathologies may require special attention, given their potential severity. In contrast, people with dementia showed the highest risk of mortality with no hospitalization. In this group of patients, a strict medical support and control (39) or the implementation of applications to promote interaction with family members (38) is necessary. Finally, the professionals involved should be aware of the existence of gender and socioeconomic biases when assessing and caring for patients, in order to avoid adopting measures that contribute to increase the existing inequalities.

DATA AVAILABILITY STATEMENT

Aragon-COVID19 data is available under request to IACS. Requests to access these datasets should be directed to https://www.iacs.es.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Clinical Research Ethics Committee of Aragón (CEICA). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

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

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.928174/full#supplementary-material

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Finding a calling, not a job: How an East Tennessee girl transformed aging and public health

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Catherine Hawes, Ph.D., to me, is one of the very best role models in the aging and public health sector. Born in East Tennessee and raised conservative, Catherine proved to be a non-conformist in her beliefs, challenging norms that tended to relegate women and persons of color to second-class citizens. For women, completing a bachelor's degree was a huge accomplishment in the 1960s, and Catherine went even further to complete a doctoral program in American Government and Politics. Her lived experiences regarding fairness and gender equality, as well as caring for her sick mother contributed to Catherine's career path—which later became a calling. In an era preceding the current "wokeness" and social awareness of racism, Catherine was a trailblazer in treating everyone fairly, regardless of what or how they identified. When it comes to issues related to aging and public health, there are no ifs, ands, or buts—Catherine's mission is health equity for all older adults. Her passion for aging and public health is infectious, and as I find myself doing more work along this line, I cannot think of anyone more deserving or "sufficiently brilliant[1]" to write about.

I met Catherine in August 2009, when started a PhD program in Health Services Research at Texas A&M University. She taught health policy in a manner that made one never want the class to end—something I cannot say about other courses taught by other professors. Monday afternoons was like sitting with a former President and learning the inner working of how health policy is made, the role of interest groups, and how incrementalism over the years had shaped our current healthcare delivery system. Since this period was before the passage of the Affordable Care Act (ACA), we had many conversations on how the Obama administration should shape healthcare health care reform. Including examples from her time working on the Hill to consulting with numerous leaders in Congress, state health departments, and national think tanks, Catherine's class was a must for all health services researchers-in-training. As an immigrant, I found it surprising that the U.S. Health care system that I came to the U.S. to learn about, although much better that in my home country of Nigeria, was far from perfect—and without a quick fix.

1 During a conversation with Catherine Hawes, on June 28, 2022, she recounted how a male colleague once questioned whether females and racialized groups were sufficiently brilliant to become faculty members.

We discussed comparative health systems and how learnings from other countries, such as medical homes and accountable care, could inform health care reform strategies under consideration by the Obama administration. By the end of the semester, I wanted to work with this intellectual giant and mentor to many researchers in aging and public health. I asked Catherine about working as a research assistant with her and her husband, Charles, who was also at Texas A&M. Together, their role in positively impacting scholars kindles inspiration and propensities to pursue performance excellence.

In addition to her wealth of knowledge, Catherine is hardworking and graceful, always willing to engage in civil discourse on all things health policy. We have often disagreed on political stance, but her ability to promote judgment-free dialogues has endeared her to many. Not surprisingly, for almost 40 years (1976–2013), Catherine was active in research, teaching, and health policymaking, with an emphasis on defining, measuring, and assuring quality in long-term care. She led several projects on assisted living and residential care, including quality measurement and improvement in residential care and assisted living for the Agency for Healthcare Research and Quality. Her landmark study on the effect of regulation on the quality of care in board and care homes recognized licensures alone as insufficient in ensuring that homes provide care above a threshold of minimum performance (board and care homes provide supervised living environments in the absence of family support and serve as an alternative to nursing home placement) (1). This work resulted in significant policy changes, with an emphasis on federal oversight of nursing home quality. In addition, Catherine served on a number of national advisory committees, including the Institute of Medicine's (IOM) Committee on Nursing Home Regulation. She has also provided papers and testimony to other IOM committees on quality assurance in Medicare, improving quality in long-term care, and preventing elder abuse in residential long-term care settings. She currently serves on the National Policy Council of AARP, which makes recommendations on public policy to the AARP Board of Directors.

Perhaps her most visible contribution is Catherine's role in the development of the Minimum Dataset for Nursing Home Resident Assessment and Care Screening (MDS), the holy grail of clinical assessments in long-term care facilities. The MDS is used to screen and assess physical, psychological and psycho-social functioning, providing a multidimensional view of a resident's functional status (2). Anyone who has had a parent, grandparent, aunt, uncle, friend, or child in a nursing home has benefited from Catherine's work on the MDS. This comprehensive assessment is conducted annually for all long-term care residents, regardless of payer type. Over the past 20 years, the MDS has played a vital role in the Medicare and Medicaid reimbursement system and in monitoring the quality of care provided to nursing facility residents. From a scholarly perspective, this work (3) has been cited almost 1,000 times.

To the best of my knowledge, Catherine has mentored more than 100 health services researchers currently studying aging and public health across diverse settings, including universities, health departments, Congress, and non-profit think tanks. Like me, many of her mentees have continued work in aging and public health, focusing on shifts in the demographic dividend, care for the aging boomers (who now live longer than their parents), mental health for older adults, and going beyond measurements to address barriers that promote racial and ethnic disparities in health.

Author contributions

OA conceptualized and wrote the manuscript.

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Association between disability, social support and depressive symptoms in Chinese older adults: A national study

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Objective: Disability and social support can impact depressive symptoms of the elderly. Yet, studies infrequently discuss the moderating role of social support when evaluating the association between disability and depressive symptoms. The purpose of this study was to explore the association between disability, social support, and depressive symptoms among the Chinese elderly, and further examine the moderating effect of social support.

Materials and methods: Using the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS) data set, we finally selected 9,231 Chinese elderly after screening. The Center for Epidemiologic Studies Depression Scale (CESD-10) was used to evaluate depressive symptoms in the elderly. Disability was measured by basic activities of daily living (B-ADL) and instrumental activities of daily living (I-ADL). Social support included contact with family and friends, sick care, and money received, measured by five self-reported questions. We used multiple linear regression and moderating model to explore the association between disability, social support, and depressive symptoms.

Results: A total of 9,231 patients were included in this study, and approximately 26.75% of the elderly had depressive symptoms. Study found that depressive symptoms were associated with social support ($\beta_{B-ADL} = -0.108$, 95% CI: −0.168– −0.047; $\beta_{I-ADL} = -0.098$, 95% CI: −0.156– −0.039), β_{B-ADL} ($\beta = 0.296$, 95% CI: 0.248–0.343) and I-ADL ($\beta = 0.174$, 95% CI: 0.152–0.195). Moreover, the result also showed that social support moderated the effects of B-ADL ($\beta_{B-ADL*social\ support} = 0.034$, 95% CI: 0.014–0.053, F = 11.57, $p = 0.001$) and I-ADL ($\beta_{I-ADL*social\ support} = 0.025$, 95% CI: 0.017–0.033) on depressive symptoms.

Conclusions: The study suggests that disability and social support can affect depressive symptoms, and social support moderates the effect of disability on depressive symptoms. Therefore, taking effective measures to reduce the elderly disability rate of disability and increase their social support are necessary condition for realizing mental health.

KEYWORDS

depressive symptoms, social support, moderating effect, elderly people, disability

Introduction

Most countries in the world, including China, are experiencing serious aging problems (1). According to the seventh National Census in 2021, the number of Chinese over 65 years old has reached 190 million, accounting for 13.50% of the total population, and the proportion of the population aged 65 and above rose by 4.63 percentage points (2). From 2005 to 2017, the life expectancy of Chinese residents showed an upward trend. However, the accompanying health problems have seriously affected the physical and mental health of the elderly (3–5). The World Health Organization (WHO) expects that the disease burden of depression will top all other diseases by 2030 (6). In China (2019), depression is one of the top ten causes of disability-adjusted life years (DALYs) (7). Studies have shown that depressive symptoms are a highly prevalent disease in elderly people (8). Beyond personal suffering and family disruption, depression worsens the outcomes of many medical disorders and promotes disability (9, 10).

Functional ability refers to the ability of individuals to participate in social activities according to their intentions and life preferences. It is usually measured by basic activities of daily living (B-ADL) and instrumental activities of daily living (I-ADL) (11). At present, the current situation of disability in the elderly is not optimistic. A study in European countries shows that the I-ADL disability rate of the elderly over 65 years old was 23.8% (12), while the B-ADL and I-ADL disability rates of the elderly over 60 years old in China are 23.8 and 35.4%, respectively (13). Since the elderly with disability usually need help from family or caregivers, their self-choice ability decreases and their social networks shrink (14–16). The elderly often experience low self-control ability and a strong sense of loneliness or meaninglessness, which are the risk factors for increased depressive symptoms in the elderly (16–19). Therefore, the disability of the old adults seriously affects the quality of life of the elderly and brings a burden to the family and society.

With the increase of age, it is inevitable to suffer the disability. Therefore, how to reduce the health problems brought by the disability to the elderly, such as depressive symptoms, was particularly important. It is worth noting that social support, especially from family and friends, is likely to be one factor that can play a key role in against depression for older adults (20). For example, previous studies have shown that older people with limited social support are vulnerable to psychological problems, such as depression and anxiety (21, 22). Although previous studies have indicated the association between disability, social support, and depressive symptoms (20, 23, 24), few studies have discussed the potential role of social support in assessing the association between disability and depressive symptoms. A study indicated that social networks with sufficient scale, quality, and interaction frequency will give the elderly a feeling of being valued and loved (25). Especially when the elderly are unable to integrate into social groups due to restricted movement, the support from family and friends can alleviate psychological pressure, give the elderly a sense of security and relief, and eventually improve life satisfaction (26–29). Therefore, social support, especially from family and friends, may moderate the effect of disability on depressive symptoms in the elderly.

From what has been discussed above, we can see that there is some association between disability, social support, and depressive symptoms. Therefore, one of the purposes of this study is to explore the association between disability, social support, and depressive symptoms among the Chinese elderly, and further examine the moderating effects of social support. To provide a theoretical basis for the prevention and improvement of depressive symptoms in the elderly.

Methods and measurements

Data source and sample

The data in this study came from the Chinese Longitudinal Healthy Longevity Survey (CLHLS 2017-2018). CLHLS is a follow-up survey of the elderly in China organized by the Center for Healthy Aging and Development Studies (CHADS) of Peking University, which was firstly conducted in 1998. Based on the baseline survey, CLHLS conducted another seven surveys in 2000, 2002, 2005, 2008-2009, 2011–2012, 2014, and 2017–2018. The main subjects of this survey are elderly people over 65 years old in 23 Chinese provinces. Considering that the sample data should be representative and reliable, the sampling design of CLHLS adopted a multi-stage disproportionate and targeted random sampling method (30). In addition, more details about the CLHLS survey have been described in other studies (31). In the latest survey, CLHLS collected information on their depressive symptoms, the activity of daily living, and social support, as well as demographic, behavioral, and health-related information. Inclusion criteria in this study were age $\geq$ 65 (15773). Additionally, the cases with missing values and outliers from the main variables (n = 6,542) were further excluded, detail are shown in the Supplementary Figure 1. Therefore, the final sample was 9,231 elderly respondents, which were included in the analysis.

Measurements

Depressive symptoms

The Center for Epidemiologic Studies Depression Scale (CESD-10) was used to evaluate depressive symptoms in

the elderly. The CESD-10 consisted of 10 items using a 4-point Likert scale. For the two positive questions, "I was happy" and "I felt hopeful about the future," answers were reversely coded before summation. We then coded all answers from 0 to 3 as "rarely" to "most of the time," respectively. The total range of CESD-10 scores in this study was 0–30, with higher scores indicating greater severity of depressive symptoms. A person is considered to have depressive symptoms if he/she scored no <10 on the CESD-10 (32). Previous studies have confirmed the reliability and effectiveness of CESD-10 in measuring depressive symptoms in older adults (32).

Disability

Disability was measured by B-ADL and I-ADL. B-ADL was measured with the following six subscales (1) Bathing; (2) Dressing; (3) Toileting; (4) Indoor moving; (5) Continence of defecation; (6) Eating. I-ADL was rated with eight questions (1) Can you visit your neighbors by yourself? (2) Can you go shopping by yourself? (3) Can you cook a meal by yourself when necessary? (4) Can you wash clothes by yourself when necessary? (5) Can you walk a kilometer at a time by yourself? (6) Can you lift a weight of 5 kg, such as a heavy bag of groceries? (7) Can you continuously squat and stand up three times? (8) Can you take public transportation by yourself? Each item was scored from 0 (complete independence) to 2 (complete dependence). The more scores the respondents obtained, the higher B-ADL and I-ADL dependence would be. In addition, a question measured the overall activity ability of the elderly, "for the last 6 months, were you limited in activities because of a health problem?" and coded all answers from 1 to 3 as "yes, strongly limited" to "not limited," respectively.

Social support

Social support from family and friends included contact with family and friends, sick care, and money received (whether participants received money from children). Three questions measured contact with family and friends, "contact1: to whom do you usually talk most frequently in daily life?" "contact2: to whom do you talk first when you need to share something of your thoughts?" and "contact3: who do you ask first for help when you have problems or difficulties?" Sick care is measured in one sentence, "who takes care of you when you are sick?" Answer options included spouse, son, daughter, daughter-in-law, son-in-law, grandchildren, other relatives, friends/neighbors, social workers, housekeeper, or nobody. If the person was the spouse, the item scored 3. If the person was a child, friend, or relative, the item scored 2. If the person was a social worker or housekeeper, the item scored 1. If the option was nobody, the item scored 0. Finally, one question measured money received, "Do you receive money from the children," if an answer was yes, then the answer was coded as 1, otherwise, it was coded as 0 (33). These five items were summed up with a score ranging from 0 to 13 and higher scores denoting more extensive social support.

Covariate

Control variables include demographic variables (age, sex, education, and rural residence), behavioral variables (marital status, living pattern, physical exercise, smoking, and drinking), and subjective relative poverty. Physical exercise is measured by "Do you often exercise now? (refers to purposeful fitness activities, such as walking, playing ball, running, square dance, Tai Chi, etc.)." Subjective relative poverty is measured in one sentence, "how do you rate your economic status compared with other local people?" We then coded all answers from 1 to 5 as "very rich" to "very poor," respectively.

Statistical analysis

In this study, depression symptoms score was the response variable, disability was the predictor and the social support moderator variable. Descriptive analysis was used to describe the general characteristics of the study population, one-way analysis of variance (ANOVA), t-test, and χ^2 test were performed to compare depression symptoms score between different groups. Moreover, to prove whether social support plays a moderating role between disability and depressive symptoms, we used moderating effect model to verify the impact of interaction items on depressive symptoms, and the mathematical formula is as follows:

$$Y = \beta_0 + \beta_{disability}X + \beta_{social\ support}M + \beta_{disability*social\ support}XM + \varepsilon$$

All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS 26.0 and R 4.0.0. We used SPSS to describe the basic information of the study population and establish the moderating effect model. R performs data visualization and correlation test.

Results

Characteristics of the study sample

Participants' characteristics are shown in Table 1. In the present study, more than 50% of the older adults were female and most of the participants lived in rural regions. Of the 9231 participants, 2469 (26.75%) developing depressive symptoms. After case weighted, the mean age was 72.35 years (standard deviation = 6.55), 70.60% were married and living with a

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TABLE 1 Describe the characteristics of depressive symptoms in Chinese adults aged 65 years and older.

Variables	*n*	Percent*	Depression symptoms score*	*P*-value*	Depression		*P*-value*
					No	Yes	
Age group, years							
65–79	3,784	84.10%	6.72 ± 4.34	<0.001	2,923	861	<0.001
80–99	4,288	15.80%	7.62 ± 4.51		3,032	1,256	
≥100	1,159	0.01%	7.63 ± 5.49		807	352	
Sex							
Men	4,260	47.40%	6.39 ± 4.11	<0.001	3,316	944	<0.001
Women	4,971	52.60%	7.29 ± 4.56		3,446	1,525	
Education level, years							
0	4,026	27.60%	7.90 ± 4.52	<0.001	2,694	1,332	<0.001
1–6	3,213	42.00%	6.69 ± 4.15		2,461	752	
≥7	1,992	30.40%	6.17 ± 4.38		1,607	385	
Residence							
City	2,338	22.80%	6.66 ± 4.66	<0.001	1,831	507	<0.001
Town	3,036	29.80%	7.03 ± 4.48		2,152	884	
Rural	3,857	47.40%	6.86 ± 4.16		2,779	1,078	
Marital status							
Married and living with spouse	4,195	70.60%	6.49 ± 4.20	<0.001	3,275	920	<0.001
Separated	172	2.40%	7.03 ± 4.30		123	49	
Divorced	32	0.50%	7.50 ± 3.85		24	8	
Widowed	4,769	25.80%	7.80 ± 4.69		3,307	1,462	
Never married	63	0.70%	8.89 ± 4.77		33	30	
Living pattern							
With household member(s)	7,415	85.60%	6.64 ± 4.25	<0.001	5,585	1,830	<0.001
Alone	1,505	12.80%	8.06 ± .79		984	521	
In an institution	311	1.60%	9.09 ± 5.24		193	118	
Subjective poverty							
Very rich	261	2.50%	5.29 ± 3.89	<0.001	225	36	<0.001
Rich	1,614	16.00%	5.50 ± 3.87		1,377	237	
General level	6,446	71.40%	6.77 ± 4.12		4,719	1,727	
Poor	802	8.90%	9.90 ± 5.09		397	405	
Very poor	108	1.10%	11.82 ± 6.79		44	64	
Smoking							
Yes	1,490	19.90%	6.49 ± 4.04	<0.001	1,168	322	<0.001
No	7,741	80.10%	6.96 ± 4.45		5,594	2,147	
Drinking							
Yes	1,398	18.50%	5.92 ± 4.09	<0.001	1,124	274	<0.001
No	7,833	81.50%	7.08 ± 4.41		5,638	2,195	
Physical exercise							
Yes, often	3,245	42.50%	6.02 ± 4.00	<0.001	2,684	561	<0.001
No, rarely	5,986	57.50%	7.49 ± 4.54		4,078	1,908	

*Case weighted results.

spouse, 14.40% living alone or in an institution, and 27.60% of the participants were uneducated. Additionally, 80.10% of the participants currently do not smoke, 81.50% do not drink, and 57.50% rarely took part in physical exercise. Depressive symptoms participants are more likely to be women, living in rural, less educated, never married, living in pension institutions, subjective relative poverty, and rarely participate in physical exercise.

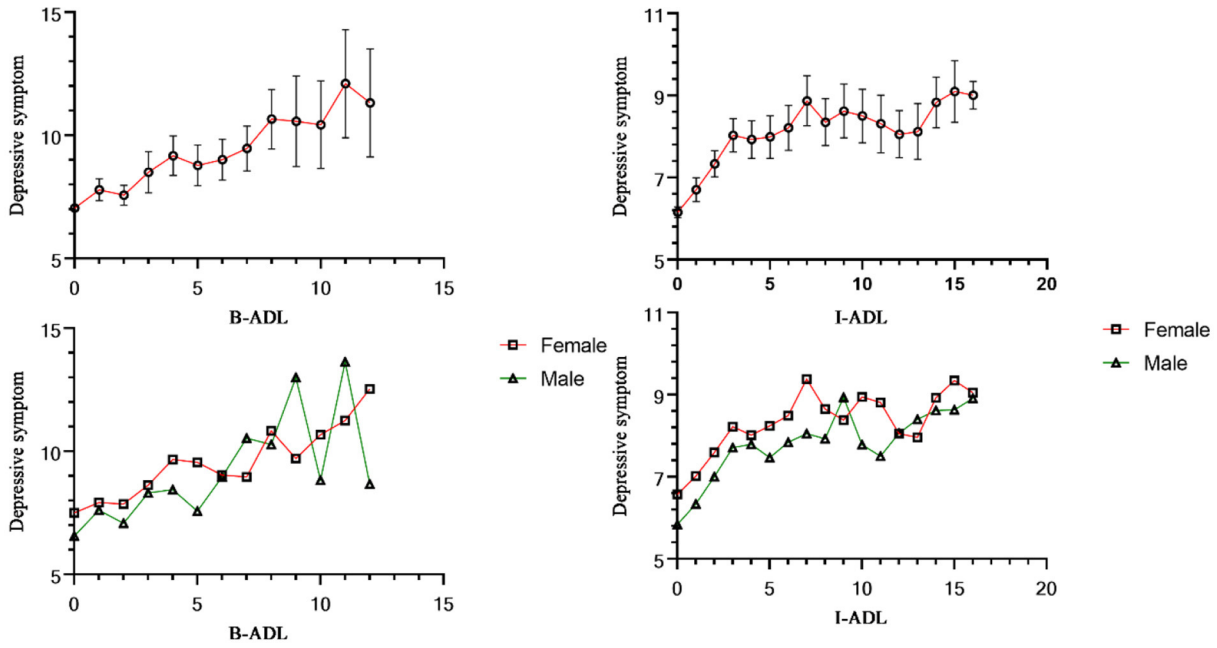

FIGURE 1
Association between disability and depressive symptoms in the elderly.

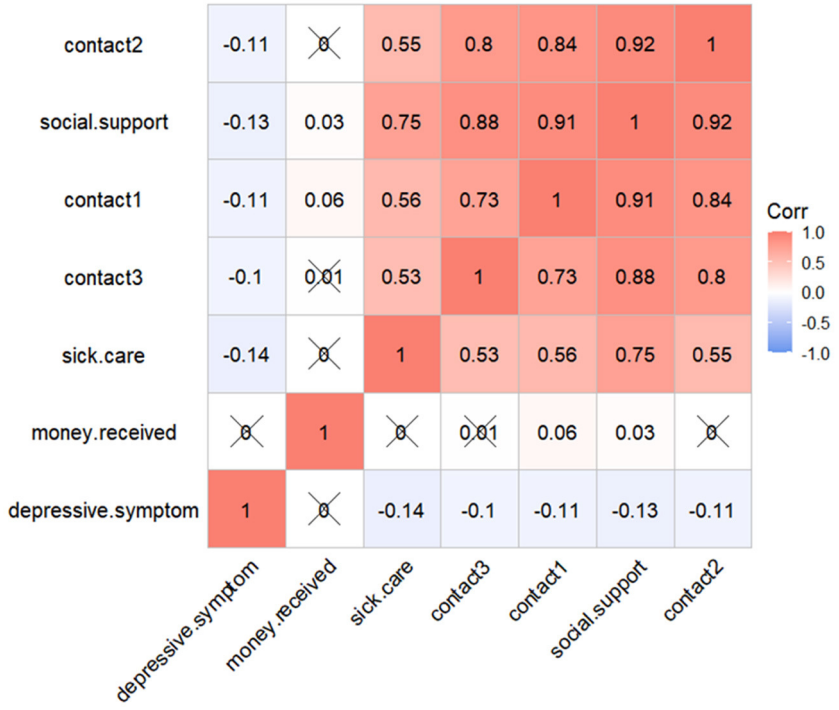

FIGURE 2
Correlation coefficient of social support and depressive symptoms. $^{\times}P > 0.05$.

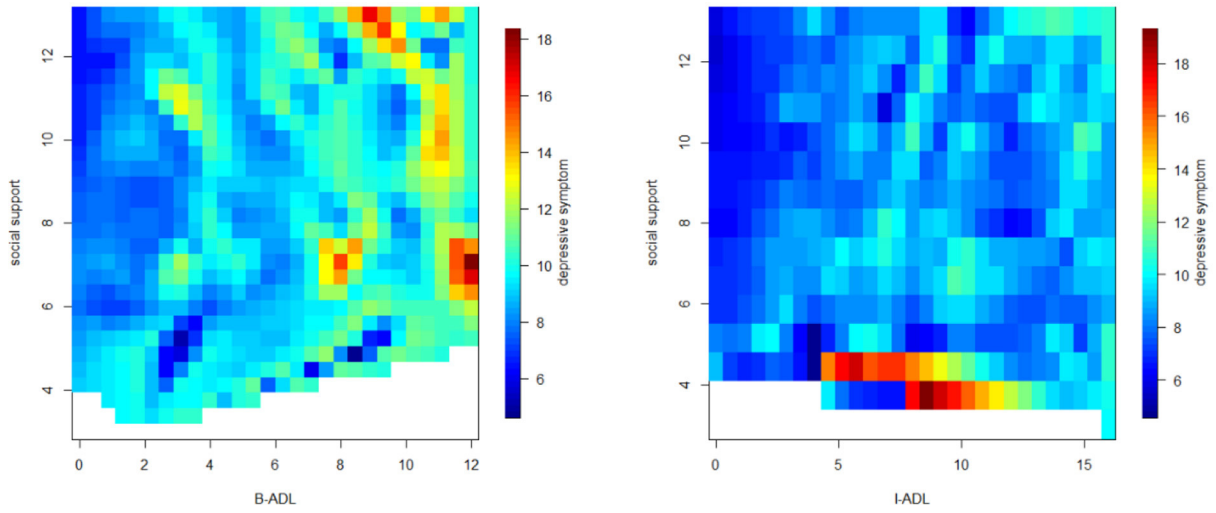

FIGURE 3
Association between disability, social support, and depressive symptoms in the elderly.

TABLE 2 Moderation analysis of social support for the association between B-ADL and depressive symptoms.

Variable	Standardized coefficients	Coefficients	SE	*t*-value	*P*-value	95% CI	
						Lower	Upper
Model 1 (unadjusted) ($R^2 = 0.04$ $F = 127.134$ $p < 0.001$)							
R^2 change due to the moderator = 0.002 ($F = 20.99$, $p < 0.001$)							
B-ADL	0.170	0.387	0.023	16.523	< 0.001	0.342	0.432
Social support	−0.096	−0.184	0.020	−9.17	< 0.001	−0.223	−0.145
B-ADL*social support	0.054	0.050	0.011	4.582	< 0.001	0.028	0.072
Model 2 (adjusted) ($R^2 = 0.130$ F = 84.96 $p < 0.001$)							
R^2 change due to the moderator = 0.001 ($F = 11.57$, $p = 0.001$)							
B-ADL	0.130	0.296	0.024	12.075	< 0.001	0.248	0.343
Social support	−0.056	−0.108	0.031	−3.527	< 0.001	−0.168	−0.047
B-ADL*social support	0.037	0.034	0.010	3.188	0.001	0.014	0.053

Model 2 adjusted for age, gender, educational level, subjective poverty, marital status, living pattern, residence, smoking, drinking, and physical exercise. Set residence, living pattern, and marital status as dummy variables. SE: standard error; CI: confidence interval; disability *social support: the interaction effect between disability and social support.

Association between disability, social support and depressive symptoms

Of the 9,231 individuals, 2,867 (31.06%) activities of daily living were limited due to health problems, of which 771 were strongly limited. Figure 1 showed the association between disability and depressive symptoms. B-ADL ($r = 0.170$, $P < 0.001$) and I-ADL ($r = 0.224$, $P < 0.001$) were significantly correlated with depressive symptoms. In addition, if men and women were limited by the same activities of daily living, the depression symptoms score of women is higher than men ($P < 0.05$), detailed data are shown in the Supplementary Table 1. However, when the limitation of activities of daily living was higher than a certain threshold, this difference will no longer be obvious. Specifically, when B-ADL was not <6 and I-ADL was not <9.

Figure 2 indicated that social support ($r = -0.13$, $P < 0.001$) was significantly correlated with depressive symptoms. Specifically, sick care ($r = -0.14$, $P < 0.001$), contact1 ($r = -0.11$, $P < 0.001$), contact2 ($r = -0.11$, $P < 0.001$), and contact3 ($r = -0.10$, $P < 0.001$) were negatively correlated with depressive symptoms. Finally, Figure 3 showed the association between disability, social support, and depressive symptoms. The elderly with less social support and higher disability were more likely to be depressed.

TABLE 3 Moderation analysis of social support for the association between I-ADL and depressive symptoms.

Variable	Standardized coefficients	Coefficients	SE	*t*-value	*p*-value	95% CI	
						Lower	Upper
Model 3 (unadjusted) ($R^2 = 0.057$ $F = 186.49$ $p < 0.001$)							
R^2 change due to the moderator = 0.004 ($F = 43.97$, $p < 0.001$)							
I-ADL	0.224	0.177	0.008	22.087	<0.001	0.161	0.192
Social support	−0.053	−0.102	0.021	−4.908	<0.001	−0.143	−0.060
I-ADL*social support	0.071	0.025	0.004	6.631	<0.001	0.017	0.033
Model 4 (adjusted) ($R^2 = 0.143$ $F = 94.89$ $p < 0.001$)							
R^2 change due to the moderator = 0.003($F = 23.93$, $p < 0.001$)							
I-ADL	0.220	0.174	0.011	16.407	<0.001	0.152	0.195
Social support	−0.051	−0.098	0.030	−3.231	0.001	−0.156	−0.039
I-ADL*social support	0.051	0.018	0.004	4.836	<0.001	0.010	0.025

Model 4 adjusted for age, gender, educational level, subjective poverty, marital status, living pattern, residence, smoking, drinking, and physical exercise. Set residence, living pattern, and marital status as dummy variables. SE: standard error; CI: confidence interval; disability *social support: the interaction effect between disability and social support.

The moderating role of social support in the effect of disability on depressive symptoms

The moderating effect of social support between disability and depressive symptoms was shown in Tables 2, 3. After controlling for potential confounders, the results showed that the effects of social support ($\beta_{B-ADL} = -0.108$, 95% CI: −0.168– −0.047; $\beta_{I-ADL} = -0.098$, 95% CI: −0.156– −0.039), B-ADL ($\beta = 0.296$, 95% CI: 0.248–0.343) and I-ADL ($\beta = 0.174$, 95% CI: 0.152–0.195) on depression were statistically significant. Moreover, social support moderated the effects of B-ADL ($\beta_{B-ADL*socialsupport} = 0.034$, 95% CI: 0.014–0.053, $F = 11.57$, $p = 0.001$) and I-ADL ($\beta_{I-ADL*socialsupport} = 0.018$, 95% CI: 0.010–0.025, $F = 23.93$, $p < 0.001$) on depressive symptoms. Additionally, to better explain the regulatory role of social support, we visualized the association between social support, disability, and depressive symptoms, as shown in Figure 4.

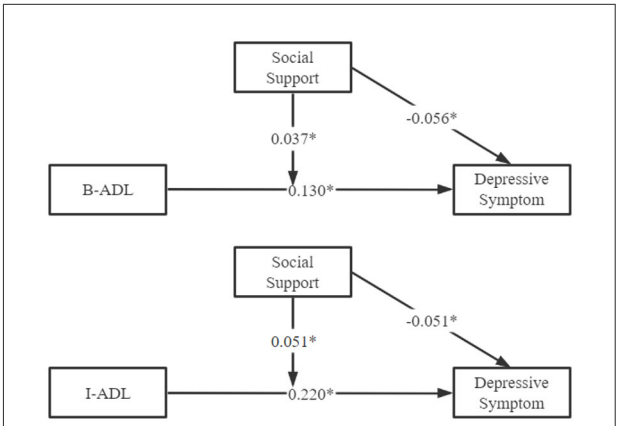

FIGURE 4
Model of moderation by social support. *$P < 0.05$.

Discussion

The purpose of the study was to explore the association between disability, social support, and depressive symptoms, and further examine whether social support could moderate the association between disability and depressive symptoms among the Chinese elderly. After adjusting for potential confounding factors, the results showed that disability and social support significantly affected depressive symptoms in the elderly. Meanwhile, social support played a potentially moderating effect between disability and depressive symptoms of the elderly. Therefore, the findings of this study supported that social support was an effective way to promote positive and healthy aging, especially among older adults with disability.

In this study, we found that approximately 26.75% of the Chinese elderly had depressive symptoms. This was similar to previous research, which showed that the prevalence of depressive symptoms was 25.55% among older Chinese (34). In addition, the current research shows that about 31.06% of the elderly have limited activities of daily living due to health reasons. This was also consistent with previous research, which reported that the B-ADL and I-ADL disability rates of the elderly over 60 years old in China were 23.8 and 35.4%, respectively (13). With the increase of age, the activities of daily living of the elderly gradually decreased. A study, based on six provinces in China, reported that the incidence of disability among 23,803 participants aged 60 and over was 12% during a 2-year follow-up (35). Although the overall disability rate had a slight downward trend with the development of social economy and the improvement of medical levels, the disability rate of

rural elderly people still showed an upward trend (36). Thus, the current situation of disability and depressive symptoms in the Chinese elderly was not optimistic.

This study's results suggested that activities of daily living negatively correlated with depressive symptoms in the Chinese elderly. In addition, results also showed that social support, especially from spouses and children, significantly affected the depressive symptoms of the elderly. Those were in agreement with the previous research (37–40). Elderly with disabilities increased the likelihood of comorbidity, early mortality, and mental health problems, which increased the obstacles for the elderly to achieve a high quality of life (41, 42). Nevertheless, family support, especially emotional support, was an important guarantee to maintaining the mental health of the elderly (43). Based on the above, we tried to reveal the potential association between disability, social support, and depressive symptoms of the elderly in China. The current study found that social support can moderate the effect of disability on depressive symptoms. This finding may be explained by the theory of psychological elasticity, which refers to demonstrating positive psychological results in the face of adversity (44). When the activities of daily living of the elderly was limited, the effective mobilization of psychological and social resources can increase the psychological elasticity of the elderly, which was fundamental to achieving good outcomes (45). It could be argued that social support can alleviate psychological stress and reduce the feelings of helplessness brought by disability to the elderly, thereby decreasing depressive symptoms. Therefore, social support was a crucial factor in preventing depression in the elderly and buffering the impact of disability on their mental health.

The strength of this study is that study used data from a national survey, the population is representative. In addition, the study explored the potential moderating role of social support between disability and depressive symptoms in the elderly. There is no denying that there are still many shortcomings in this study. First of all, this research design was a cross-sectional study, all questions were self-reported, which cannot determine the causal association between variables. Furthermore, social support as a protective factor against depressive symptoms of the elderly, can improve the quality of life of the elderly and have a positive impact on actively coping with aging. Therefore, it may be more instructive to explore the impact of social support from specific groups, such as spouses, sons, daughters, and grandchildren, on depressive symptoms of the elderly in the future.

In conclusion, this study found that disability and social support can affect depressive symptoms among older adults. In addition, social support moderates the effect of disability on depressive symptoms. Now the prevalence of depression in the elderly is increasing year by year, which brings a serious burden to the family and society. Taking effective measures to reduce the elderly disability rate and increase their social support is a necessary condition for realizing mental health. Therefore, future studies should explore diversified pension models to meet the needs of the elderly. On the one hand, institutions could integrate eldercare services with medical care to meet the needs of the elderly, especially for the elderly living alone. On the other hand, communities can be linked by kinship, to realize the life concept of two generations living together, and increase the communication between the elderly and family members.

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

RL designed the study question, performed the statistical analyses, and wrote the first draft and revision. GT performed the statistical analyses and critical revision. YC, TZ, YS, WY, YM, and JS critical revision. YY was responsible for the overall supervision of the study design and revised the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.980465/full#supplementary-material

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A novel nomogram for predicting long-term heart-disease specific survival among older female primary breast cancer patients that underwent chemotherapy: A real-world data retrospective cohort study

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Background: The past decade has witnessed an improvement in survival rates for breast cancer, with significant inroads achieved in diagnosis and treatment approaches. Even though chemotherapy is effective for this patient population, cardiotoxicity remains a major challenge, especially in older people. It has been established that cardiovascular events are a major cause of death in older female primary breast cancer patients that underwent chemotherapy. In the present study, the independent prognostic factors were identified to develop a novel nomogram for predicting long-term heart disease-specific survival (HDSS) and improving patient management.

Method: Older female primary breast cancer patients that underwent chemotherapy from 2010 to 2015 were retrieved from the Surveillance, Epidemiology, and End Results (SEER) database and randomly assigned to a training cohort and a validation cohort at a ratio of 7:3. HDSS was the primary endpoint of this study. Univariate and multivariate Cox regression analyses were conducted on the training cohort to identify independent prognostic factors of HDSS and construct a nomogram to predict the 5- and 8-year HDSS. The performance of the constructed nomogram was evaluated by calibration curve, receiver operating characteristic (ROC) curve, and decision curve analyses. Finally, a risk classification system was constructed to assist in patient management.

Result: A total of 16,340 patients were included in this study. Multivariate Cox regression analysis identified six independent prognostic factors: age, race, tumor stage, marital status, surgery, and radiotherapy. A nomogram based on these six factors yielded excellent performance, with areas under the curve of the ROC for 5- and 8-year HDSS of 0.759 and 0.727 in the training cohort and 0.718 and 0.747 in the validation cohort. Moreover, the established risk classification system could effectively identify patients at

low-, middle-, and high- risk of heart disease-associated death and achieve targeted management.

Conclusion: Independent prognostic factors of HDSS in older female primary breast cancer patients that underwent chemotherapy were determined in this study. A novel nomogram for predicting 5- and 8-year HDSS in this patient population was also established and validated to help physicians during clinical decision-making and screen high-risk patients to improve outcomes.

KEYWORDS

breast cancer, heart disease-specific survival, female, chemotherapy, nomogram, risk classification system, SEER

Introduction

Cancer is the second most common cause of death in the US, behind heart disease (1). According to the latest data released by the American Cancer Society, the expected number of female breast cancer cases will increase by 287,850 in the US in 2022, leading to an estimated 43,250 deaths. Interestingly, it has been reported that since the 1950s, the incidence of breast cancer has increased by 0.5% per year. However, with early detection of breast cancer through screening, increased sensitization, and improved treatments, breast cancer mortality has fallen by 42% over the past 30 years (2). Increasing age and female gender are reportedly significant risk factors for breast cancer. The risk of developing invasive breast cancer in women under 49, 50–59, 60–69, and older than 70 years old has been reported to be 2.1, 2.4, 3.5, and 7%, respectively (2).

Increasing age is a natural driver of cardiovascular morbidity and mortality in the general population; cardiovascular diseases have been documented to be a significant risk factor for mortality in older females with breast cancer. Abdel-Qadir et al. showed that among breast cancer women aged 66 years or older with no cardiovascular disease, the 10-year risk of breast cancer- and cardiovascular disease-associated death were 11.9 and 7.6%, respectively. Interestingly, among patients with pre-existing cardiovascular disease, the risk of death from cardiovascular disease and breast cancer was comparable for the first 5 years. However, the risk of death from cardiovascular disease exceeded breast cancer over time, with a 10-year cumulative mortality rate of 16.9 and 14.6%, respectively (3). Over the years, anthracycline-based chemotherapy has exhibited high efficacy in treating breast cancer. However, it has been shown that cardiotoxicity and heart failure risks increase with cumulative doses of anthracyclines (4, 5). Accordingly, mortality caused by cardiovascular disease in older breast cancer patients that underwent chemotherapy accounts for poor long-term heart disease specific survival (HDSS).

Although risk factors associated with HDSS in breast cancer have been identified, there is currently no universally accepted scoring system to predict long-term HDSS in this subpopulation. Given that different clinical-pathological variables can affect the patient prognosis, a new approach that integrates key prognostic predictors is warranted to help during treatment selection and improve patient quality of life. Nomograms are nowadays widely accepted as a simple multivariate visualization tool for predicting individual patient survival outcomes, especially in oncology (6, 7). Compared with the tumor-node-metastasis staging system, nomograms can more accurately estimate the survival of individual patients by integrating key variables to aid in clinical decision-making and facilitate the development of precision medicine (6). To our knowledge, no nomogram has been documented in the literature for predicting HDSS in this subpopulation. More in-depth analysis of this subpopulation is necessary to identify prognostic factors associated with HDSS and develop scientifically appropriate cardiovascular mortality prevention measures to improve survival outcomes. Therefore, this study aimed to identify independent prognostic factors associated with HDSS in this subpopulation by analyzing relevant data from the Surveillance, Epidemiology, and End Results (SEER) database and to develop a novel nomogram for predicting the 5- and 8-year HDSS.

Abbreviations: HDSS, heart disease-specific survival; SEER, Surveillance, Epidemiology and End Results; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; ROC, receiver operating characteristic; DCA, decision curve analysis; AUC, area under the curve; LVEF, left ventricular ejection fraction.

Methods

Database

The SEER database (https://seer.cancer.gov/seerstat/) collects data from 18 separate cancer registries covering ∼30% of the US population. It was used in this retrospective cohort

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TABLE 1 The baseline demographic and clinicopathologic characteristics of the HDSS-related variables of older female primary breast cancer patients that underwent chemotherapy.

Variables	Training cohort		Validation cohort		Total	
	11,440	70.00%	4,900	30.00%	16,340	100.00%
Age (years)						
65–70	6,953	60.78%	3,060	62.45%	10,013	61.28%
71–76	3,231	28.24%	1,361	27.78%	4,592	28.10%
>76	1,256	10.98%	479	9.77%	1,735	10.62%
Race						
Black	1,312	11.47%	542	11.06%	1,854	11.35%
White	9,246	80.82%	3,979	81.20%	13,225	80.94%
Other	882	7.71%	379	7.74%	1261	7.71%
Marital status						
Single/other	4,980	43.53%	2,051	41.86%	7,031	43.03%
Married	6,460	56.47%	2,849	58.14%	9,309	56.97%
Primary site						
C50.0 (Nipple)	54	0.47%	12	0.24%	66	0.40%
C50.1 (Central portion of breast)	665	5.81%	273	5.57%	938	5.74%
C50.2 (Upper-inner quadrant of breast)	1,264	11.05%	548	11.18%	1,812	11.09%
C50.3 (Lower-inner quadrant of breast)	622	5.44%	289	5.90%	911	5.58%
C50.4 (Upper-outer quadrant of breast)	3,999	34.96%	1,707	34.84%	5,706	34.92%
C50.5 (Lower-outer quadrant of breast)	940	8.22%	391	7.98%	1,331	8.15%
C50.6 (Axillary tail of breast)	58	0.51%	18	0.37%	76	0.47%
C50.8 (Overlapping lesion of breast)	2,674	23.37%	1,144	23.35%	3,818	23.37%
C50.9 (Breast, NOS)	1,164	10.17%	518	10.57%	1,682	10.29%
Tumor grade						
I	996	8.70%	448	9.14%	1,444	8.84%
II	4,666	40.79%	1,949	39.78%	6,615	40.48%
III	5,744	50.21%	2,485	50.71%	8,229	50.36%
IV	34	0.30%	18	0.37%	52	0.32%
Tumor stage						
I	3,250	28.40%	1,490	30.40%	4,740	29.01%
II	5,715	49.96%	2,345	47.86%	8,060	49.33%
III	2,220	19.41%	968	19.76%	3,188	19.51%
IV	255	2.23%	97	1.98%	352	2.15%
Tumor size (mm)						
<22	5,466	47.78%	2,448	49.96%	7,914	48.44%
22-36	3,676	32.13%	1,480	30.20%	5,156	31.55%
>36	2,298	20.09%	972	19.84%	3,270	20.01%
Breast subtype						
HR-/HER2- (Triple Negative)	2,205	19.27%	1,022	20.86%	3,227	19.75%
HR-/HER2+ (HER2 enriched)	1,060	9.27%	393	8.02%	1,453	8.89%
HR+/HER2- (Luminal A)	5,903	51.60%	2,513	51.28%	8,416	51.51%
HR+/HER2+ (Luminal B)	2,272	19.86%	972	19.84%	3,244	19.85%
ER status						
Negative	3,449	30.15%	1,498	30.57%	4,947	30.28%

(Continued)

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TABLE 1 (Continued)

Variables	Training cohort		Validation cohort		Total	
	11,440	70.00%	4,900	30.00%	16,340	100.00%
Positive	7,991	69.85%	3,402	69.43%	11,393	69.72%
PR status						
Negative	5,096	44.55%	2,159	44.06%	7,255	44.40%
Positive	6,344	55.45%	2,741	55.94%	9,085	55.60%
HER2 status						
Negative	8,108	70.87%	3,535	72.14%	11,643	71.25%
Positive	3,332	29.13%	1,365	27.86%	4,697	28.75%
Radiotherapy						
No	4,275	37.37%	1,783	36.39%	6,058	37.07%
Yes	7,165	62.63%	3,117	63.61%	10,282	62.93%
Surgery						
No	335	2.93%	106	2.16%	441	2.70%
Yes	11,105	97.07%	4,794	97.84%	15,899	97.30%
Bone metastasis						
Absent	11,276	98.57%	4,844	98.86%	16,120	98.65%
Present	164	1.43%	56	1.14%	220	1.35%
Lung metastasis						
Absent	11,346	99.18%	4,863	99.24%	16,209	99.20%
Present	94	0.82%	37	0.76%	131	0.80%
Liver metastasis						
Absent	11,396	99.62%	4,880	99.59%	16,276	99.61%
Present	44	0.38%	20	0.41%	64	0.39%
Brain metastasis						
Absent	11,434	99.95%	4,897	99.94%	16,331	99.94%
Present	6	0.05%	3	0.06%	9	0.06%

HDSS, heart disease-specific survival.

study (8). SEER Stat software v8.3.9.2 was used to identify the relevant data of this subpopulation in the SEER database from 2000 to 2018 with the reference number 16336-Nov2020 [Incidence-SEER Research Plus Data, 18 Registries, Nov 2020 Sub (2000–2018)]. Since SEER is a publicly available database, and the acquired data does not include personal information, no ethics approval and informed consent are required. This research was conducted following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (9).

Patient selection

The inclusion criteria consisted of (i) patients with the following site-specific codes for cancer that originated in the breast: C50.0 (Nipple), C50.1 (Central portion of the breast), C50.2 (Upper-inner quadrant of the breast), C50.3 (Lower-inner quadrant of the breast), C50.4 (Upper-outer quadrant of the breast), C50.5 (Lower-outer quadrant of the breast), C50.6 (Axillary tail of the breast), C50.8 (Overlapping lesion of the breast), and C50.9 (Breast, NOS) (10); (ii) older female (age ≥65) (11–14); (iii) patient underwent chemotherapy; (iv) "diseases of the heart" and "alive" were used to classify patient death classification according to "COD to site rec KM"; (v) primary tumor; and (6) complete follow-up data available. Patients were excluded for the following reasons: (i) male; (ii) no chemotherapy; (iii) age <65; (iv) breast cancer is not the primary tumor; (v) demographic and clinical data, including age, race, marital status, Breast-Adjusted AJCC 6th Stage (tumor stage), tumor grade, surgery, radiotherapy, and tumor size, were not available; (vi) survival time <1 month. Finally, 16,340 patients were included in this study and randomly divided into training (n = 11,440) and

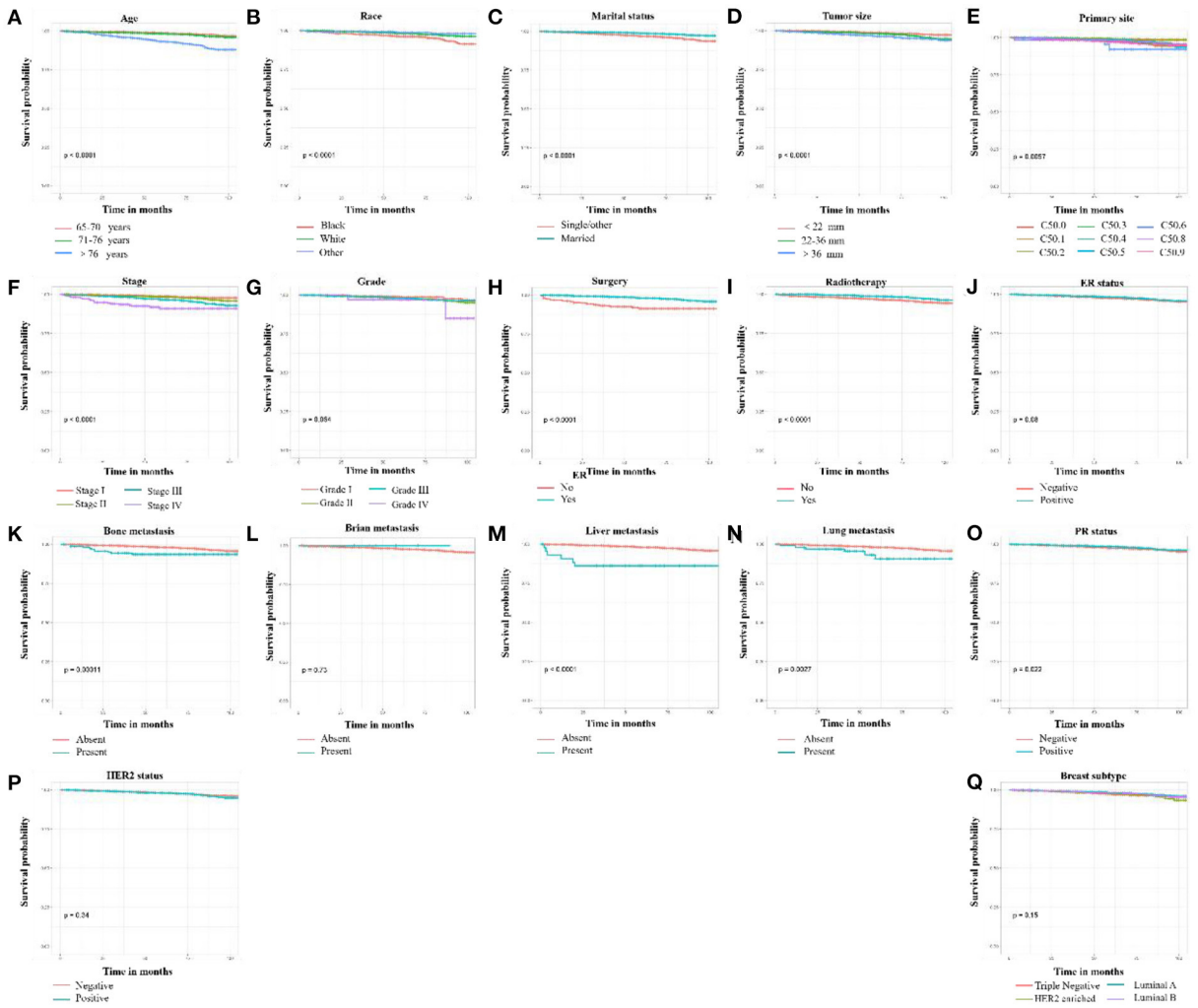

FIGURE 1
Kaplan-Meier curves of HDSS-related variables in older female primary breast cancer patients that underwent chemotherapy. **(A)** age, **(B)** race, **(C)** marital status, **(D)** tumor size, **(E)** primary site, **(F)** tumor stage, **(G)** tumor grade, **(H)** surgery, **(I)** radiotherapy, **(J)** ER status, **(K)** bone metastasis, **(L)** brain metastasis, **(M)** liver metastasis, **(N)** lung metastasis, **(O)** PR status, **(P)** HER2 status, and **(Q)** breast subtype.

validation cohorts (n = 4,900) according to a ratio of 7:3. The former was used to identify HDSS-related independent prognostic factors and establish a prognostic nomogram and risk classification system for this subpopulation. The latter was used to verify the constructed nomogram and risk classification system.

Variable definitions

Patient demographic characteristics (age, race, and marital status), tumor factors (tumor size, tumor grade, and tumor stage), disease characteristics (primary site, breast subtype, ER status, PR status, HER2 status, and distant (bone, brain, liver, and lung) metastasis, and treatment information (surgery and radiotherapy) were analyzed in this study. The optimal cut-off values for age and tumor size in the training and validation cohorts determined by the X-tile software were 71 and 76 years old and 22 and 36 mm, respectively (Supplementary File 1) (15). Patients were categorized into white, black, and others (American Indian/AK Native, Asian/Pacific Islander) based on race. Marital status was divided into "married" and "single/other". Surgery and radiotherapy were categorized into "Yes" and "No" groups. Distant (bone, brain, liver, and lung) metastasis was divided into "Present" and "Absent". Tumor grades were divided into grades I, II, III, and IV, and clinical tumor stages were classified as stages I, II, III, and IV. The breast subtypes were divided into HR-/HER2- (Triple Negative), HR-/HER2+ (HER2 enriched), HR+/HER2- (Luminal A), and HR+/HER2+ (Luminal B). Moreover, the HER2, PR, and ER

statuses were divided into "Positive" or "Negative". The HDSS, defined as the time interval from the date of diagnosis until death due to heart disease, was the primary endpoint of this study.

Statistical analysis

All data were analyzed using SPSS (version 22.0) and R (version 4.0.3) software. A p-value <0.05 was statistically significant. First, values were assigned to each variable included in this study. The statistical difference between the enrolled variables was identified using the Kaplan-Meier method and univariate Cox regression analysis. Then, variables with a p-value <0.05 were incorporated into a multivariate Cox regression analysis to eliminate confounding effects and identify HDSS-related independent prognostic factors in this subpopulation. HDSS-related independent prognostic factors were then used to construct a nomogram to predict 5- and 8-year HDSS. The corresponding scores of the independent prognostic factors in the HDSS nomogram were obtained. Then, the bootstrap-corrected concordance index (C-index) and calibration curves were constructed to verify the prediction and discrimination performance of the nomogram, and a decision curve analysis (DCA) was constructed to demonstrate the clinical utility value of the nomogram. The discriminative power of the nomogram was assessed by constructing the receiver operating characteristic (ROC) curves for the 5- and 8-year HDSS based on the area under the curve (AUC) values of the corresponding variables. In addition, the total score was calculated as the sum of the scores corresponding to the HDSS-related independent prognostic factors, and the optimal cut-off value for the total score was obtained using the X-tile software. Then, a risk classification system was established to stratify the cardiovascular mortality risk of this subpopulation into low-, middle-, and high-risk subgroups. Finally, Kaplan-Meier method was used to identify the differences between the three risk subgroups.

Results

Demographic and clinicopathologic characteristics

16,340 older female primary breast cancer patients that underwent chemotherapy retrieved from the SEER database were randomly divided into training (n = 11,440, 70%) and validation (n = 4,900, 30%) cohorts. The majority of patients were aged between 65 and 70 years old (n = 10,013, 61.28%), white (n = 13,225, 80.94%), and married (n = 9,309, 56.97%). No significant difference was found between low-grade (grade I–II) and high-grade (grade III–IV) tumors. Moreover, low-stage (stage I–II) tumors occupied a higher proportion (78.34%) of cases than high-stage (stage III–IV) tumors. The size of most tumors was <22 mm, while C50.4, C50.8, and C50.2 represented the top three primary sites, accounting for 69.38%. The incidence of distant metastases was relatively low. Besides, luminal A was the most common molecular subtype, accounting for 51.51%. Most patients were classified as ER-positive (n = 11,393, 69.72%), PR-positive (n = 9,085, 55.60%), and HER2-negative (n = 11,643, 71.25%). As for the treatment, 97.3 and 62.93% of patients underwent surgery and radiotherapy, respectively (Table 1).

Identification of independent prognostic factors for HDSS

According to the results of univariate Cox regression analysis and Kaplan–Meier curves, age, race, marital status, primary site, tumor grade, tumor stage, tumor size, breast subtype, PR status, surgery, radiotherapy, and distant (bone, liver, and lung) metastasis were significantly associated with HDSS (p < 0.05). In contrast, no significant difference in ER status, HER2 status, and brain metastasis were found (Figure 1). Then, HDSS-related variables with a p-value<0.05 during univariate Cox regression analysis were used to perform multivariate Cox regression analysis to eliminate the effects of confounding variables. The results showed that age, race, marital status, tumor stage, surgery, and radiotherapy were independent prognostic factors of HDSS in this subpopulation (Table 2).

Establishment and verification of the prognostic nomogram for HDSS

The six aforementioned HDSS-related independent prognostic factors were used to establish a prognostic nomogram for predicting long-term HDSS in older female primary breast cancer patients that underwent chemotherapy (Figure 2). As shown in Figure 2, the corresponding point value of the independent prognostic factors in the HDSS nomogram were obtained by drawing a straight line to the top point row and then were summed to get the total point. The 5- and 8-year HDSS were obtained by drawing vertical lines from the total point row to the bottom timeline. A good prognosis was found for 65–70 years old married patients of other races (American Indian/AK Native, Asian/Pacific Islander) and lower tumor stage (stage I) that underwent surgery and radiotherapy. The calibration curves for 5- and 8-year survival showed good agreement between actual and predicted outcomes based on the constructed nomogram in this subpopulation (Figure 3). The bootstrap-corrected C-index was 0.757 (95% CI: 0.694–0.820) and 0.730 (95% CI: 0.634–0.826) in the training cohort and validation cohort.

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TABLE 2 The univariate and multivariate Cox regression analyses of the HDSS-related variables of older female primary breast cancer patients that underwent chemotherapy.

Variables	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (years)				
65–70	Reference		Reference	
71–76	1.343 (1.000–1.804)	0.050	1.260 (0.937–1.695)	0.125
>76	4.727 (3.598–6.210)	≤0.001	3.861 (2.927–5.093)	≤0.001
Race				
Black	Reference		Reference	
White	0.469 (0.353–0.623)	≤0.001	0.542 (0.406–0.724)	≤0.001
Other	0.291 (0.157–0.541)	≤0.001	0.337 (0.181–0.627)	≤0.001
Marital status				
Single/other	Reference		Reference	
Married	0.423 (0.331–0.540)	≤0.001	0.544 (0.423–0.698)	≤0.001
Primary site				
C50.0 (Nipple)	Reference		Reference	
C50.1 (Central portion of breast)	1.684 (0.227–12.522)	0.610	1.922 (0.258–14.297)	0.523
C50.2 (Upper-inner quadrant of breast)	0.446 (0.058–3.454)	0.439	0.586 (0.076–4.542)	0.609
C50.3 (Lower-inner quadrant of breast)	1.468 (0.196–10.999)	0.709	1.989 (0.265–14.916)	0.503
C50.4 (Upper-outer quadrant of breast)	1.224 (0.171–8.778)	0.841	1.623 (0.226–11.645)	0.630
C50.5 (Lower-outer quadrant of breast)	1.208 (0.163–8.960)	0.854	1.660 (0.224–12.325)	0.620
C50.6 (Axillary tail of breast)	2.736 (0.285–26.306)	0.383	2.950 (0.306–28.416)	0.349
C50.8 (Overlapping lesion of breast)	1.328 (0.184–9.568)	0.778	1.800 (0.250–12.972)	0.560
C50.9 (Breast, NOS)	1.737 (0.239–12.638)	0.585	1.909 (0.262–13.893)	0.523
Tumor grade				
I	Reference			
II	1.649 (0.979–2.778)	0.060		
III	1.571 (0.937–2.635)	0.087		
IV	4.487 (1.307–15.404)	0.017		
Tumor stage				
I	Reference		Reference	
II	1.521 (1.085–2.133)	0.015	1.354 (0.964–1.901)	0.081
III	2.796 (1.959–3.992)	≤0.001	2.438 (1.697–3.503)	≤0.001
IV	6.965 (4.118–11.779)	≤0.001	3.045 (1.620–5.722)	≤0.001
Tumor size (mm)				
<22	Reference			
22–36	1.631 (1.226–2.169)	≤0.001		
>36	2.449 (1.832–3.275)	≤0.001		
Breast subtype				
HR–/HER2– (Triple Negative)	Reference			
HR–/HER2+ (HER2 enriched)	1.063 (0.695–1.627)	0.778		
HR+/HER2– (Luminal A)	0.752 (0.557–1.016)	0.063		
HR+/HER2+ (Luminal B)	0.859 (0.597–1.236)	0.413		
ER status				
Negative	Reference			
Positive	0.803 (0.628–1.027)	0.081		
PR status				
Negative	Reference			

(Continued)

TABLE 2 (Continued)

Variables	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Positive	0.762 (0.603–0.963)	0.023		
HER2 status				
Negative	Reference			
Positive	1.131 (0.877–1.458)	0.343		
Radiotherapy				
No	Reference		Reference	
Yes	0.465 (0.367–0.588)	≤0.001	0.513 (0.401–0.656)	≤0.001
Surgery				
No	Reference		Reference	
Yes	0.222 (0.148–0.333)	≤0.001	0.552 (0.333–0.914)	0.021
Bone metastasis				
Absent	Reference			
Present	3.256 (1.731–6.125)	≤0.001		
Lung metastasis				
Absent	Reference			
Present	3.218 (1.433–7.227)	0.005		
Liver metastasis				
Absent	Reference			
Present	7.590 (3.379–17.052)	≤0.001		
Brain metastasis				
Absent	Reference			
Present	0.050 (0.000-4323712331)	0.815		

HDSS: heart disease-specific survival.

The AUCs for the 5-year HDSS in the training and validation cohorts were 0.759 and 0.718, respectively. Consistently, the AUCs for the 8-year HDSS in the training and validation cohorts were 0.718 and 0.747, respectively (Figure 4). These findings suggested that the constructed nomogram had good discriminatory power (Figure 4). Moreover, we compared the predictive accuracy between individual independent prognostic factors and the constructed nomogram (Figure 5). The results showed that the AUC of the constructed nomogram was higher than each factor at 5- and 8-years in the training and validation cohorts, indicating that the nomogram yielded a more accurate predictive performance for HDSS in this subpopulation. In addition, DCA showed that the constructed nomogram had high prospects for clinical application (Figure 6).

Risk classification system for HDSS

In addition to predicting patient HDSS, it is essential to classify patients based on their cardiovascular mortality risk for individualized management. A cardiovascular mortality risk classification system was constructed using the six HDSS-related independent prognostic factors. Specifically, the total points of all patients were obtained by summing the assigned point values for each independent prognostic factor. The optimal cut-off values for the total point were 223 and 260, according to the results of the X-tile software (Supplementary File 1). Accordingly, patients were further divided into three cardiovascular mortality risk subgroups: low- (<223), middle- (223–260), and high- (>260), and a Kaplan-Meier survival curve was generated (Figure 7). As shown in Figure 7, the risk classification system could effectively classify older female primary breast cancer patients that underwent chemotherapy into three subgroups, indicating that the HDSS nomogram could classify patients based on the cardiovascular mortality risk to improve patient management.

Discussion

Depending on the tumor stage, subtype, and gene expression results, treatment modalities for breast cancer mainly involve local therapy, including surgery and radiotherapy, and

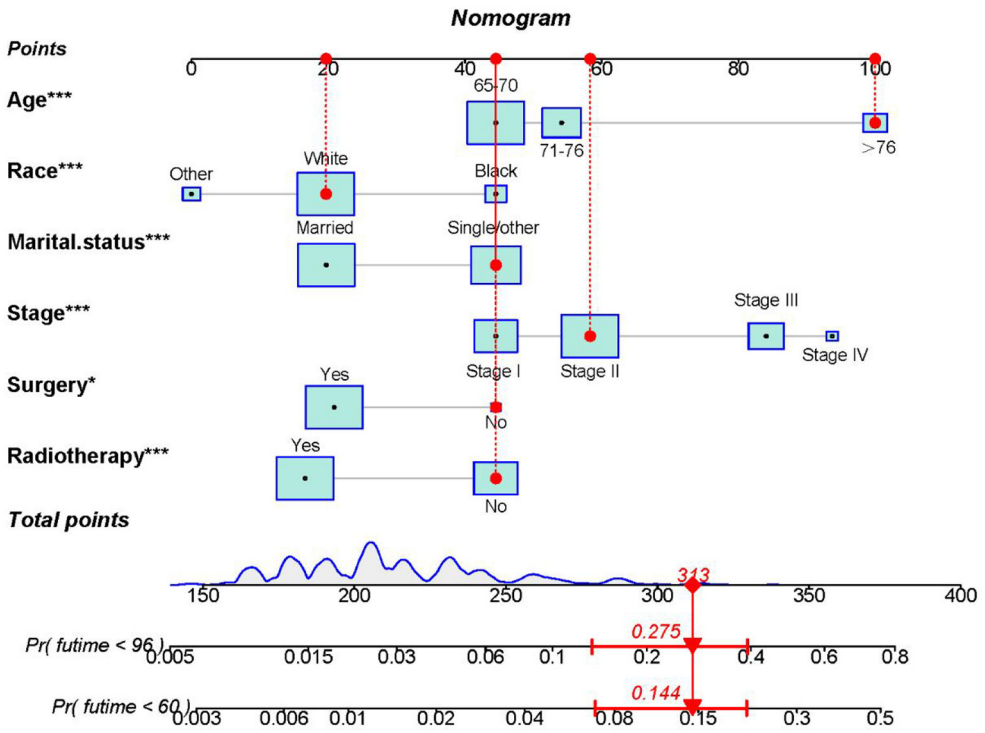

FIGURE 2
The nomogram was constructed to predict the 5- and 8-year HDSS in older female primary breast cancer patients that underwent chemotherapy. To calculate the HDSS of an individual patient, point values for each prognostic predictor were obtained by drawing a straight line to the top point row. Next, the corresponding point values were summed to get the total score below. The 5- and 8-year HDSS were obtained by drawing vertical lines from the total score row to the bottom timeline. For example, for an 80-year-old unmarried white race female patient with stage II disease that did not undergo surgery or radiotherapy, the total score is 100 (80 years old) +20 (white race) +45 (single/other) +58 (stage II) +45 (no surgery) +45 (no radiotherapy) = 313, and the corresponding risk of heart disease-associated death at 5- and 8-year are 0.144 and 0.275, while the corresponding HDSS of the patient at 5- and 8-year are 0.856 and 0.725.

systemic therapy, encompassing chemotherapy, hormone therapy, targeted therapy, and immunotherapy. Among these, chemotherapy is well-established as an effective treatment for breast cancer. Anthracycline-based treatment regimens have been used to treat breast cancer since the 1970s. Nonetheless, its use can reportedly cause cardiac side effects, including cardiomyopathy, ischemia, arrhythmias, and myocardial necrosis, resulting in severe and irreversible left ventricular dysfunction (16, 17). Two main mechanisms can explain this cardiotoxicity: (i) anthracyclines cause myocyte DNA damage, bind to topoisomerase IIβ and disrupt replication (18, 19); (ii) anthracyclines form complexes with intracellular iron, which in turn generate reactive oxygen species that damage DNA, proteins, and lipids, including mitochondrial membranes, and accelerate myocyte death (20, 21). In this regard, Howard et al. showed that doxorubicin-based adjuvant chemotherapy for breast cancer could cause arrhythmias and conduction abnormalities in 2.6% of patients compared to 1% of patients who did not receive doxorubicin (4). Consistently, Guglin et al. showed that anthracyclines could cause atrial fibrillation in 2–10% of patients during or after chemotherapy (22). In addition, cardiotoxicity caused by chemotherapeutic drugs is usually progressive and irreversible. Cardinale et al. showed that recovery of left ventricular function and reduced cardiac events was feasible with early detection and prompt treatment. However, complete left ventricular ejection fraction (LVEF) recovery was not observed in patients treated with chemotherapy over 6 months. On average, LVEF decreases moderately but consistently by ∼4% after 3 years of anthracycline exposure (23, 24). Based on these findings, McGowan et al. hypothesized that in the new era of targeted therapy, most breast cancer patients treated with anthracyclines might become the heart disease patients of tomorrow (18).

In addition to anthracycline-based chemotherapy, age is another major risk factor for heart disease. Interestingly, Jeon et al. showed that patients aged ≥50 years old sustained a significant increase in the risk of heart disease compared with those aged <50 years old (16). The incidence of breast cancer increases with age, doubling approximately every 10 years until menopause, where breast cancer growth slows (25). The incidence of heart disease increases steadily with

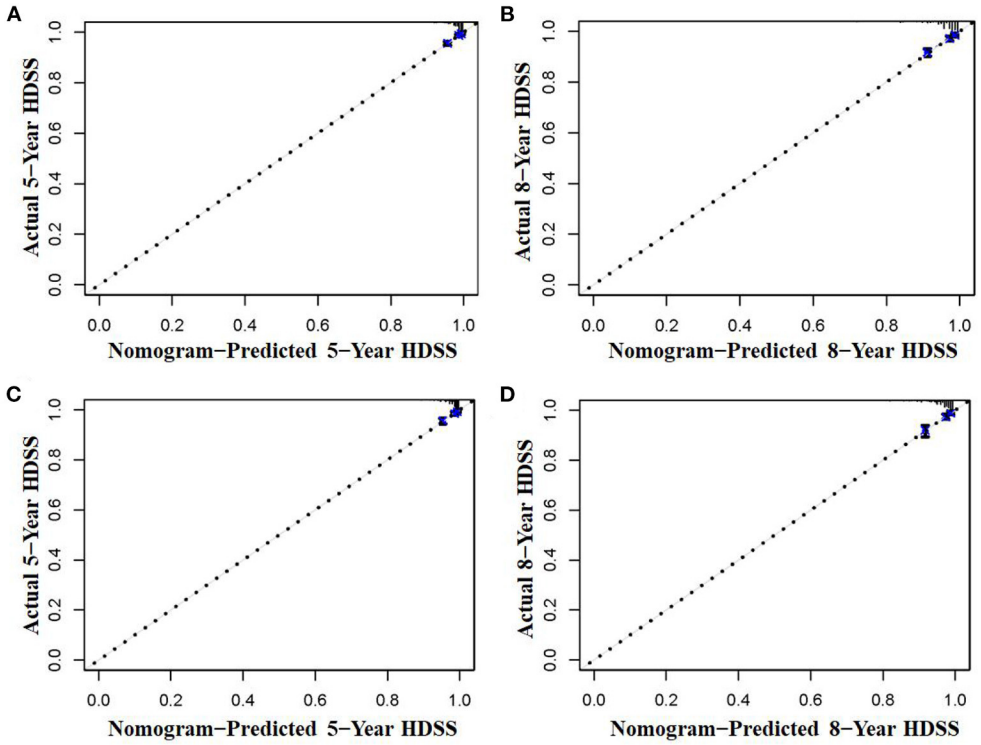

FIGURE 3
The calibration curves of the nomogram were used to predict the 5- and 8-year HDSS in older female primary breast cancer patients that underwent chemotherapy in the training **(A,B)** and validation cohorts **(C,D)**.

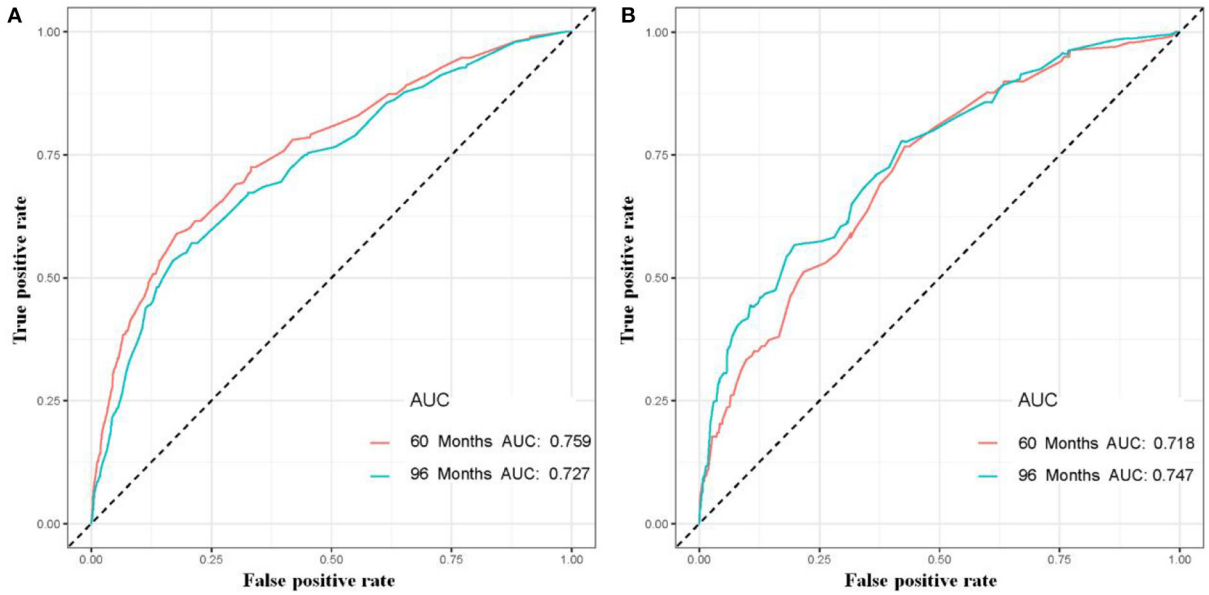

FIGURE 4
The 5- and 8-year receiver operating characteristic curves of older female primary breast cancer patients that underwent chemotherapy in the training **(A)** and validation **(B)** cohorts.

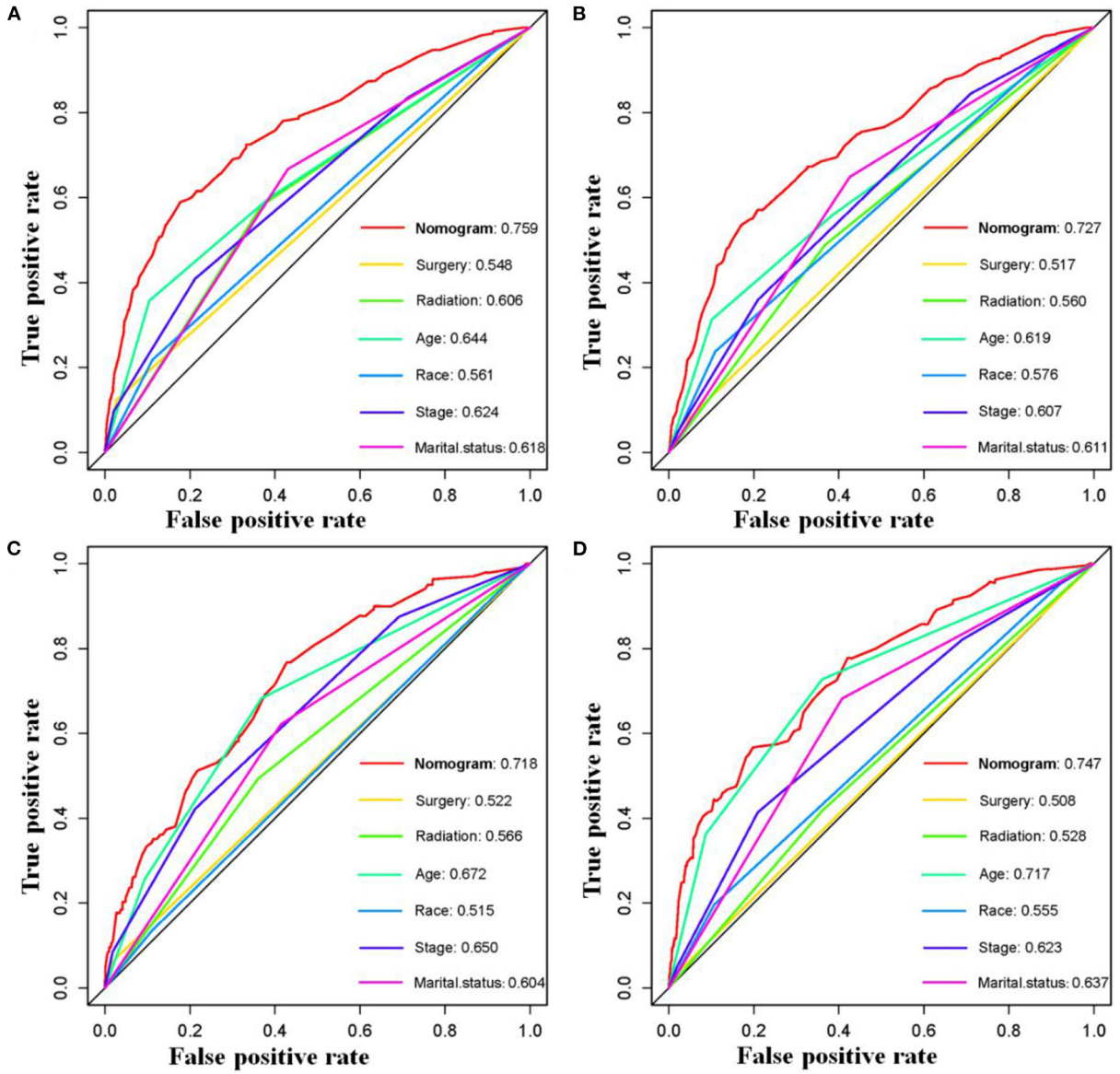

FIGURE 5
Comparison of prediction accuracy between the constructed novel nomogram and each HDSS-related independent prognostic factors in older female primary breast cancer patients that underwent chemotherapy at 5-**(A)** and 8-**(B)** year in the training cohort and 5-**(C)** and 8-**(D)** year in the validation cohort, respectively.

age, but the rate of increase becomes steeper at menopause (26). Gernaat et al. showed that heart disease-related mortality in breast cancer patients ranged from 1.6 to 10.4% (27). In addition, older patients are widely thought to have a poorer prognosis, associated with reduced physical function, cognitive impairment, and comorbidities, such as hypertension, hyperlipidemia, and diabetes. In such circumstances, aggressive treatment is not indicated, and the course of treatment may be shortened, thus affecting the treatment outcome (28, 29). Therefore, there is an urgent need for research on survival and risk factors associated with HDSS in this subpopulation.

In this study, a large-scale population-based data analysis was conducted on 16,340 older female primary breast cancer patients that underwent chemotherapy from the SEER database. Age, race, marital status, tumor stage, surgery, and radiotherapy were identified as independent prognostic factors of HDSS and used to establish a nomogram to predict the HDSS at 5 and 8 years in this subpopulation. The nomogram constructed could provide a quantitative method for HDSS prediction for

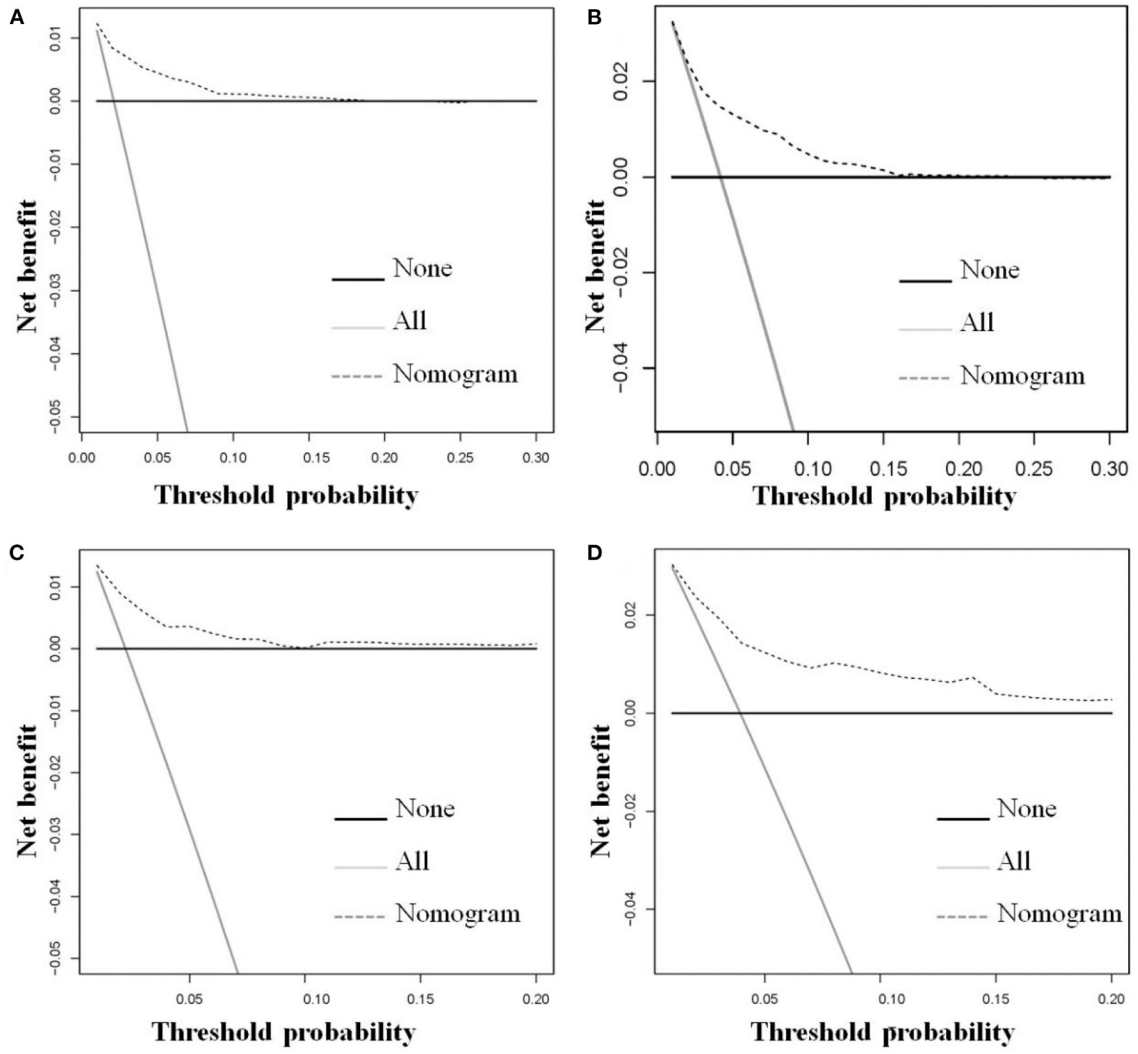

FIGURE 6
The decision curve analysis of the constructed novel nomogram was used to predict the 5-**(A)** and 8-**(B)** year HDSS in the training cohort and the 5-**(C)** and 8-**(D)** year HDSS in the validation cohort for older female primary breast cancer patients that underwent chemotherapy.

individual patients in this subpopulation. Importantly, we also used this nomogram to develop a cardiovascular mortality risk classification system that could classify these patients into three risk subgroups: high, middle, and low, allowing clinicians to assess various parameters more objectively and accurately, leading to better patient management.

Herein, we found that race was an independent prognostic factors of HDSS in this subpopulation. Our study showed that black women had a poorer prognosis than white women. Consistently, Berkman et al. showed that among women diagnosed with breast cancer between 1990 and 2010, the heart disease-associated mortality in black women was 6.43 times higher than white women, which may be explained by a lack of regular screening and poor access to health care resources and surgical treatment than whites (30–33). Besides, a shortage of educational resources could contribute to the lack of early recognition and intervention of risk factors associated with cardiovascular disease. Last but not least, lack of exercise, smoking, and shortage of healthy food have been documented to contribute to racial disparities in cardiovascular mortality (33, 34). Indeed, surgery remains the mainstay of breast cancer treatment, allowing effective tumor resection and improving survival. An increasing body of evidence suggests that older female patients with stage IV breast cancer who undergo surgery have better overall survival and cancer-specific survival than those who do not, even in patients with bone metastases

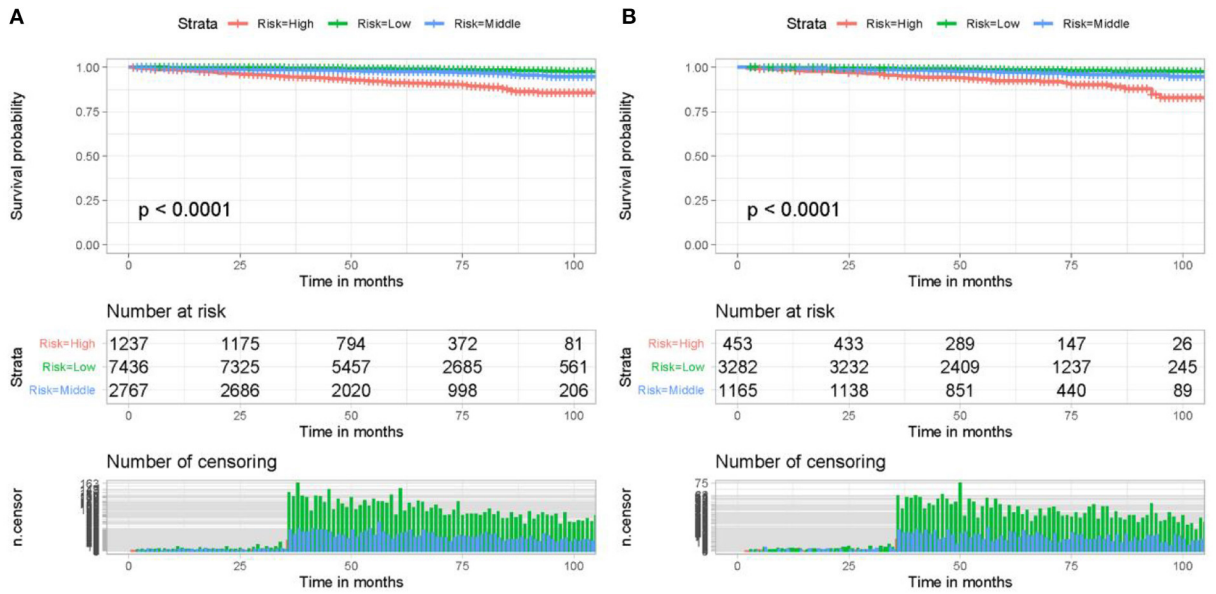

FIGURE 7
The risk classification system could effectively classify older female primary breast cancer patients that underwent chemotherapy in the training cohort **(A)** and validation cohort **(B)** into three risk subgroups with significant differences. Kaplan-Meier survival curves demonstrated that older female primary breast cancer patients that underwent chemotherapy in the high-risk subgroup had a worse prognosis than those in the low-risk subgroup.

(35–38). The similar conclusions were reached in our study, where patients who underwent surgery had significantly higher HDSS than those who did not. In addition, radiotherapy was also a protective factor for HDSS in this subpopulation. Radiotherapy can reduce the tumor size and allow control of distant metastases, reducing the burden of the primary tumor on the body and improving the body's ability to cope with the risk of heart disease.

Interestingly, our study showed that marital status was an independent prognostic factor for HDSS in this patient population. The 5-and 8-year HDSS of married patients was higher than that of divorced, widowed, and single patients regardless of age, race, and tumor grade. Previous studies have shown that married patients, who receive help and encouragement from their spouses, exhibit better compliance with prescribed treatment regimens, and married patients with greater financial resources are more likely to have access to early screening facilities and medical assistance (39–41). Moreover, we observed that the HDSS of patients with stage III/IV disease was lower than those with stage I/II, providing compelling evidence of the importance of improving early diagnosis rates.

Although this study constructed a novel nomogram with good performance for predicting HDSS, some limitations were present. Given the retrospective nature of clinical studies, selection bias was inevitable in our study. Moreover, much uncertainty surrounded the specific cardiovascular causes of death due to the coding system used in the SEER database. Besides, there were missing records for treatment data, such as patient chemotherapy regimen and duration and the presence of coexisting cardiovascular disease at diagnosis. Indeed, further studies in other centers or databases are essential to validate our nomogram.

Conclusions

Extra caution should be taken by clinicians when treating older female primary breast cancer patients with chemotherapy, given the risk of cardiac disease. Our study showed that unmarried patients with old age, black race, and higher tumor stage with no surgery or radiotherapy had a poor HDSS. Management of heart disease in this patient population should be strengthened, and prompt interventions should be taken to improve outcomes. Our established nomogram and risk classification system for predicting the HDSS at 5 and 8 years could assist physicians in clinical decision-making and managing this subpopulation.

Data availability statement

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

Ethics statement

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

Author contributions

MY designed and supervised the study. CH and ZD undertook the study, performed the literature review, extracted the data, and analyzed the pooled data. ZD and HL drew the figures and organized the tables. MY and ZZ provided critical comments and revised the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.964609/full#supplementary-material

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Trajectories of physical functioning and its predictors in older adults: A 16-year longitudinal study in China

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Objective: Maintaining and delaying a decline in physical function in older adults is critical for healthy aging. This study aimed to explore trajectories, critical points of the trajectory changes, and predictors among older people in the Chinese community.

Design: This study was one with a longitudinal design performed in China.

Setting and participants: The target population was community-dwelling older adults aged over 65 years. A total of 2,503 older adults from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) were included in this study.

Methods: Physical functioning was measured by instrumental activities of daily living (IADL). Population-based trajectory models were used to identify potential heterogeneity in longitudinal changes over 16 years and to investigate associations between baseline predictors and different trajectories for different cohort members using LASSO regression and logistic regression.

Results: Four trajectories of physical function were identified: slow decline (33.0%), poor function and moderate decline (8.1%), rapid decline (23.5%), and stable function (35.4%). Older age, male sex, worse self-reported health status, worse vision status, more chronic diseases, worse cognitive function, and a decreased frequency of leisure activity influenced changes in the trajectory of physical function. Having fewer teeth, stronger depressive symptoms, a lack of exercise, and reduced hearing may increase the rate of decline.

Conclusion and implications: Four trajectories of physical function were identified in the Chinese elderly population. Early prevention or intervention of the determinants of these trajectories can maintain or delay the rate of decline in physical function and improve healthy aging.

KEYWORDS

physical function, older people, longitudinal survey, trajectory, predictors

Introduction

With the rapid aging of the population, significant challenges arise from the sheer diversity of health and functional states of older people (1). In China, the aging population, those aged 80 years or over, has led to a sharp increase in the number of disabled older people (2). As a result, China's annual financial demand for long-term care has surged and is expected to reach 8,530.8 billion yuan by 2050 (2).

Physical function is often measured by the basic activities of daily living (ADL) and the instrumental activities of daily living (IADL) (3, 4). ADL refers to activities for self-care, which are fundamental to living in society. In contrast, IADL refers to activities supporting daily life within the home and community and are more concerned with self-reliant functioning in a given environment and often require more complex interactions (5). Therefore, ADL disability is more suitable for identifying people with severe functional losses, most of whom are care-dependent. In contrast, IADL is more suitable for identifying people with functional decline, most of whom are at high risk of becoming care-dependent (1, 6).

The trajectories of change in physical function and associated influences are the first steps in the study of older adult health. In recent years, research has emerged on the potential determinants of the functional states of older people. The research results show that, from a clinical or public education perspective, it would make sense that sociodemographic, health, and lifestyle factors are associated with functional status and may cause people to follow specific trajectories of physical functional decline (7–12). It is worth noting that there are many modifiable lifestyle risk factors, such as smoking, alcohol abuse, sedentary behavior, poor sleep, and poor dietary habits

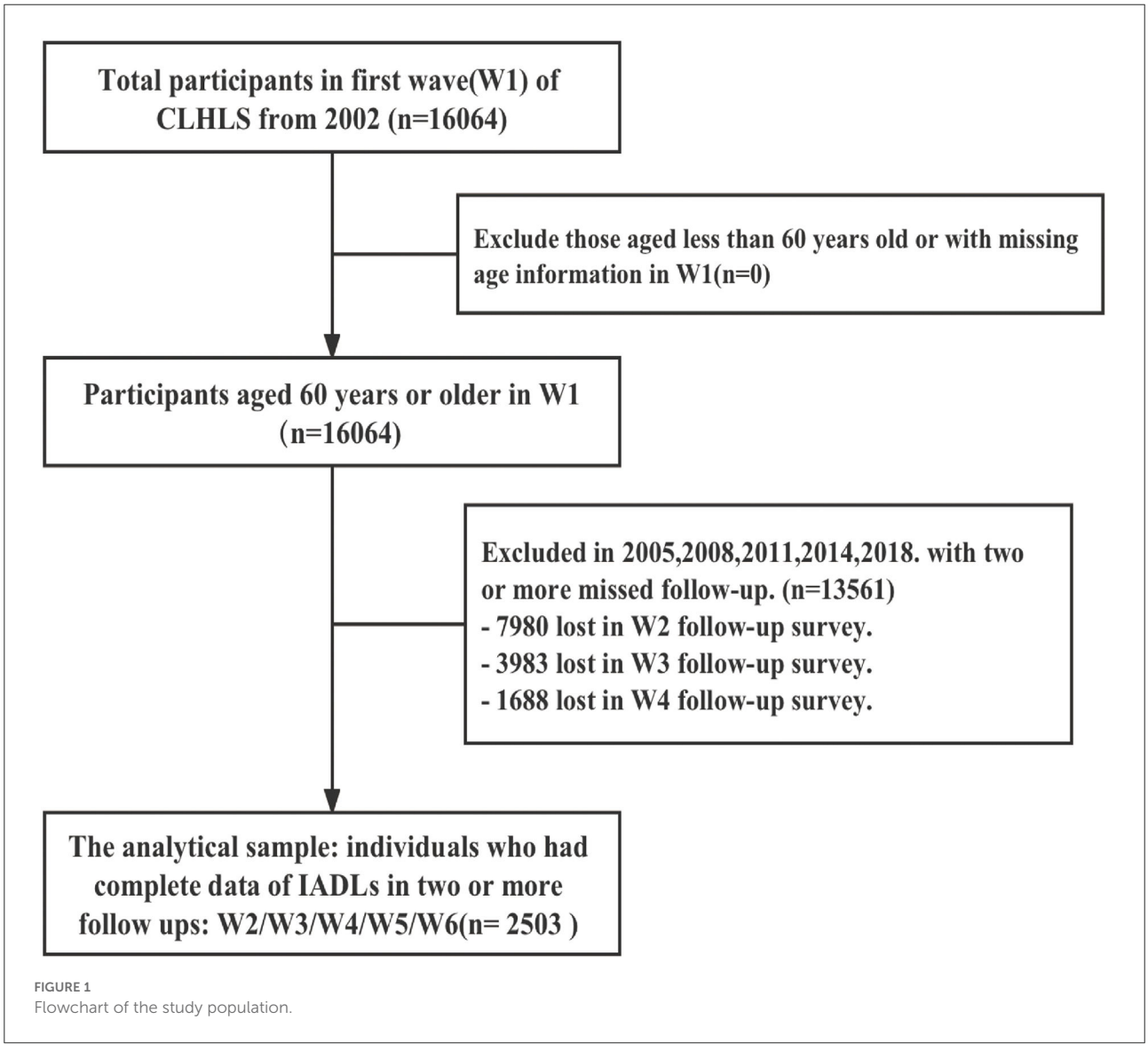

FIGURE 1
Flowchart of the study population.

(8, 9, 11–22). However, existing studies focusing on lifestyle and disability have several shortcomings, including (1) focusing only on special populations with functional decline in some domains; (2) focusing only on one behavior; (3) short follow-up periods; and (4) using ADL disability as the primary outcome but lacking evidence regarding IADL disability as the primary outcome.

The trajectory analysis of physical function in older people, which is important for determining whether a trajectory occurs and providing some support at key points of the trajectory, has potential benefits for maintaining intrinsic capacity and reducing the incidence of disability and care dependency. However, research on the most significant variables among the multifaceted influences by machine learning methods for different trajectories of physical functional decline is lacking. Accordingly, this study aimed to explore the trajectories and critical points of the trajectory changes and the relationship between sociodemographic characteristics, sociopsychological factors, and lifestyles among older people in the Chinese community.

Methods

Design and study sample

All data were obtained from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) database. The CLHLS is an ongoing study of the physical, emotional, cognitive, social functioning, lifestyle, and environment of older people in China. It is one of the largest research studies on the health and related factors of older people in China and is based on a nationally representative sample (23). We excluded older people who had missing values for two or more waves. A total of 2,503 samples were included according to the selection criteria. This study followed the GRoLTS checklist (24).

Measurement

Physical function

Physical function was measured by instrumental activities of daily living (IADL) and ADL. IADL was rated using eight questions, including the ability to visit neighbors, cook a meal, go shopping, wash clothes, walk 1 km at a time, lift a weight of 5 kg, continuously squat and stand three times, and take public transportation. ADL was measured across six subdomains, namely, bathing, dressing, toileting, indoor moving, continence of defecation, and eating. The CLHLS sample showed good internal consistency in ADL/IADL, with a Cronbach's α of 0.818 (25).

Health-related information

The general health information included perceptual function (vision, hearing), the number of natural teeth, and chronic diseases. The self-rated health status was assessed using the question "How do you feel about your health?" Self-rated quality-of-life was assessed using the question "How do you feel about your quality of life?" The emotional status was assessed with two questions: "Do you feel fearful or anxious?" and "Do you feel lonely and isolated?". CMMSE was used to assess the cognitive function; in this study, the internal consistency of CMMSE was 0.808 (26, 27).

Lifestyle assessment

In Jin's study, five lifestyle factors, namely, smoking, alcohol consumption, exercise status, diet and mental health (28) were examined, and a lifestyle index was created. The researchers asked participants four questions about four foods (vegetables, fruits, meat, and eggs) and the frequency at which they were consumed. Participants were defined as

TABLE 1 Baseline characteristics between participants and non-participants.

Variable	Participants ($N = 2,503$)	Non-participants ($N = 13,561$)
Age, *M* (SD)	74.71 (7.81)	88.47 (11.02)
Gender, (*n*, %)		
Male	1,177 (47.0)	7,893 (58.2)
Female	1,326 (53.0)	5,668 (41.8)
Residence, (*n*, %)		
City	421 (16.8)	3,424 (25.3)
Town	534 (21.3)	3,015 (22.2)
Rural	1,548 (61.8)	7,122 (52.5)
Years of schooling, *M* (SD)	2.70 (3.58)	2.63 (8.74)
Current marital status, (*n*, %)		
Currently married	1,357 (54.2)	3,385 (25.0)
Separated	69 (2.8)	227 (1.7)
Divorced	19 (0.8)	75 (0.6)
Widowed	1,039 (41.5)	9,692 (71.5)
Never married	10 (0.8)	182 (1.3)
Number of natural teeth, *M* (SD)	14.07 (10.78)	7.48 (9.41)
Number of chronic diseases, *M* (SD)	0.80 (1.01)	0.92 (1.13)
ADL, *M* (SD)	6.13 (0.70)	7.40 (2.61)
MMSE score, *M* (SD)	18.75 (3.59)	15.51 (6.16)
Lifestyle, *M* (SD)	2.52 (1.00)	2.56 (0.93)
Smoke, *M* (SD)	0.75 (0.43)	0.83 (0.38)
Drink, *M* (SD)	0.76 (0.43)	0.80 (0.40)
Exercise, *M* (SD)	0.37 (0.48)	0.30 (0.46)
Diet, *M* (SD)	0.64 (0.48)	0.63 (0.48)
Depression symptoms, *M* (SD)	0.48 (0.72)	0.56 (0.77)
Self-reported quality of life, *M* (SD)	2.40 (0.98)	4.49 (1.56)
Self-reported health, *M* (SD)	2.47 (1.02)	4.39 (1.65)
Leisure activities, *M* (SD)	26.53 (5.35)	31.91 (6.44)

consuming a healthy diet if they answered "almost every day" or "not every day, but at least once a week" for at least two of the four foods (vegetables, fruits, meat, and eggs).

Leisure activities

Leisure activities were assessed using a total of eight questions: "Do you do housework at present?", "Do you do any outdoor activities at present?", "Do you do garden work?", "Do you read newspapers/books at present?", "Do you raise domestic animals/pets at present?", "Do you play cards/mah-jong at present?", and "Do you watch TV or listen to the radio at present?" Each question had five answers: almost every day (score of 1), not daily but once per week (score of 2), not weekly (score of 3) but at least once per month (score of 4), and not monthly but sometimes or never (score of 5). The sum of the eight activities ranged from 8 to 40, with a low score representing a high frequency of leisure activities (29).

TABLE 2 Baseline characteristics of the total sample and the sample by the different trajectory groups.

Variable	Total (N = 2,503)	Trajectory group			
		Stable (N = 905)	Slow decline (N = 817)	Poor function with moderate decline (N = 191)	Rapid decline (N = 590)
Age, *M* (SD)	74.71 (7.81)	70.15 (4.87)	74.25 (6.44)	84.48 (8.43)	79.18 (7.71)
Gender, (*n*, %)					
Male	1,177 (47.0)	563 (62.2)	348 (42.6)	46 (24.1)	220 (37.3)
Female	1,326 (53.0)	342 (37.8)	469 (57.4)	145 (75.9)	370 (62.7)
Residence, (*n*, %)					
City	421 (16.8)	166 (18.3)	109 (13.3)	47 (24.6)	99 (16.8)
Town	534 (21.3)	184 (20.3)	174 (21.3)	42 (22.0)	134 (22.7)
Rural	1,548 (61.8)	555 (61.3)	590 (60.5)	102 (53.4)	357 (60.5)
Years of schooling, *M* (SD)	2.70 (3.58)	3.63 (5.05)	2.30 (5.63)	1.76 (7.59)	2.16 (6.56)
Current marital status, (*n*, %)					
Currently married	1,357 (54.2)	615 (68.0)	438 (53.6)	49 (25.7)	255 (43.2)
Separated	69 (2.8)	33 (3.6)	25 (3.1)	/	11 (1.9)
Divorced	19 (0.8)	8 (0.9)	10 (1.2)	/	1 (0.2)
Widowed	1,039 (41.5)	241 (26.6)	337 (41.2)	142 (74.3)	319 (54.1)
Never married	10 (0.8)	8 (0.9)	7 (0.9)	/	4 (0.7)
Number of natural teeth, *M* (SD)	14.07 (10.78)	17.97 (10.56)	14.14 (10.14)	6.58 (8.57)	10.40 (10.09)
Number of chronic diseases, *M* (SD)	0.80 (1.01)	0.63 (0.84)	0.82 (0.98)	1.26 (1.37)	0.89 (1.09)
ADL, *M* (SD)	6.13 (0.70)	6.02 (0.16)	6.07 (0.41)	6.93 (1.99)	6.12 (0.60)
IADL, *M* (SD)	22.59 (2.96)	23.86 (0.59)	22.86 (2.22)	16.38 (4.94)	22.23 (2.58)
MMSE score, *M* (SD)	18.75 (3.59)	19.90 (2.32)	18.59 (3.38)	16.45 (5.84)	17.95 (3.90)
Lifestyle, *M* (SD)	2.52 (1.00)	2.44 (1.05)	2.52 (1.00)	2.60 (0.89)	2.62 (0.95)
Smoke, *M* (SD)	0.75 (0.43)	0.67 (0.47)	0.77 (0.42)	0.86 (0.35)	0.81 (0.39)
Drink, *M* (SD)	0.76 (0.43)	0.68 (0.47)	0.78 (0.41)	0.87 (0.34)	0.81 (0.39)
Exercise, *M* (SD)	0.37 (0.48)	0.41 (0.49)	0.34 (0.47)	0.29 (0.45)	0.38 (0.49)
Diet, *M* (SD)	0.64 (0.48)	0.68 (0.47)	0.63 (0.48)	0.59 (0.49)	0.62 (0.49)
Depression symptoms, *M* (SD)	0.48 (0.72)	0.37 (0.65)	0.55 (0.77)	0.56 (0.75)	0.50 (0.72)
Self-reported quality of life, *M* (SD)	2.40 (0.98)	2.29 (0.79)	2.39 (0.88)	2.91 (1.78)	2.41 (0.97)
Self-reported health, *M* (SD)	2.47 (1.02)	2.22 (0.81)	2.51 (0.92)	3.19 (1.71)	2.55 (1.00)
Leisure activities, *M* (SD)	26.53 (5.35)	24.65 (4.86)	26.64 (4.88)	32.00 (5.65)	27.50 (5.10)

ADL, activities of daily living; IADL, instrumental activities of daily living; MMSE, the Mini-Mental State Exam.

Covariates

All covariates were obtained at baseline and included age, gender (male or female), residence (city, town and rural), years of school, and current marital status (currently married, separated, divorced, widowed, never married).

Statistical analysis

Participants' physical function trajectories were modeled using a group-based trajectory model (GBTM). A GBTM is a type of latent class growth model used to identify clusters of individuals who follow similar developmental trajectories on outcomes of interest by fitting a semiparametric mixture model to longitudinal data using a maximum likelihood estimate and is widely used in clinical research (30, 31).

The most predictive features among the fundamental characteristics in the primary dataset were selected by performing least absolute shrinkage and selection operator (LASSO) regression using R (https://www.r-project.org/), which is very suitable for the shrinkage of a high-dimensional dataset. The aim of this analysis is to explore the predictors between different trajectories. We considered a multivariable prediction model obtained by multinomial logistic regression to explore the predictors between different trajectories. A two-sided $p < 0.05$ was considered statistically significant. We analyzed the dataset using multivariate interpolation of chained equations (MICEs). MICE adds new functionality for imputing multilevel data, automatic predictor selection, data handling, post-processing imputed values, specialized pooling routines, model selection tools, and diagnostic graphs. Imputation of categorical data is improved in order to bypass problems caused by perfect prediction (32).

TABLE 3 Latent classes mixed model fit parameter estimates for 1–4 classes using a linear function.

N classes	*N* of parameter	AIC[b]	BIC[c]	Class parameter	1	2	3	4
1	2	34,323.19	34,334.85	*N*	2,503			
				%	100			
				APPA[d]	1			
	3	34,323.85	34,338.41	*N*	2,503			
				%	100			
				APPA[d]	1			
2	2	32,081.46	32,098.94	*N*	959	1,544		
				%	38.31	61.68		
				APPA[d]	0.9442	0.9606		
	3	32,083.83	32,107.13	*N*	959	1,544		
				%	38.31	61.68		
				APPA[d]	0.9438	0.9610		
3	4	31,561.02	31,590.14	*N*	343	964	1,196	
				%	13.72	38.52	47.76	
				APPA[d]	0.9110	0.8935	0.9407	
	4	31,560.98	31,593.02	*N*	343	964	1,196	
				%	13.71	38.51	47.78	
				APPA[d]	0.9108	0.8934	0.9409	
4	7[a]	31,421.81	31,465.50	*N*	205	841	601	856
				%	8.18	33.61	24.01	34.20
				APPA[d]	0.8981	0.8114	0.8500	0.8821
4	8[a]	31,423.25	31,469.85	*N*	205	841	601	856
				%	8.15	24.00	33.62	34.23
				APPA[d]	0.8987	0.8504	0.8114	0.8822

[a]Preferred model.
[b]Akaike information criterion.
[c]Bayesian information criterion.
[d]Average posterior probability of assignment.

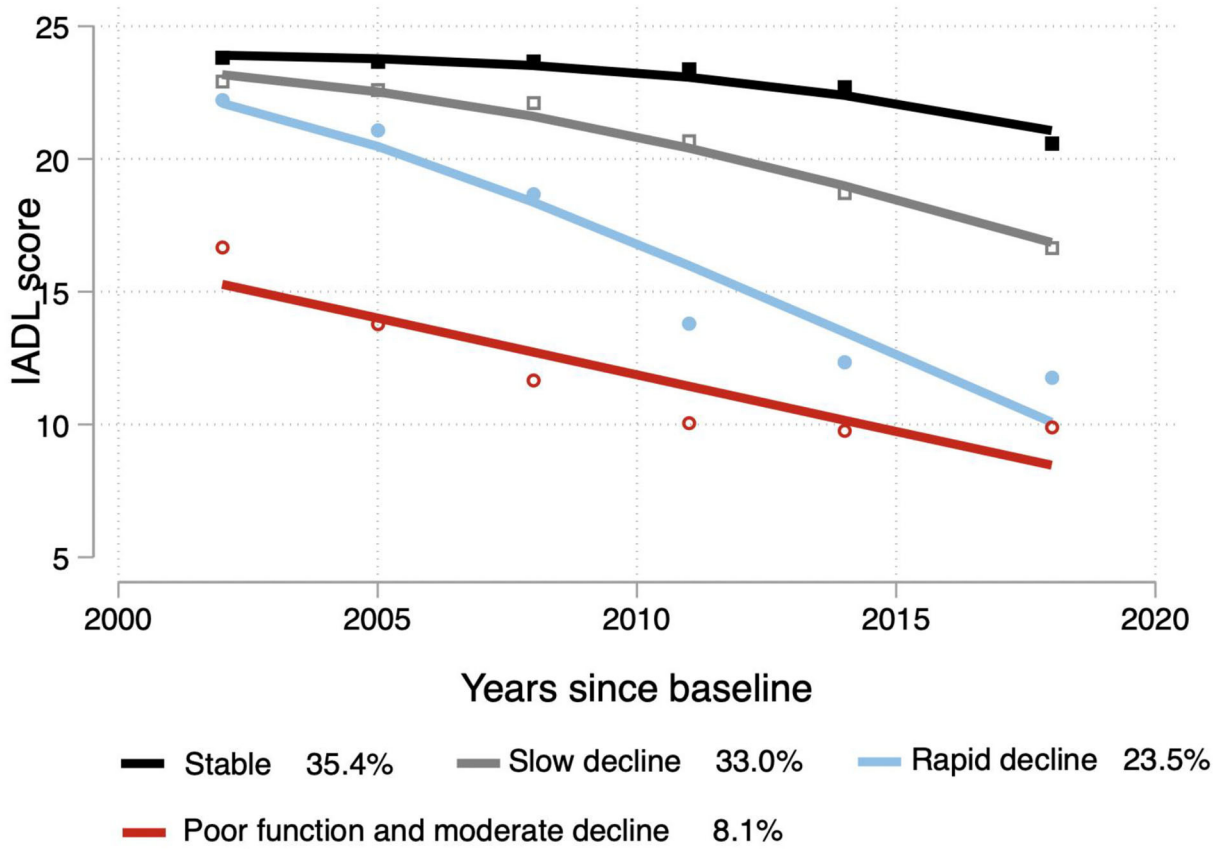

FIGURE 2
Trajectories of the IADL scores. The solid lines (black: stable; gray: slow decline; blue: rapid decline; red: poor function and moderate decline) represent estimated values.

Results

Characteristics of the study samples

To obtain the most accurate results, all six waves of subjects were included in this study, with the sample size adjusted to the number of subjects who were excluded. The participants in the final analysis (n = 2,503) were younger, more educated, had a better marital status, and were less lonely and isolated (all $p < 0.05$; Figure 1; Table 1). At baseline, the age of the study participants ranged from 65 to 104 years, with an average age of 74.71 years (SD 7.81). The number of males and females was balanced (1,177 vs. 1,326). Most of the older people lived in rural areas (61.8%). Nearly half of the older people did not complete primary education. The baseline characteristics of the participants for different trajectory groups are shown in Table 2.

Physical function trajectory models

After several data processing sessions, we found that among the models in groups 1–4, the absolute BIC values of the models in group 4 were lower than those of the other models, and the average posterior probability (Ave PP) values were high, all being greater than 0.8. A comparison of the models identified by GBTM for 1–4 trajectory classes is reported in Table 3. There were four different trajectory groups in which the model reached optimal values and maintained clinical applicability (Figure 2). The first group consisted of 35.4% of the population, marked as "stable." The second cohort consisted of 33.0% of the population, labeled "slow decline." The third cohort consisted of 23.5% of the population, labeled "rapid decline". Finally, 8.1% of the population were labeled "poor function and moderate decline."

Predictors of the physical function trajectory membership

We used the LASSO algorithm by the "Predict" function to explore the factors influencing the degree of decline in the different groups. To achieve more valuable clinical results, we have created six models. Model 1 (stable vs. slow decline), model 2 (stable vs. rapid decline), model 3 (slow decline

vs. rapid decline), model 4 (rapid decline vs. poor function with moderate decline), model 5 (slow decline vs. poor function with moderate decline), and model 6 (stable vs. poor function with moderate decline).We determined that in model 1, all 19 variables remained in the model (i.e., not zero) when $\lambda = 0.004915$. In Figure 3, we show that 19 variables (age, sex, residence status, etc.) remained in the model the longest as physical function increases, with the remaining variables approaching zero more quickly. When the value was increased to 0.0322, only 11 variables, which may have an enormous effect on IADL scores, remained in the model. A comparison of our findings to those of others is shown in Figures 3, 4.

Next, the above-incorporated variables were regressed using logistic regression. In the multivariate-adjusted multinomial logistic regression analyses, age, sex, self-reported health status, visual status, number of diseases, cognitive function, and leisure activity had statistically significant ratios (ORs) in both the slow and rapid decline groups relative to the stable group. Furthermore, compared to the stable group, depressed status

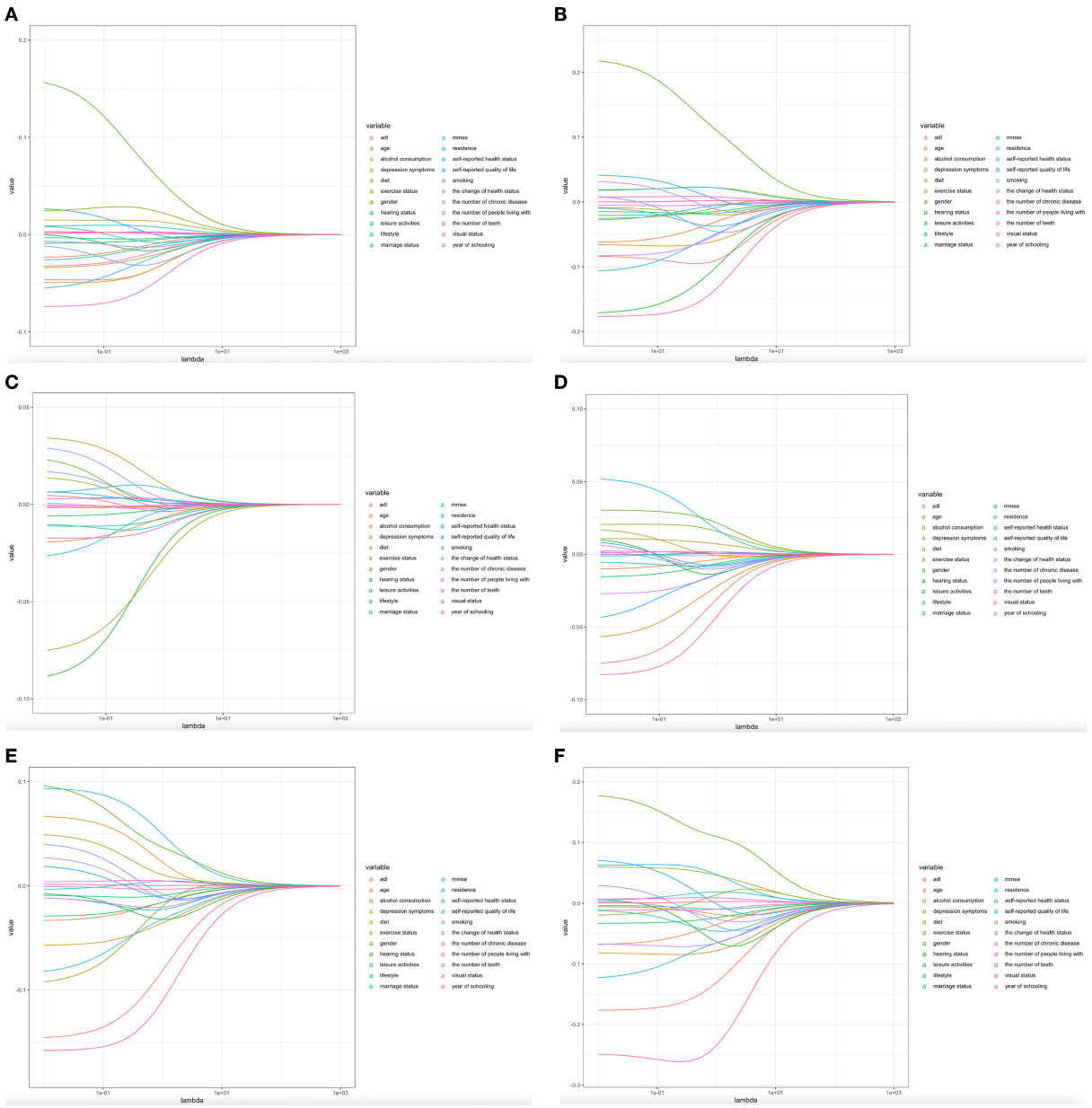

FIGURE 3
Predictors' selection using Lasso regression. **(A–F)** Lasso coefficient profiles of all the clinical features.

(OR = 0.97, $p < 0.001$) and alcohol consumption (OR = 0.95, $p < 0.01$) contributed to the slow decline in physical function, while the number of teeth (OR = 1.01, $p < 0.001$) and hearing status (OR = 0.98, $p < 0.05$) may have increased the rate of decline. A comparison of the slow decline group with the rapid decline group revealed that age (OR = 0.98, $p < 0.001$), number of teeth (OR = 1.00, $p < 0.05$), depressive state (OR = 1.04, $p < 0.05$), exercise state (OR = 0.99, $p < 0.001$), and hearing state (OR = 0.91, $p < 0.05$) may accelerate the rate of decline when the slow decline group was used as a benchmark. More details are shown in Table 4. The two-way linear prediction plots of the changes in the IADL score with the follow-up years based on each determinant also demonstrated the same trend (Figure 5).

Sensitivity analysis

A receiver operating characteristic (ROC) curve analysis was performed to assess the sensitivity and specificity of this risk prediction model, and we calculated the AUC to validate the precision of the established risk prediction model (Appendix A1). We removed the missing values from the dataset, and the remaining 769 values were subjected to a repeat analysis and yielded similar results (Appendix A2).

Discussion

To the best of our knowledge, this is the first study to analyse physical function trajectories using data from a 16-year longitudinal study and explore their predictors using LASSO regression. This modern, robust statistical technique minimizes multicollinearity between variables. Our findings indicated four different trajectories of physical function in older people, namely, stable state (35.4%), slow decline (33.0%), rapid decline (23.5%), and poor function and moderate decline (8.1%). We found several characteristics that can be used to predict a decline in physical capacity. Regarding sociodemographic characteristics, age, sex, leisure activities, self-reported health status, worse vision status, more chronic diseases, worse cognitive function, and a decreased frequency of leisure activity influence the trajectory of physical function. Worse mental health and increased alcohol consumption are predictors of slow decline, whereas fewer teeth and worse hearing states are predictors of rapid decline. In terms of the rate of decline, using the slow decline group as a benchmark, fewer teeth, stronger depressive symptoms, lack of exercise, and reduced hearing may increase the rate of decline.

The pattern of identified trajectories varies across studies. These variations may be due to differences in the study populations, sample sizes, methods used to identify trajectories, and assessment schedules. A study of ADL trajectories in

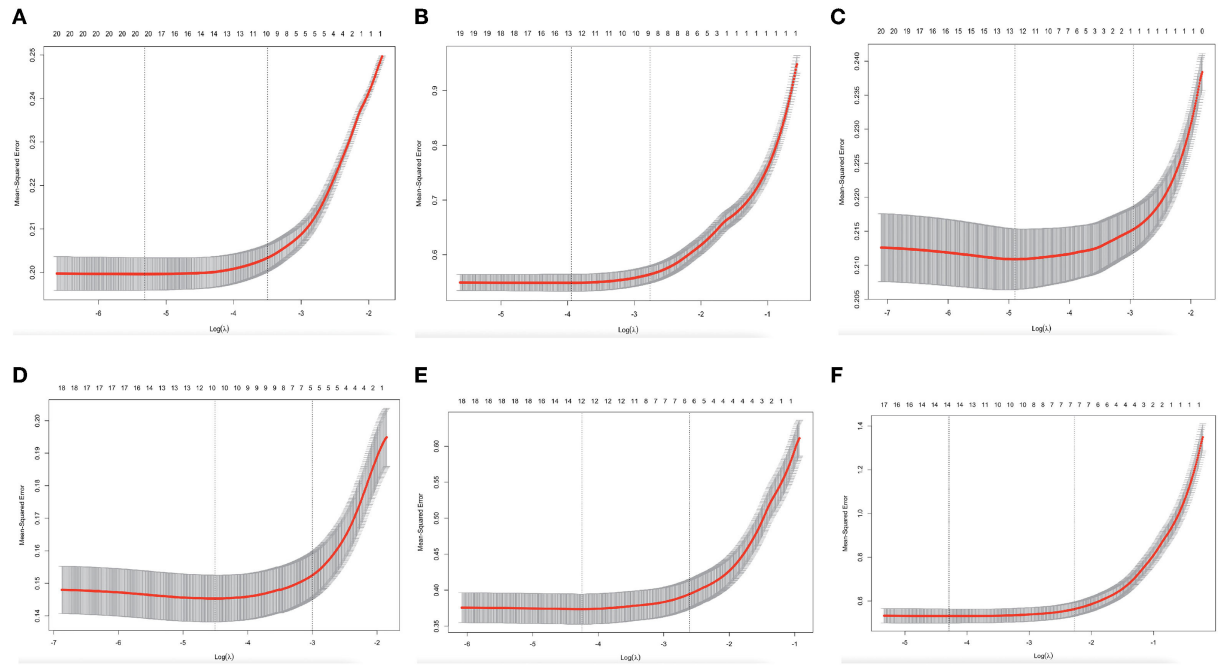

FIGURE 4
Predictors' selection using Lasso regression. **(A–F)** Identification of the optimal penalization coefficient λ in the Lasso model with 10-fold cross-validation and the minimum criterion.

TABLE 4 Associations between different development trends of IADL.

Baseline variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age	0.98***	(0.97–0.98)	0.93***	(0.93–0.94)	0.98***	(0.97–0.98)	0.99***	(0.99–0.99)	0.97***	(0.96–0.97)	0.93***	(0.92–0.94)
Gender	1.18***	(1.10–1.23)	1.25***	(1.14–1.37)	1.03	(0.96–1.08)	1.04	(0.98–1.10)	1.09*	(1.01–1.19)	1.20***	(1.08–1.33)
Residence	0.97	(0.94–1.00)	/	/	/	/	1.05**	(1.01–1.09)	1.09***	(1.04–1.16)	1.06*	(1.00–1.13)
Number of nature teeth	1.00*	(0.99–1.00)	1.01***	(1.00–1.01)	1.00*	(1.00–1.01)	/	/	/	/	/	/
Self-reported quality of life	1.03	(0.99–1.05)			/	/	/	/	/	/	1.09**	(1.02–1.15)
Self-reported health status	0.94***	(0.91–0.97)	0.93**	(0.89–0.97)	0.97	(0.95–1.00)	0.97**	(0.95–0.99)	0.95**	(0.92–0.98)	0.88***	(0.83–0.94)
Depression symptoms	0.97*	(0.93–0.98)	/	/	1.04*	(1.00–1.07)	/	/	1.06*	(1.01–1.12)	/	/
The number of people living with	/	/	/	/	1.32	(1.00–1.07)	/	/	/	/	/	/
The marriage status	1.01	(0.99–1.03)	/	/	0.99	(0.97–1.01)	/	/	0.99	(0.96–1.02)	0.98	(0.95–1.02)
Change in self-perceived health status	1.00	(0.99–1.01)	/	/	/	/	/	/	/	/	0.99	(0.97–1.01)
Years of schooling	1.00	(0.99–1.00)	/	/	/	/	1.00	(1.00–1.01)	/	/	/	/
visual status	0.93*	(0.87–0.98)	0.83***	(0.75–0.93)	0.98	(0.93–1.04)	0.92***	(0.88–0.96)	0.85***	(0.80–0.91)	0.78***	(0.71–0.86)
Smoking	0.99	(0.93–1.04)	/	/	/	/	/	/	/	/	/	/
Alcohol consumption	0.95*	(0.90–0.99)	0.92	(0.84–1.00)	/	/	0.95	(0.88–1.02)	0.94	(0.85–1.03)	0.93	(0.84–1.03)
Exercise	1.02	(0.97–1.07)	/	/	0.91***	(0.87–0.96)	/	/	0.91*	(0.82–0.98)	/	/
Lifestyle	/	/	/	/	/	/	/	/	/	/	/	/
MMSE	1.00*	(1.00–1.01)	1.02*	(1.00–1.03)	1.00	(1.00–1.01)	/	/	/	/	1.01	(0.99–1.02)
ADL	0.95	(0.89–1.01)	0.92	(0.81–1.04)			0.93***	(0.90–0.95)	0.86***	(0.83–0.90)	0.84***	(0.80–0.88)
Leisure activities	0.99***	(0.98–0.99)	0.98***	(0.97–0.99)	0.99*	(0.99–1.00)	0.98***	(0.98–0.99)	0.97***	(0.96–0.98)	0.97***	(0.96–0.98)
Diet	1.01	(0.96–1.05)	/	/	/	/	/	/	/	/	1.06	(0.96–1.17)
Hearing status	/	/	0.85*	(0.72–1.00)	0.91*	(0.83–0.99)	/	/	/	/	/	/
The number of chronic disease	0.97**	(0.94–0.99)	0.92***	(1.88–0.96)	/	/	0.97*	(0.95–1.00)	0.98	(0.95–1.02)	0.93**	(0.89–0.98)

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
Model 1 (stable vs. slow decline), model 2 (stable vs. rapid decline), model 3 (slow decline vs. rapid decline), model 4 (rapid decline vs. poor function with moderate decline), model 5 (slow decline vs. poor function with moderate decline), model 6 (stable vs. poor function with moderate decline).

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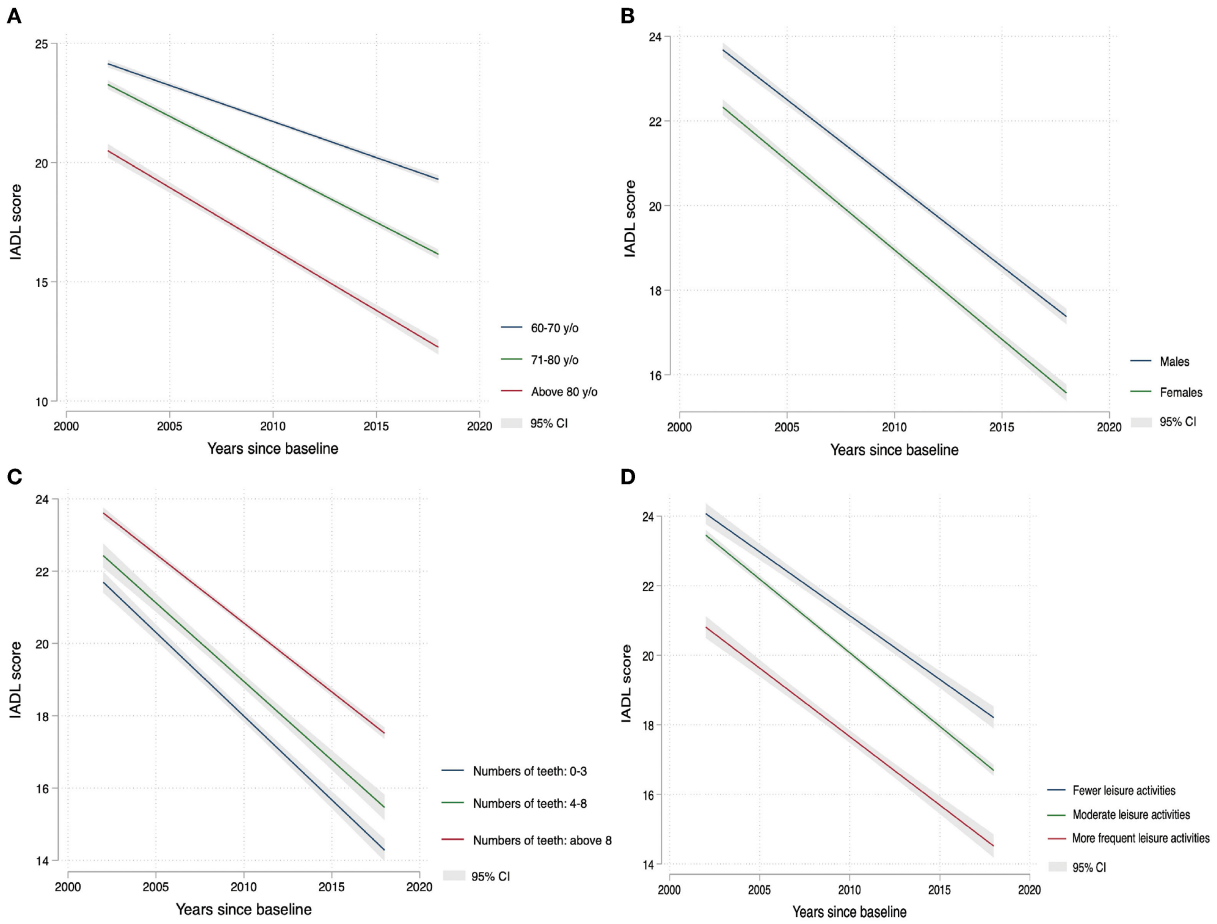

FIGURE 5
Linear variation of IADL scores with years of follow-up in different subgroups since the baseline: **(A)** age (y/o years), **(B)** gender, **(C)** the number of teeth, and **(D)** leisure activites.

younger adults in the US revealed five cohorts, but most participants had good functional health, with 8% of subjects losing physical function after 10 years (33). In addition, the results of a 22-year cohort study from 1988 in two administrative regions of southwestern France showed that five different characteristics of physical decline were identified in the past two decades of life: persistently high (12%), moderate (26%), persistently low (40%), accelerated high dependence (15%), and no dependence (8%) (34). In contrast, one notable finding of our study was that more than half of the sample (69.1%) showed a sustained or slow decline in physical function throughout the 16 years, with only a minority showing a dramatic decline, slightly less than that in Arlette Edjolo's study. The possible reason for this is that the CLHLS contains national longitudinal data covering 32 geographically wide and representative regions.

Our results of the association of well-established physical function risk factors, including age, sex, education level, and multiple chronic diseases, are consistent with those of other studies (7, 34–36). Age and sex remained in the model and were strongly related to physical functioning decline. Cross-sectional data from a longitudinal study of Irish aging (TILDA) showed that marital status was a predictor of IADL, but this result was not found in our study (37). More people with poor marital status were excluded from our baseline population. With an increasing aging population, it would be expected that the prevalence of IADL disabilities will increase and maintaining the physical function of older people has become an urgent concern. In 2017, the WHO published guidelines for integrating caregiving for older adults and suggested that intrinsic capacity is key to preventing and slowing disability and promoting healthy aging (38, 39). IADL can be used to evaluate the overall intrinsic capacity, but researchers should be aware of and address the modifiable factors associated with IADL.

In contrast, our results also demonstrated that the number of teeth is another risk factor for physical function limitations. Oral health, especially tooth loss, is considered an early indicator of

physical function limitations and is often overlooked in research. Our study showed that the number of teeth was associated with a trajectory in both the contrast stable and slow decline groups (OR = 1.00) and in the stable and rapidly declining groups (OR = 1.01). Furthermore, fewer teeth increased the rate of decline in physical function (OR = 1.00). A cross-sectional study from the United States that surveyed 114,602 Americans aged 65 years and older found that the number of teeth lost was significantly associated with PFL. Similarly, those who have lost six or more teeth but not all may have PFL (40). The same results were also found in other studies (41, 42). Nutritional status may be related to the mechanism of tooth loss associated with physical condition (43). It is well known that adequate protein intake helps to limit and treat age-related declines in muscle mass, strength, and functional capacity and prevents the onset of frailty (44).

Another interesting result is that we found that changes in perceptual function (including vision and hearing status) were positively correlated with changes in physical function. The possible reason for this finding is that hearing loss leads to a possible reduction in an individual's ability to communicate, reducing their social participation and thus IADL (45, 46). A geriatric assessment includes an evaluation of an individual's hearing and vision, which are key components of older adult health (47). In the 2015 Global Burden of Disease Study (GBDS), visual impairment and hearing loss were the second and third leading causes of various impairments, respectively (48). Moreover, dual sensory impairment is associated with a higher risk of all-cause mortality than a single impairment (49, 50). Hearing loss may lead to decreased physical function through several possible pathways. There are several hypotheses, first, that movement may be dependent on sound input from the external environment and that hearing loss may reduce the ability to perform complex movements effectively (51). Second, factors such as social participation and mental health are mediating variables between hearing loss and physical function (52–55). Also, more indirect confounding pathways may exist (56).

In addition, our results showed that older adults who were less involved in leisure activities such as playing cards, watching TV, and working in the garden were more likely to experience and rapidly develop physical functional limitations, with significant differences in all three models. This suggests that leisure activities have a protective effect on physical function. Additionally, in the first and third models, we found that depression positively influenced IADL, similar to the self-rated health status in the first and second models. According to previous reports, depression affects physical function limitations, while leisure activities improve social participation, enhance cognitive function, and increase mental health status (29, 57). We conjecture that the mechanism is that depressive symptoms and the self-rated health status are mediating factors of leisure activities and IADL levels.

It is important to note that many previous studies have emphasized that lifestyle strongly affects physical function (22, 58–60). However, in our study, alcohol consumption showed a positive correlation, and the results were insignificant in Model 3. This may be due to our inaccurate definition of diet, and many studies are now constantly seeking the optimal components of a healthy diet. In addition, in terms of exercise, its frequency and intensity may affect the outcomes (61), and future prospective studies could further explore exercise.

The strengths of our study include, first, the large sample size provided through the CLHLS. The CLHLS provides sufficient power to identify trajectories and find differences between them. The results are generalizable due to the national representativeness of the CLHLS data. Second, in this study, we used a GBTM, which can identify clusters of individuals who follow similar developmental trajectories on a given outcome by fitting a semiparametric mixture model to longitudinal data to maximize the quality of the data. Third, we used variables that were filtered by LASSO regression to be incorporated into a logistic regression model to improve the test efficacy of logistic regression and increase the significance of the variables.

The results of this study should be interpreted with some caution. First, the variables we used were derived from self-reported surveys, which may lead to bias. However, self-reported data are commonly used in physical status studies of older adults and can more accurately reflect the statuses of individuals interacting with the real world. Second, we used multiple imputation (MI) approach to handling attrition and missing data, the sensitivity analysis was also done, however, bias due to the other sources of potential threats could still not be completely avoided. Third, causality could not be determined due to the current cohort design. Given that a decline in physical function is a long-term process, although the 16-year cohort has been considered current, the length of the study is relatively long for a physical function analysis, and this may have resulted in an underestimation of the number of trajectories.

Conclusions and implications

Overall, this study shows four trajectories of physical function that were identified in a national, 16-year follow-up sample of community-dwelling older adults. Declining physical function results from a multifactorial process that includes sociodemographic characteristics, psychosocial factors, and lifestyle factors. Our study used a machine learning approach to identify variables that are more significant to the trajectory of physical function, and the accuracy of the six risk models was verified using ROC curves. Currently, many scholars focus on early prevention and timely intervention for age-related problems. This research helps maintain or slow the rate of decline in body function and improves healthy aging.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://charls.charlsdata.com/pages/data/111/zh-cn.html.

Ethics statement

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

Author contributions

Systematic concept and designed: YZ, YD, HF, and LX. Analysis the data: YZ, JN, and XL. Drifting the manuscript: YZ and YD. Revised the manuscript, read, and approved the submission of this manuscript: all authors.

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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

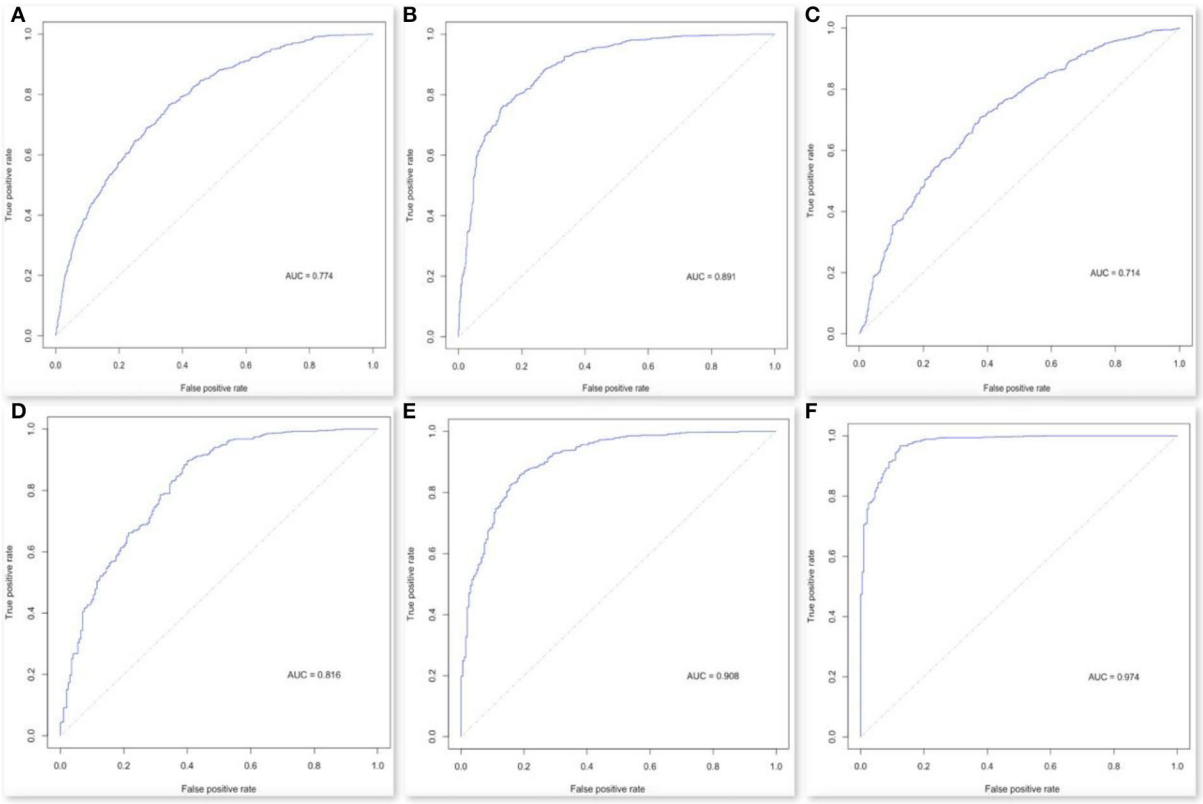

FIGURE A1
ROC in Lasso regression. The ROC scores range in six models. **(A)** model 1, **(B)** model 2, **(C)** model 3, **(D)** model 4, **(E)** model 5, and **(F)** model 6.

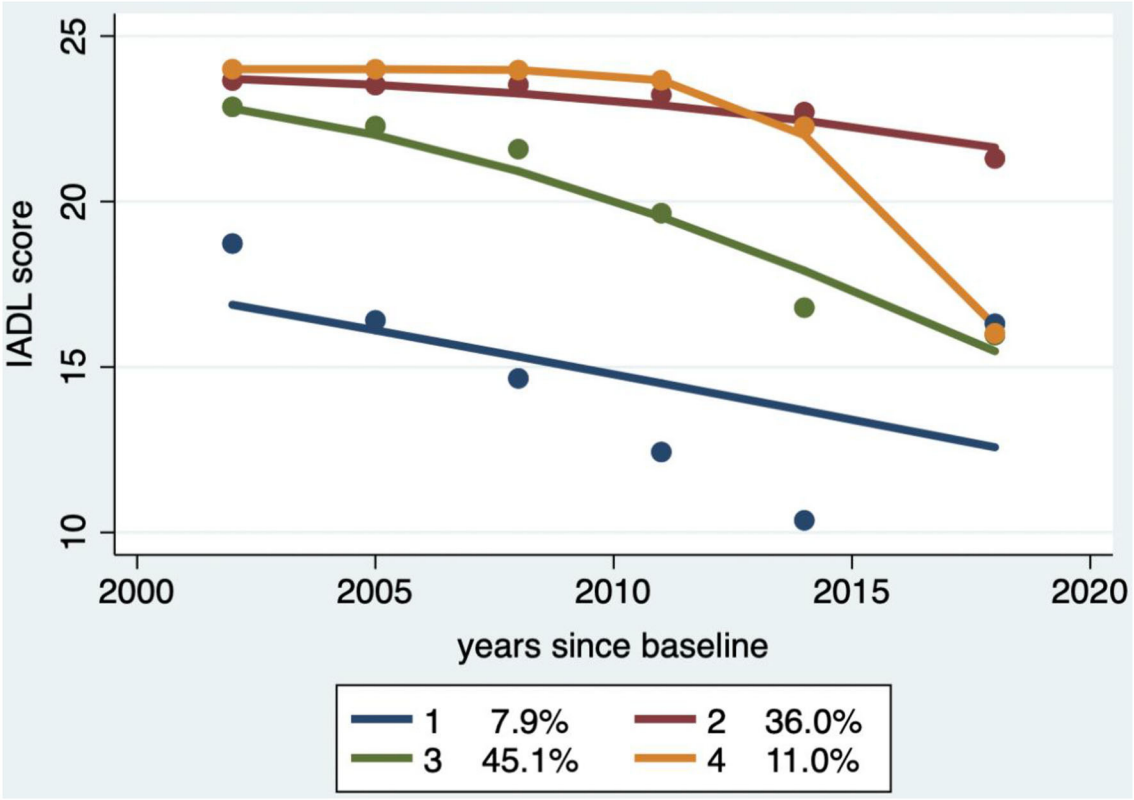

FIGURE A2
Results of physical function trajectories in 769 older adults.

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Pioneer thought leader and scientist: Dr. Marcia G. Ory and her contributions to aging and public health across the life course

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KEYWORDS

female, mentor, public health, thought leader, aging, life course

It is not often you remember the first time you laid eyes on a person. For me, meeting Marcia at a conference on aging and cancer in 2010 was one of those life-changing events. Marcia is Marcia G. Ory, Ph.D., MPH, a Regents and Distinguished Professor of Environmental and Occupational Health at Texas A&M's School of Public Health. Marcia's contributions to research and health sciences are many, as is the national and international recognition she continues to receive, demonstrating her stature and leadership. Leading collaborative research teams, she has published prolifically (10 edited books, 45 book chapters, 20 special issues in professional journals, and approximately 470 peer-reviewed articles), cited in about 30,000 scholarly products, and been a key investigator in grants totaling more than $50 million. Just this year (2022), she made the Stanford University List of the World's Top 2% Scientists (1). She is listed as 88th in the United States and 177th globally among the Top 1,000 Scientists in Social Sciences and Humanities. Standing with her on this list are thought leaders such as Drs. Noam Chomsky, Talcott Parsons, and Everett Rogers (2).

Marcia's thought leadership in aging and public health is founded in her most cited articles including work on frailty and injuries, effects of exercise on falling among older adults, and chronic disease self-management (3–5). She has been recognized as a leading public health researcher by the American Public Health Association Aging and Public Health Section for her many contributions. These include the 2005 Archstone Foundation Excellence in Program Innovation Award (Honorable Mention), 2010 Philip G. Weiler Leadership in Aging Award, and 2014 Lifetime Achievement Award. She was also a finalist for the 2018 ASPPH Harrison C. Spencer Outstanding Community Service Award for her research and service in South Texas. Other notable accomplishments include Fellow status in several Professional Organizations: the Texas Public Health Association, the American Academy of Health Behavior (AAHB), the Gerontological Society of America (GSA), and the Society for Behavioral Medicine (SBM). She has also received the AAHB 2016 Research Laureate, GSA 2001 Award for Excellence in Applied Gerontology and 2007 Distinguished Mentorship in Gerontology Award, 2018 HealthCare Leadership Council Redefining Health in America Award, and 2019 Texas Department of Health and Human Services Innovators in Aging Award.

When I met Marcia, I was looking for a doctoral program in public health and was considering the University of Texas (UT) in Austin, where we lived, or maybe UT San Antonio, where I worked at the Cancer Therapy and Research Center and knew professors at the school. Marcia suggested I consider the Texas A&M School of Public Health in College Station, TX. It took just one visit to the school, the one where I had my interview with the recruitment committee, to lock me into driving 5 h round trip twice weekly from Austin to College Station to attend classes. I don't think I ever took a class with Marcia, but she certainly took me under her wing as an advisor and mentor and made sure that my experience at Texas A&M was everything it could be and that whatever I wanted my doctoral education to be was likely possible.

The classical idea of a mentor/mentee relationship is one of a more experienced, usually older, adult who supports and encourages a less experienced person in their professional endeavors. I was a well-experienced 61-year-old when I started my doctoral program at Texas A&M—the same age as Marcia. Our experiences were vastly different. In my 12 years of consulting at McKinsey & Company and Deloitte and Touche, LLC, and over 20 years in technology entrepreneurship and cancer care, I had only a few mentors—all of them male. Academia was a foreign land to me, and I was lucky to have Marcia as my guide. As a distinctly non-traditional student, my chosen subject area of adolescent and young adult (AYA) cancer survivorship was not, at least at that time, a traditional area of public health research, nor was my interest in building mobile applications to help AYAs live healthier lives. Marcia was relentless in finding ways for me to accomplish my vision, and she soon shared that vision. As an academic leader and mentor, Marcia just didn't lead the way; she helped me find and open the paths I needed to accomplish my goals. Beyond being a mentor, as she was and continues to be for many master's and doctoral students at Texas A&M's School of Public Health, Marcia is a transformational leader.

In the summer after my first semester as a doctoral student, Marcia approached me with an offer. She had grant funds related to a healthy living project that needed to be expended by the following August. Did I have any ideas? As we embarked on building the Healthy Survivorship mobile application for AYAs, I had no idea we were breaking new ground at the University. In my prior world of technology entrepreneurship, you built and tested new technology, but there were seldom any visible barriers or hurdles that weren't related to the technology or one's skill set. Academia was a different world, as I came to understand when we were summoned to meet with the Texas A&M University System's legal department. Marcia suggested I might want to wear a suit. The University attorneys were appropriately concerned with several things in the design, ownership, privacy, and disclaimers for the mobile application. Soon, we learned that our small effort was the first mobile application being built and released for the Texas A&M System. It was in this experience that I recognized Marcia's unique and powerful skill in creative problem-solving. Together, we developed ways to insulate the University from possible harm from the mobile app or legal threats from its potential future users. We also recognized the importance of having apps be theoretically based (6). Marcia's demonstration of creative problem-solving, negotiation, and communication skills were priceless lessons she often demonstrated throughout my doctoral journey.

Marcia is no stranger to the need to foster creative organizational change through direct and inspirational thought leadership. She has an outstanding research career starting with the 20 years she spent engaging in and promoting behavioral sciences research at the National Institute on Aging[1]. Her early research was transformational in defining the complex interactions among aging, health, and behavior processes. Marcia joined the Texas A&M University faculty in 2001 with a vision to create a robust aging and public health research agenda. As founding director of the Center for Population Health and Aging, she is known for her work on identifying risk factors for morbidity and mortality across the life course and for implementation and dissemination research on designing and evaluating multifaceted behavioral, social, technological, and environmental interventions. In a male-dominated environment, Marcia rose to become the only regents and distinguished professor at the School of Public Health, and one of the few across the entire Texas A&M University System with this combined distinction, an especially rare accomplishment for female scientists.

In 2016, Marcia helped transition the Texas A&M Program on Healthy Aging to an established Board of Regents Center for Population Health and Aging—the Center cut across all of the University campuses statewide and involved researchers from across the University System including Texas A&M's Rangel College of Pharmacy, Department of Biomedical Engineering, and College of Veterinary Medicine in addition to the School of Public Health (7). In 2018, she was named the Associate Vice President for Strategic Partnerships and Initiatives at Texas A&M and helped spearhead the Healthy South Texas Initiative which was designed to reduce chronic and infectious diseases prevalent in low-resourced communities (8, 9). Most recently, she has focused on furthering translational behavioral science with a passion for putting research into practice that can change the lives of older individuals, their families, and communities (10–12).

Marcia continues to propel the spread of evidence-based programs for older adults by identifying how they can meet the triple health care aims of better health, better healthcare, and better value. Her research, based on sound public health concepts and methodologies, continues to challenge aging

1 Available online at: https://en.wikipedia.org/wiki/Marcia_G._Ory [Retrieved May 31, 2022].

stereotypes, including our collaborative work on new technology use by both aging adults and their caregivers (13, 14). Marcia didn't coin the term "healthy aging," but she has undoubtedly helped to reconceptualize it as the new normal (15). In addition, Marcia continues her leadership to bring evidence-based programs to rural and underserved populations to reduce health disparities in access to care, including access to clinical trials and healthcare delivery through broadband access (16).

Throughout her career at Texas A&M, Marcia has mentored many students and junior faculty as recognized by receipt of the 2021 TAMU Women's Faculty Network Outstanding Mentoring Award. These mentees continue as researchers and leaders locally, nationally and globally in public health, health policy, and non-profit health organizations. The community of practice fostered by Marcia will continue with the vision and missions she inspired to change perceptions of aging to those of healthy aging, to find ways to creatively address economic, age, race/ethnicity, and geographic barriers to health and healthy lifestyles across the life course.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

Author DVD was employed by DVD Associates.

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The effects of health insurance and physical exercise participation on life satisfaction of older people in China—Based on CHNS panel data from 2006 to 2015

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Background: In China, the problem of aging population has become more and more serious. The factors influencing life satisfaction of older people are becoming a significant issue. This study explores the effects of health insurance and physical exercise on life satisfaction of older people in China.

Method: This study used an unbalanced panel dataset (n = 6,393, T = 4) of older adults aged 60–80 years from the 2006 to 2015 China Health and Nutrition Survey (CHNS). A panel ordered logistic regression model was developed to examine the effects of health insurance and physical exercise on older people' life satisfaction. Mediation tests were used to examine the mediating role of physical exercise in the effect of health insurance on life satisfaction of older people.

Result: Life satisfaction of older people was positively associated with participation in health insurance (OR = 1.439) and physical exercise (OR = 1.033).Participation in government health insurance, urban employee health insurance (UEBMI), new rural cooperative health insurance (NRCMI), and other commercial health insurance all have positive effects on life satisfaction of older people. Physical exercise plays a masking role in the effect of health insurance on life satisfaction of older people.

Conclusion: Participation in health insurance and physical exercise are important means to promote life satisfaction among older people. Physical exercise affects the impact of health insurance on older people's life satisfaction.

KEYWORDS

older people, active aging, physical exercise, health insurance, CHNS

Introduction

Over the past three decades, China has experienced rapid economic growth and tremendous demographic change (1, 2). By the end of 2017, China's population aged over 60 reached 241 million, accounting for 17.3% of the total population (3), with a serious trend of population aging (4). Actively coping with population aging is not only related to the quality of life of the elderly, but will also have far-reaching effects on the whole society and economy.

The World Health Organization (WHO) adopted the term active aging in the late 1990s and played an important role in its rapid spread (5). The WHO envisages active aging as a broad process of optimizing opportunities for health, participation, and security to improve the quality of life of people as they age (6). The WHO states that the goal of active aging is to improve the quality of life of older people (7). Life satisfaction is not only a subjective perception of older people's living conditions, but also an important indicator of their quality of life (8). Therefore, a more detailed and in-depth study of the factors influencing the life satisfaction of older people will help to further improve the quality of life of older people and has important practical significance in promoting the formulation of public policies on active aging.

Literature review

Factors influencing the life satisfaction of older people

In addition to reflecting an individual's life evaluation of emotions, happiness, and subjective wellbeing, life satisfaction indirectly reflects an individual's perception and judgement of the difference between their expectations and the reality of their quality of life (9, 10). Changes in older people's life satisfaction are a complex and dynamic process that may be the result of a combination of subtle individual and environmental changes over time (6). As the process of population aging continues, the factors influencing older people's life satisfaction have received increasing attention.

Research findings are inconsistent in terms of the impact of gender on life satisfaction among older adults. Li and Liu and Du and Wang found that older men had lower life satisfaction than women (11, 12). Akifusa et al. found that older men were more satisfied with their lives than women (13). Massey et al. found no significant relationship between gender and life satisfaction in older people (14). In terms of the effect of age on life satisfaction among older people, Angelini et al. and Liu et al. found a positive relationship between age and life satisfaction among older people (15, 16), but Li et al. only observed this relationship in older people aged 80 years and above (11). George et al. found little age variability in life satisfaction among older adults (17). Although Li et al. and Du and Wang found that life satisfaction was higher among urban older people than rural older people in the early years (11, 12). However, the gap in life satisfaction between the urban and rural elderly populations is gradually narrowing as people's income levels in rural areas increase (12). In terms of the effect of spouse status on older adults' life satisfaction, Massey et al. and Liu et al. found that older adults with a spouse had higher life satisfaction (12, 14, 16). However, Li et al. found that spousal status did not significantly affect older adults' life satisfaction (11). Li et al. and Du and Wang found that educational attainment had a significant positive impact on older people's life satisfaction (11, 12). However, Knight et al. found that educational attainment *per se* did not affect older people's life satisfaction. It is the other material and spiritual income gained through education that is an important factor in older people's life satisfaction (18). In terms of the relationship between income and life satisfaction, Wu and Chen found a "threshold effect" between income levels and older people's life satisfaction, with the effect of income on life satisfaction decreasing after a certain level is reached (19). Tavares' study found that income was a driver of life satisfaction among older people (20). In terms of the impact of health status on life satisfaction in older adults, Celso et al. and Celik et al. found a statistically significant relationship between health status and life satisfaction in older adults (21, 22). Jung et al. found that older adults with chronic conditions had significantly lower life satisfaction compared to those without chronic conditions (23). Wiesmann et al. found that the higher the number of chronic conditions, the lower the life satisfaction scores of older people (24). There are also environmental factors that may have an impact on the life satisfaction of older people. There are also environmental factors that may have an impact on the life satisfaction of older people. For example, Proto et al. found that regional GDP also influences people's life satisfaction (25). Rajani et al. (26) found that higher GDP was associated with higher life satisfaction scores. Dingemans et al., however, found that in regions with poorer GDP, it was continuing to work after retirement that had a positive effect on older people's life satisfaction (27). In summary, existing studies have found that gender, age, educational attainment, income, Chronic disease, GDP, and work after retirement may all have a significant impact on older people's life satisfaction.

Health insurance and life satisfaction of older people

Chinese scholars have used data from the China Longevity Health Influence Survey (CLHLS), the China Health and Aging Tracking Survey (CHARLS), the China Sample Survey on the Living Conditions of the Elderly in Urban and Rural Areas (SSAPUR), the China Elderly Social Tracking Survey (CLASS), the Sixth Population Census, or survey data collected

independently by researchers to conduct an in-depth study of older people's Life satisfaction has been explored in depth. Easterlin et al., Walker, and Li et al., found that although economic development has led to a significant increase in life satisfaction among Chinese residents, the growth trend of their life satisfaction has been declining (1, 5, 9). Yu et al., Appleton et al., and Knight et al., found that changes in life satisfaction among Chinese residents were mainly related to two factors: the transition of the Chinese economy (from a planned to a free market economy) accompanied by an increase in income inequality and the disintegration of the traditional social security system (28–30). Wang et al. found that despite the increase in household income among urban residents, income inequality and fear of unemployment reduced their life satisfaction (31). Ng et al. found that the change in the social security system from an employer-based system to an insurance-based system led to uncertainty about unemployment, which in turn reduced people's life satisfaction (32). Wang et al. and WTO found that this inequality and insecurity was particularly present among vulnerable groups, such as the elderly and economically economically disadvantaged people (31, 33).

Older people are often particularly concerned about the disintegration of the traditional social security system and the high cost of health care in a market-oriented healthcare system. As older people age, they are at high risk of deteriorating health status. For example, Cai and Wang found that over 100 million people aged 60 and over suffered from at least one chronic disease (e.g., stroke, heart disease). Approximately 5 million older people suffer from mental health problems (e.g., depression and dementia) (34). Health insurance is therefore particularly important for older people with chronic diseases and other illnesses, and can go some way to safeguarding their quality of life (33). Yip and Hsiao point out that the cost of healthcare services has been rising under the influence of economic restructuring and the marketisation of the healthcare delivery system (35). Data from the World Bank shows that more and more elderly people are falling into poverty due to high out-of-pocket health care costs (36). Li and Liu found that in 2008 ~31% of rural older people reported that they were unable to access adequate health services (11). Sun et al. found that 14% of urban older self-reported illnesses were the main cause of financial insecurity (37).

In response to this situation, the Chinese government has initiated a series of comprehensive health insurance system reforms to provide basic health insurance services to all citizens, including the elderly. In 2003 and 2007, the New Rural Cooperative Medical Scheme (NCMS) and the Urban Residents Basic Health Insurance (URBMI) for rural residents were set up. Together with the Government Health Insurance (GMI) and the Urban Employees' Health Insurance (UEMI) for staff of government agencies or state institutions, they form the country's universal health insurance system. Older people in particular also benefit from the government's expanded health insurance services. In 2012, Sun et al. found that 98.4% of older Chinese reported being covered by some kind of health insurance (37).

Although the coverage and scope of different health insurance schemes vary, studies by Keng et al. and Tran et al. found that access to health insurance can counter the insecurity associated with health shocks and uncertainty about health expenditures. This is particularly important for older people who are at greater risk of deteriorating health and financial status (38, 39). Rao and Gao found that people with health insurance tended to make greater use of health services and reported better health and wellbeing (40). Wu and Li found that health insurance could help older people feel secure and was positively associated with their physical and mental health (41). Kim and Koh found that lack of health insurance had a negative impact on the subjective wellbeing of the general population after controlling for individual self-assessed health status and other socioeconomic factors (42). While the aim of universal health coverage is to ensure equal access to health services, Liao et al. found that universal health coverage also improved subjective wellbeing among older people, particularly older women (43). A previous study by Yang and Hanewald reported that the life satisfaction of middle-aged and older Chinese (aged 45–60 years) was not related to whether they had health insurance, but rather to the type of health insurance they chose. Compared to residents who participated in government health insurance, those who participated in urban employees' health insurance, urban residents' health insurance and the New Agricultural Cooperative had lower life satisfaction scores of 0.155, 0.106, and 0.112 standard deviations, respectively (44).

Physical exercise and life satisfaction of older people

Physical exercise is an active and healthy lifestyle. Physical exercise can have physiological, psychological and social effects. Reyes et al. and Leitner and Leitner found a positive relationship between Physical exercise and personal life satisfaction (45, 46). Sardeli et al. and Papi and Cheraghi found that greater acquisition of physical ability can promote individuals to have a sense of competence and increased motivation to make motivation to make decisions. This in turn promotes intrinsic motivation through the achievement of practical satisfaction (47, 48). Physical exercise is a self-selected experience with a sense of freedom and intrinsic motivation. In addition, Physical exercise may have additional health benefits for older adults. Hao et al. and Dai and Yao found that Physical exercise increased muscle mass, reduced the risk of fat and obesity, improved balance and reduced fear of falling in older adults (49, 50). Papi and Cheraghi and Liao et al. found that older adults' cognitive abilities, such

as short-term and long-term memory, verbal reasoning and risk of cognitive impairment, were also positively influenced by Physical exercise (48, 51). However, previous literature suggests that not all Physical exercise contributes to life satisfaction in older adults. Life satisfaction may depend on the type of exercise or the duration of the exercise. For example, Mudrák et al. found a significant relationship between participation in Physical exercise and life satisfaction. Participants who achieved the recommended level of Physical exercise (moderate and/or vigorous exercise) were more satisfied with their lives (52). In a Swedish study of 176 community-dwelling older adults, Hao et al. found that older participants in the moderate and vigorous Physical exercise groups had higher life satisfaction than those in the low Physical exercise group (49). However, there are studies with different perspectives, such as Dai and Yao, which found no direct relationship between Physical exercise and life satisfaction in older adults. Physical exercise only indirectly influences older people's life satisfaction through self-efficacy and the support of friends (50).

Numerous scholars have conducted a large number of studies on life satisfaction among the elderly and its influencing factors, from which it can be concluded that the influencing factors of life satisfaction among the elderly may be complex, involving various aspects of the individual, family and society. Existing research has begun to actively focus on the relationship between health insurance and life satisfaction among older people. However, the relationship between health insurance participation and life satisfaction among older people over 60 years of age in China is not yet clear. Also, further confirmation is needed as to whether physical exercise also has a positive effect on enhancing life satisfaction among older people in China. In terms of data, scholars have mostly used census data, sample survey data or tracking survey data for their analyses, however, most studies have used cross-sectional data for their analyses. The limited sample size of survey data other than census makes it difficult to achieve panel data studies with large samples. In terms of research methods, descriptive statistical analysis, logistic regression models and other generalized linear models or multiple linear regression analysis are mostly used. Although significant factors affecting the life satisfaction of older people can be identified, it is difficult to control for variables that do not change over time and to identify the significant influencing factors that cause changes in life satisfaction of older people. In view of this, this study uses the theory of "active coping theory" as the theoretical support to explore the effects of health insurance coverage and physical exercise participation on older people's life satisfaction based on previous studies. At the same time, based on the China Health and Nutrition Survey (CHNS) data from 2006 to 2015, a random effects ordered logistic regression model is used to analyse the large sample panel data, which can control for individual heterogeneity and identify potential factors affecting changes in life satisfaction of the elderly, and then determine the effects and mechanisms of health insurance participation and physical exercise participation on life satisfaction of the elderly. This study will provide a reference for the formulation of public policies on active aging.

Research hypothesis

In 1997, Aspinwall and Taylor introduced the well-known "active coping theory," which considers active coping as efforts made before a potentially stressful event occurs (53). Parada and Verlhiac define coping as activities that master, tolerate, reduce, or minimize environmental or psychological demands (54). There are important differences between active coping and anticipatory coping for stressful events. Active coping refers to the need for skills and activities that are different from, and potentially more successful than, coping with an existing stressor prior to coping and anticipatory coping. Lee et al. argue that active coping theory can provide an adequate theoretical context for Physical exercise and health insurance participation among older adults (55). Older adults have potential health and economic stressors due to their declining physical and economic status. Therefore, Salamene et al. suggest that physical exercise and health insurance participation can be seen as a positive coping behavior and a positive action to prevent future health stress (56). Based on active coping theory and combined with the findings of previous studies, this study proposes the following hypotheses.

H1: Participation in health insurance is positively associated with life satisfaction among older adults.

H2: Physical exercise participation is positively associated with life satisfaction among older adults.

In addition, Salamene et al. found that older adults' coping resources and current health status can significantly influence active coping styles (56). Physical and mental health of older adults found by Cao and Lu (57) and Lawless et al. (58) can influence physical exercise behavior. Hyun and Ku, Vannini et al., and Aldwin et al. found that coping resources such as income (59), education (60), and other factors that may influence stressors (61), such as chronic illness, may also influence older adults' physical exercise behavior. Blanco-Molina et al. found that health insurance was one of the factors that may influence one of the factors of stressors (62). Therefore, health insurance may also influence physical exercise behavior of older adults. For example, de Boer et al. found that societies with a higher proportion of sports club members had lower average health insurance consumption (63). Cheah et al. found that exercisers who participated in sporting activities were more likely to have health insurance (64), which may of course be related to the potentially higher socioeconomic status of the participants. Zhang et al. found in values for older adults aged 55–75 years that those with more health insurance had less

physical exercise behavior compared to the group without health insurance (65). While it is not possible to determine whether participation in health insurance has a positive effect on physical exercise among older adults based on the available studies, it can be hypothesized that health insurance can influence individuals' physical exercise behavior. Therefore, physical exercise may be a mediating variable in the mechanism of the effect of health insurance participation on life satisfaction of older adults. To this end, the following hypotheses were formulated for this study.

H3: The impact of physical exercise-mediated health insurance participation on older people's life satisfaction.

Based on theoretical assumptions, a theoretical model was developed for this study (see Figure 1). The model suggests that health insurance participation can directly affect older people's life satisfaction (path a). Physical exercise can directly affect older people's life satisfaction (path b). And participation in health insurance can indirectly affect older people's life satisfaction through physical exercise (path c). Other factors such as gender, age, education level, health status, urban/rural category, spousal status, annual income, and regional economic development may also influence older people's life satisfaction (path d).

Research subjects and methods

Research sample

This study used original data from the China Health and Nutrition Tracking Survey (CHNS) conducted by the Population Center of the University of Carolina at Chapel Hill and the Chinese Center for Disease Control and Prevention since 1989 (66). The CHNS is longitudinal and includes 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015, with a total of 10 waves covering nine provinces (Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Henan, Hubei, Hunan, Guangxi, and Guizhou) and three autonomous cities (Beijing, Shanghai, and Chongqing). The questionnaires used in each wave were kept as similar as possible.

In order to achieve the aims of the study, the research team used three criteria to limit the sample for the study. Firstly, the CHNS survey team has only been studying people's physical exercise since 2004 and their life satisfaction since 2006. Therefore, this study aimed to use data from 2006 and onwards for the analysis of the study. Secondly, given the timing of retirement and the actual physical exercise of most Chinese residents, the age range of the study population was restricted to 60–80 years. Thirdly, those with limitations in activities of daily living were excluded. After considering these inclusion and exclusion criteria and after data cleaning, this study resulted in an unbalanced short panel dataset ($n = 6393$, $T = 4$).

Dependent and independent variables

CHNS used the question "How do you feel about your life now?" to survey the life satisfaction of older people (67). This study defines the sum of various health-related insurance policies purchased by residents as the main explanatory variable health insurance for this study. The CHNS survey on individual health insurance covers various types of health insurance, including Urban Employees' Health Insurance (UEBMI), New Rural Cooperative Health Insurance (NRCMI), Urban Residents' Basic Health Insurance (URBMI), and the purchase of various commercial health insurance policies. The Urban Employees' Health Insurance (68) is a medical benefit provided to employees of Chinese companies, but the amount of contribution varies from company to company. In addition to the company's contribution, individuals are also required to pay a portion of their own costs. The New Rural Cooperative Health Insurance Scheme is a highly subsidized voluntary health insurance scheme (69). The Basic Health Insurance for Urban Residents is a subsidized voluntary public health insurance scheme introduced by the Chinese government for urban residents who are not formally employed (70). There are some differences in the categorization of health-related insurance surveys conducted by CHNS in different years. And with reference to the relevant category settings of the 2015 questionnaire, this study combined the insurance categories of health insurance for the elderly into three categories: employee health insurance (EMI), resident health insurance (RMI) (both NPS and resident) and commercial health insurance (CHI).Thus, the "health insurance" variable in the study is actually a combination of RMI, EMI, and CHI. In addition, a focus on annual individual health insurance premiums (including all types of health insurance premiums paid by individuals) was added. The CHNS survey covers questions on physical exercise participation, including how much time residents spend on martial arts (kung fu, etc.), gymnastics, dance, acrobatics, athletics (running), swimming, football, basketball, tennis, badminton, volleyball, and other sports. It asks all older people "How much time (minutes) do you spend on average each day doing the following physical activities, Monday to Friday or Saturday to Sunday? In this study, the time spent by older people on physical exercise during the week was aggregated and named as physical exercise (minutes/week).

Covariates

In this study, gender, age, education level, spouse status, place of residence, chronic illness, annual income, GDP per capita, and work were selected as Covariates. With reference to Cheng's study (68), GDP per capita in this study was used as the source of data from the China Urban Statistical Yearbook published by the National Bureau of Statistics in the current year.

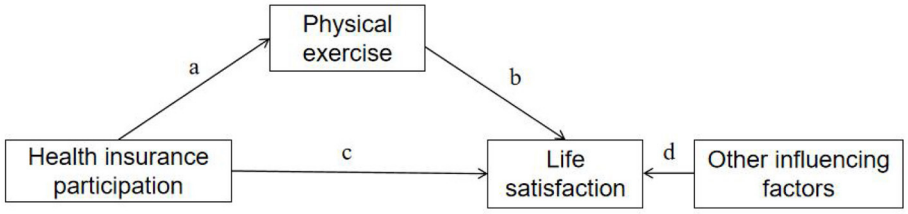

FIGURE 1
Theoretical assumptions model.

This study also controls for the dummy variables of province and occupation of the study population.

Description of variables

Annual income, GDP per capita, physical exercise, and health insurance premiums were continuous variables in this study and their logarithmic form was used when included in the analytical model. The remaining variables are categorical, with life satisfaction being an ordered categorical variable. The results of the descriptive analysis of the study variables are shown in Table 1.

Statistical methods

This study used STATA 16.0 software for statistical processing of the survey data. Logistic regression models were used in analyzing the effects of physical exercise and health insurance participation on the life satisfaction of older people. CHNS is an unbalanced panel. This study conducted a joint F-test for time effects and found no significant time effect ($p = 0.419$) on the change in life satisfaction of older people. A Sobel test was used to analyse the mediating effect of participation in health insurance on the life satisfaction of older people.

Ethics, approval, and informed consent

We used the public dataset from CHNS official website (https://www.cpc.unc.edu/projects/china). Therefore, the Academic Committee of the School of Physical Education of Guizhou Normal University waived the requirement for ethical approval. CHNS provides interviewees with guarantees of privacy and confidentiality. All participants provided written informed consent. Detailed information about the research design is on its official website.

Result

Factors influencing the life satisfaction of older people

Before conducting an ordered logistic regression model analysis, in order for the model to fit better, the relationship between the independent and dependent variables needs to be tested first and unnecessary variables eliminated. The stepwise regression analysis revealed no significant relationship between gender, spouse status and life satisfaction of the elderly, so these two variables were excluded. To prevent endogeneity, the variables needed to be tested for independence from each other and the absence of multicollinearity. Therefore, the study continued with the regression analysis of the remaining independent and dependent variables, and all independent variables had VIF < 10 and 1/VIF > 0.1, suggesting that there was no serious co-linearity between the independent variables. The study included all independent variables, except gender and spouse status, in the subsequent analysis model. This study used a random effects ordered logistic regression model to analyse the factors influencing life satisfaction among older people, with the output being the Odds Ratio (OR) (see Table 2). Model (1) is a regression of age, education attainment, residence, chronic disease, log annual income, log GDP, and job on life satisfaction. Model (2) is a regression incorporating log health insurance premiums based on model (1). Model (3) is a regression that incorporates health insurance participation based on model (1). Model (4) is a regression based on model (1) that continues to include different health insurance participation. Model (5) is a regression based on model (3) that continues to include log physical exercise. All regression models control for dummy variables for individual's previous occupation and province.

From the regression results of the five models, age, education attainment, residence, chronic disease, log annual income, log GDP, job, health insurance participation, EMI, RMI, CMI, and log physical exercise all had significant effects on life satisfaction of the elderly, indicating that these factors play an important

TABLE 1 Descriptive statistics for variables ($n = 6,393$).

Variable	Description	*Mean (SD)*
Health insurance participation	EMI/RMI/CHI (No = 0, Yes = 1)	0.874 (0.276)
Health insurance premium	The total annual payment of individual healthl insurance (RMB). Take the logarithm for analysis	175.203 (0.802)
EMI	Government Health Insurance (GMI)/UEBMI(No = 0, Yes = 1)	0.240 (0.406)
RMI	NRCMI/URBMI(No = 0, Yes = 1)	0.596 (0.446)
CHI	Various commercial health insurance/commercial medical insurance (No = 0, Yes = 1)	0.021 (0.125)
Life satisfaction	How do you think your life is now? (1 = very bad ∼ 5 = very good)	3.595 (0.763)
Gender	Male = 0, Female = 1	0.527 (0.499)
Age (year)	60–64 = 1; 65–69 = 2; 70–74 = 3; 75–80 = 4	2.140 (1.050)
Education attainment	Primary school and below = 1; Junior high school = 2; High School/Higher Vocational School/Secondary School = 3; College and above = 4	1.602 (0.908)
Spouse status	None (single, divorced) = 0, Yes (married, separated, widowed) = 1	0.983 (0.123)
Residence	City = 0, Rural = 1	0.505 (0.484)
Chronic disease	Whether you have high blood pressure, diabetes, myocardial infarction, stroke, tumor, asthma? (No = 0, Yes = 1, total number of diseases)	0.251 (0.408)
Annual income	Annual salary income + annual bonus + annual pension + annual income from other sources (RMB). Take the logarithm for analysis	12350.240 (3285.940)
GDP per capita	GDP per capita (RMB). Take the logarithm for analysis	41422.860 (5787.601)
Physical exercise (PE)	Average weekly physical exercise time (min/week)	157.580 (394.511)
Job	Are you still working? No = 0, Yes = 1	0.223 (0.363)

role in terms of life satisfaction of the elderly. However, the relationship between log health insurance premiums and life satisfaction of the elderly was not significant.

Specifically, the results from Model 1 reveal that there is a negative relationship between age and life satisfaction of older people. Compared to the reference group of 60–64 year old, the OR of increased life satisfaction for 65–69, 70–74, and 75–80 year olds decreased by 9.0, 14.1, and 16% respectively. There was a positive relationship between education attainment and life satisfaction of older people. Compared to the primary school and below reference group, the OR for increased life satisfaction increased by 38.2, 86.5, and 91.2% for Middle school, High/Higher Vocational/Secondary School, College and above, respectively. The OR of increased life satisfaction for rural older adults decreased by 29.4% compared to the city reference group. There was a negative relationship between the number of Chronic disease and life satisfaction of older people. For each unit increase in chronic disease, the OR of increased life satisfaction for older people decreased by 23.7%. There was a positive relationship between log annual income and life satisfaction among older people. For each unit increase in log annual income, the OR for increase in life satisfaction of older people increased by 0.9%. There was a positive relationship between log GDP and older people's life satisfaction. For each unit increase in log GDP, the OR for increased life satisfaction of older people increased by 48.8%. Compared to the no job reference group, the OR of increase in life satisfaction for older people with a job increased by 235%.

The results from model 2 show that the relationship between the independent variables and life satisfaction of older people remains significant after the inclusion of log health insurance premiums, but the effect of log health insurance premiums on health insurance for older people is not significant.

The results of model 3 showed that the relationship between the independent variable and life satisfaction of the elderly remained significant after the inclusion of health insurance premiums, and that there was a significant effect of health insurance premiums on the life satisfaction of the elderly. There was a 40.4% increase in the likelihood of increased life satisfaction for those with health insurance participation compared to those without health insurance participation. The results of Model 4 showed that participation in EMI, RMI, and CMI all had a positive effect on the increase in life satisfaction of older people. Compared to uninsured older adults, the ORs of increased life satisfaction for EMI, RMI, and CMI were 50.6, 20.8, and 58.1%, respectively. The results from Model 5 revealed that the relationship between the independent variables and life satisfaction of older adults remained significant after the inclusion of log physical exercise, and log physical exercise had a significant effect on life satisfaction of older adults. Each unit

TABLE 2 Results of randomized ordered logistic regression of factors influencing older people's life satisfaction (n = 6,393).

Variable	Health insurance participation				
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Age[a]					
65–69	0.910** (0.042)	0.911** (0.042)	0.915** (0.042)	0.918** (0.042)	0.913** (0.042)
70–74	0.859*** (0.046)	0.859*** (0.046)	0.862*** (0.046)	0.859*** (0.046)	0.864*** (0.046)
75–80	0.840*** (0.050)	0.841*** (0.051)	0.849*** (0.051)	0.843*** (0.051)	0.858*** (0.051)
Education attainment[b]					
Middle school	1.382*** (0.078)	1.382*** (0.075)	1.365*** (0.074)	1.343*** (0.074)	1.330*** (0.074)
High/Higher Vocational/Secondary School	1.865*** (0.132)	1.862*** (0.124)	1.828*** (0.122)	1.756*** (0.122)	1.736*** (0.122)
College and above	1.912*** (0.202)	1.917*** (0.185)	1.872*** (0.180)	1.775*** (0.180)	1.749*** (0.180)
Residence[c]	0.709*** (0.036)	0.707** (0.039)	0.711*** (0.044)	0.758*** (0.044)	0.745*** (0.044)
Chronic disease	0.763*** (0.041)	0.763*** (0.041)	0.764*** (0.041)	0.759*** (0.041)	0.770*** (0.041)
Ln annual income	1.009** (0.003)	1.009** (0.003)	1.009** (0.003)	1.009** (0.003)	1.009** (0.003)
Ln GDP	1.488*** (0.068)	1.476*** (0.068)	1.330*** (0.069)	1.323*** (0.069)	1.185*** (0.069)
Job[d]	3.350** (1.684)	3.354** (1.839)	3.223** (1.847)	3.195** (1.767)	3.531** (1.767)
Ln Health insurance premium		1.001 (0.005)			
Health insurance participation[e]			1.404*** (0.094)		1.439** (0.097)
EMI[f]				1.506*** (0.108)	
RMI[i]				1.208*** (0.083)	
CHI[j]				1.581*** (0.207)	
Ln PE					1.033*** (0.004)
Dummy province variable	**Control**				
Cut1	−1.069 (0.519)	−1.156 (0.544)	−1.952 (0.607)	−2.081 (0.617)	−3.156 (0.638)
Cut2	1.041 (0.514)	−0.955 (0.538)	0.161 (0.602)	0.313 (0.612)	−1.042 (0.633)
Cut3	3.929 (0.516)	23.842 (0.540)	3.049 (0.603)	2.921 (0.613)	1.845 (0.633)
Cut4	6.112 (0.519)	6.025 (0.542)	5.231 (0.605)	5.108 (0.614)	4.031 (0.635)
Sigma_u	0.772 (0.069)	0.772 (0.069)	0.759 (0.068)	0.765 (0.068)	0.746 (0.068)
Wald test value	1061.91	1062.06	1088.21	1098.31	1133.55
Chibar2	228.54	228.56	222.73	224.53	216.68

The values outside and inside the brackets are the OR and standard errors, respectively.
, and * indicate significance at the 5%, and 1% levels, respectively.
Reference groups: a for 60–64 group, b for Primary school and below group, c for City group, d for no job group, e for no health insurance participation, f for no EMI group, i for no RMI group, j for no CMI group.

increase in log physical exercise was associated with a 3.3% increase in life satisfaction OR for older people.

The results of Models 1, 3, and 5 show that health insurance participation and log physical exercise moderate the effects of age and educational attainment on older people's life satisfaction to some extent. Logarithmic physical exercise is more likely to increase life satisfaction among rural older people than health insurance participation. Logarithmic physical exercise also improves the life satisfaction of older people with chronic diseases. Health insurance participation moderates the effect of job on older people's satisfaction and increases the life satisfaction of older people who are no job. Both health insurance participation and log physical exercise moderate the effect of GDP on older people's life satisfaction and reduce the effect of regional economic development on older people's life satisfaction.

Intermediary test

The results of the regression analysis of this study (Table 2) showed that older people's participation in physical exercise and health insurance had a positive impact on their life satisfaction. However, the pathways through which health insurance participation affects older people's life satisfaction merit further research. A review analysis of past studies suggests that health insurance participation may affect older people's life satisfaction by either promoting or discouraging their

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TABLE 3 Intermediary test results.

	Model (6) Life satisfaction	Model (7) Ln PE	Model (8) Life satisfaction
Health insurance participation	0.163***	−0.235*	0.166***
	(0.027)	(0.136)	(0.027)
Ln PE			0.015***
			(0.002)
Control variable		**Control**	
_cons	2.305	−45.113	2.960
	(0.249)	(1.247)	(0.262)
R-squared	0.109	0.241	0.114

The control variables are individual characteristics, regional macroeconomic characteristics, and provincial dummy variables.
Values outside and in parentheses are estimated coefficients and standard errors, respectively.
*, and *** indicate significance at the 10 and 1% levels.

physical exercise. Therefore, in this paper, regular physical activity was chosen as a mediating variable to examine the potential mechanisms of health insurance participation on older people's life satisfaction. Models (6)—(8) in Table 3 report the regression results of the mediation test for the effect of health insurance participation on older people's life satisfaction. Model (6) reflects the results of the test without the inclusion of mediating variables. It can be seen that, similar to the previous section, there is a significant positive effect of health insurance participation on older people's life satisfaction. The results of model (7) show that participation in health insurance has a significant negative effect on log physical exercise among older people. Model (8) reflects the results of the test after the inclusion of mediating variables, showing that the effect of health insurance participation on older people's life satisfaction remains significantly positive after the inclusion of log physical exercise, and the regression coefficient becomes larger. The results suggest that the variable log physical exercise masks to some extent the effect of health insurance participation on older people's life satisfaction. Controlling for the variable log physical exercise significantly increases the effect of health insurance participation on life satisfaction. This suggests that some older adults with health insurance may reduce their physical exercise time, thereby affecting their life satisfaction.

Discussion

In this study research hypotheses H1, H2, and H3 were all validated by the empirical data. The regression results showed that after controlling for age, educational attainment, residence, chronic disease, annual income, GDP, job, occupation, and province, there was a significant positive effect on older people's life satisfaction, regardless of the type of health insurance participation. Consistent with the findings of Rao and Gao (40) and Wu and Li (41), but different from the findings of Yang and Hanewald (44). Yang and Hanewald concluded that older adults' life satisfaction was not related to whether they participated in health insurance, but rather to the type of health insurance they chose. Although the ORs of EMI, RMI, and CMI on the increase of life satisfaction in old age were not the same in this study, simply having health insurance could have a significant positive effect on the life satisfaction of older adults. The main reason for analyzing the difference between the results of this study and those of Yang et al. may be related to the age of the study population in that study, which was 45–60 years old (44). Those aged 45–60 were more likely to be involved in the workforce and to receive work-plus-health insurance benefits than those aged 60 and beyond. Also in this study, no significant relationship was found between health insurance premiums and life satisfaction among older adults. A previous study by Liao et al. found that the impact of health insurance premiums on older people's life satisfaction varied by gender, with women being more affected than men (43).

This study found that health insurance participation and physical activity moderated the effect of age on life satisfaction among older people to some extent. As older people age, their physical functioning will continue to decline at any time. At the same time, physical exercise for older people decreases as some of the physical activities they used to do are gradually reduced or replaced by other tasks due to changes in lifestyle. In addition, physical exercise for older people not only enhances physical fitness, prevents disease and improves immunity, but also increases their social participation and social interaction (33), which in turn improves the impact of age or older people's life satisfaction. As age increases, older people's health risks increase, and increased health risks can increase the level of health care consumption among older people. Without the help of health insurance, this may result in an increased financial burden for older people's families. Therefore, participation in health insurance can increase older people's sense of security against uncertain future health risks and financial risks (65).

This study found that health insurance participation and physical exercise moderated to some extent the effect of educational attainment on life satisfaction among older adults." Data collected by the "Gallup World Poll" shows a positive relationship between education and life satisfaction (71). Although the components of life satisfaction are complex, research suggests that social and emotional skills play a role in determining life satisfaction. Social and emotional skills come primarily from schooling, but also from the family and cultural environment (72). In countries with greater educational differences, higher educational attainment increases the proportion of adults who self-report life satisfaction (73). In countries with greater educational disparities, higher educational attainment increases the proportion of adults who self-report life satisfaction (74). Physical exercise is beneficial in

promoting health equity (75). This study found that physical exercise reduces the significant effect of education on older adults' life satisfaction, which may be related to the fact that physical exercise helps to reduce health disparities between older adults with different levels of education, which in turn reduces the effect of educational attainment on older adults' life satisfaction. Health insurance participation reduced the significant effect of education on older adults' life satisfaction, which may be related to the fact that health insurance helps to reduce health disparities and health coverage disparities among older adults with different levels of education, increasing the accessibility of health care for older adults with different levels of education, and thus reducing the effect of education on older adults' life satisfaction. Sun et al. used data from a nationwide panel and confirmed improved health outcomes for residents who utilized health insurance coverage provided to urban residents (37). Su et al. found that older adults with health insurance participation had higher subjective wellbeing than those without health insurance participation. Health insurance participation helped to reduce health inequities associated with education and thus increased life satisfaction among older adults with different levels of education (75).

This study found that health insurance participation and physical exercise helped to reduce the impact of urban-rural differences on older people's life satisfaction. Looking at the urban and rural typologies, life satisfaction was significantly lower among rural older people than urban older people. A previous study reported that urban older people with chronic diseases had higher life satisfaction than rural older people with chronic diseases (76). There are significant differences between urban and rural areas in terms of lifestyle, household economic level and social security, and these factors may contribute to the differences in life satisfaction between urban and rural older people (77). Health insurance participation increases the level of health care coverage for older people in both urban and rural areas. Health insurance is particularly important for older people, which basically guarantees their quality of life (78). With socio-economic development, the health needs of older people have escalated and physical exercise can improve not only their health but also their lifestyles. Physical exercise can reduce the impact of urban-rural differences on older people's life satisfaction and help to improve the life satisfaction of rural older people.

Physical exercise can also improve the life satisfaction of older people with chronic illnesses, as the decline in physical function and health risks are more pronounced with age than when they were younger. This confirms the adage that "life is about exercise." Health insurance participation moderates the impact of work on older people's satisfaction and increases the life satisfaction of older people who are not working. Individuals who are employed are also likely to have higher health insurance contributions, which may potentially reduce their sense of security against uncertain future health and financial risks, thereby increasing their life satisfaction. The "Easterlin paradox" suggests that the relationship between the level of economic development and life satisfaction in a country or region is not a positive one (79). Xiang and Yao found a positive correlation between life satisfaction and household income in China, while there was no significant correlation between life satisfaction and regional economic development at the macro level (76). In contrast, this study found that GDP of the elderly significantly affects the life satisfaction of the elderly. The original intention of our government to set up different types of health insurance was to promote equity in health protection for different residents (79). However, due to regional differences in the level of economic development, the accessibility of health insurance for older people in economically developed regions may be better than that in less economically developed regions. Health insurance plays an important role in reducing the impact of differences in economic development on the life satisfaction of older people. Physical activity and health insurance both have a significant impact on life satisfaction among older people. Therefore, encouraging older people to take part in health insurance and physical exercise is one of the important means to achieve active aging strategies.

Cheah et al. study reported that individuals who participated in physical exercise were more likely to have health insurance (64). However, Zhang et al. the higher the amount of health insurance purchase, the less physical exercise behavior (65). The results of this study found that the effect of health insurance participation on older adults' life satisfaction remained significantly positive after the inclusion of regular physical exercise, and the regression coefficient became larger, thus indicating that physical exercise masked the effect of health insurance participation on older adults' life satisfaction to some extent, and that controlling for the variable of physical exercise significantly amplified the effect of health insurance participation on life satisfaction. The results of the study suggest that in the process of promoting active aging and healthy aging in China, special attention should be paid to those older people who have reduced their physical activity behavior as a result of their participation in health insurance.

This study also has some limitations, which should be taken into account when interpreting the results of this study. First, health insurance and physical exercise in this study were derived from self-reports by participants. Consequently, the results may have been affected by false positives, which may have weakened the associations observed in the study. Second, although many factors influencing life satisfaction in older adults have been documented in the literature, this study was unable to control for them as covariates in the study because they were not in the original study and these data were not available for this study. This study does not use instrumental variables and other test analysis methods for the endogeneity of variables, and hopes to further improve in future research. Finally, due to the second-hand public data used in this study, which is

affected by the sampling method and sample distribution of the CHNS database, the relevant conclusions of this study need to be further verified in other large national samples in the future.

Conclusion

Participation in health insurance and physical exercise are important means to promote life satisfaction among older people. Physical exercise affects the impact of health insurance on older people's life satisfaction.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by CHNS provides interviewees with guarantees of privacy and confidentiality. All participants provided written informed consent. Detailed information about the research design is on its official website. The patients/participants provided their written informed consent to participate in this study.

Author contributions

LL conceived the study and performed the data analysis and interpretation. LL, XZ, and XW drafted the manuscript. LL and XZ participated in the refinement of the manuscript. All authors have read and approved the final manuscript.

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Conflict of interest

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

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The impact of social support on the quality of life among older adults in China: An empirical study based on the 2020 CFPS

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Background: As aging issues become serious, how to guarantee and improve the quality of life among older adults has become a hot topic in China. This article is aimed to discuss the impact of formal and informal social support on the quality of life among older adults and the differences in gender and urban–rural areas.

Methods: The data used in this article are from the 2020 China Family Panel Studies (CFPS). Quality of life is measured from three dimensions of life: satisfaction, self-rated health, and mental state. This article uses the ordered logistic regression model to analyze the impact of social support on life satisfaction and self-rated health, and the binary logistic regression model to analyze the impact of social support on the mental state. The method of Shapley value decomposition further analyzes the contribution of influencing factors to the quality of life.

Results: The activities of daily living (ADL) and income significantly impact the quality of life among older adults. Formal and informal social support positively improved the quality of life among older adults, but the effect of informal social support is greater than that of formal social support. The male older adults are significantly better than the female adults across all three dimensions of quality of life. The mental state of urban older adults is better than that of rural older adults.

Conclusion: Formal and informal social support should be strengthened to improve the income of older adults. Older adults should be encouraged to participate in social activities and good interpersonal relationships should be established actively. Female older adults should be paid more attention. The proportion of female older adults participating in insurance should be increased, and the family and intergenerational care burden for female older adults should be reduced. The leisure life of urban older adults should be enriched. The basic social insurance and health service systems in rural areas should be improved.

KEYWORDS

older adults, quality of life, formal social support, informal social support, Shapley value decomposition

Introduction

Aging has been accelerating, and the population has shown a trend of advanced age since China entered an aging society around 2000 (1). According to the Seventh National Population Census from the National Bureau of Statistics in China, the population aged 60 and above was 264.02 million in 2020, accounting for 18.70% of the total population, an increase of 5.44% points over 2010 and 8.37% points over 2000 (2, 3). The number of people aged 65 and above was 190.64 million in 2020, accounting for 13.5%, an increase of 4.63% points over 2010 and 6.54% points over 2000 (2, 3). It is expected that the population aged 65 and above will exceed 200 million in China by 2022, with an aging rate of over 14%, and China will enter a deeply aging society (4). The pressure on the governments and families is increasing in the face of severe aging. The pension problem has become an urgent social problem to be solved. Ensuring older adults enjoy their twilight years and have a healthy and decent old life has become one of the major social development issues.

To deal with the aging of the population actively, the World Health Organization has put forward the concept of healthy aging and active aging. The core is to improve the quality of life among older adults and guarantee their right to development. The State Council issued a guideline to promote the development of national undertakings for the aged and improve the older adults' care service system during the 14th Five-Year Plan period (2021–2025) in China. The guideline proposes incorporating the concept of active aging and healthy aging into the economic and social development process to meet the need for high-quality services for the elder (5). Quality of life is one of the important indicators reflecting the living conditions of older adults, which is the basis for implementing healthy aging and active aging strategies. There are many factors influencing the quality of life among older adults, such as income status, education attainment, marriage, and living conditions. Social support also plays an important role in the improvement of the social security system.

Literature review

The concept of quality of life is dynamic, complex, and multidimensional. This concept first appeared in the book The Affluent Society, written by American economist John Kenneth Galbraith. The author believes the quality of life is a subjective experience in nature, including personal satisfaction with life experience, internal sense of contentment, and self-realization in society (6). Later scholars gradually crystallized the quality of life and understood it from multiple dimensions but failed to form a unified definition. The first understanding is to define the quality of life as a comprehensive reflection of objective living conditions, such as the area of the living house (7). The second understanding is to regard the quality of life as a subjective feeling of the overall life, such as life satisfaction and other subjective evaluation indicators (8, 9). The third understanding is to combine the objective part and the subjective part. The quality of life comprises two parts: the objective conditions reflecting living conditions and subjective feelings about the living conditions (10, 11). For older adults as a special group, a lot of literature defines and measures the quality of life among older adults according to research objectives. The quality of life among older adults proposed by the Chinese Medical Association in 1994 includes 11 aspects: health status, living habits, functions of daily living, family harmony, living conditions, economic income, nutritional status, mental health, social interaction, life satisfaction, and physical examination (12). Wu believed that the quality of life among older adults includes material life, spiritual and cultural life, life quality, personal quality, rights and interests, and living environment (13). After analyzing 48 studies on older adults, Van Leeuwen et al. determined that the quality of life among older adults should include nine domains: autonomy, role and activity, health perception, relationships, attitude and adaptation, emotional comfort, spirituality, home and neighborhood, and financial security (14). Due to the availability of survey data, this article refers to research of Li and determines three dimensions of the quality of life among older adults: life satisfaction, self-rated health, and mental state (1).

The concept of social support was first developed as a technical term in psychiatric literature. It is defined as information leading one to believe that he/she is cared for, loved, esteemed, and a member of a network of mutual obligations (15). Subsequently, many scholars have extensively researched social support as a science, and there are many definitions of social support. In general, the definition of social support can be viewed in four ways. Social support, which can be generated from helping behavioral, is a kind of interpersonal interaction, an exchange of social resources, and a systematic psychological activity (16). Additionally, there are a variety of classifications of social support. According to the functions of social support, Flannery categorized emotional support, instrumental support, informational support, and social companionship (17). Mindel et al. categorized formal and informal social support according to the support subjects (18). Formal social support refers to the support provided by the government, institutions, communities, and other formal organizations for vulnerable groups, such as endowment insurance and the medical security system (19). Informal social support refers to the emotional, behavioral, and informational support provided by family members, neighbors, friends, and colleagues (16).

Developed countries were the first to study the impact of social support on quality of life. The results showed that social support positively impacted the quality of life and improved health and mental status (20–22). Social support has been found to play an important role in the quality of life in the literature with studies of Chinese older adults (23, 24). Various types

of formal social support have been shown to positively affect older adults' life satisfaction and physical and mental health. Tao and Shen found that the new rural endowment insurance and rural medical insurance have a positive impact on the mental health of rural older adults but little contributes to their physical health (16). Zheng and Zheng found that the basic endowment insurance for the urban working group can improve the life satisfaction of older adults, while participation in the new rural endowment insurance system and new cooperative medical system will significantly improve the intergenerational financial support for families to indirectly promote the health and life satisfaction of older adults (25). Deng and Tang found that participating in endowment insurance positively impacts the life satisfaction of older adults (26). Li et al. found that older adults participating in endowment insurance had better self-rated health and that endowment insurance, medical insurance, and other social assistance significantly affected the degree of depression (27).

Regarding informal support, it is usually the impact of factors, such as intergenerational support and family support on the quality of life among older adults. Li found that practical, emotional, and spiritual social support positively affected older adults' life satisfaction, health status, and mental health (1). Wei et al. found that intergenerational support and social interaction can reduce the loneliness of rural older women and promote their physical and mental health (28). Li analyzed the impact of social support (emotional support, economic support, and daily care) on the quality of life among older adults and found that all social support variables positively impacted the quality of life (29). Fu and Cheng found a significant contribution of intergenerational support to older adults' life satisfaction (30).

To sum up, this article analyzes the impact of formal and informal social support on the quality of life (life satisfaction, self-rated health, and mental state) among older adults. The influence of activities of daily living and income status on the quality of life is also considered because a good quality of life for older adults is based on a certain material basis and independent activity ability (31). The research framework of this article is shown in Figure 1. This article lies in the comprehensive analysis of the impact of social support on the different aspects of quality of life for older adults. It further analyzes the difference of this impact in different groups of older adults, which is helpful to put forward targeted suggestions on the pension cause and better achieve a balanced pension.

Materials and methods

Data sources

The data come from the 2020 China Family Panel Students (CFPS), conducted by the Institute of Social Science Survey of Peking University. The adult questionnaire includes questions on basic personal information, retirement, insurance, marriage, and health status. The research topic of this article is the impact of social support on the quality of life among older adults. First, 6,976 older adults aged 60 and above were screened from 28,590 adult samples. Second, 1,847 older adults answered the questionnaire on behalf of others without answering subjective questions, such as life satisfaction and income status. Another 1,268 older adults did not answer questions about the physical test due to telephone interviews. Then, some samples with missing variables, such as whether they have a pension, were removed. Finally, 3,323 older adults with complete variable values were obtained after elimination.

Research variables

Explained variable

This article measures the quality of life among older adults from life satisfaction, self-rated health, and mental state, considering these three dimensions as explanatory variables. Life satisfaction was measured using a question in subjective attitude section, "How satisfied do you rate your life?" (30). Respondents were asked to rate their life satisfaction on a scale of 1–5, from 1 = being very dissatisfied to 5 = being very satisfied. Self-rated health was assessed using a question in the health section, "How do you feel about your health?" (1). Respondents could choose from five options, "Very good, Good, Fair, Poor, Very poor". For the convenience of data analysis, these options were assigned a value from "Very poor" to "Very good" (Very poor = 1, Poor = 2, Fair = 3, Good = 4, Very good = 5). The mental state was measured by choosing the degree of depression. Center for Epidemiological Studies Depression Scale (CES-D) was used in the 2020 CFPS questionnaire to reflect the degree of depression. This article adopts the answer options of CES-D8 to calculate depression scores (32). CES-D8 is a simplified version of CES-D, asking respondents eight of the 20 questions from CES-D. The corresponding score is assigned according to the frequency of the occurrence of a specific emotion, "Hardly (<1 day)" = 0, "Sometimes (1–2 days)" = 1, "Often (3–4 days)" = 2, and "Most of the time (5–7 days)" = 3. CES-D8 has two positive and six negative indicators, of which the positive indicators are assigned inversely. The total score of CES-D8 is 24, with higher scores indicating higher levels of depression. The threshold for depression was set at 9 (32). The degree of depression was reassigned to 1 (no depression) for respondents with a score of <9 and 0 (depression) for respondents with scores of 9 or above.

Explanatory variables

Social support is used as the explanatory variable, divided into formal and informal social support. This article chose endowment insurance, medical insurance, and pension as the formal social support (19, 27). Informal social support is mainly

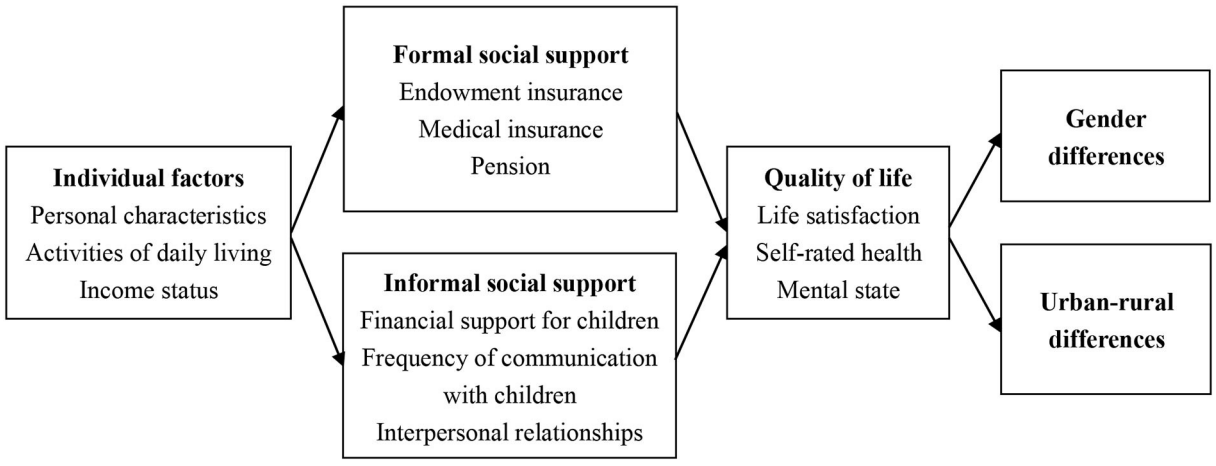

FIGURE 1
Research framework.

measured by whether children provide financial support (16), the frequency of communication with children (26), and the interpersonal relationship.

Control variables

This article considers some personal characteristics, such as age, gender, educational background, marital status, and household registration, as control variables. The CFPS divides educational background into nine types. To facilitate analysis, they are combined into four types, i.e., no schooling (no schooling), primary school and below (illiterate and semiliterate, primary school), junior high school and high school (junior high school, high school/secondary school/technical school/vocational high school), junior college and above (college, bachelor, master, doctorate). In terms of marital status, "Unmarried," "Divorced," and "Widowed" were classified as living without a spouse or partner, while "Married" and "Cohabiting" were classified as living with a spouse or partner. This article selects seven questions in the physical test to measure the activities of daily living (ADL) (29), i.e., "Can you go outdoors/eat/do kitchen activities/use public transportation/go shopping/clean/do the laundry independently?". Assign the answer "Yes" to 1 and "No" to 0. The scores of the seven questions were summed up as the variable value of ADL in this article. The range from 0 for "complete disability" to 7 for "complete self-care" reflects the level of ADL among older adults. Income status was measured using the question, "How would you rate your income in local area?" (30). Respondents were asked to rate their income on a scale of 1 (very low) to 5 (very high).

The description of explained, explanatory, and control variables is shown in Table 1.

Model design

Ordered logistic regression model

The two variables of life satisfaction and self-rated health are ordered categorical variables, so the ordered logistic regression model was used to analyze the impact of social support on life satisfaction and self-rated health. The model is as follows:

$$\ln\left[\frac{P(y \le j\,|x)}{1 - P(y \le j\,|x)}\right] = \alpha_j + \sum_{i=1}^{n} \beta_i x_i$$

where y represents life satisfaction and self-rated health, j represents the grade value of options ($j = 1, 2, 3, 4, 5$), x_i represents social support variables or control variables, n represents the number of explanatory variables, β represents a set of regression coefficients, and α is the intercept term.

Binary logistic regression model

The mental state is a binary variable. The binary logistic regression model was used to analyze the impact of social support on the mental state of older adults. The model is as follows:

$$\ln\left[\frac{P(y = 1\,|x)}{1 - P(y = 1\,|x)}\right] = \alpha + \sum_{i=1}^{n} \beta_i x_i$$

where y is the mental state (the value of 1 indicates no depression), x_i represents social support variables or control variables, n represents the number of explanatory variables, β represents a set of regression coefficients, and α is the intercept term.

TABLE 1 Variable definition.

Type of variables	Categorical variables	Name	Descriptions and assignment
Explained variable	Quality of life	Life satisfaction	A scale of 1–5 is from very dissatisfied to very satisfied
		Self-rated health	A scale of 1–5 is from unhealthy to very healthy
		Mental state	1 = No Depression, 0 = Depression
Explanatory variables	Formal social support	Endowment insurance	1 = Have, 0 = No
		Medical insurance	1 = Have, 0 = No
		Pension	1 = Have, 0 = No
	Informal social support	Financial support by children	1 = Have, 0 = No
		Frequency of communication with children	A scale of 1–7 is from low to high
		Interpersonal relationships	A scale of 0–10 is from very worse to very good
Control variables	Personal characteristics	Age	60 years old and above
		Gender	1 = Male, 0 = Female
		Marriage	1 = Live with a spouse or partner, 0 = Live without a spouse or partner
		Education	1 = No schooling
			2 = Primary school and below
			3 = Junior High School / High School
			4 = Junior college and above
		Household registration	1 = Urban, 0 = Rural
		Activities of daily living (ADL)	A scale of 0–7 is from complete disability to complete self-care
		Income	A scale of 1–5 is from very low to very high

Discussion

Descriptive statistics

The selected older adults are between 60 and 95 years old, with an average age of 68.06. Regarding gender, 52.33% of older adults are male, and 47.67% are female, with a male to female ratio of 1.1:1. The gender distribution of the samples is balanced. Most of the older adults are married, accounting for 87.3%. The overall education level of older adults is relatively low. The older adults with primary school education and below accounted for 62.8%, while the older adults with junior college and above accounted for only 2.8%. Regarding urban–rural distribution, the proportion of the urban older adults is 47.19%, slightly less than that of the rural older adults. And the proportion of rural older adults is 52.81%.

The impact of social support on life satisfaction

Table 2 shows the empirical results of the impact of social support on life satisfaction among older adults. Model 1a only considers the impact of control variables on life satisfaction, and the results show that gender, marital status, education level, ADL, and income significantly influence life satisfaction. The life satisfaction of male older adults is higher than that of female older adults. The life satisfaction of older adults without a spouse or partner is lower than that of older adults with a spouse or partner. Educational attainment had a negative effect on life satisfaction, i.e., the higher the educational attainment, the lower the life satisfaction. ADL also significantly negatively influences life satisfaction, which goes against our general perception that better activities of daily living are associated with higher life satisfaction. The negative effect may be explained by the fact that the seven activities reflect instrumental activities of daily living. Older adults with better ADL will continue to work or take care of family or grandchildren, which is detrimental to improving life satisfaction. Income has a positive effect on life satisfaction. Only a high income can guarantee daily life and contribute to the improvement of life satisfaction. Model 2a also considers the impact of formal and informal support on life satisfaction based on Model 1a. The results show that in terms of formal social support, endowment insurance and medical insurance positively impact the life satisfaction of older adults, indicating that having endowment insurance and medical insurance is conducive to improving the life satisfaction of older adults. Regarding informal social support, the results show that the frequency of communication with children and interpersonal relationships significantly positively impact the life satisfaction of older adults. Better emotional support is more likely to improve life satisfaction.

Models 3a and 4a further show gender differences in life satisfaction among older adults. ADL has a significant negative effect on life satisfaction in female older adults but not in male older adults. Female older adults with better activities of daily

TABLE 2 The impact of formal and informal social support on life satisfaction.

Variable	Model 1a	Model 2a	Model 3a Male	Model 4a Female	Model 5a Urban	Model 6a Rural
Control variable						
Age	0.003 (1.003)	0.001 (1.001)	−0.003 (0.997)	0.007 (1.007)	0.004 (1.004)	−0.003 (0.997)
Gender	0.145** (1.156)	0.194*** (1.215)	–	–	0.305*** (1.357)	0.11 (1.117)
Marriage	0.193* (1.213)	0.191* (1.211)	0.243 (1.275)	0.164 (1.178)	0.156 (1.169)	0.238 (1.269)
Education	−0.321*** (0.726)	−0.358*** (0.699)	−0.349*** (0.705)	−0.384*** (0.681)	−0.305*** (0.737)	−0.459*** (0.632)
Household registration	0.05 (1.05)	0.088 (1.092)	0.226** (1.253)	−0.059 (0.942)	–	–
ADL	−0.058* (0.944)	−0.076** (0.927)	−0.061 (0.941)	−0.089** (0.915)	−0.11** (0.896)	−0.058 (0.944)
Income	0.668*** (1.949)	0.63*** (1.877)	0.603*** (1.828)	0.659*** (1.933)	0.612*** (1.844)	0.65*** (1.916)
Formal social support						
Endowment insurance		0.244** (1.276)	0.528*** (1.695)	−0.127 (0.88)	0.231* (1.26)	0.347 (1.415)
Medical insurance		0.216* (1.241)	0.313* (1.368)	0.14 (1.15)	0.138 (1.148)	0.325* (1.384)
Pension		−0.166 (0.847)	−0.39 (0.677)	0.152 (1.165)	−0.124 (0.884)	−0.268 (0.765)
Informal social support						
Financial support by children		0.088 (1.092)	0.095 (1.099)	0.073 (1.076)	−0.019 (0.981)	0.179* (1.196)
Frequency of communication with children		0.034* (1.035)	0.053** (1.054)	0.017 (1.017)	0.021 (1.021)	0.047* (1.048)
Interpersonal relationships		0.237*** (1.267)	0.251*** (1.286)	0.225*** (1.253)	0.264*** (1.303)	0.218*** (1.244)
N	3,323	3,323	1,739	1,584	1,568	1,755
LR chi2	487.39***	683.7***	340.48***	356.54***	330.63***	361.93***
Pseudo R^2	0.0662	0.0929	0.0906	0.0991	0.0958	0.0929

***, **, and * were significant at 1, 5, and 10% levels, respectively. OR values are in parentheses.

living are more likely to take care of family or grandchildren. Trivial household work is not conducive to improving the life satisfaction of female older adults. Access to endowment and medical insurance can significantly improve the life satisfaction of male older adults, while these two formal social support variables do not affect the life satisfaction of women. Male older adults are more likely to work outside the home at a younger age, while female older adults are more likely to take care of their families. More men than women have access to endowment and medical insurance. In terms of informal social support, the frequency of communication with children has a significant positive impact on life satisfaction among male older adults, while it has no effect on female older adults. The reason may be that male older adults tend to be serious and uncommunicative, while female older adults have multiple options for confiding and communicating. The effect of emotional support from frequent communication with children was greater in men than in women.

Although model 2a shows no significant difference in the overall life satisfaction among older adults in urban and rural areas, model 5a and model 6a can further show the difference in influencing factors of life satisfaction between urban and rural older adults. ADL has a significant negative impact on the life satisfaction of urban older adults but has no impact on rural older adults. The urban older adults with better ADL have lower life satisfaction. Urban older adults face higher living costs than rural older adults and tend to continue working after retirement. Different insurances have different effects on the satisfaction among older adults in urban and rural areas. Endowment insurance can significantly improve the life satisfaction of urban older adults, while medical insurance is more important to the life satisfaction of rural older adults. In terms of informal social support, receiving financial support from their children and high frequency of communication with children can significantly improve the life satisfaction of rural older adults but has no effect on urban older adults. The reason may be that urban older adults have a higher pension than rural older adults and do not need financial support from their children. Urban older adults can participate in more leisure activities than the rural older adults after retirement. The way of emotional sustenance for urban older adults is also diverse.

The impact of social support on self-rated health

Table 3 shows the results of the impact of social support on self-rated health among older adults. Model 1b only considers the influence of control variables on self-rated health, and the results show that gender, education level, ADL, and income significantly influence self-rated health. Male older adults are in better health than female older adults, and older

TABLE 3 The impact of formal and informal social support on self-rated health.

Variable	Model 1b	Model 2b	Model 3b Male	Model 4b Female	Model 5b Urban	Model 6b Rural
Control variable						
Age	−0.003 (0.997)	−0.004 (0.996)	−0.013 (0.987)	0.007 (1.007)	−0.005 (0.995)	−0.001 (0.999)
Gender	0.29*** (1.336)	0.309*** (1.362)	–	–	0.371*** (1.449)	0.253*** (1.288)
Marriage	0.001 (1.001)	0.012 (1.012)	0.199 (1.22)	−0.06 (0.942)	−0.071 (0.932)	0.076 (1.079)
Education	0.172*** (1.187)	0.177*** (1.193)	0.126 (1.134)	0.258** (1.294)	0.188** (1.206)	0.18* (1.197)
Household registration	0.046 (1.047)	0.074 (1.077)	0.096 (1.101)	0.036 (1.037)	–	–
ADL	0.347*** (1.414)	0.346*** (1.414)	0.312*** (1.366)	0.389*** (1.476)	0.395*** (1.484)	0.314*** (1.369)
Income	0.274*** (1.316)	0.25*** (1.284)	0.258*** (1.295)	0.242*** (1.274)	0.204*** (1.226)	0.282*** (1.325)
Formal social support						
Endowment insurance		0.138 (1.147)	0.048 (1.049)	0.248 (1.281)	0.258** (1.294)	−0.131 (0.877)
Medical insurance		0.006 (1.006)	0.074 (1.077)	−0.042 (0.959)	−0.071 (0.932)	0.09 (1.094)
Pension		−0.127 (0.881)	−0.088 (0.916)	−0.18 (0.835)	−0.227 (0.797)	0.115 (1.122)
Informal social support						
Financial support by children		0.091 (1.095)	0.053 (1.054)	0.125 (1.133)	0.16 (1.173)	0.059 (1.061)
Frequency of communication with children		0.001 (1.001)	0.017 (1.017)	−0.013 (0.987)	0.005 (1.005)	0.001 (1)
Interpersonal relationship		0.099*** (1.104)	0.102*** (1.108)	0.0934*** (1.098)	0.125*** (1.134)	0.078*** (1.081)
N	3,323	3,323	1,739	1,584	1,568	1,755
LR chi2	305.65***	346.95***	161.7***	160.13***	166.06***	185.84***
Pseudo R^2	0.0308	0.0349	0.0311	0.0342	0.0359	0.0353

***, **, and * were significant at 1, 5, and 10% levels, respectively. OR values are in parentheses.

adults with higher levels of education are in better health. Older adults with better activities of daily living have better health, which is consistent with the process of human aging. Older adults with higher incomes spend more on health care and have better health. Model 2b considers the impact of social support on self-rated health among older adults. None of the three variables of formal support significantly impacts self-rated health, indicating that these basic insurances have no significant effect on improving the health status of older adults. Regarding informal support, interpersonal relationships significantly positively impact self-rated health. Good interpersonal relationships can play an important role in maintaining older adults' physical and mental health.

Models 3b and 4b further show the differences in self-rated health between male and female older adults. The three variables of formal support do not affect the self-rated health of male and female older adults. Interpersonal relationships significantly influence both male and female older adults in terms of informal support. Although there is no significant difference in self-rated health between urban and rural older adults, model 5b and model 6b further demonstrate the difference in influencing factors. Endowment insurance has a significant positive effect on the health status of urban older adults but has no effect on rural older adults. Endowment insurance can increase the disposable income of urban retired older adults, increasing health expenditure and improving health status.

The impact of social support on the mental state

Table 4 shows the empirical results of the impact of social support on older adults' mental state. Model 1c shows that all control variables had significant positive effects on the mental state of older adults. The mental health of older adults becomes better as they get older. Male older adults are in better mental health than female older adults. The older adults with a spouse or partner have a better mental state than without a spouse or partner. The older adults with a higher education level have a better mental state. Urban older adults have better mental states than rural older adults. Older adults with better ADL and higher incomes have better mental health status. Model 2c further considers the influence of social support on the mental health of older adults. None of the three formal support variables significantly impact the mental state. More frequent communication with children and better interpersonal relationships are beneficial in improving mental state. Emotional support is more important than economic support for the mental health of older adults.

Models 3c and 4c show gender differences in the effect of social support on mental state. The three variables of formal support still have no significant effect on the mental state of male and female older adults. In terms of informal support, receiving financial support from children has a significant positive effect

TABLE 4 The impact of formal and informal social support on mental state.

Variable	Model 1c	Model 2c	Model 3c Male	Model 4c Female	Model 5c Urban	Model 6c Rural
Control variable						
Age	0.021** (1.021)	0.021** (1.021)	0.025* (1.025)	0.018 (1.018)	0.02 (1.02)	0.02* (1.021)
Gender	0.517*** (1.677)	0.551*** (1.736)	–	–	0.635*** (1.887)	0.496*** (1.642)
Marriage	0.565*** (1.76)	0.564*** (1.758)	1.008*** (2.739)	0.357** (1.428)	0.676*** (1.965)	0.473*** (1.604)
Education	0.351*** (1.421)	0.323*** (1.381)	0.223* (1.249)	0.433*** (1.541)	0.397*** (1.487)	0.255* (1.291)
Household registration	0.477*** (1.611)	0.484*** (1.622)	0.6*** (1.822)	0.368*** (1.446)	–	–
ADL	0.223*** (1.249)	0.217*** (1.243)	0.147*** (1.158)	0.28*** (1.323)	0.22*** (1.246)	0.22*** (1.246)
Income	0.262*** (1.3)	0.234*** (1.264)	0.268*** (1.308)	0.213*** (1.237)	0.26*** (1.297)	0.219*** (1.245)
Formal social support						
Endowment insurance		−0.035 (0.965)	0.019 (1.019)	−0.043 (0.958)	0.001 (1.001)	−0.139 (0.87)
Medical insurance		0.129 (1.138)	0.281 (1.324)	0.015 (1.015)	0.083 (1.087)	0.187 (1.205)
Pension		0.045 (1.046)	−0.121 (0.886)	0.159 (1.172)	−0.133 (0.876)	0.224 (1.251)
Informal social support						
Financial support by children		0.11 (1.116)	−0.156 (0.856)	0.316** (1.371)	0.126 (1.134)	0.095 (1.1)
Frequency of communication with children		0.038* (1.039)	0.049 (1.05)	0.032 (1.033)	0.052 (1.054)	0.026 (1.026)
Interpersonal relationship		0.105*** (1.111)	0.118*** (1.125)	0.094*** (1.099)	0.155*** (1.168)	0.074***(1.077)
N	3,323	3,323	1,739	1,584	1,586	1,755
LR chi2	251.66***	284.66***	118.59***	126.88***	126.81***	123.65***
Pseudo R^2	0.07	0.0792	0.0732	0.0664	0.0855	0.0598

***, **, and * were significant at 1, 5, and 10% levels, respectively. OR values are in parentheses.

on the mental state of female older adults but does not affect the mental state of male older adults. The reason may be that the income of female older adults is lower than that of male older adults. Receiving financial support from children can significantly improve the mental state of female older adults. Models 5c and 6c show the difference in the impact of social support on mental health between urban and rural older adults. The three variables of formal social support do not affect the mental health of urban and rural older adults. Only interpersonal relationships have a significant positive effect on mental health regarding informal social support.

Shapley value decomposition of factors influencing quality of life among older adults

The method of Shapley value decomposition was first proposed by Shorrocks (33), which is used to compare the degree of impact of independent variables on dependent variables based on cooperative game theory. This article applies the Shapley value decomposition method to determine the contribution of explanatory variables to the quality of life among older adults. The results of Shapley value decomposition are shown in Table 5. For all older adults, income and interpersonal relationships are the main factors in improving life satisfaction, accounting for more than 90%. ADL and income are the main factors in improving health status, with a combined share of 72.44%. There is no absolute dominant influencing factor for the mental state. Comparatively, ADL, gender, and income are the key determinants, accounting for more than 15%, respectively. Overall, income status plays a vital role in three aspects of quality of life, and ADL plays a more critical role in self-rated health and mental state. For formal support, endowment insurance and medical insurance only play a weak role in improving life satisfaction. For informal support, interpersonal relationships considerably impact all three aspects of quality of life.

The gender differences in the contribution of each fact were observed further. For life satisfaction and self-rated health, the primary determining factors for male and female older adults are identical. Good income status and interpersonal relationships considerably contribute to life satisfaction. For formal support, only the life satisfaction among male older adults is affected by endowment insurance and medical insurance, which account for 4.56% of the total. The ADL, income, and interpersonal relationships have a greater influence on the self-rated health of male and female older adults. In terms of mental state, there is a significant difference between male and female older adults. For male older adults, income is the most crucial determinant in maintaining mental health, followed by having a spouse or partner and an urban household registration. But having a

TABLE 5 Shapley value decomposition.

	All		Male		Female		Urban		Rural	
Life satisfaction	Income	61.28	Income	54.16	Income	67.08	Income	56.21	Income	65.44
	Interpersonal relationship	30.43	Interpersonal relationship	34.63	Interpersonal relationship	26.62	Interpersonal relationship	34.19	Interpersonal relationship	27.41
	Education	4.13	Education	4.14	Education	4.95	Education	3.85	Education	3.77
	Endowment insurance	0.86	Endowment insurance	2.62	ADL	1.35	Gender	2.44	Medical insurance	1.27
	ADL	0.84	Frequency of communication with children	2.02			ADL	1.92	Frequency of communication with children	1.17
	Frequency of communication with children	0.68	Medical insurance	1.94			Endowment insurance	1.39	Financial support by children	0.94
	Gender	0.64	Household registration	0.49						
	Marriage	0.57								
	Medical insurance	0.57								
Self-rated health	ADL	47.87	ADL	52.44	ADL	55.21	ADL	47.78	ADL	45.14
	Income	24.57	Income	29.66	Income	25.97	Interpersonal relationship	19.11	Income	32.75
	Interpersonal relationship	13.51	Interpersonal relationship	17.9	Interpersonal relationship	14.17	Income	15.86	Interpersonal relationship	9.81
	Gender	8.13			Education	4.65	Gender	10.56	Gender	6.59
	Education	5.92					Education	5.5	Education	5.71
							Endowment insurance	1.18		
Mental health	ADL	18.36	Income	23.39	ADL	34.42	Interpersonal relationship	21.03	ADL	28.07
	Gender	17.17	Marriage	22.11	Income	18.47	Gender	20.71	Income	22.55
	Income	16.74	Household registration	19.28	Household registration	13.28	Income	19.7	Gender	21.56
	Household registration	12.33	Interpersonal relationship	16.1	Interpersonal relationship	13.18	ADL	13.41	Interpersonal relationship	9.66
	Interpersonal relationship	11.32	ADL	10.77	Education	13.03	Marriage	13.31	Marriage	8.56
	Education	10.9	Education	6.73	Financial support by children	4.09	Education	11.84	Education	8.22
	Marriage	8.88	Age	1.62	Marriage	3.53			Age	1.38
	Frequency of communication with children	3.04								
	Age	1.26								

The explanatory variables are sorted by contribution rate. The unit of value is percent.

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spouse or partner has a negligible effect on improving female older adults' mental health. Better ADL is critical for preserving the mental health of female older adults, followed by income and urban household registration. However, the effect of ADL on the alleviation of depressive degree in male older adults is just 10.77%.

In addition, the contribution rate of explanatory variables differs between urban and rural areas. Life satisfaction of urban and rural older adults can be improved by focusing on their income status and interpersonal relationships. In terms of formal social support, the impact of endowment insurance and medical insurance on life satisfaction remains modest. Except for interpersonal relationships, the other two variables of informal social support have a relatively minor impact on the life satisfaction of rural older adults. For self-rated health, the ADL continues to have the greatest impact on improving health status. The contribution rate of interpersonal relationships is somewhat higher than income for the health of urban older adults, and the opposite is true for rural older adults' health. Endowment insurance has little influence on the health of urban older adults. Regarding mental state, the contribution rate of influencing factors between urban and rural older adults is quite different. Interpersonal relationships significantly impact the mental state of urban older adults, while the influence on the mental state of rural older adults is only fourth in importance. ADL has a significant impact on the mental state of rural older adults but a much smaller impact on the mental health of urban older adults.

Conclusion

Based on data from the 2020 CFPS, this article analyzes the impact of social support on quality of life among older adults and determines the contribution of factors to quality of life. Overall, ADL and income improve quality of life considerably. Income plays a significant role in improving life satisfaction, and ADL has the greatest impact on self-rated health and mental state. Both formal and informal social support positively influenced the improvement of the quality of life among older adults, although the contribution of informal social support was greater than that of formal social support. Only life satisfaction is affected by endowment insurance and medical insurance, but their contribution is small. Interpersonal relationships substantially positively affect all three aspects of quality of life.

There are differences in the quality of life among different groups of older adults. For formal social support, endowment and medical insurance play a significant role in increasing life satisfaction among male older adults but have no effect on female older adults. Education level positively affects the self-rated health of female older adults but does not affect male older adults. Male older adults with a spouse or partner have a better mental state. But marital status has a minor effect on the mental state of female older adults. ADL has the most significant impact on the mental state of female older adults but has no discernible impact on the mental health of male older adults. Regarding life satisfaction differences between urban and rural areas, urban older adults are more concerned with endowment insurance, whereas rural older adults pay more attention to medical insurance. Informal social support has a more considerable effect on the life satisfaction of rural older adults than formal social support. Endowment insurance has a slight effect on improving the health status of older adults in urban areas but has no effect on rural older adults. Interpersonal relationships can considerably improve the mental state of urban older adults, while ADL can significantly improve the mental health of rural older adults.

This article attempts to make some suggestions to help improve the quality of life among older adults and the old age security system based on the above findings. The income status considerably impacts all three dimensions of quality of life. Older adults will lose their primary source of income after retirement, diminishing their quality of life. At the national level, formal social support should be strengthened to improve the basic endowment and medical insurance systems. Faced with a massive pension shortfall, the government can delay the retirement age, improve the coverage of enterprise annuities, and establish the third pillar of pension insurance, among other measures. The government should also strengthen the implementation of the basic medical insurance policy, implement cross-provincial direct payment of outpatient fees, broaden the area of medical reimbursement for chronic diseases, and reduce the burden of medicines for older adults. At the family level, the community encourages family members to fulfill their support commitments and increases the willingness of children to support older adults financially. Older adults should be encouraged to re-enter the workforce, demonstrate their social value, and expand their sources of income.

Interpersonal relationships in informal social support had a favorable effect on all three aspects of quality of life, indicating that establishing a good social circle among older adults significantly improved quality of life. Positive interpersonal relationships are fostered through engaging in social activities, such as community governance and entertainment. Older adults should also be instructed and assisted in using intelligent devices and the Internet to expand communication channels and objects. Children's emotional support is also vital. Numerous older adults do not live with their children and live alone, which is detrimental to their physical and emotional health. Children should frequently visit or communicate with older adults through phone or video, be concerned with older adults' living situations, and provide the necessary nursing and financial support.

The impact of social support on quality of life varied among different groups of older adults. Male older adults outperformed female older adults in terms of life satisfaction, self-rated health, and mental state. Therefore, it is important to increase the participation of female older adults in endowment and medical

insurance and reduce the burden of family and intergenerational care for female older adults. The policies and services for older adults in urban areas are gradually improving. More attention should be devoted to the spiritual life of urban older adults, and leisure activities should be increased, such as supporting cultural performances and boosting exercise facilities for older adults. It is necessary to expand the coverage of basic endowment and basic medical insurance for rural older adults, raise the level of pension and medical insurance reimbursement standards, and establish a health service and social security system covering rural areas.

There are still some limitations in this article. To ensure the completeness of the data, this article directly deletes samples with missing variable values and does not use interpolation to make up for the data, resulting in a relatively small sample size. This article only analyses the CFPS data in 2020, without considering the survey data of other years, and cannot obtain the dynamic changes of the impact of social support on quality of life. Lastly, this article uses ADL and income status as control variables to determine a direct impact on quality of life and does not consider how both factors affect the correlation between social support and quality of life. This moderating effect will be examined in future research.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: http://www.isss.pku.edu.cn/cfps/.

Author contributions

TS drafted the article and conducted the data interpretation. DL conceptualized and designed the research. ZH revised and polished this article. JL and XW collected data and obtained preliminary data results. 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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High-intensity interval training among middle-aged and older adults for body composition and muscle strength: A systematic review

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Background: The aging of population is leading to the investigation of new options to achieve healthy aging. One of these options is high-intensity interval training (HIIT), although its effects on body composition and muscle strength are currently unclear. The objective of this systematic review is to examine the scientific publications on the effects of HIIT on the body composition and muscle strength of middle-aged and older adults.

Methods: The search was carried out in the PubMed, Cochrane Plus, Web of Science, CINAHL and SciELO databases without limitation of publication dates. The literature search, data extraction and systematic review were performed following the PRISMA standards and the risk of bias of the selected studies was assessed using the Cochrane Collaboration Risk-of-Bias.

Results: Initially 520 publications were identified, out of which a total of 8 articles were finally selected to be included in this systematic review. Improvements in body composition were seen in six of the selected items and an increase in muscle strength in seven of the eight. Regarding physical function, improvements were found in both gait speed and balance.

Conclusions: This systematic review found that HIIT is effective in improving body composition and increasing muscle strength. However, when comparing HIIT to moderate-intensity continuous training, it is not clear that HIIT is more beneficial; a firm conclusion cannot be drawn due to the scarcity of published studies, their variety in methodology and the ambiguity of their results, so it is suggested to carry out more research in this area.

KEYWORDS

high-intensity interval training (HIIT), middle-aged, older adults, body composition, muscle strength, systematic review

Introduction

Worldwide, the demographic trend toward an aging population is having far-reaching social and financial consequences (1). It is expected that by the year 2050 the aged will have surpassed in number those between the ages of 10 and 24 years old (2). As a matter of fact, in 2018 the percentage of the elderly among the Spanish population was 18.5%, and projections indicate that it could reach 35.5% of the total by 2050 (3). From the point of view of health, the aging process is associated with a variety of complications which include cognitive and functional deterioration, gait alterations, an increased number of falls, greater fragility, as well as the associated increase in disability and dependency (4, 5).

Aging involves an increase in fat deposits between and within muscles. This growth of intramuscular adipose tissue and its lipotoxic effect have been considered to contribute to decreases in muscle quality and strength, given that the infiltration of fat in muscles may alter the orientation of fibers and, as a consequence, the muscle's ability to exert force (6, 7). Additionally, obesity is linked to several non-communicable diseases, among which diabetes, some types of cancer, and cardiovascular diseases stand out (8). This leads to a decrease in life expectancy and higher mortality rates for those affected (9, 10). This situation, however, can be resolved or ameliorated through weight loss and the adoption of healthy lifestyle habits (10).

Sarcopenia is yet another common complication associated with aging. Defined in 2019 by the European Working Group on Sarcopenia in Older People as a decrease in muscle strength as the main diagnostic criterion, sarcopenia is also characterized by a decrease in the quantity or quality of muscle mass. It is considered severe when poor physical performance is added to the criteria mentioned above. Sarcopenia is associated with an increase in the number of falls and fractures, as well as with decreased quality of life, physical disability, and mortality (11).

Physical activity has been shown to provide great benefits for the physical and mental health of older people (12). It has also been proven to increase their quality of life and functional independence, and to decrease their risk of mortality, thus increasing life expectancy (13).

When many individuals consider getting involved in a physical exercise program, lack of time is often cited as a main hurdle. One possible solution to this problem is provided by high-intensity interval training (HIIT), which combines high-intensity intervals with rest or low-intensity periods (14). HIIT allows training to be performed in shorter bouts of time, and is commonly regarded to be more fun and pleasant than moderately intense continuous training. Additionally, HIIT appears to induce more physiological benefits than other traditional kinds of training, and to require shorter training periods (15). Furthermore, HIIT has been reported to be safe and effective for a healthy older population (16).

Despite the health benefits of HIIT and the widespread need to devise and implement active aging plans, to date little research has been done regarding the effects of high-intensity interval training among older and middle-aged people. To the best of our knowledge few studies have focused on measuring body composition and muscle strength, and those that did failed to analyze healthy populations (17). The main goal of this systematic review is to provide an analysis of what data has been published regarding the effects of high-intensity interval training on the body composition and muscle strength of middle-aged and older adults.

Materials and methods

The bibliographic search, data extraction, and systematic review were carried out in compliance with PRISMA guidelines.

Eligibility criteria

The inclusion criteria for this systematic review were as follows: Randomized Controlled Trials (RCTs) in which at least one group of the study participated in a HIIT program; that studied the effects of HIIT on obesity and muscle strength; conducted on healthy participants over 55 years old; and published in either English or Spanish. Studies were excluded if: they did not include a control group; or their participants were taking vitamin or protein supplements that might have influenced the results of the study.

Information sources and search strategy

A systematic literature search was performed in the PubMed, Cochrane Plus, Web of Science, CINAHL, and SciELO databases without any limitation to publication dates. A search was conducted in the title and abstract fields by entering the free terms ("high intensity interval") AND ("body composition" OR obes* OR fat OR adipos* OR "body mass") AND (strength OR "muscle strength" OR "muscle quality") AND (old OR older OR elder* OR aging OR aging OR aged OR menop* OR postmenop*). An iterative process was employed to assure that all relevant articles were selected. The search was conducted from May 2, 2021 to August 16, 2021.

Study selection and data extraction

The study selection was carried out independently by three of the authors (AAA, FHC, MAT). First, duplicate articles were removed. Then, titles and abstracts were examined to reject the articles that did not meet the eligibility criteria mentioned above.

Lastly, full-text articles were screened to confirm that they met the inclusion criteria. Disagreements were solved by discussion until consensus was reached. For each paper, data were extracted concerning authors, year, country, studied population (age, sample size, and group allocation), study design, outcomes, measuring tools used, description of the intervention procedures (type of HIIT and duration), measurement time points, dropout rate by groups, adverse effects, and main findings.

Outcomes

The primary outcomes of this study were muscle strength and body composition, including body mass index (BMI), body weight, fat mass, or fat-free mass. Secondary outcomes included physical function or physical performance.

Study quality

The risk of bias of the studies selected was assessed independently by three authors (MCF, AMA, JDJG) using the Cochrane Collaboration Risk-of-Bias tool (18). Any disagreements regarding methodological quality were resolved by discussion until a consensus was reached. The items included in the quality assessment were: selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other potential biases. Each item was categorized into one of three levels: low risk (unlikely to alter the results), unclear risk (no specific details or description were reported; raises doubts about the results), or high risk (did not meet the criteria; may alter the results seriously).

Results

Included studies

In the first search 520 publications were identified, out of which 8 articles were finally selected to be included in this systematic review. Figure 1 shows the study selection flowchart, in accordance with the PRISMA (19) statement.

Quality of included studies

Table 1 shows the risk-of-bias assessment. All included articles were classified as having a low risk of bias in all items. The eight RCTs included in this systematic review described the exclusions and losses to follow-up (16, 20–26). Only two RCTs did not present exclusions or losses to follow-up.

Study and participants characteristics

Table 2 shows the full descriptive details of the RCTs included in this review. Out of the eight articles analyzed, four were two-armed trials (16, 22–24), three were three-armed (21, 25, 26), and the remaining one had four arms (20). Two RCTs were conducted in America (both in California, United States) (20, 22), five in Europe (one in Italy, three in Spain, and one in the United Kingdom) (16, 23–26), and one took place in Asia (Japan) (21).

Two articles enrolled only men (22, 23), one article enrolled only women (26), and five articles included both genders. A total of 615 participants took part in the eight articles included in this systematic review, and out of those 65.04% were women. Table 2 shows mean age by groups. The types of exercises reported were high-intensity interval aerobic or resistance training, either alone or combined. Out of the eight RCTs included, only four studies used active rest in their interventions (21, 23, 25, 26). The duration of the interventions was measured in weeks in 6 of the 8 studies, with an average of 14 (range: 6–24), including several weekly sessions, with a distribution of 12 weeks in the articles by Villanueva et al. (22), Jiménez-García et al. (25) and García-Pinillos et al. (16), 24 weeks in the article by Taaffe et al. (20), 18 weeks in Ballesta-García et al. (26), and 6 weeks in Sculthorpe et al. (23). Meanwhile, the articles by Moro et al. (24) and Nemoto et al. (21) reached lengths of 2 and 5 months, respectively. The dropout rate was 24.7% (152/615 participants). Two of the RCTs (25, 26) reported adverse effects, three other articles (16, 22, 23) did not register adverse effects, and the articles by Taaffe et al. (20), Nemoto et al. (21) and Moro et al. (24) did not provide any statement regarding adverse effects.

Outcomes

Body composition

Body composition was assessed by whole-body dual-energy X-ray absorptiometry in two of the articles (20, 22), Bioelectrical Impedance Analysis was used in four articles (16, 23–25), which also employed an electronic scale and a height rod. Four studies reported that high-intensity strength-resistance training improved lean body mass measurements (16, 22, 23, 26). In two of those BMI also improved (16, 26), and two others showed a significant decrease in total body fat after the intervention (16, 23). Two articles looked into body weight differences within a high-intensity interval resistance group and reported improvement in this outcome. Moro et al. (24) also found improvements in fat mass and lean body mass, while Nemoto et al. (21) reported a decrease in body weight.

When intervention groups were compared with controls, changes in body composition were observed. Three studies that included high-intensity strength-resistance training reported improvements in lean body mass compared with a control

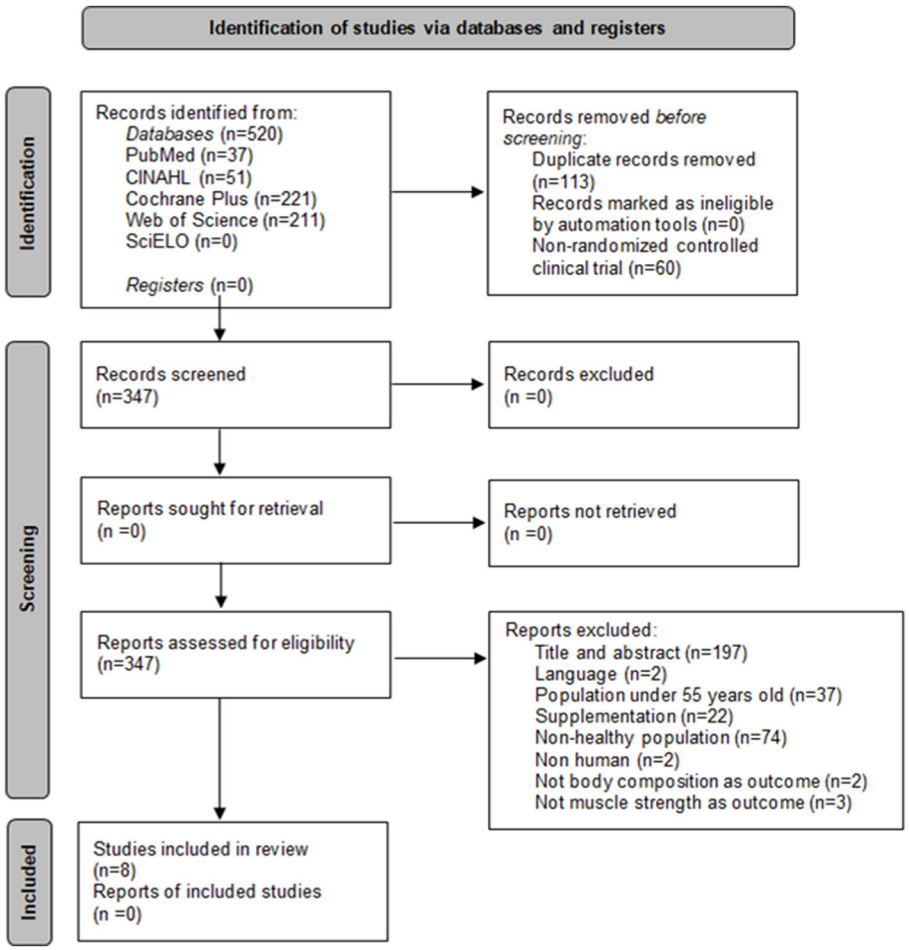

FIGURE 1
PRISMA flowchart showing the inclusion and exclusion of studies in the systematic review.

group (16, 22, 23). Taaffe et al. (20) also found significant improvements in lean mass in all intervention groups compared with controls, for which this outcome did not change. Two other articles (21, 26) reported significant differences in BMI, and one of them observed improvements in body weight (21). Finally, Jiménez-García et al. (25) found that a group engaged in a training program including high-intensity intervals of TRX suspension exercises improved their outcomes more effectively than a continuous-intensity interval training group or a control.

Muscle strength

Muscle strength was assessed using hand-grip, knee extension, knee flexion, lower-body and upper-limb strength as proxies. Measurements were performed with the help of a dynamometer, a cycle ergometer, repetition maximums, the 30-s Arm Curl Test, and the 30-s Chair Stand Test.

Regarding within-group comparisons, six articles found improvements in muscle strength after high-intensity interval resistance training (16, 21–23, 25, 26). As far as between-groups comparisons were concerned, results were mixed. Jiménez-García et al. (25) did not observe increases in muscle strength after 12 weeks of high-intensity interval suspension training compared with moderate-intensity training and a control group. However, four studies reported significant increases in muscle strength after high-intensity interval strength-resistance training compared with a control group (16, 22, 23, 26). Out of these four studies, one reported significant differences in upper-limb strength compared with moderate-intensity continuous training (26). Furthermore, two articles showed an increase in muscle strength after a high-intensity interval resistance training intervention, compared with an inactive control group (20, 21). Taaffe et al. (20) failed to find differences between performing the intervention one, two, or 3 days per week, and Nemoto et al. (21)

TABLE 1 Assessment of risk of bias for included studies.

Articles	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcomes assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Taaffe et al. (20)	U	U	H	H	L	L	L
Nemoto et al. (21)	L	H	H	H	U	L	L
Villanueva et al. (22)	U	U	H	U	L	L	L
Sculthorpe et al. (23)	L	U	H	U	L	L	L
Moro et al. (24)	L	L	H	H	U	L	L
García-Pinillos et al. (16)	U	H	H	H	U	L	L
Jiménez-García et al. (25)	L	L	H	L	L	L	L
Ballesta-García et al. (26)	L	L	H	L	L	L	L

L, Low risk; H, High risk; U, Unclear.

found significant improvements in muscle strength compared with moderate-intensity training. On the other hand, Moro et al. (24) reported significant increases in muscle strength in a high-intensity interval resistance training and in a traditional resistance training, but no differences were apparent between these two forms of exercise.

Physical function

Physical function included the domains of balance, gait speed, and muscle performance. Balance was assessed through the Star Excursion Balance Test, the 6-meter backward tandem walk, the Footscan portable foot pressure plate and stability software, ratings of perceived exertion, and the FreeMed© BASE model baropodometric platform. Gait speed was evaluated using the 400-meter walk test, the Timed Up-and-Go Test, and the gait speed test. Finally, muscle performance was assessed through the Margaria power test and the chair-rise test.

Out of the eight articles included in this systematic review, six assessed physical function outcomes. Jiménez-García et al. (25), García-Pinillos et al. (16), and Ballesta-García et al. (26) reported significant within-group differences in gait speed, also in comparison with a moderate-intensity interval training group. Jiménez-García et al. (25) and Ballesta-García et al. (26) also observed significant differences compared with a control group that stuck to their usual physical activity habits. Five of the articles assessed balance (16, 20, 22, 23, 26). García-Pinillos et al. (16) reported improvements in ellipse area balance and length balance in within-group comparisons, and also in length balance compared with a control group. Ballesta-García et al. (26) also reported significant differences in balance in within-group comparisons. However, three other articles did not observe significant differences in within-group comparisons (20, 22, 23), but one of them reported significant differences in balance, assessed by the 6-meter backward tandem walk, compared with a control group (20). Two articles measured muscle performance, and both reported improvements compared with control groups after their high-intensity interval resistance training (20, 22).

Discussion

The goal of this systematic review of control trials was to analyze the effects of high-intensity interval training on the body composition, muscle strength, and physical function of healthy elderly individuals.

Aging is associated with increased odds of developing one or several financially costly conditions (27). On the other hand, the consequences of a sedentary lifestyle have become a public health problem across all age groups. Physical inactivity during the aging process accelerates the loss of muscle strength and function, increases fat mass, decreases quality of life, and increases the risk of mortality (28). All the reasons stated above highlight the need to promote and achieve among the population an active attitude toward aging, which is why recent years have witnessed a sharp increase in the number of studies

TABLE 2 Summary of included studies ($n = 8$).

Study, year, and location	Studied population, groups, and study design	Outcomes and measuring tools	Intervention	Measure time points, dropout, and adverse effects	Main findings
Taaffe et al. (20) 1999 California, United States	53 healthy community-dwelling adults (65–79 years) (19 women; 34 men) IG1 ($n = 14$, 68.5 ± 3.6 years; 5 women, 9 men) IG2 ($n = 14$, 69.4 ± 3 years; 4 women, 10 men) IG3 ($n = 11$, 71 ± 4.1 years; 4 women, 10 men) CG ($n = 14$, 68.9 ± 3.6 years; 6 women, 8 men) Design: Randomized controlled trial.	Primary outcome Muscle strength: 1-RM Body Composition: Lean mass, fat mass (DXA) Secondary Outcome Physical Function: Balance (6-meter backward tandem walk) Muscle performance (Chair-rise test)	IG1: 24 weeks. High-intensity resistance training 1 day per week. (Minimum of 30-s rest between sets and at least 2 min between exercises) IG2: 24 weeks. High-intensity resistance training 2 days per week. (Minimum of 30-s rest between sets and at least 2 min between exercises) IG3: 24 weeks. High-intensity resistance training 3 days per week. (Minimum of 30-s rest between sets and at least 2 min between exercises) CG: Inactive	Measurements: At baseline After the intervention Dropout: IG1: 3 IG2: 2 IG3: 0 CG: 2 Adverse effects: Not mentioned.	Between-group comparisons: Muscle strength: Compared with CG: IG1, IG2, and IG3 showed significant improvements in muscle strength ($p < 0.01$). No differences were found between IG1, IG2 and IG3. Body composition: Compared with CG: IG1, IG2, and IG3 showed significant improvements in lean mass. No change in fat mass. Physical Function: Compared with CG: Chair-rise time decreased significantly in IG1, IG2, and IG3 ($p < 0.01$). The highest percentage of decreased was observed in IG3 (30.2 ± 11%). There were significant improvements in the time spent in 6-meter backward walk for the IG groups ($p = 0.01$) Within-group comparisons: Muscle strength: No significant differences were observed ($p = 0.87$) No other measures were reported.
Nemoto et al. (21) 2007 Matsumoto, Japan	246 older adults (63 ± 6 years) (186 women; 60 men) IG1 ($n = 84$; men = 25, 67 ± 4 years; women = 59, 64 ± 6 years) IG2 ($n = 75$; men = 16, 67 ± 5 years; women = 59, 62 ± 5 years) CG ($n = 87$; men = 19, 66 ± 5 years; women = 68, 62 ± 6 years) Design: Randomized controlled trial.	Primary Outcome: Muscle strength: Knee extension and flexion forces (dynamometer) Body Composition: Body weight and BMI	IG1: High-intensity interval walking training. 5 sets (3 min low-intensity walking at 40% VO_2 peak followed by 3-min high-intensity walking (>70% VO2 peak). Four or more days per week for 5 months. IG2: Moderate intensity continuous walking training: walk (50% VO2peak) 8,000 steps per day. 4 or more days per week for 5 months CG: No walking training	Measurements: At baseline At 5 months Dropout: IG1: 42 IG2: 24 CG: 41 Adverse effects: Not mentioned.	Between-group comparisons: Compared with CG, IG1 showed significant improvements in knee extension and flexion forces ($p < 0.001$) and in body weight ($p < 0.001$) and BMI ($p < 0.004$) in women. Compared with CG, IG2 showed a significant decrease in body weight and BMI ($p < 0.001$) in women. Compared with IG2, IG1 showed significant differences in knee flexion forces in men ($p = 0.003$), women ($p = 0.02$) and total number of participants ($p = 0.004$) Within-group comparisons: IG1 showed significant differences in isometric knee flexion ($p < 0.001$) and extension in women, men and total number of participants ($p < 0.001$), in BMI ($p = 0.01$) and body weight ($p = 0.02$) IG2 showed significant differences from pre-training values in isometric knee flexion in total number or participants ($p < 0.001$) in BMI ($p < 0.001$) and body weight ($p < 0.001$)

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TABLE 2 (Continued)

Study, year, and location	Studied population, groups, and study design	Outcomes and measuring tools	Intervention	Measure time points, dropout, and adverse effects	Main findings
Villanueva et al. (22) 2014 California United States	22 men (68 ± 4.1 years) IG (n = 11, 65.6 ± 3.4 years) CG (n = 11, 70.3 ± 4.9 years) Design: Randomized controlled trial.	Primary Outcome Body composition: (DEXA) Muscle strength: chest press and bilateral leg press exercises with (1-RM) Secondary Outcome Physical Function: Muscle performance (Margaria power test), balance (SEBT) and gait speed (400-m walk)	12 weeks (4 weeks preparatory training + 8 weeks strength training). 36 Sessions (45–60 min), 3 days per week. IG: High intensity strength resistance training with short rest interval (60 s) CG: High intensity strength resistance training with extended rest interval (4 min)	Measurements: Prior to a 4-week control period. At baseline At 4 weeks At 8 weeks At 12 weeks Dropout: IG: 0 CG: 0 Adverse effects: No injuries, illness or personal choice were observed.	Between-group comparisons: Compared with CG, IG showed significant increases in lean body mass (p = 0.001), dynamic muscle strength ($p < 0.001$), and muscle performance ($p < 0.001$) Within-group comparisons: After intervention, IG showed significant improvements in lean body mass correlated with muscle strength: chest press ($r = 0.88$, $p < 0.01$), pulldown strength ($r = 0.68$, $p < 0.05$), and single-leg knee extension strength ($r = 0.69$, $p < 0.05$).
Sculthorpe et al. (23) 2017 Scotland United Kingdom	33 sedentary men 56–65 years) IG (n = 22, 62.3 ± 4.1 years) CG (n = 11, 61.6 ± 5 years) Design: Randomized controlled trial.	Primary outcome: Muscle strength: Peak muscle power (Cycle ergometer) Body composition: TBM, FFM, FM (BIA) Secondary Outcome: Physical function: Static balance (Footscan portable foot pressure plate and stability)	IG: Conditioning exercise: 6 weeks. ≥5 days per week. Sessions of ≥ 30 min. HIIT_intervention: 6 weeks. One session every 5 days. 5 min warm-up; 6 x 30 s sprints with 3-min intervals of active recovery. CG: Inactive	Measurements: At baseline At 6 weeks At 6 weeks Dropout: IG: 0 CG:0 Adverse effects: No adverse effects were reported.	Between-group comparisons: Compared with CG, IG showed significant differences in peak muscle power ($p < 0.01$) and lean body mass ($p < 0.01$). Regarding static balance, no significant differences were observed. Within-group comparisons: After the intervention, IG showed significant improvements in peak muscle power ($p < 0.01$), lean body mass ($p < 0.05$), and a significant decrease in total body fat ($p < 0.05$)
Moro et al. (24) 2017 Padua Italy	35 older adults (15 women; 20 men) IG1 (n = 18, 64.1 ± 2.3 years; women = 8; men = 10) CG (n = 17, 61.7 ± 4.2 years; women = 7; men = 10) Design: Randomized controlled clinical trial.	Primary Outcome: Body composition: Height and body weight (digital electronic scale), FFM and FM (BIA) Muscle strength: 3–6 RM strength (leg extension, chest press, lat pull down and arm curl)	IG1: 2 months. 2 times per week (45 min). HIIRT (high intensity interval resistance training): 2 series of 6RM at 80% 1RM followed by 20″ of rest, repetitions to failure, another 20″ of rest, and repetitions to failure. CG: 2 months. 2 times per week TRT (traditional resistance training): 3 series of 8 repetitions at 75% 1RM.	Measurements: At baseline After the intervention Dropout: IG1: 4 CG:8 Adverse effects: Not mentioned.	Between-group comparisons: Strength increased in IG1 and in CG ($p < 0.001$), without significant difference between them. Within-group comparisons: IG1 and CG showed a small Cohen's effect size for body weight: CG (0.01) IG1 (0.02), FFM: CG (0.26) IG1 (0.15), and FM: CG (0.07) and IG (0.11).

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TABLE 2 (Continued)

Study, year, and location	Studied population, groups, and study design	Outcomes and measuring tools	Intervention	Measure time points, dropout, and adverse effects	Main findings
García-Pinillos et al. (16) 2017 Jaén, Spain	90 older adults (72 ± 5 years) (64 women; 26 men) IG1 [$n = 47$, 73.50 ± 5.58 years; women = 34 (72.3%), men = 13 (27.7%)] CG [$n = 43$, 72.09 ± 5.78 years; women= 30 (69.8%), men = 13 (30.2%)] Design: Randomized controlled clinical trial.	Primary Outcome: Body composition: BMI, body mass, fat mass, SMM (eight-polar tactile electrode BIA) Muscle strength: Lower-body muscle strength (30-s CST) and upper-body muscle strength Hand-grip strength (hand dynamometer) Secondary Outcome Physical function: Gait speed (GS) and Balance (FreeMed© BASE model baropodometric platform)	IG1: 12 weeks; 3 times per week (35–40 min). HIIT: High-intensity strength training combined with high-intensity interval endurance training Warm-up (5–7 min) High-intensity strength training + high-intensity interval endurance training + High-intensity strength training and cool down (4–5 min) CG: Walking (150–200 min per week at low-moderate intensity)	Measurements: At baseline At 12 weeks Dropout: IG1: 0 CG:4 Adverse effects: No adverse events were reported.	Between-group comparisons: Compared with CG, IG1 showed significant improvements in BMI, fat mass, and SMM ($p < 0.005$). Also showed significant differences in 30-s CST ($p < 0.001$) and hand-grip strength ($p = 0.048$), GS ($p = 0.007$), and length balance ($p = 0.003$). Within-group comparisons: IG1 showed significant interactions in body mass, fat mass, muscle mass, BMI, 30-s CST, hand-grip strength, GS ($p < 0.001$), and balance for ellipse area ($p = 0.031$) and length ($p < 0.001$) CG: No significant differences were observed ($p \geq 0.05$)
Jiménez-García et al. (25) 2019 Málaga, Spain	82 older adults (68.23 ± 2.97 years) (women 75.61%) IG1 ($n = 28$, 68.23 ± 2.97 years; women 92.3%) IG2 ($n = 27$, 68.75 ± 5.98 years, women 70.8%) CG ($n = 27$, 68.52 ± 6.33 years; women 65.2%) Design: Randomized controlled clinical trial.	Primary Outcome: Muscle strength: Hand-grip strength (hand-grip dynamometer) Body composition: SMM and PBF (BIA) Secondary Outcome Physical Function: Gait speed (TUG)	IG1: High-intensity interval exercise (HIIT). 12 weeks; 2 times per week. Warm-up (10 min); 4 sets of squat activity with suspension 90–95% max HR followed by active rest intervals (90–95% max HR) followed by 3-min active rest intervals (50–70%) and a cool-down (10 min). IG2: Continuous-intensity-training (MIIT). 12 weeks; 2 times per week. Warm-up (10 min); 4 sets of squat activity with suspension 70–50% max HR followed by active rest intervals (70–50% max HR) followed by 3-min active rest intervals (50–70%) and a cool-down (10 min). CG: their daily lifestyle and a guideline to encourage physical activity	Measurements: At baseline At 12 weeks Dropout: IG1: 2 IG2:3 CG:4 Adverse effects: Injuries and other effects were observed.	Between-group comparisons: Compared with CG, IG1 showed significant differences in BMI ($p < 0.001$) and gait speed ($p < 0.001$). Compared with IG2, IG1 showed significant improvements in BMI ($p = 0.002$) and gait speed ($p < 0.001$). Compared with CG, IG2 showed significant differences in BMI ($p = 0.01$). No significant differences were observed for SMM, PBF, or hand-grip strength. Within-group comparisons: IG1 showed significant improvements in hand-grip strength (p = 0.002), gait speed (p = 0.002)

(Continued)

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TABLE 2 (Continued)

Study, year, and location	Studied population, groups, and study design	Outcomes and measuring tools	Intervention	Measure time points, dropout, and adverse effects	Main findings
Ballesta-García et al. (26) 2019 Murcia, Spain	54 women (67.8 ± 6.2 years) IG1 ($n = 18$, 66.3 ± 5.44 years) IG2 ($n = 18$, 70 ± 8.76 years) CG ($n = 18$, 67.4 ± 5.71 years) Design: Randomized controlled trial.	Primary Outcome: Body composition: BMI (electronic balance and a height rod) Muscle strength: Hand-grip strength (dynamometer); Upper-limb strength (ACT-30) and lower-limb strength (STS-30) Secondary Outcome: Physical function: Gait speed (TUG) and balance (OLS)	IG1: 18 weeks; 2 times per week (1 h). High-intensity interval training in a circuit program: (Warm-up, HIIT (14–18 point of RPE) and cool-down) IG2: 18 weeks; 2 times per week (1h). Moderate-intensity continuous training: (Warm-up, (9–14 point of RPE) and cool-down) CG: Their physical activity habits.	Measurements: At baseline At 18 weeks Dropout: IG1: 1 IG2:6 CG:6 Adverse effects: 5 subjects presented adverse effects during the study.	Between-group comparisons: Compared with CG, IG1 showed significant improvements in ACT-30 ($p < 0.001$), STS-30 ($p < 0.001$), TUG ($p < 0.001$) and BMI ($p < 0.001$). Compared with CG, IG2 showed significant improvements STS-30 ($p < 0.001$) and TUG ($p < 0.001$). Compared with IG2, IG1 showed significant improvements in 30-second ACT ($p < 0.001$). Within-group comparisons: IG1 showed significant improvements in STS-30 ($p < 0.001$), TUG ($p < 0.001$), ACT-30 ($p = 0.022$), right OLS ($p = 0.024$), and BMI ($p = 0.035$). IG2 showed significant improvements ($p < 0.001$) in STS-30 and TUG. CG showed significant improvements in ACT-30 ($p < 0.001$), STS-30 ($p < 0.001$), TUG ($p = 0.016$), and BMI ($p = 0.019$).

ACT-30, 30-second Arm Curl Test; BIA, Bioelectrical Impedance Analysis; BMI, Body Mass Index (weight in kilograms divided by the square of height in meters); CG, Control Group; CSA, cross-sectional area; 30-CST, 30 second chair stand test; DXA, Dual energy X-ray absorptiometry; FFM, Fat-Free Mass; FM, Fat Mass; GS, Gait speed test; HR, Heart rate; IG, Intervention Group; OLS, one-leg standing test; RPE, rating of perceived exertion; PBF, body fat; SEBT, Star Excursion Balance Test; STS-30, 30-second sit-to-stand; SMM, Skeletal muscle mass percentage; TBM, Total body mass; TUG, Timed Up-and-Go Test; UGS, Usual gait speed; VO2 peak, peak oxygen consumpt.

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looking into the effects of a variety of programs centered on physical activity.

A total of eight articles were included in this systematic review. Regarding within-group results all of them, with the exception of the one carried out by Taaffe et al. (20), reported improvements in some of the parameters analyzed. Improvements in body composition were observed in six of them (16, 21–24, 26), and increases in muscle strength were observed in seven of the eight (16, 21–26). Regarding physical function, only six of the eight articles considered this parameter, with two reporting improvements in gait speed (25, 26) and one finding improvements in balance (16).

As for the frequency of training sessions, only Taaffe et al. (20) evaluated the weekly frequency with which HIIT was performed. Regarding body composition and muscle strength, they did not find differences between training 1, 2, or 3 days per week. Other investigations are in line with these results, having concluded that in the first phases of training the volume or frequency of the same does not significantly affect strength adaptations (29, 30). Despite this, when subjects find themselves at a more advanced phase of training, frequency becomes a relevant factor in the achievement of increased muscle strength (29). Regarding the secondary outcomes, it has been shown that engaging in HIIT 3 days per week is more effective than 2-day or 1-day-per-week regimes regarding muscle performance, whereas no differences were found in balance outcomes.

The results of this systematic review suggest that HIIT-based interventions have beneficial effects on body composition. However, when a comparison was made between HIIT and moderate-intensity training groups, contradictory results were observed. On the one hand, two articles found significant improvements in BMI (16, 25), and one of them also found significant improvements in fat mass (16). On the other hand, two other articles did not find any significant difference (21, 24). These results are in line with those obtained by Wewege et al. (17) in their systematic review and meta-analysis involving overweight and obese adults aged 18–45 years, in which it was concluded that both interventions present similar results across all body composition measures. It was proposed that HIIT might be a better option, as it is more time-effective in weight management programs. Furthermore, in this regard Moro et al. (24) explained that the intensity achieved during HIIT may not have been enough to induce significant fat loss, but succeeded at preventing fat gain more effectively than traditional resistance training.

Aging leads to a decrease in the elements necessary for axonal regeneration (31). This is likely to influence corticocortical and corticospinal connectivity and cause a loss of muscle strength (32). As a matter of fact, this deterioration of maximum muscle force and of its rate of development has also been observed in professional athletes (33). These results are in line with those reported in the studies included in this review, in which HIIT was shown to improve muscle strength in untrained subjects when compared with people who did not perform any physical activity. Be that as it may, two authors (24, 25), while failing to find statistically significant differences, did register some improvement within the HIIT group, which indicates that if muscle strength did not increase at least it was not decreased.

On the other hand, Onambélé-Pearson et al. (34) determined, in their study on the influence of exercise intensity among older people that as far as muscle strength is concerned high-intensity training turns out to be more effective than comparable low-intensity regimes. Their observations agree with the conclusions obtained by two (21, 26) of the three (21, 25, 26) articles included in this review in which HIIT was compared with MIIT. However, although Jiménez-García et al. (25) did not agree with these results, they did report an increase in the muscle strength of participants who engaged in HIIT. Such differences between groups of high-intensity and moderate-intensity training may have been due to the duration of the interventions, which in the case of Jiménez-García et al. (25) was of 12 weeks in contrast to those carried out by Nemoto et al. (21) and Ballesta et al. (26), which took 5 months and 18 weeks respectively. Another potential reason behind such differences may lie in the measurement tools employed: in the intervention devised by Jiménez-García et al. (25) hand-grip strength was evaluated using a dynamometer, similarly to Ballesta-García et al. (26), in which no differences were found in muscle strength. However, differences appeared when upper-limb strength was assessed by means of the 30-s push-up test. These conclusions are particularly relevant given that greater muscle strength in the upper limbs is associated with improved quality of life in women over 60 years of age (35). In addition, current scientific evidence also provides evidence concerning the association of grip strength with the function of the upper extremities, bone mineral density, fractures, falls, and increased risk of mortality among older people. This appears, therefore, to be a particularly relevant parameter which should be analyzed more thoroughly in future research (36).

In the analysis of physical function, significant improvements were observed in muscle performance (20), gait speed (25), and balance (26) with respect to their control group. These last results are in contradiction with those of Sculthorpe et al. (23), which did not find significant improvements in balance. This could be attributed to the type of intervention, as it was performed on a cycle ergometer with five stability points which may have hampered the recording of balance improvements. It has been reported that improvements to physical function may reduce the risk of falls (37). In addition, three (16, 25, 26) articles looked at the physical function of HIIT groups in comparison with moderate-intensity interval training, and their results also turned to be contradictory in that regard. On the one hand, Jiménez-García et al. (25) reported differences in gait speed, and García-Pinillos et al. (16) in length balance, in contrast to the results of the study by Ballesta-García et al. (26),

in which no significant differences were found for either balance or gait speed.

There are some limitations to this systematic review that should be noted. The heterogeneity of the measurement instruments for the variables under analysis in each of the articles renders a meta-analysis impossible. Another limitation concerns the fact that the effects of the interventions were only measured in the short term. In addition, the differences between types of HIIT, the length of the series, the number of repetitions, and the duration of the sessions may be considered as limitations, since such factors may influence the results. Future HIIT interventions should consider longer intervention periods, as well as looking into the long-term effects of their interventions in order to better understand the beneficial effects of this type of training on general health, and particularly on muscle strength, body composition, and physical function.

Conclusion

After conducting a systematic review of published data to assess the effects of HIIT on the body composition and muscle strength of middle-aged and older adults, HIIT was found to be an effective tool for improving body composition and increasing muscle strength; however, regarding physical function, the results do not allow for clear conclusions and although it seems that HIIT may have positive effects on this parameter, its disparity indicates that caution should be used when drawing a firm conclusion. On the other hand, when HIIT is compared with other types of training, such as continuous training of moderate intensity, it is not clear if HIIT is more effective, due to the limited published evidence in this regard, the great variety in the methodology used in the studies and the ambiguity of the data provided make it impossible to draw a firm conclusion; nevertheless it appears that both types of training have beneficial effects on body composition, muscle strength and physical function in a population of middle-aged and older people. It is important to emphasize that more quality randomized controlled trials with an adequate sample size are still needed to lead to a correct understanding of the effects of HIIT on the variables studied in the short and long term in among middle-aged and older adults. Likewise, more studies are required to determine if HIIT is a better, worse or equivalent alternative to other types of physical training to confirm these results. This step is essential for advising specific training characteristics that will improve body composition and maximize physical function and muscle strength.

Data availability statement

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

Author contributions

Conceptualization: YC-C and MA-T. Methodology: AA-A and FH-C. Performing literature review and synthesis of literature: MC-F, AA-A, and RF-C. Quality assessment: JJ-G, FH-C, and MA-T. Writing—original draft preparation: MC-F, AA-A, and MA-T. Writing—reviewing and editing: AM-A, YC-C, JJ-G, and RF-C. Funding acquisition: FH-C and AM-A. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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Role of caregivers on medication adherence management in polymedicated patients with Alzheimer's disease or other types of dementia

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Background: Alzheimer's disease (AD) and other dementia patients may have severe difficulties to ensure medication adherence due to their generally advanced age, polymedicated and multi-pathological situations as well as certain degree of cognitive impairment. Thus, the role of patient caregivers becomes crucial to warrantee treatment compliance.

Purpose: To assess the factors associated to patients and caregivers on medication adherence of patients with AD and other types of dementia as well as the degree of caregiver satisfaction with respect to treatment.

Methods: An observational, descriptive, cross-sectional study among the caregivers of 100 patients with AD and other types of dementia of the "Cartagena and Region Association of Relatives of Patients with Alzheimer's Disease and other Neurodegenerative Diseases" was conducted to assess patient and caregiver factors that influence medication adherence evaluated with the Morisky-Green-Levine test.

Results: Overall, adherence to treatment was 71%, with similar proportions between male and female patients. Greater adherence was found in married or widowed patients (49.3%), first degree (85.9%) or female (81.7%) caregivers but lower in AD patients (75.9%). Multivariate analysis showed a statistically significant positive association between non-adherence and male sex of the caregiver (OR 3.512 [95%IC 1.124–10.973]), dementia (OR 3.065 [95%IC 1.019–9.219]), type of caregiver (non-first-degree relative) (OR 0.325 [95%IC 0.054–0.672]) and civil status of the patient (OR 2.011 [95%IC 1.155–3.501]) favorable for married or widowed patients. No or week association was found with gender, age, education level, number of drugs used or polymedicated status of the patient. Caregivers considered the use (90%) and administration (91%) of the treatment easy or very easy and rarely interfered with their daily life,

especially for female caregivers ($p = 0.016$). Finally, 71% indicated that they were satisfied or very satisfied with the treatment received by the patient.

Conclusions: Caregivers influence therapeutic management with predictors for improved adherence including female gender and first-degree kinship, together with patient's marital status. Thus, training caregivers about the disease and the importance of medication adherence in AD patients may ensure optimal treatment.

KEYWORDS

adherence, Alzheimer, dementia, caregivers, gender, treatment satisfaction, polymedication

Introduction

Dementia is a chronic and progressive syndrome in which there is a deterioration of cognitive functions, the ability to process thought, beyond what would be expected along normal aging (1). It is characterized by progressive short- and long-term memory loss and behavioral disturbances (2). Currently, dementia is one of the leading causes of death (3), as well as dependency and disability among people over 65 years of age, being a major global health problem that leads to increased morbidity and mortality (4). The total number of people affected with dementia is expected to reach 78 million by 2030 and 139 million by 2050 (5), a consequence of continued population aging that have led to increasing prevalence of neurodegenerative diseases (6).

Alzheimer's disease (AD) is presently the most common cause of dementia, accounting for 60 to 70% of cases (1), and there is currently no curative treatment. People with Alzheimer's disease have changes in blood-brain barrier permeability and endogenous neurotransmitter levels that increase the likelihood of drugs reaching the central nervous system (7–9). In addition, age-related physiological changes in the elderly lead to pharmacokinetic and pharmacodynamic alterations in the body, which increase sensitivity to drugs (8, 9). Thus, elderly people with Alzheimer's disease are extremely susceptible to medication-related problems (DRP) (8–10). This increased drug susceptibility of AD patients, coupled with the progression of cognitive impairment, frailty and the high prevalence of additional chronic diseases in this population results in the need for caregiver support (6, 11).

About 87.7% of people aged 62 to 85 years are prescribed a medication, of whom 35.8% have concomitant use of at least five medications (12). The complexity of pharmacological treatments prescribed to patients with dementia can cause problems of adherence to treatment, preventing the expected therapeutic benefits (13), hence the need for medication management and administration depend on the caregiver or immediate family member, playing a key role in the treatment of dementia (14).

Adherence to treatment, as defined by the World Health Organization (WHO), is the degree of a person's compliance in taking medication in accordance with the dosage schedule prescribed by a health professional (15). Hence, In dementia, polymedication and drug side effects are predictors of poor medication adherence (16–19). Lack of adherence can have serious health implications, including increased hospitalizations and worsening of disease (20). In general, it is estimated that 20–50% of patients do not take their medications as prescribed, and more specifically, non-compliance in the elderly with AD can range from 17 to 100% (21). Taking into account that, in general, this type of patients is multi-pathological and polymedicated patients and more prone to suffer drug-related problems, a multidisciplinary team is necessary to treat them and achieve the therapeutic objectives. In this sense, the pharmacist can monitor compliance with the patient's prescription, participate effectively in the identification of possible drug-related problems and provide information to patients and their caregivers.

Therefore, given the potential importance of non-adherence to treatment in these patients, the aims of this research were to assess the degree of adherence to treatment in patients with AD through the role of caregivers and to evaluate the degree of caregiver satisfaction with respect to treatment.

Materials and methods

Study design and population

An observational, descriptive, cross-sectional study was conducted (during 2018–2021) to assess the quality of care of these patients by means of treatment adherence and caregiver satisfaction. The study was developed in collaboration with the Cartagena and Region Association of Relatives of Patients with Alzheimer's Disease and other Neurodegenerative Diseases. This association provides support for this kind of patients and their

families. Its objective is to improve the quality of life of patients through non-pharmacological treatments, as well as, to promote research and creation of social and health projects.

The study was reviewed and approved by the Institutional Ethics Committee of the Catholic University of Murcia (CE041808). An information sheet about the study was given to the caregiver together with the informed consent form. Those who agreed to the informed consent and met the following inclusion criteria were recruited and included in the study: male or female patient with a diagnosis of Alzheimer's disease or other type of dementia/neurodegenerative disease. The exclusion criteria were patient without a caregiver or family member who could act as a reliable assistant.

The pharmacological treatment was reviewed by means of the electronic prescription and updated medical reports. Finally, the pharmacist conducted a clinical interview with the person responsible for administering the medication.

Variables and sources

Different types of sociodemographic and clinical variables of the patient and related to the caregivers were included in the study: age, sex, civil status, level of education, type of caregiver, gender of caregiver, type of dementia, number of prescribed medications and whether the patient was undergoing polymedication. Although there are various interpretations of polypharmacy, the most common one refers to the use of 5 or more different medications in the same person (22). The greater the number of medications a person takes and complexity of the treatment, the greater the incidence of poor adherence, adverse reactions or hospital admissions (23). This situation of polymedication is very common in older people as well as patients with chronic pathologies which in general lead to higher treatment burden and decreased adherence (24). Caregivers were considered either "informal," usually a family member or close relative of the patient, or "formal," a healthcare professional usually unrelated to the patient.

Adherence to treatment was evaluated with the Morisky-Green-Levine test (25) which has been used in other studies for this purpose (26–29). This test comprises of four questions with a dichotomous answer (yes/no) and to be considered "adherent," the caregiver must answer "Yes" to question 2 and "No" to the other three questions. Their answers allowed to group the patient population in in two groups based on their adherence or lack of adherence (adherent and non-adherent groups).

The caregiver's satisfaction with the treatment was measured with an *ad hoc* questionnaire, similar to the ones used in study KAPPA (30) and the ENTERPRISE (26) studies, which assessed satisfaction with the use of rivastigmine patches *vs.* the oral route. The test consists of four questions which address the easiness of use of the treatment, the easiness to follow the administration regimen, the frequency with which the treatment interferes with the caregiver's daily life, and the overall satisfaction with the treatment. The measurement scale presents four response categories for each question: from easy to very difficult for questions 1 and 2, from always to never for question 3, and from satisfied to very dissatisfied for question 4 (Figure 2).

Statistical analysis

A descriptive analysis of the data variables included in the study was performed. Qualitative variables were expressed as absolute frequency and their relative frequency in percentages. Continuous variables were evaluated to ensure that followed a normal distribution and were represented as mean ± standard deviation (SD).

The relationship of the variables under study with therapeutic adherence *vs.* non-adherence was analyzed using the Pearson Chi-square test for qualitative variables and the student's *t*-test to analyze quantitative variables with normal distribution (31).

Two logistic regression models of patient-related and caregiver-related variables, which were shown to be associated with the dependent variable adherence at a significant level $p < 0.2$ were included to assess the impact of each factor on medication adherence (32, 33). The independent effect of each explanatory variable, the odds ratio (OR) and their respective confidence intervals (95% CI) were used to assess the strength of their association with patient adherence to treatment in which case $p < 0.05$ was considered significant and normality was assessed previously using the Kolmogorov-Smirnov test. The data was processed using SPSS 23.0 for Windows®.

Results

Patient population features

A total of 100 patients were included in the study, 64% women and 36% men, with a mean age of 77.83 ± 10.14 and 81.56 ± 7.41 years for male and female patients, respectively (overall range: 42–95). Their civil status was mostly married (48%) or widow/widower (46%), 5% were single and 1% divorced. The educational level was diverse: the majority of participants had basic education (59%), 16% had secondary education (average), 9% had higher education (university) and 16% had no formal education.

Regarding their pathologies, most of the patients (61%) suffered from AD, 10% fronto-temporal dementia, 9% mixed dementia (AD and vascular dementia), 8% vascular dementia and 12% other types dementia. Comorbidities were present in most of the patients being hypertension (64%) and depressive syndrome (61%) the most frequent ones. In fact, 33% of the patients had between 1 and 3 comorbidities, 27% had

between 4 and 5, 36% had more than 6 comorbidities and only 4% had no comorbidity. In addition, the mean number of drugs used during the chronic treatment phase was 7.7 ± 3.3 (range 2–17) with 82% of patients polymedicated (≥5 drugs) and 19% patients taking more than 10 different drugs in their pharmacological treatment concomitantly. Amongst the patients with AD, it was found that 13% had no specific treatment for dementia. The sociodemographic and clinical features of the study population are listed in Table 1 for the adherent and non-adherent patient groups.

Caregiver population characteristics

The large majority of patients (77%) had a female caregiver. The usual caregiver was a first degree relative (81%), either the son or the daughter (52%) or the spouse (29%) and in 6% of patients the caregiver was another family member. Last, a formal caregiver was in the 13% of patients. Unlike the patient population, the educational level of the caregivers was different: 30% had higher education studies, 23% had secondary education and 39% had basic education. Only 7% had no formal education studies. Table 2 shows these characteristics for the adherent and non-adherent patient groups.

Medication adherence evaluation

Medication adherence was measured with the Morisky-Green-Levine test (25) by the caregivers. The results showed that 29% of the patients did not adhere to their chronic treatment (Figure 1) with similar proportions between male and female patients (Table 1). Both patient (sociodemographic and clinical features) and caregiver (characteristics) related factors that affected non-adherence to treatment were also evaluated (Tables 1, 2, respectively).

The most important factors related to the patient which showed a stronger association were the patient's marital status ($p = 0.025$), with greater adherence (49.3%) in currently married or widowed patients ($p = 0.024$) and the type of dementia with lower adherence in patients with Alzheimer's disease (75.9%) *vs.* other types of dementia ($p = 0.051$). Regarding factors associated with the caregiver, it was found greater adherence (85.9%) when the caregiver was a first-degree relative (child or spouse) *vs.* other types of caregivers ($p = 0.050$) as well as the gender of the caregiver ($p = 0.081$) with greater patient therapeutic adherence (81.7%) with female caregivers. On the other hand, weak or no association seemed to exist with the sex ($p = 0.359$), age ($p = 0.190$) or educational level of the patient ($p = 0.685$), the number of chronic drugs used concomitantly ($p = 0.727$), the number of comorbidities ($p = 0.553$), being a polymedicated patient ($p = 0.655$) nor the educational level of the caregiver ($p = 0.449$).

Other items that were evaluated with the Morisky-Green-Levine test indicated that 97% of the caregivers gave the medication at the prescribed time, 98% of the caregivers did not stop giving the medication if the patient felt well, and 76% of caregivers stated that even if the patient felt ill, they never stopped giving it. On the other hand, 6% of the caregivers surveyed reported they would forget to give the medication to the patient (Figure 1). Lastly, in those patients who did not adhere to pharmacological treatment, 79.3% of caregivers would stop giving them the medication when the patient felt unwell.

Caregiver satisfaction level

The treatment satisfaction survey showed that 90% of the caregivers considered easy or very easy to use the medication, 95% found it easy or very easy to follow the treatment regimen, 91% indicated that the administration of the treatment never or rarely affected or interfered with their daily life, and 71% indicated that they were satisfied or very satisfied with the treatment received by the patient (Figure 2). Further statistical analysis showed possible association between sex of the caregiver (female) and satisfaction with the treatment received by the patient ($p = 0.056$) as well as the type of caregiver and the caregiver's use of the patient's pharmacological treatment, being easier to use among first-degree relatives than among others relatives ($p = 0.007$). In addition, statistically significant differences were observed between the sex of the caregiver and whether the administration of the treatment affected the caregiver's daily life, with lesser effects being observed in female caregivers ($p = 0.016$).

Discussion

The present study evaluated the degree of treatment adherence of polymedicated patients with dementia and with several other pathologies through their caregivers as well as their degree of satisfaction. The sociodemographic and clinical data of the sample studied are similar to those of other studies with mean age of 76–77.2 years (14, 34–36), higher proportion of women around 60–65% (14, 34–36), educational level (37, 38), the caregiver was usually a family member (34) (child or spouse), and presents high presence of comorbidities (14) (hypertension). In general, the results showed non-adherence to treatment was 29% which was similar to values previously found which ranged from 10.7 to 38% (17).

There are several literature reviews on adherence to treatment in elderly patients with dementia (16, 17, 37–39) although mostly focused on the adherence to pharmacotherapy and the duration of the treatment rather than factors that could increase it (38) unlike the current study focused on adherence. Another study (16) identified factors contributing

TABLE 1 Prevalence of the adherence and non-adherence groups according to the results of the Morisky-Green-Levine test related to the sociodemographic factors of the patients[++].

Feature and descriptor		Patient adherence		*p*
		Yes ($n = 71$)	No ($n = 29$)	
Patient gender	Male	39.4% (28)	27.6% (8)	0.263
	Female	60.6% (43)	72.4% (21)	
Age		79.63 ± 8.97	81.66 ± 7.73	0.190
Civil status of patient	Single	1.4% (1)	13.8% (4)	0.024
	Married	49.3% (35)	44.8% (13)	
	Divorced	0% (0)	3.4% (1)	
	Widow/widower	49.3% (35)	37.9% (11)	
Education level of patient[+++]	No studies	15.5% (11)	17.2% (5)	0.685
	Basic studies	62% (44)	51.7% (15)	
	Average studies	15.5% (11)	17.2% (5)	
	University studies	7% (5)	13.8% (4)	
Dementia	Alzheimer's disease	54.9% (39)	75.9% (22)	0.051
	Other dementia types	45.2% (32)	24.1% (7)	
N° drugs		7.77 ± 3.32	7.55 ± 3.32	0.562[+]
Polymedicated patient	Yes	83.1% (59)	79.3% (23)	0.655
	No	16.9% (12)	20.7% (6)	

[+] Student t-test.
[++] A license has been obtained from Dr. Morisky for use of the MMAS-4 scale.
[+++] Basic studies would refer prior high school and average would include high school studies.

TABLE 2 Prevalence of the adherence and non-adherence groups according to the results of the Morisky-Green-Levine test related to the features of the caregiver.

Feature and descriptor		Patient adherence		*p*
		Yes ($n = 71$)	No ($n = 29$)	
Type of caregiver	First degree relative	85.9% (61)	69% (20)	0.050
	Other	14.1% (10)	31% (9)	
Gender of caregiver	Male	18.3% (13)	34.5(10)	0.081
	Female	81.7% (58)	65.5% (19)	
Education level of caregiver[$]	No studies	5.6% (4)	10.3% (3)	0.449
	Basic studies	43.7% (31)	27.6% (8)	
	Average studies	21.1% (15)	27.6% (8)	
	University studies	28.2% (20)	34.5% (10)	

[$] n = 70 for the adherent group as one non-respondent in the adherent group was removed.

to non-adherence to medication including those related to the treatment, the patient, the health professionals, the disease itself, as well as socioeconomic factors. The results found in our study for the association between dementia or cognitive impairment and medication non-compliance are in agreement with their findings. In addition, it was observed that patients with Alzheimer's type dementia had lower adherence to treatment compared to patients with other types of dementia, e.g., vascular, frontotemporal, etc. This low adherence may be associated with the prescription of higher number of specific drugs (e.g., acetylcholinesterase inhibitors, NMDA receptor antagonists) and polymedication with the subsequent potential greater incidence of adverse effects (40). Both scenarios together with impaired cognitive function (41, 42) have been shown to be factors for non-adherence to treatment (20, 43, 44). On the other hand, another review (37) focused on the main barriers to adherence in patients with cognitive impairment, regardless the degree of impairment, and the interventions aimed to improve treatment adherence. Their results indicated a wide variety of barriers to treatment adherence, including inadequate

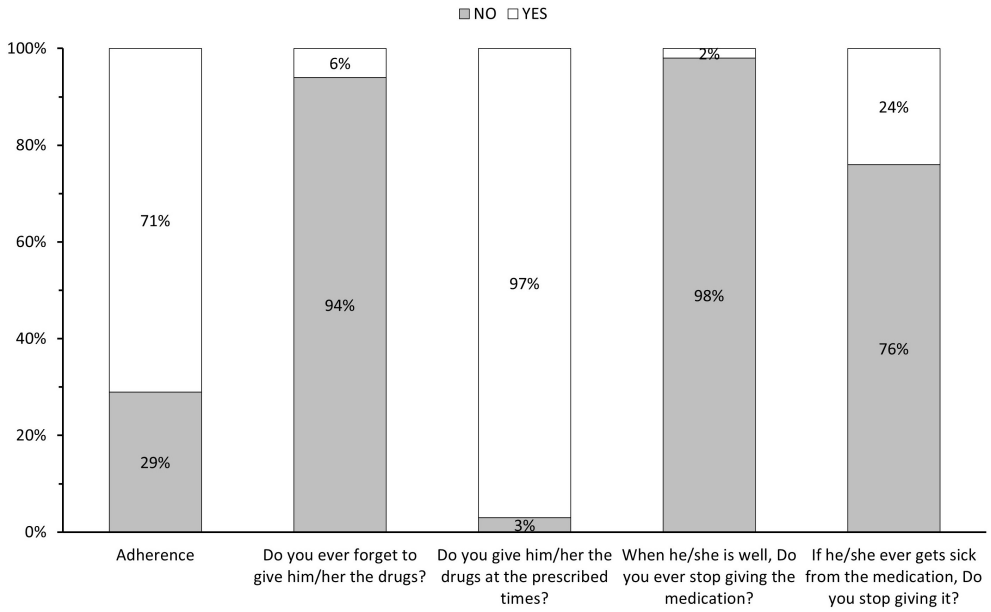

FIGURE 1
Results of the Morisky-Green-Levine test.

communication with healthcare professionals, poor patient-caregiver relationships and difficulties scheduling logistics within care routines. However, it was observed that the scheduling of medication administration did not affect the caregiver's life and did not act as a barrier to adherence.

Overall, the results showed that 71% of the patients presented satisfactory treatment adherence, which is similar to other studies which measured adherence also through the patient's caregiver (27, 28). In a multicenter, cross-sectional, observational study (27) found a 63% treatment adherence, although they evaluated the degree of adherence to transdermal *vs.* oral formulation of rivastigmine, a different study goal from the current study but with similar values of adherence. Another similar study (28) observed a 70.2% degree of adherence to dementia drugs before and after a pharmaceutical intervention at a geriatric outpatient clinic of the university hospital.

The findings are in accordance with previous studies, and identified possible factors that may enhance treatment adherence, particularly those related to the caregiver. In fact, it has been suggested that high social support, and especially when it is provided by family members, improves adherence to treatment (45). Thus, when it was analyzed the role of the caregiver to enhance treatment adherence, a higher degree of adherence was observed when the caregiver was either female and/or a first-degree relative (Table 3), especially the spouse, probably associated with a higher dedication and affectivity due to a high personal affinity which seems to have a major role in monitoring the patient's medication providing high quality care (46). This is in contrast to other studies (36, 39, 47) where the patient-caregiver relationship or caregiver gender are not determining factors for better adherence to treatment or were considered to be included in the groups with lower adherence. Unlike the present study, which found that married patients have a higher degree of adherence to treatment. Other caregiver-related factors that have been shown to be strong determinants of medication adherence (17), whereby lower levels of cognitive functioning, self-efficacy, health literacy, and patient-provider relationship were significant characteristics of the lowest adherence group, in contrast to the present work, where the degree of kinship is associated with better adherence (Table 3).

The study demonstrates that the presence of a caregiver, especially when the caregiver is a first-degree relative, improves adherence to treatment (85.9%) in multi-pathological and polymedicated patients. A similar result was found in other study (48) which related the presence of a caregiver to better therapeutic adherence (83% vs. 65%; $p = 0.005$). It is worthwhile to note that these findings were achieved using different approaches. In the current study, adherence to treatment was evaluated using the Morisky-Green-Levine test, unlike their study which analyzed medication adherence in patients also with multiple pathologies using a validated questionnaire (49) for the identification of medication-related problems in users of a hospital emergency department (48). Thus, using different ways to measure it may be concluded that this factor (a first degree relative) may be crucial to reach around 80% treatment

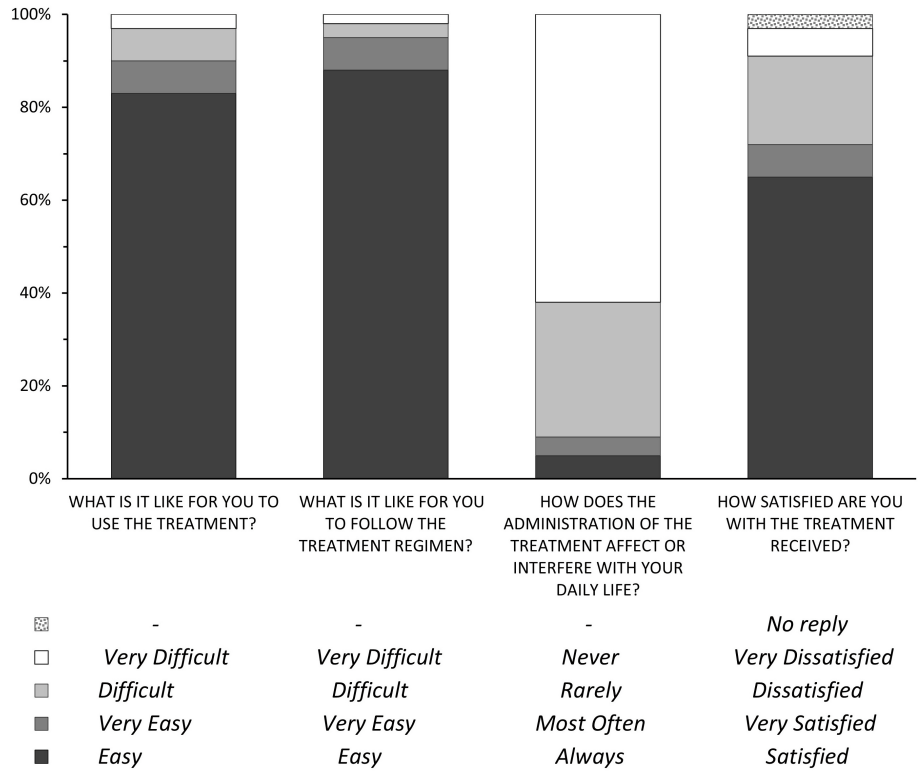

FIGURE 2
Results of the satisfaction survey.

adherence. Also, it was found (50) that patients with a caregiver were 40% less likely to be non-adherent to their medications compared to patients without a caregiver, although the studies were not conducted with patients with dementia but cardiac patients, and therefore the role of the caregiver may be different. Besides, in their study, a patient was defined as adherent when the patient took more than 80% of all the doses of the prescribed medication in the last week (48), a different criterion.

Conversely, the multivariate analysis identified the male gender of the caregiver and having a caregiver who is not a first-degree relative (Table 3), the Alzheimer's disease type of dementia, the single and/or divorce marital status (Table 4) were predictor variables of potential therapeutic non-adherence. This gender gap has been reported also in different studies: a statistically significant association between non-adherence and male caregivers was found among caregivers of children undergoing anti-tuberculosis treatment (29) using also a multivariate analysis. Furthermore, these results, as other studies (47), may support the hypothesis that certain characteristics of the caregiver, such as male gender or degree of kinship with the patient may contribute to reduced and poor patient compliance.

Finally, the results show greater satisfaction with the patient treatment by female caregivers. In addition, first-degree family caregivers find the usage of the patient's prescribed treatments easy. Approximately three quarters of the caregivers are satisfied with the treatment received by the patients and 95% of them consider it easy or very easy to follow the prescribed treatment

TABLE 3 Logistic regression model for therapeutic adherence on caregiver level.

Variable	Binary logistic regression	
	Adjusted OR (IC 95%)	*p*
Gender of caregiver	3.692 (1.267–10.759)	0.017
Type of caregiver	0.231 (0.075–0.716)	0.011

TABLE 4 Logistic regression model for therapeutic adherence on patient level.

Variable	Binary logistic regression	
	Adjusted OR (IC 95%)	*p*
Dementia*	2.879 (1.039–7.979)	0.042
Civil status	1.762 (1.070–2.904)	0.026
Age of patient	0.946 (0.885–1.011)	0.100

*Dementia: (AD vs. other dementia types).

regimen. This factor seems to be intrinsic to the caregiver as it is consistent with another study focused on adherence and satisfaction in patients with hypertension (51). Furthermore, dementia is a disease that affects the well-being of caregivers (52), and the inclusion of the caregivers' perspective is necessary to gain a better understanding of the experience of those living with dementia as included in the study.

Perspective of the study

The increase in life expectancy will result in a larger aging population, with increasing cases of dementia, most likely with multiple pathologies and therefore polymedicated. Since these factors may be contributors to lack of adherence (20, 42, 44), treatment adherence may become a serious public health problem and a challenge for health systems to ensure optimal treatment. Furthermore, the increasing physical and emotional caregiver's burden (53), on whom it depends, in most cases, to provide the correct pharmacological treatment to the patient on a daily basis, open new challenges to ensure treatment adherence.

Therefore, it is necessary to highlight those factors that predict non-adherence in this type of patients and thus increase attention to them and their caregivers (13, 54), so that they can receive more help on the quality and safety of pharmacological treatment. This in turn, may lead to a greater patient-centered approach which would ensure better treatment adherence as seen with the type and gender of caregiver (e.g., a first degree relative *vs.* other types of relation and female gender) (55–57) as well as to develop future working hypothesis to better understand and enhance their care, both patients and caregivers. Of particular interest would be addressing the needs and features of caregivers, whether formal or informal, to enhance patient care through longitudinal, interventional studies along the course of the pathology which could prolong several years as life expectancy increases.

Limitations

The study has several limitations that also require their analysis. It is a cross-sectional study with a large sample but limited to fully understand the impact on clinical events that may take place. The use of an indirect method for measuring adherence has been used extensively in the past in contrast to a direct method (pharmacological follow-up) or another indirect method (tablet count) may not only overestimate adherence but may not ensure that the patient has been taking the medication. However, the impact of these limitations may be small since the assessment of the adherence is not through the patient themselves but the caregiver whose role is to ensure taking the medication. On the other hand, other the possible variables that could affect patient adherence, such as the caregiver's level of knowledge of the pathologies or the medication or the route of administration which could influence patient care were not evaluated. A much larger sample size could bring forward the significance of other variables that may affect adherence.

In summary, factors such as female gender of the caregivers, the patient's marital status and the degree of kinship of caregivers with the patient, may improve adherence to treatment in patients with dementia. Thus, there may be other factors which could be addressed in future studies including communication skills, specific training and competence of caregivers, which have not been address in the current study. Attention should be focused on predictors of adherence/non-adherence and train and educate caregivers about the importance of their role end dedication to ensure adherence in patients with dementia, especially as most of the patients may be multi-pathological, polymedicated and with some degree of cognitive impairment. In addition, the relationship between the degree or cognitive impairment of the patients and adherence was not addressed in this study and remains an essential question for further exploration.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Ethics Committee of the Catholic University of Murcia (CE041808). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MM-C, BC, and IS conceived and designed the study. MM-C and RG carried out participants recruitment and data collection. MM-C and FJL-R performed the statistical analysis. MM-C, BC, and IS carried out the data analysis and interpretation and wrote and edited the manuscript. All authors read and agreed to the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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a license has been obtained from Dr. Morisky for use of the MMAS-4 scale.

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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Effects of combined training during the COVID-19 pandemic on metabolic health and quality of life in sedentary workers: A randomized controlled study

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This study aimed to analyze the effects of a combined training (CT) program performed during the first national lockdown due to the COVID-19 pandemic on body composition, metabolic profile, quality of life and stress in sedentary workers, and examines whether changes in the metabolic profile are associated with changes in health-related outcomes which are modifiable by exercise. We evaluated 31 sedentary workers (48.26 ± 7.89 years old). Participants were randomly assigned to a CT group (i.e., performed 16 weeks of exercise) or to a non-exercise control group. The CT program consisted of 16-week of resistance and aerobic exercise. Body composition, glycemic and lipidic profiles, cardiorespiratory fitness (CRF), health-related quality of life and stress levels were assessed pre- and post-intervention. After the intervention period, the CT group demonstrated significantly lower waist and hip circumference ($p < 0.05$) values than the control group. The control group significantly increased the fasting glucose and HOMA-IR after 16 weeks follow-up (+4.74 mg/dL, $p = 0.029$; and +0.41 units, $p = 0.010$, respectively), whiles no significant changes were observed in the CT group in the same parameters (+3.33 mg/dL, $p = 0.176$; and +0.04 units, $p = 0.628$, respectively). No changes were observed in the lipid profile for either group ($p > 0.05$). A significant positive relationship was detected between the change in BMI with the changes in insulin and HOMA-IR ($r = 0.643$, $p = 0.024$; and $r = 0.605$, $p = 0.037$, respectively). In addition, the changes in CRF were negatively associated with the changes in total cholesterol ($r = -0.578$, $p = 0.049$). We observed differences between groups on perceived stress levels and physical, psychological, and environmental domains of quality of life, with the CT group showing better results. Moreover, the CT group improved

perceived life satisfaction (+3.17 points, $p = 0.038$). The findings of the present study suggest that the participants who remained physically active during the first pandemic-related lockdown were able to mitigate the deleterious effects associated with a sedentary lifestyle.

KEYWORDS

physical activity, insulin resistance, stress-reducing interventions, COVID-19, quality of life

Introduction

Before the outbreak of the Coronavirus Disease 2019 (COVID-19) pandemic – an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus - European adults spent on average 8.83 h/day in sedentary behaviors, and 72% did not meet the recommended 150 min/week dose of moderate-intensity physical activity (PA) (1). Evidence shows that the occupational category has a significant impact on daily PA levels, with desk-based workers presenting the lowest number of steps and the higher sedentary time both at work and during awake hours (2, 3). After the World Health Organization (WHO) declared (on March 11th, 2020) the novel coronavirus outbreak as a pandemic, governments of the mainly affected countries implemented lockdowns and/or requested nationwide stay-at-home orders to counteract the spread of the virus (4). Furthermore, many working adults were required to work remotely from home (i.e., whenever the functions in question allowed it to stay safe) (5). Studies report that during the COVID-19 pandemic, due to lockdowns and working remotely, physical inactivity and sedentary behaviors were greatly exacerbated, in the adult population (5–7). These results have had grave health implications, particularly since prolonged sedentary behavior and physical inactivity are major risk factors for obesity, insulin resistance, and type 2 diabetes mellitus (T2DM) development (8–12). A sedentary lifestyle is associated with unfavorable changes in body composition with loss of muscle mass and accumulation of body fat (BF), mainly abdominal fat. This in turn stimulates chronic low-grade systemic inflammation and an increase in the prevalence of related comorbidities including insulin resistance and T2DM (9, 13). Furthermore, these behaviors have also been associated with poor mental health and wellbeing, including reduced health-related quality of life (HRQoL) (14, 15) and higher levels of stress (16, 17), among adults. It is vital to emphasize that the COVID-19 pandemic itself has become a threat to psychological health, due to stressors such as physical inactivity, quarantine/lockdowns, economic and financial instability, and fear (18).

Effective stress-reducing interventions such as, regular exercise are key to diminishing the deleterious impact of sedentary behaviors and physical inactivity on health outcomes (19, 20). Regular exercise is a cornerstone in the prevention of chronic non-communicable diseases, including metabolic disorders, since it induces metabolic and immunological health benefits (13, 21). In non-pandemic contexts, studies show that combined training (CT) (i.e., aerobic and resistance exercise) is an important tool to ameliorate levels of abdominal obesity (22–24), insulin resistance (22, 25–28), total cholesterol, low-density lipoprotein (LDL), and triglycerides (26, 27), among adults. However, these studies included subjects with different biological characteristics (i.e., elderly) (22) or with associated comorbidities (i.e., metabolic syndrome or T2DM) (22, 25, 27). Moreover, although studies have shown the benefits of regular PA in stress regulation and quality of life improvements (16, 17), the effectiveness of a specific CT program on these outcomes is unknown, in middle-aged adults.

According to Narici et al. (20), although the exercise to dose-response relationship is currently unknown, it appears that low-to-medium intensity exercise, even implementable in home-settings, will promote important health benefits. To our knowledge, this is the first experimental study to assess whether middle aged adult workers, who remained active (i.e., through a CT program supported by digital solutions) during the first wave of COVID-19 in Portugal, were able to mitigate the deleterious effects of sedentarism on body composition, metabolic profile, subjective quality of life and stress. Therefore, the main purpose of this study was to evaluate the effects of a CT program performed during the first national lockdown, due to the COVID-19 pandemic, on body composition, metabolic profile (i.e., glycemic and lipid profiles), quality of life and stress, in sedentary workers. In addition, we aimed to assess whether changes in the metabolic profile are associated with changes in health-related outcomes, which are modifiable by exercise [i.e., cardiorespiratory fitness (CRF), body composition]. We hypothesized that the workers who kept active through the CT program, during an adverse context of the COVID-19 pandemic-related lockdown, were not metabolically affected and presented a better perception of HRQoL and lower levels of stress compared to workers who maintained their usual sedentary habits.

Methods

Experimental approach

This study was designed as a 16-week randomized controlled trial (RCT) with parallel groups and it follows the Consolidated Standards of Reporting Trials (CONSORT) guidelines (29). The intervention was carried out over a period of 16 weeks (between January and May 2020). Following the baseline assessments, the participants were allocated into two groups with a 1:1 allocation, using a computer-generated simple randomization software: (a) an experimental group that performed 16 weeks of a CT program and, (b) a control group that maintained their current lifestyle (i.e., sedentary lifestyle), including no engagement in any structured exercise program. This randomization process was generated by an independent biostatistician. The study participants were enrolled and assigned to their respective groups by the principal investigator (participants were notified by e-mail or telephone). All participants were instructed to maintain the same dietary intake and daily PA levels over the intervention period. The result of randomization process was blinded to the research team responsible for carrying out body composition and CRF assessments to minimize the risk of bias.

Assessments were performed at baseline (pre-intervention, before the implementation of social distancing rules) and 16 weeks later (post-intervention, performed at the end of the first pandemic lockdown), in both groups. It involved the following: biochemical assessment (fasting blood and salivary samples were collected), body composition, PA levels, dietary patterns, CRF, and HRQoL. At the end of the intervention program, 16 weeks later, the experimental group assessment was performed 72 h after the last exercise session, to prevent possible residual effects. Data and sample collection were carried out by invited specialists (nurses, health technicians) and co-investigators of the research team. The same testing staff performed the data and sample collection in the same order at baseline and 16 weeks later. The training program performed by the experimental group underwent some changes due to the unexpected first pandemic lockdown by COVID-19 in Portugal. Thus, the exercise sessions were performed in person until the eighth week (weeks 1 to 8), and in the following weeks (weeks 9–16), the training sessions were carried out online *via* the ZOOM platform (this period corresponds to the duration of the first lockdown due to the COVID-19 pandemic). Figure 1 presents the study design with the critical time points and tasks identified.

Participants

A total of 54 participants with sedentary occupations were recruited and assessed for eligibility. Posters and flyers were disseminated to the busiest places in the workplaces, so that employees were aware of the study. The interested subjects contacted the research team, and an appointment was set up for a more extensive interview, during which the subjects were pre-screened for initial eligibility criteria. The possible eligible individuals were then invited to an in-person screening visit, where they signed an informed consent form and completed other screening measurements. Subjects that met the eligibility criteria returned for the baseline assessments. The inclusion criteria were as follows: [i] working adults with sedentary occupations (i.e., report spending $\geq$ 65% of their workday in sedentary behaviors); [ii] low levels of moderate-to-vigorous PA (30); [iii] having no chronic metabolic disease, cardiovascular disease, cancer, or other major illness; [iv] having no cognitive or psychiatric conditions that could interfere with the study outcomes; [v] no participation in any exercise program in the 6 months prior to screening; [vi] willingness to maintain the same dietary intake and participate in all of the study's procedures. We determined the sample size necessary for each group using the G*Power software (version 3.1.9.2, University of Kiel, Germany). For a medium effect size of 0.30, a sample size of 12 participants in each group (CT group vs. control group) achieves 80% power ($\beta = 0.80$) to detect significant differences within and between groups using an F test (α-level of 5%). More participants were recruited due to possible participant lost to follow-up. We also determined the sample size necessary for the association analysis, that results in a sample size of 12 participants (effect size $d = 0.55$; $\alpha = 0.05$; statistical power = 0.65).

Only 43 of the 54 participants who took part in the first screening met all the eligibility criteria and agreed to take part in this study. Participants who met all eligibility criteria were randomly assigned to either the CT group ($n = 22$) or the control group ($n = 21$). However, only 31 participants (48.13 $\pm$ 7.68 years old) of both genders completed the study (CT, $n = 12$; control group, $n = 19$). The reasons for withdrawal in the CT group were (a) did not participate in the online training sessions ($n = 7$); (b) failure to comply with over 70% of frequency during the whole training program ($n = 2$); and (c) injury unrelated to the intervention ($n = 1$). In the control group, 2 participants withdrew from the study for personal reasons or for not finishing all post-test assessments. A CONSORT diagram is shown in Figure 2. All participants included in this study signed a written informed consent, which complied with the recommendations of the Declaration of Helsinki (31) and was approved by the Ethical Committee for Health of the Faculty of Sport Sciences and Physical Education, University of Coimbra (reference: CE/FCDEF-UC/00512019).

Exercise training

Attendance at sessions was recorded and entered on a database. To be integrated into the analysis, attendance of at least 70% of exercise sessions was required. The CT program was

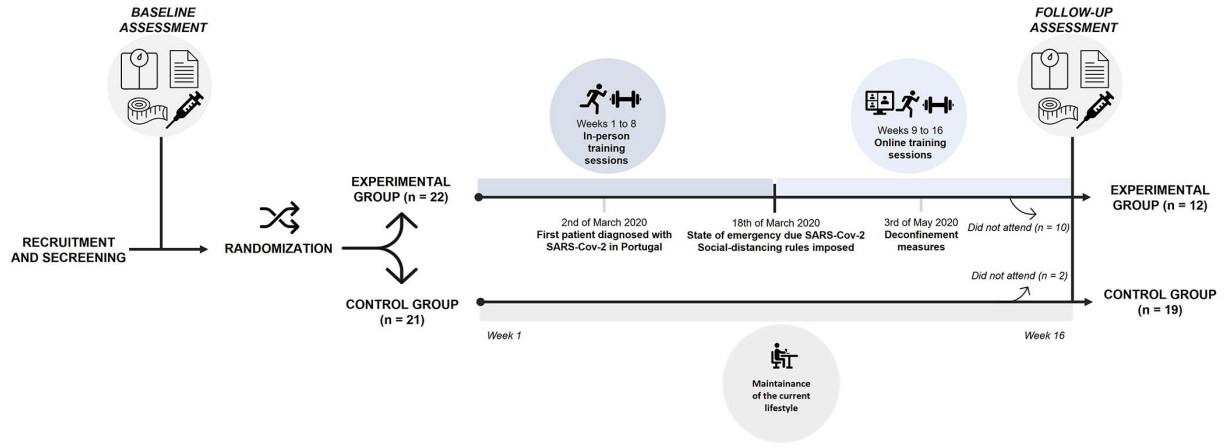

FIGURE 1
Study design with critical time points and tasks.

conducted following the American College of Sports Medicine (ACSM) guidelines (32, 33). The exercise sessions took place 3 times per week on non-consecutive days (i.e., Tuesday, Thursday, and Saturday), with duration of ∼ 55 min/session, over 16 weeks. As mentioned above, in the first 8 weeks of intervention (phase I, weeks 1–8) the exercise sessions were held in-person in an enclosed gymnastics pavilion. In the following 8 weeks (phase II, weeks 9–16), the exercise sessions were performed online through the Zoom platform. This led to some adaptations in the training program. All exercise sessions were conducted and supervised by 2 instructors who graduated in Sport Sciences. Initially, the participants of exercise program were provided with two exercise sessions for familiarization with the exercise techniques and load of the free weights. After this period of familiarization, the maximal dynamic strength tests for determining training load were performed. Next, the training program carried out in the phase I (before the pandemic-related lockdown) and in the phase II (during the pandemic-related lockdown), will be described.

Phase I (weeks 1–8): In-person training sessions

The main part of each session included resistance training followed by aerobic training exercise. The resistance training lasted ∼25 min per session and included seven workout stations/exercises. The resistance exercises (chest press, incline or flat push-ups, bent-over two-arm row, abdominal exercises (i.e., regular plank), front squat, calf raises, glute bridge) were performed with free weights or own subjects' body mass. Participants completed 10–15 tempo-controlled repetitions of each exercise in a 60-s period followed by 30-s of interval rest, before going on to the next exercise. Two rounds of the seven exercises circuit, with a recommended interval rest of 60–90 seconds, were completed in each session for resistance training. For the free weight exercises, the load was adjusted individually to work between 50–75% of the estimated 1-repetition maximum (1RM). A gradual progression in intensity was followed throughout the weeks (i.e., weeks 1–4, 12–15 tempo-controlled repetitions at 50–65% of 1RM, and rate of perceived exertion (RPE) of 5–6; weeks 5–8, 10–12 tempo-controlled repetitions at 60–75% of 1RM, and RPE of 5–6). Once an exercise could be performed comfortably in two consecutive training sessions, an ∼5% increase in weight lifting was added to ensure that a progressive overload was provided. Participants were instructed to inhale and exhale during the eccentric and concentric phase, respectively. The aerobic training lasted ∼15 min per session and involved fast walking and running with an intensity at 60–80% of the participant's maximum heart rate (HRmax). The aerobic training followed a gradual increase in intensity throughout the weeks (i.e., weeks 1–4, 60–70% HRmax, and RPE of 5–6; weeks 5–8, 70–80% HRmax, and RPE of 6–7). To assess and monitor the heart rate intensity interval, the participants used the Polar FT7 (Polar Electro Oy, Finland) monitor during all sessions. The target HR intensity was indirectly predicted by applying Karvonen's formula (34). HRmax was determined using the equation proposed by Gellish et al. (35). The resting HR was reassessed after 4 weeks so that target HR prescriptions could be continuously updated. To ensure that participants were exercising at the planned intensity, the intensity throughout the exercise sessions was also monitored through the RPE, using the Borg CR-10 scale (36). Each exercise session started with a dynamic standardized warm-up at a light-to-moderate intensity to increase body temperature (10 min) and finished with a cool-down period with aerobic activities of light intensity, and static stretching movements (5 min). All participants showed good exercise tolerance and none reported any injury or other

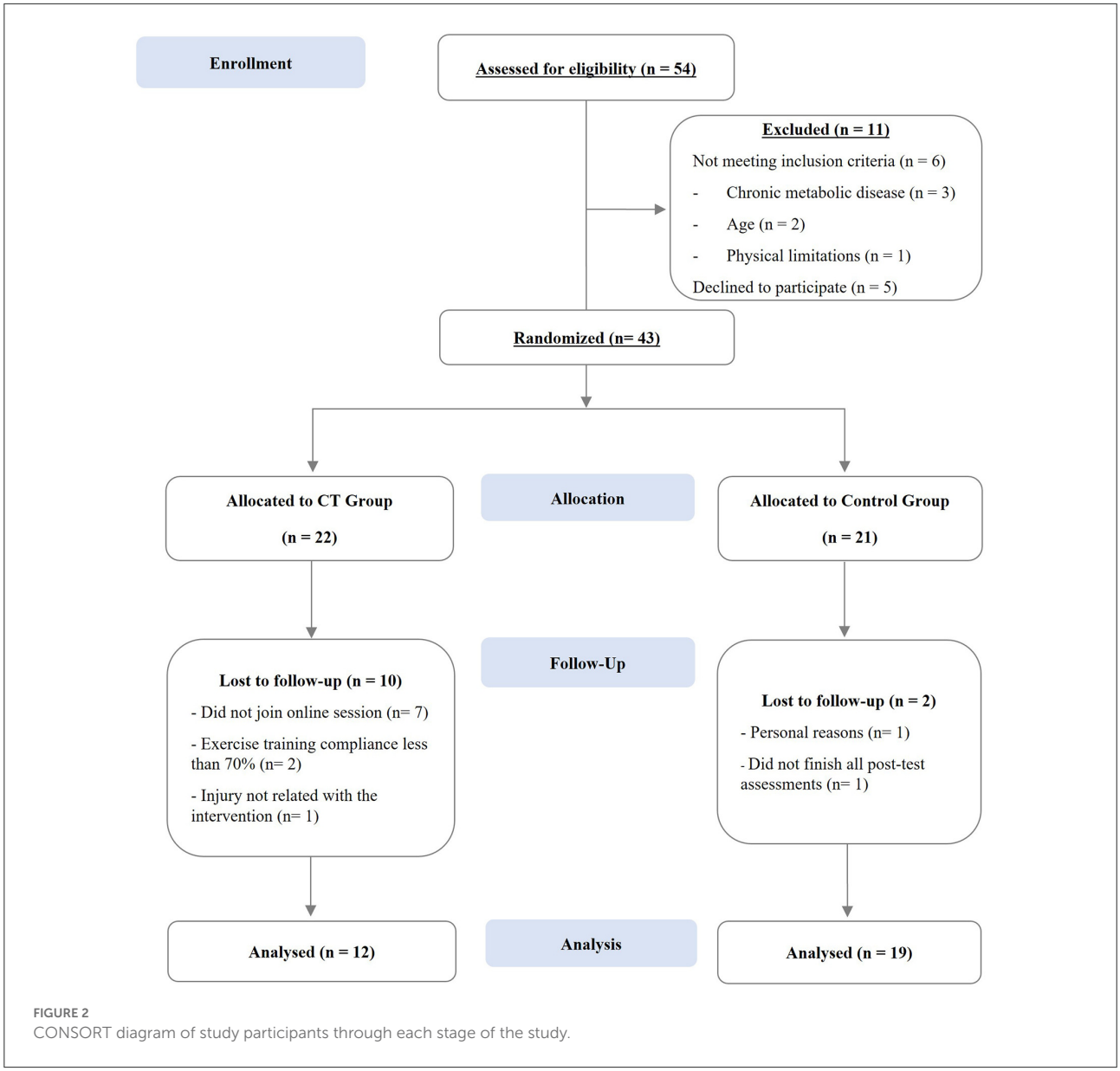

FIGURE 2
CONSORT diagram of study participants through each stage of the study.

major health problems related with the exercise intervention (i.e., injury or other).

Phase II (weeks 9–16): Online training sessions

With the lockdown and inherent policies imposed by the Portuguese government on March 18, 2020, the training sessions moved to an online format. This was the only way to proceed with the exercise program. As a result, the training program experienced various alterations, since participants did not have free weights adjusted to their capacities, nor did they have sufficient vast areas in their homes. For resistance training, participants did mostly the same exercises as in phase I, however, for exercises that required external loads, materials accessible to all participants were used, such as water bottles (5 L and 1.5L), milk packaging, etc. Due to these adaptations, it was not possible to continue to monitor the training intensity using the estimated 1RM. Thus, resistance training intensity was measured only through the RPE scale. The participants performed 12–15 tempo-controlled repetitions of one exercise in a 60-s period (RPE of 5–7 as a target intensity for each exercise), followed by 30 s of rest before advancing to the next exercise, respectively. A total of 2 rounds of the seven exercises circuit, with a recommended interval rest of 60–90 s, were performed in each resistance training session. The aerobic training also follows a circuit training methodology. In this way, 2 rounds of the 5–6 exercises circuit were completed in each session for aerobic training. The working time in each exercise was 40 s in

the weeks 9 to 12 (RPE of 6–7) and 60 s in weeks 13 to 16 (RPE of 7–8). The resting times between workout exercises was 20 s in the first 4 weeks (weeks 9–12) and 30 s in the following weeks (weeks 13–16). Some of the aerobic exercises performed were jogging in place, jumping jacks, modified mountain climbers, etc. Appropriate adaptations were given to participants with more difficulties. RPE values were collected immediately after each exercise.

Procedures

The baseline and the 16-week follow-up assessments were organized on 2 days, respectively. On day one, fasting blood and saliva samples were collected in the laboratory. On day two, body composition, CRF, HRQoL and the dietary pattern were assessed. The body composition and CRF were measured in a large room in both assessment moments. The follow-up assessment took place after the end of the lockdown and was carried out by a marking system, i.e., evaluation of 2 subjects per hour. All the participants and the research team wore surgical masks and disposable gowns to prevent the risk of contamination by the virus SARS-CoV-2. The research team also ensured the disinfection of all material used.

Anthropometry and body composition

Body mass (SECA 761, Germany) and height (Seca Bodymeter 208, Germany) were measured in duplicate using the standard protocols (37). The body mass index (BMI) was calculated dividing the body mass (in kg) by stature in square meters (kg/m^2). Waist circumference (WC) and hip circumference (HC) were taken twice using a flexible steel tape (Hoechstmass-Rollfix, Germany) with an accuracy of 0.1 cm (38). These measures were used to calculate waist-to-hip ratio (WHR) and waist-to-heigh ratio (WHtR). Skeletal muscle mass (SMM), fat mass (FM), total BF, and fat free mass (FFM) were measured by a tetrapolar bioimpedance (Inbody 270, USA), following the standardized protocols and manufacturer' procedures (39).

Venous blood sampling

Blood samples (10 mL; venous) were collected in a seated position from the antecubital vein after a 12-h overnight fast into dry tubes and into tubes containing ethylenediaminetetra-acetic acid. Participants were reminded to maintain a hydrated state and to avoid strenuous physical efforts for 24 h prior to the collection. The tubes were refrigerated for 1 h before centrifugation for 10 min at 1,500 rpm at 4°C. Next, the serum and plasma content were stored at −80°Celsus (C), until the study was concluded, so that all samples could be analyzed together. Serum samples were used to analyze the lipid profile and glucose metabolism of the study participants. This included quantification of total cholesterol, high-density lipoprotein (HDL-C), triglycerides, and fasting glucose using the standard enzymatic assays (ABX Pentra, Germany). Fasting insulin concentration was assessed employing enzyme-linked immunosorbent assay (ELISA) (Crystal Chem, USA) according to the manufacturer's protocol. The LDL-C was determined using the Friedewald et al. (40) formula:

$$\text{LDL} - \text{C(mg/dL)} = \textit{Total cholesterol} - \text{HDL} - \text{C} - (\text{Triglycerides}/5)$$

Fasting insulin and glucose concentrations were used to calculate the homeostatic model assessment (HOMA-IR) using the following equation (41):

$$HOMA - IR = \frac{fGlucose\ (mg/dL)\ x\ fInsulin\ (uU/L)}{405}$$

A person is classified as insulin resistant when their HOMA-IR was >2.0 (42, 43). The blood sample collections (at baseline and at the 16 weeks follow-up) occurred at the same time in the morning (between 07:30 a.m. and 09:30 a.m.) in the laboratory.

Saliva samples

Saliva samples were taken from the study participants in a seated position by the passive drool method (44). Participants were reminded to maintain a hydrated state and to avoid alcohol drinks for 12 h, physical efforts for 24 h, brush teeth for 1 h, and consume foods with high acidity and/or sugar immediately before sampling (45). Moreover, 10 min before taking the saliva, participants were instructed to wash their mouth for 1 min with water to remove any food residues (45, 46). The polypropylene tubes were weighed before use. Once collected, saliva samples were immediately weighed and stored frozen at −20°C for posterior analysis. On the day of the analysis, samples were centrifuged for 4 min (13.0 × g) to remove particulate matter. Salivary levels of cortisol were analyzed by ELISA (Salimetrics, USA). The sensitivity and range of detection limits for cortisol were <0.007 and 0.012–3.000 μg/dl. The α-amylase was analyzed by a kinetic reaction assay (Salimetrics, USA), according to the manufacturer's instructions. The saliva sample collections (at baseline- and 16 weeks later) occurred at the same time in the morning (between 08:00 a.m. and 10:00 a.m.) in the laboratory to minimize circadian effects.

Cardiorespiratory fitness

Maximal oxygen consumption (VO_{2max}) was predicted using a valid and reliable submaximal step test – Chester Step Test (CST) (47, 48). The VO_{2max} predicted by the CST showed a strong and positive association with the VO_{2max} determined by a cardiopulmonary exercise test ($r = 0.989$) (49). The CST is a multistage test and starts with a very slow step rate of 15

steps/min, and every 2 minutes the HR and RPE are checked and recorded, in addition, the stepping rate is then increased slightly (47). The test stopped when the participants reached 80% of their HRmax (estimated by 220-age) or/and reports moderately vigorous level of exertion (RPE = 14) (47). One of our participants did not meet the CST requirements (i.e., complete at least 2 levels) and was therefore excluded from the VO_{2max} analyses. VO_{2max} (mlO_2/kg/min) was determined using the Graphical Datasheets (47).

Subjective HRQoL

The brief version of the World Health Organization Quality of Life (WHOQOL-BREF) questionnaire (50, 51) was used to assess the study participants subjective quality of life. This questionnaire included 24 items (responses on 5-point Likert scale), in addition to 2 more that assessed the overall quality of life and health. This tool included 4 quality of life domains: physical health (7 items), environmental factors (8 items), social relationships (3 items), and psychological health (6 items) (51). Items 3, 4 and 26 were inverted to calculate the final score. Higher scores correspond to a better perception of quality of life (51). At baseline, there was sufficient internal consistency in the separate domains: physical (α =0.81), psychological ($\alpha = 0.79$), social ($\alpha = 0.68$) and environmental ($\alpha = 0.68$). At the follow-up the results also show sufficient internal consistency in the different domains: physical ($\alpha = 0.82$), psychological ($\alpha = 0.83$), social ($\alpha = 0.42$) and environmental ($\alpha = 0.80$).

The Satisfaction with Life Scale [SWLS; (52, 53)] was used to assesses the participant's global judgment of life satisfaction. This scale comprised a 5-item (responses on a 5-point Likert scale; 1 = strongly disagree to 5 = strongly agree). A higher score corresponded to a high life satisfaction (52). Reliability of internal consistency in this study at baseline and after 16 weeks was $\alpha = 0.84$ and $\alpha = 0.81$, respectively, showing a good internal consistency for the SWLS.

Lastly, the Perceived Stress Scale [PSS; (54, 55)] was also used to measure the participant's life situations, assessed as stressful, during the previous month. Seven out of the 13-items was considered negative and 6 as positive, rated on a 5-point Likert scale (0 = never and 4 = very frequently). Items 4–7, 9, 10 and 13 were inverted to calculate the final score. Final scores range between 0 and 52 points, with a higher score representing higher stress (54, 55). Reliability of internal consistency in this study at baseline and 16 week later was $\alpha = 0.72$ and $\alpha = 0.83$, respectively, showing a good internal consistency for the PSS.

PA and sedentary time assessment

The PA levels (light-, moderate-to-vigorous intensity) and sedentary behavior were measured before the study started and 16 weeks later using a triaxial accelerometer (Actigraph wGT3X+, Actigraph Corporation, Florida, USA). Each study participant received the wGT3X+ accelerometer and a detailed explanation regarding its use. Study participants wore accelerometers on their waist during all waking hours, for seven consecutive days. Participants were instructed to only remove the accelerometer for sleeping and water activities. Additionally, each participant received an activity diary to report their daily bed and waking times moreover to record when and why the accelerometer was removed. These records allowed for a better interpretation and analysis of the accelerometer data. Data were processed using the ActiLife software V6 13.3 (ActiGraph, Florida, US), and raw data were reintegrated into 60-second epochs. The Troiano et al. (56) cut points and wear time validation criteria were used. The accelerometer data were considered valid for a minimum of 4 days (i.e., 3 weekdays and 1 weekend) with 600 min of wear time per day.

Assessment of dietary intake

The dietary intake of the participants was assessed using the semi-quantitative Food Frequency Questionnaire (FFQ) (57, 58). The FFQ comprises 8 food groups and frequency consumption with 9 qualitative options (varying from "never or less than once a month" to "6 or more times per day"). The conversion of food into nutrients was performed by specialized nutritionists, using the Food Processor Plus program (ESHA Research, Salem, Oregon, version 11.1) software as a basis, and with nutritional information from US Department of Agriculture food composition tables, adapted to typical Portuguese food (such as, olive, codfish, "feijoada") (https://portfir-insa.min-saude.pt/).

Antibodies against SARS-CoV-2-S1-RBD protein

SARS-CoV-2 infection can manifest itself in different ways, ranging from asymptomatic to mild- or moderate- respiratory and/ or non-respiratory symptoms, as well as severe pneumonia and multiorgan failure (59). SARS-CoV-2 infection has also been linked to a number of long-term problems (called "the post-COVID syndrome") (59). During this study intervention, none of our study participants reported symptoms of SARS-CoV-2. However, on the premise that not all individuals have symptoms of SARS-CoV-2 infection, laboratory tests were performed to detect the presence or absence of IgG antibodies against SARS-CoV-2. The purpose was to confirm if any of the participants had been infected with the virus during the study, and if so, how this might affect the study outcomes. Serum samples (16-week follow-up samples) were used to qualitative detection of IgG antibodies against the SARS-CoV-2 receptor binding domain (RBD). The ELISA test system E 111-IVD developed by Mediagnost (Reutlingen, Germany) was applied according to the manufacturer's protocol (https://mediagnost.de/en/anti-SARS-CoV-2-elisa/). The test is considered valid if a P/N ratio was >

5. The cut-off is calculated 3x and 5x mean values of negative controls. Thus, values under 3x cut-off are considered negative and values above 5x are considered positive, (i.e., contain anti-SARS-CoV-2-S1 RBD antibodies). Assays were performed and results calculated according to the manufacturer's protocol.

Statistical analysis

Data are expressed as mean followed by standard deviation (SD) for continuous variables, and as frequency and percentage for categorical variables. The assumption of normality was checked through the z-values from the skewness and kurtosis tests and using visual inspection of the histograms and normal probability plots (P-P plot). The Shapiro-Wilk test and Levene's test were also used to confirm normal distribution and homogeneity of variances. Assuming data normality, the student's independent *T*-test and chi-square test were used to identify differences between the control and CT group at baseline. In case of non-normality of the data, an equivalent non-parametric test was used. Based on our aim, a per-protocol analysis was performed considering only those participants who completed the exercise program. A two-way analysis of variance (ANOVA) for repeated measures was used for intra- and inter-group comparisons. When a *F*-ratio was significant (i.e., $p \leq 0.05$), the Bonferroni's *post-hoc* test was used to identify mean differences. Log transformation was applied to the outcomes whenever necessary to achieve a normal distribution of the data. For a better interpretation of the data, the values were back transformed from the log scale for presentation in the results section. To compare within groups changes (baseline and 16 weeks later) the magnitude of the effect was calculated using Cohen's *d* effect size and was interpreted as follows: < 0.20 (small), 0.20–0.79 (moderate) and > 0.80 (large) (60). Pearson and Spearman correlation coefficients were also calculated to study the associations between changes (Δ) in the metabolic profile (glycemic and lipid profile), and those in body composition, CRF, and dietary intake variables. The strength of the correlation was classified as follows (61): 0.10–0.30 (little), 0.30–0.50 (low), 0.50–0.70 (moderate), 0.70–0.90 (high) and 0.90–1.00 (very high). The coefficient of determination (r^2) was also calculated. Data analyses were performed using the SPSS Statistics version 27.0 (SPSS Inc., IBM Company, Chicago, Illinois, USA). GraphPad Prism 9.0 software (GraphPad Software, San Diego, CA, USA) was used for plotting graphs. Significance level was set at $p \leq 0.05$.

Results

Thirty-one sedentary middle aged study participants (48.26 $\pm$ 7.89 years old) successfully completed the study with 12 in the CT group and 19 in the control group. No adverse events were identified during the intervention. Table 1 presents the baseline characteristics of all study participants and then by group. There were no statistical differences in anthropometric, demographic, dietary intake, CRF, and PA characteristics between groups at baseline. The serum results of the IgG antibodies against the SARS-CoV-2 showed that all participants presented a value lower than OD 0.484, [i.e., anti-SARS-CoV-2 S1 (RBD)] indicating antibodies were not detectable (mean $\pm$ SD: 0.266 $\pm$ 0.144 units).

The total daily energy and macronutrient intake both at baseline and at the 16 weeks of follow-up are presented in Supplementary Table S1. There were no significant effects for group comparisons, time, or their interaction ($p > 0.05$). This indicates that the daily energy or macronutrient intake were not different between the groups and did not change over the course of the 16-week follow-up period. In relation to sedentary time and PA levels, there was a significant time by group interaction for MVPA (min/day) (Supplementary Table S2). *Post-hoc* analysis showed that MVPA increased significantly by 9.67 min/day ($p = 0.019$, $d = 0.788$ [moderate]) in the CT group, and there was a significant difference between the groups at the 16-week follow-up ($p = 0.018$). No significant differences were found for sedentary time or LPA.

Table 2 presents body composition, lipidic and glycaemic profile outcomes assessed at baseline and at the 16 weeks follow-up by group. In relation to body composition outcomes, there was a significant time by group interaction for WC ($F = 17.813$, $p < 0.001$), HC ($F = 14.205$, $p = 0.001$), WHtR ($F = 18.521$, $p < 0.001$) and WHR ($F = 7.404$, $p = 0.011$), in which improvements were observed for the CT group at post-training. *Post-hoc* analysis showed that WC decreased significantly by -2.43 cm ($p = 0.010$, $d = -1.32$ [large]) in the CT group and increased significantly by 2.29 cm ($p = 0.030$, $d = 0.642$ [moderate]) in the control group. The HC decreased -1.60 cm ($p = 0.009$, $d = -0.73$ [moderate]) in the CT group, while the control group increased 1.17 cm ($p = 0.016$, $d = 0.628$ [moderate]). The WHtR decreased -0.015 cm ($p = 0.009$, $d = -1.33$ [large]) in the CT group, while the control group increased 0.01 cm ($p = 0.002$, $d = 0.662$ [moderate]), with a significant difference between the groups at the 16-week follow-up ($p = 0.013$). Finally, results showed that the WHR increased 0.01 cm in the control group ($p = 0.029$, $d = 0.484$ [moderate]).

Furthermore, a significant effect of time was observed in the fasting glucose levels ($F = 6.341$, $p = 0.018$) and the HOMA-IR index ($F = 4.389$, $p = 0.045$) (Table 2). *Post-hoc* analysis showed that fasting glucose and HOMA-IR index increased significantly by 4.74 mg/dL ($p = 0.029$; $d = 0.466$ [moderate]) and 0.41 ($p = 0.010$; $d = 0.522$ [moderate]), respectively, after a 16-week follow up in the control group, compared to baseline. Fasting insulin levels show no effect of time ($F = 1.770$, $p = 0.194$) or interaction ($F = 2.310$, $p = 0.139$). No significant differences were found for the CT group, regarding the glycaemic profile (Table 2). The significant increase in glucose

TABLE 1 Baseline characteristics of all the study participants and after their randomization into control or the combined training protocol.

Variables	All ($n = 31$)	Control group ($n = 19$)	Combined training group ($n = 12$)	p-value between group
Age, years	48.26 ± 7.89	49.32 ± 7.13	46.58 ± 9.02	0.356
Women, *n* (%)	24 (77.4)	15 (78.9)	9 (75.0)	0.798
Menopausal, *n* (%)	10 (32.3)	6 (31.6)	4 (33.3)	0.831
Married, n (%)	15 (48.4)	10 (52.6)	5 (41.7)	0.222
Medical history				
Hypertension, *n* (%)	8 (25.8)	6 (31.6)	2 (16.7)	0.273
Dyslipidaemia, *n* (%)	2 (6.5)	1 (5.3)	1 (8.3)	0.796
Asthma, *n* (%)	2 (6.5)	2 (10.5)	0 (0)	0.284
Regular medication, *n* (%)	12 (38.7)	8 (42.1)	4 (33.3)	0.625
Current-smoking, *n* (%)	2 (6.5)	0 (0)	2 (16.7)	0.066
Morphological parameters, mean ± SD				
Body mass (kg)	72.27 ± 15.36	74.12 ± 16.21	69.33 ± 14.07	0.407
Height (cm)	160.49 ± 8.46	159.81 ± 8.96	161.57 ± 7.86	0.581
BMI (kg/m^2)	27.83 ± 4.26	28.75 ± 4.29	26.37 ± 3.93	0.131
Waist circumference (cm)	93.94 ± 11.99	95.59 ± 11.30	91.32 ± 13.06	0.343
Hip circumference (cm)	105.89 ± 10.91	106.68 ± 11.27	104.63 ± 10.68	0.619
Sedentary behavior and PA levels				
Valid days (days) #	6.39 ± 0.92	6.53 ± 0.77	6.17 ± 1.12	0.535
Wear time (min/day)	808.95 ± 67.35	811.55 ± 74.02	804.85 ± 58.11	0.793
Sedentary time (min/day)	486.01 ± 88.11	469.68 ± 101.25	511.86 ± 56.64	0.148
LPA (min/day)	305.34 ± 93.97	324.54 ± 105.35	274.94 ± 65.39	0.156
MVPA (min/day) [a]	16.54 ± 10.69	15.59 ± 11.31	18.05 ± 9.88	0.418
Dietary intake				
Energy intake (kcal/day)	2,098.68 ± 773.79	2,092.7 ± 723.0	2,108.2 ± 881.8	0.958
Fat intake (g/day)	84.17 ± 36.46	83.1 ± 32.1	85.8 ± 43.9	0.847
Carbohydrate intake (g/day)	239.48 ± 95.05	236.7 ± 87.3	244.0 ± 110.2	0.839
Protein intake (g/day)	103.52 ± 43.77	106.1 ± 47.7	99.4 ± 38.3	0.683
Cardiorespiratory fitness				
VO_{2max} (mlo_2/kg/min) #	31.72 ± 6.46	29.87 ± 5.10	34.48 ± 7.49	0.108

Data are expressed as mean ± standard deviation, count, or percentage as appropriate. Abbreviations: n, number; %, percentage; kg, kilograms; cm, centimeters; m, meters; BMI, body mass index; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; VO_{2max}, maximal oxygen uptake. [a]Logarithmic transformation was used for the analysis. [#]Mann-Whitney test.

and HOMA-IR index observed in the control group did not differ depending on the BMI status of the participants ($p > 0.05$) (Supplementary Table S3, Supplementary Figure S1). Moreover, there was no effect of either time (for both groups) or group interaction ($p > 0.05$) for total cholesterol, LDL-C, HDL-C, LDL/HDL ratio, and triglycerides (Table 2). In addition, most of our findings (i.e., body composition, HOMA-IR, and lipid profile) did not change after performing an analysis of variance (ANCOVA) including the menopausal status of women as a possible confounding factor (Supplementary Table S4).

A significant positive relationship was detected between the change in body mass and the change in fasting insulin ($r = 0.704$, $p = 0.011$ [high]; Figure 3A) and HOMA-IR index ($r = 0.577$, $p = 0.050$ [moderate]; Figure 3B). Moreover, changes in BMI were positively associated with changes in insulin ($r = 0.643$, $p = 0.024$ [moderate]; Figure 3C) and HOMA-IR ($r = 0.605$, $p = 0.037$ [moderate]; Figure 3D). CRF was negatively correlated with total cholesterol ($r = -0.578$, $p = 0.049$ [moderate]; Figure 3E). No significant correlations were found between changes in metabolic profile outcomes and other parameters of body composition and dietary pattern variables.

Table 3 shows the results obtained for stress and HRQoL. Regarding the salivary stress hormones (cortisol and α-amylase hormones), there were no significant effects of time, group, or interaction (time x group) ($p > 0.05$). However, there was a main effect of group for the PSS score ($F = 5.399$, $p = 0.027$), which is represented by a significant difference of

TABLE 2 Differences between baseline and after a 16-week follow-up and between groups on body composition, glucose, and lipid profile outcomes calculated with two-way ANOVA for repeated measures.

Outcome	Control group ($n = 19$)			Combined training group ($n = 12$)			Time factor		Group factor		Time x Group	
	Pre	Post	$\Delta_{mean} \pm SD$	Pre	Post	$\Delta_{mean} \pm SD$	*F*	*p* value	*F*	*p* value	*F*	*p* value
Body composition												
Body mass (kg)	74.12 ±16.21	74.68 ± 16.85	0.56 ± 1.85	69.33 ± 14.07	69.16 ± 14.08	−0.18 ± 1.79	0.323	0.574	0.801	0.378	1.182	0.286
BMI (kg/m$^{2)}$	28.75 ± 4.29	28.97 ± 4.69	0.22 ± 0.74	26.37 ± 3.93	26.31 ± 3.87	−0.07 ± 0.71	0.299	0.588	2.59	0.119	1.152	0.292
WC (cm)	95.59 ±11.30	97.88 ± 11.66*	2.29 ± 3.57	91.32 ±13.06	88.90 ± 12.74‡	−2.43 ± 1.83	0.015	0.904	2.261	0.144	17.813	**<0.001**
HC (cm)	106.68±11.27	107.84±11.44*	1.17 ± 1.86	104.63 ± 10.68	103.03 ± 9.37‡	−1.60 ± 2.19	0.350	0.559	0.739	0.397	14.205	**0.001**
WHtR	0.60 ± 0.06	0.61 ± 0.06*†	0.01 ± 0.02	0.56 ± 0.07	0.55 ± 0.07‡	−0.015 ± 0.11	0.006	0.941	4.281	**0.048**	18.521	**<0.001**
WHR	0.90 ± 0.07	0.91 ± 0.07*	0.01 ± 0.02	0.87 ± 0.07	0.86 ± 0.08	−0.01 ± 0.02	0.020	0.888	1.981	0.170	7.404	**0.011**
BF (%)	37.71 ± 7.40	37.05 ± 7.90	−0.65 ± 1.48	34.42 ± 7.85	34.13 ± 7.88	−0.29 ± 1.37	3.171	0.085	1.198	0.283	0.463	0.501
FM (kg)	28.13 ± 8.82	27.95 ± 9.50	−0.18 ± 1.62	24.24 ± 9.01	23.98 ± 8.88	−0.27 ± 0.10	0.726	0.401	1.384	0.249	0.028	0.868
SMM (kg)	25.30 ± 6.33	25.71 ± 6.53	0.41 ± 0.62	24.95 ± 5.40	24.97 ± 5.46	0.02 ± 1.00	2.215	0.147	0.060	0.808	1.883	0.181
FFM[a] (kg)	45.89 ±10.99	46.57 ± 11.17	0.68 ± 1.07	45.09 ± 8.91	45.18 ± 8.10	0.09 ± 1.56	2.190	0.150	0.041	0.841	1.300	0.264
Glucose metabolism												
Fasting glucose[a] (mg/dL)	89.89 ±12.40	94.63 ± 7.88*	4.74±10.16	89.00 ± 11.85	92.33 ± 4.91	3.33 ± 9.61	6.341	**0.018**	0.223	0.641	0.119	0.732
Fasting insulin[a] (mU/L)	8.02 ± 1.58	9.28 ± 3.61	1.26 ± 2.77	7.55 ± 1.15	7.47 ± 0.94	−0.08 ± 0.91	1.770	0.194	2.139	0.154	2.310	0.139
HOMA-IR index[a]	1.79 ± 0.46	2.18 ± 0.88*	0.41 ± 0.76	1.66 ± 0.38	1.70 ± 0.23	0.04 ± 0.31	4.389	**0.045**	2.137	0.155	1.765	0.194
Lipid Profile												
TC (mg/dL)	191.21±33.92	192.42 ± 24.47	1.21±23.28	198.50 ± 33.29	192.25 ± 35.92	−6.25 ± 24.81	0.328	0.571	0.109	0.744	0.718	0.404
HDL-C[a] (mg/dL)	49.89 ± 9.81	50.47 ± 9.42	0.58 ± 6.15	57.08 ± 14.72	55.83 ± 13.86	−1.25 ± 5.72	0.092	0.763	2.299	0.140	0.685	0.414
LDL-C (mg/dL)	122.58±26.86	122.07 ± 19.46	−0.51±19.84	122.10 ± 27.16	116.65 ± 33.94	−5.45 ± 22.17	0.606	0.443	0.108	0.745	0.417	0.523
LDL/HDL ratio	2.51 ± 0.58	2.48 ± 0.49	−0.03 ±0.38	2.25 ± 0.69	2.25 ± 0.94	−0.004 ± 0.41	0.062	0.805	1.085	0.306	0.033	0.858
Triglycerides (mg/dL)	93.68 ±30.44	99.37 ±31.67	5.68 ±32.51	96.58 ± 36.72	99.25 ± 38.01	2.67 ± 17.76	0.661	0.423	0.015	0.903	0.086	0.771

Data are expressed as mean ± standard deviation. [a]Logarithmic transformation was used for the analysis. BMI, body mass index, WC, waist circumference, HC, hip circumference, WHtR, waist-to-heigh ratio, WHR, waist-to-hip ratio, BF, total body fat, FM, fat mass, SMM, skeletal muscle mass, FFM, fat free mass, HOMA-IR, homeostatic model assessment insulin resistance, TC, total cholesterol, HDL-C, High-density lipoprotein cholesterol, LDL-C, low-density lipoprotein cholesterol, LDL/HDL, low-density lipoproteins/high-density lipoproteins ratio. $p \leq 0.05$, *control group pre × control group post; ‡exercise group pre × exercise group post, †control group post × exercise group post. Bold p values mean significant differences.

5.5 points ($p = 0.025$) between the groups at the 16-week follow-up. Regarding to HRQoL, a significant effect of time was found in satisfaction with life ($F = 5.561$, $p = 0.025$). Life satisfaction increased 3.17 points in the CT group ($p = 0.038$, $d = 0.690$ [moderate]) after the exercise intervention. No significant effect of time was verified in the control group. In relation to WHOQOL-Bref questionnaire, we observed a main effect of group to the physical health domain ($F = 7.027$, $p = 0.013$), psychological health domain ($F = 4.552$, $p = 0.041$) and environmental health domain ($F = 10.59$, $p = 0.003$). These results represent differences between groups at the 16-weeks follow-up, with better values observed in the CT group.

Discussion

This study aimed to analyse the effects of a CT program performed during the first national lockdown due to the COVID-19 pandemic on body composition, metabolic profile, quality of life, and stress in sedentary middle-aged workers. Additionally, we examined whether changes in the metabolic profile were associated with changes in health-related outcomes which are modifiable by exercise. Our results showed that a 16-week CT program reduced abdominal adiposity and improved HRQoL, while no significant changes were noted in either glycaemic or lipid profile parameters (i.e., CT participants were able to maintain their metabolic parameters). In addition, changes in body mass and BMI were positively correlated with changes in fasting insulin and HOMA-IR. Also, changes in CRF were negatively associated with changes in total cholesterol. Instead, after a period of 16 weeks, the non-exercise control group increased waist and hip circumferences, progressed into insulin resistance, as shown by the increase in glucose and HOMA-IR and had higher perceived stress levels and lower HRQoL, when compared to the CT group.

It has been previously reported that CT is an effective tool to reduce body mass and FM while increasing SMM in sedentary adults (23, 24). The study of Sillanpää et al. (24) observed that 21-weeks of CT markedly enhanced body composition, with a significant decrease of −4.8% in total FM and an increase of 2.2%

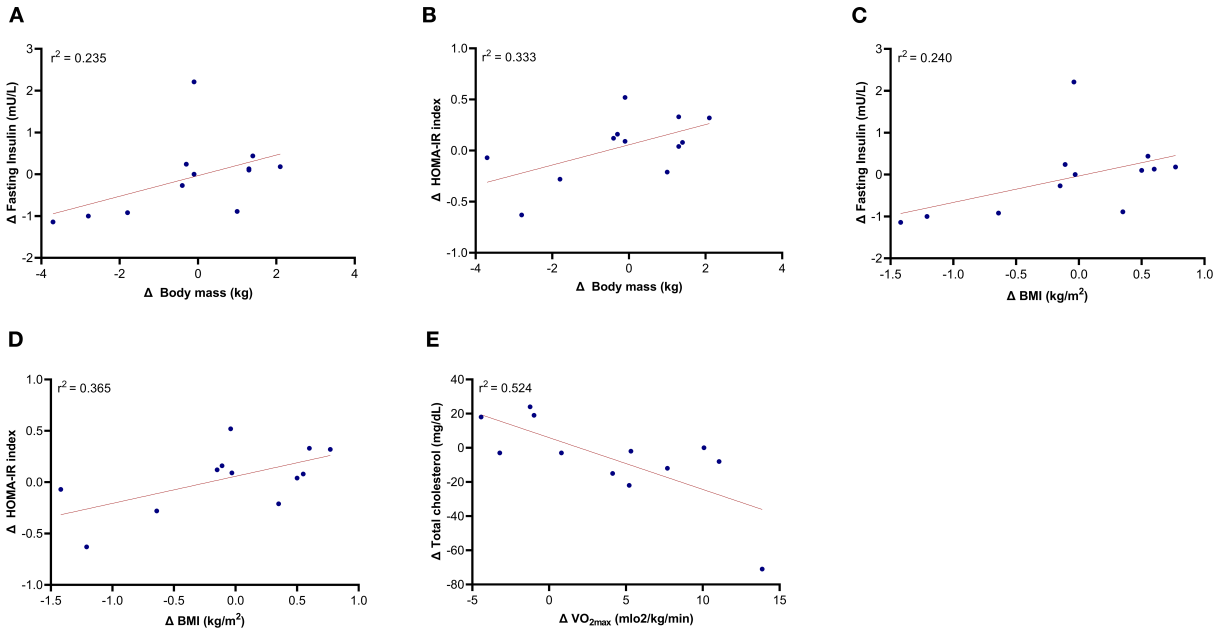

FIGURE 3
Relationship of the changes in fasting insulin, HOMA-IR, total cholesterol with the changes in body composition and cardiorespiratory fitness (excluding control group). **(A)** Δ Body mass and Δ fasting insulin; **(B)** Δ Body mass and Δ HOMA-IR index; **(C)** Δ BMI and Δ fasting insulin; **(D)** Δ BMI and Δ HOMA-IR index; **(E)** Δ Vo2max and Δ Total cholesterol.

and ∼3.0% in SMM of the arms and legs, respectively, in middle-aged and older women. These results agree with those obtained by Amaro-Gahete et al. (23), that found that 12-weeks of CT result in a significant decrease of −4% in FM and an increase of 4% in SMM, in middle-aged sedentary adults. However, in the current study, the CT program significantly decreased WC, HC and WHtR, without any significant change in other morphologic outcomes, such as SMM and FFM. It is possible that the low resistance training loads used in the last weeks of the program were not enough to promote SMM improvement. Nevertheless, other studies with low- to medium- training intensities also did not find significant changes in SMM after 12-weeks of CT in adults with the metabolic syndrome (aged 48–77 years old) (22) and obesity (aged 35–55 years old) (62).

The CT has also been positioned as a promising tool to ameliorate metabolic health, through the management of glycaemic and lipid profiles. In a study, Amanat et al. (27) observed that 12-weeks of CT exercise reduced insulin resistance, fasting insulin, glucose, triglycerides, LDL-C, and total cholesterol in overweight women (aged 46–60 years old) with the metabolic syndrome. Another study (28) also found significant improvements in fasting glucose, HbA1c, and HOMA-IR after 12-weeks of CT program in women aged over 45 years at high risk of T2DM. Similarly, Amaro-Gahete et al. (26) found that 12-weeks of CT significantly improved HDL-C, total cholesterol, and insulin sensitivity in sedentary middle-aged adults (aged 40 to 65 years old). Also, Sillanpää et al. (24) observed that 21-weeks of CT decreases serum fasting insulin in women with 39 to 64 years old, whereas no significance was observed in other metabolic outcomes. Our study findings partially disagree with those previously reported, since the present CT program did not promote any significant change in glycaemic (i.e., fasting insulin, glucose, or HOMA-IR) or lipid (total cholesterol, HDL-C, LDL-C, LDL/HDL, and triglycerides) profiles. Furthermore, there were also no significant differences between the CT group and the non-exercise control group in these outcomes. However, it is important to note that while the control group progressed into insulin resistance [HOMA-IR above 2.0 (42, 43)] during the 16-week period, the CT program was important to prevent this group from progressing to an insulin resistant phenotype.

The different intervention contexts could be a potential explanation for the discrepancies between our results and the results of the mentioned studies (i.e., our exercise program was conducted at home in the context of movement restrictions, and there was a drastic alteration in the CT program within the middle of the intervention due to lockdowns). Moreover, it is important to note that some of the studies mentioned above included participants with associated comorbidities (27, 28). Our findings could also be explained by the lack of changes in SMM since this outcome may also play a beneficial role in whole-body glucose homeostasis and metabolic health (11, 63).

But certainly, the most plausible reason can be associated with the changes in daily people's lives during the COVID-19

TABLE 3 Differences between baseline and 16-week follow-up and between groups on the salivary stress hormones and HRQoL, calculated with two-way ANOVA for repeated measures.

Outcome	Control group ($n = 19$)			Combined training group ($n = 12$)			Time factor		Group factor		Time x Group	
	Pre	Post	$\Delta_{mean} \pm SD$	Pre	Post	$\Delta_{mean} \pm SD$	*F*	*p* value	*F*	*p* value	*F*	*p* value
Stress levels												
Cortisol (μg/mL)	0.33 ± 0.18	0.28 ± 0.12	−0.05 ± 0.21	0.34 ± 0.15	0.28 ± 0.16	−0.06 ± 0.21	2.071	0.161	0.072	0.790	0.015	0.903
Alpha-amylase[a] (U/mL)	46.04 ± 29.38	34.97 ± 17.86	−11.07 ± 5.68	58.57 ± 35.78	53.19 ± 25.28	−5.38 ± 18.35	2.011	0.167	3.447	0.074	0.847	0.365
PSS (score)	23.95 ± 3.73	24.58 ± 5.39†	0.63 ± 6.21	21.67 ± 6.30	19.08 ± 7.61	−2.58 ± 7.45	0.622	0.437	5.399	**0.027**	1.689	0.204
HRQoL												
SWLS (score)	15.89 ± 4.61	17.11 ± 4.15†	1.11 ± 5.29	17.0 ± 3.74	20.17 ± 2.48‡	3.17 ± 4.59	5.561	**0.025**	3.392	0.076	1.111	0.301
WHOQOL-BREF (Score)												
Physical health (0–100)	64.66 ± 17.04	63.91 ± 12.42†	−0.75 ± 11.58	73.80 ± 11.83	79.94 ± 12.66	6.13 ± 9.34	1.830	0.187	7.027	**0.013**	2.998	0.094
Psychological health (0–100)	63.16 ± 17.64	61.62 ± 11.9†	−1.53 ± 14.38	70.14 ± 11.49	74.31 ± 14.52	4.17 ± 13.53	0.258	0.615	4.552	**0.041**	1.209	0.281
Social relationship (0–100)	72.72 ± 12.54	70.18 ± 9.28	−2.54 ± 13.98	71.53 ± 18.28	77.08 ± 13.82	5.56 ± 15.21	0.319	0.577	0.489	0.490	2.307	0.140
Environmental health (0–100)	60.36 ± 9.99	61.02 ± 10.89†	0.66 ± 10.45	68.75 ± 10.23	73.70 ± 9.28	4.95 ± 10.27	2.145	0.154	10.59	**0.003**	1.256	0.272

Data are reported as mean ± SD. [a]Logarithmic transformation was used for the analysis. PSS, perceived stress scale; SWLS, satisfaction with life scale; HRQoL, health-related quality of life. $p \leq 0.05$, * control group pre × control group post; ‡exercise group pre × exercise group post, †control group post × exercise group post. Bold p values mean significant differences.

pandemic-related lockdown. Unfortunately, we only assessed PA levels at the end of the 16-week follow-up, which corresponded to the end of the first lockdown in Portugal. An intermediate assessment would have provided relevant data, as a growing body of evidence showed that the sudden state of lockdown due to the COVID-19 pandemic had a tremendous impact on many aspects of daily life, including changes in behavioral patterns (5–7), modified dietary habits (64), as well increased feelings of distress and anxiety (18). Thus, it is expected that these and other confounding factors may have interfered with the results of this study. Furthermore, despite instructions to maintain the same nutritional pattern over the 16-week intervention, and the auto-reported unchanged (i.e., according to FFQ), people could be more careless with their calorie intake and nutritional quality, believing that exercise will compensate for these differences (22). However, our results agree with those obtained by previous studies that also found no significant changes in the lipid (22, 24, 62) and the glycaemic profile (62, 65) after a CT program in sedentary adults. Further studies are needed to confirm the current results.

Furthermore, we observed that changes in BMI positively predict 24% and 37% of the changes expected for fasting insulin and HOMA-IR, respectively. These findings have important clinical relevance and in part confirm the evidence that FM accumulation is closely associated with the increase of insulin resistance – a major risk marker of impaired glucose metabolism, T2DM, and CVD (8, 11, 66). Evidence suggests that the chronic low-grade inflammation present in adipose tissue is involved in the pathogenesis of insulin resistance (9, 13). Even in young children, a recent study observed lower adiponectin levels, a marker of adiposity secretory dysfunction, and elevated leptin secretion in insulin-resistant children in comparison to lean or obese insulin-sensitive children (67). Other studies in middle-aged adults (first-degree relatives with T2DM and massive obesity) also observed that 30% of them that have increased fat cell size and increased WHR were those that were characterized by insulin resistance (68, 69).

Consequently, it is biologically acceptable that exercise could mitigate the chronic inflammation in adipose tissues by reducing adipose tissue mass and regulating adipokine expression, resulting in enhanced insulin sensitivity (70). According to Eaton and Eaton (11) the insulin sensitivity is directly associated to %SMM but is inversely related to %BF. The mechanisms whereby SMM induces improvements in whole-body glucose homeostasis are not fully understood, however, a recent review suggests that a biological mechanism can be the greater SMM capillarity and its vasodilator response (63).

Moreover, our results suggests that the changes in CRF were associated with a decrease in total cholesterol in the exercise group. Prior research has also shown that CRF improves lipid and lipoprotein profiles (71) through mechanisms that may include increased activity of lipoprotein lipase in active SMM (71–73). This increase leads to a higher triglyceride clearance rate; enhanced HDL-C; and improved lipid and lipoprotein transport from the tissues to the liver (71–73). Moreover, a recent study also shows that higher CRF is associated with decreased probability of clinical high blood pressure and lower insulin resistance in overweight children (74). Total cholesterol, LDL-C, and triglycerides gradually increase until the mid-40's to early 50's, so it seems important to maintain a good CRF level in these ages to prevent and/or delay the manifestation of dyslipidaemia and its related non-communicable diseases (71). Notably, our results are important and show the clinical importance of regular daily exercise, even if performed at home

in contexts of movement restrictions, to maintain the glucose and lipid levels and thus delay/prevent the manifestation of metabolic disorders. In contrast, the non-exercise control group that maintained their sedentary lifestyle increased abdominal obesity, fasting glucose, and HOMA-IR. These results agree with several studies showing that a sedentary lifestyle is associated with metabolic derangements such as obesity, insulin resistance, and T2DM (8–12).

In relation to HRQoL, our results showed that the CT group increased their life satisfaction after the exercise program. Furthermore, when compared to the control group, the CT group presented lower perceived stress levels and higher HRQoL in the physical, psychological, and environmental domains at the follow-up. Our findings are consistent with other studies that confirm that the participants who were more physically active were generally more satisfied with their lives (75). Similarly, a review study (76) found that exercise (independently of the type) has a positive effect on the HRQoL of healthy older adults. On the other hand, a sedentary lifestyle is unfavorably associated with perceived stress and HRQoL (15–17, 77). Some studies showed that the imposed stay-at-home orders and other lockdown measures due to the COVID-19 pandemic affected negatively the HRQoL and mental health of the populations (78, 79). This data is alarming since that lower HRQoL has been associated with the development of non-communicable diseases and mental health issues (79, 80). Based on this evidence, it seems that our exercise program was also an important strategy to prevent a decrease in HRQoL and life satisfaction.

Taken together, our findings suggest that the practice of combined exercise for the prevention of metabolic disorders and psychologic conditions are essential in all aspects of management, particularly during the COVID-19 pandemic-related lockdowns. In addition, exercise has also been identified as an effective strategy against the increased hospitalization rates due to respiratory diseases, such as the related COVID-19 comorbidities (81). Conversely, chronic physical inactivity and sedentary behavior is associated with a higher risk of COVID-19 hospitalization, independently of age, sex, smoking, alcohol consumption, and obesity (82). These data are clinically relevant, especially nowadays, where thousands of people continue to be affected daily by the SARS-CoV-2 virus infection.

There are three important limitations to this study that should be considered when interpreting the findings. First, the insulin resistance was not determined using the golden standard, the hyperinsulinemia euglycemic glucose (HIEG) clamp technique. However, previous studies have shown that the HOMA-IR method is recognized and validated method to determine insulin resistance (83). Second, with the beginning of the pandemic-related lockdown, the exercise program underwent some changes, i.e., it was impossible to continue with the progression of loads in the resistance training as initially planned. Third, other residual confounding factors such as teleworking period, dietary pattern, sedentary and physical activity levels during the home-confinement period and other unknown factors, may have cofounded some of the results. Additionally, potential covariates such as the menopausal status of the women may also have confounded some of the results. However, we tried to mitigate this limitation by adopting specific statistical procedures, considering the menopausal status as a confounding variable.

The findings of the present study should be analyzed in the context of home-confinement due to the COVID-19 lockdown. We suggest that future experimental and longitudinal studies could be carried to confirm these results. Moreover, given the current COVID-19 pandemic, it is essential that future PA guidelines encourage the practice of PA/physical exercise, and integrate specific guidelines for home-based exercise.

Conclusion

The findings of the present study suggest that the participants who remained physically active through a supervised exercise program, during the first pandemic-related lockdown, were able to mitigate the deleterious effects associated with a sedentary lifestyle. Specifically, our results showed that a 16-week CT program helped maintain glucose and lipid levels, reduced abdominal adiposity, and improved HRQoL. In contrast, the non-exercise control group participants who remained physically inactive increased abdominal obesity, progressed into insulin resistance (as shown by the increase in fasting glucose and HOMA-IR), and had higher perceived stress levels and lower HRQoL when compared to the exercise group. Despite the inherent limitations, our findings have important clinical implications. They suggest that a CT program, even if performed at home in the context of movement restrictions, could be an effective and cost-efficient strategy to prevent metabolic disorders and mental health problems among sedentary workers.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Ethical Committee for Health of the Faculty of Sport Sciences and Physical Education, University of Coimbra (reference: CE/FCDEF-UC/00512019). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JF, AT, PD-M, and FS contributed to the conception and design of the study. FS, CF, and CS performed the experiments. FS and RR analyzed and interpreted data. JF, AT, and PD-M supervised the work. FS drafted the manuscript. JF, AT, PD-M, CS, RP, JS, EC, and AM critically reviewed the contents of the manuscript. All authors have read and approved the submitted version of the manuscript.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1040714/full#supplementary-material

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A passion for aging in cultural contexts: Dr. Colette Browning and her contributions within Australia and globally

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We are increasing a world characterized by movement, particularly the movement of people. I am part of that movement, a clinical geropsychologist trained in the United States, who has migrated first to New Zealand and who now finds her home in Australia. However, cultural contexts, whether they be original or adopted, have always intrigued me and informed my research and clinical practice with older adults. Thus, it is no surprise that upon arrival in Australia I found a kindred spirit in Colette Browning who personifies excellence in aging research in Australia and globally.

Professor Colette Browning is a health psychologist and social gerontologist with a BSc (Hons) and MSc in psychology and a PhD in public health, currently working at Federation University in Australia. She is an international leader in health psychology, with a research focus on public health and aging, particularly in diverse cultural contexts. Her interests led her to have strong collaborations with colleagues in China, where her research focused primarily on health care reform, aging and health services evaluation in that country. We often had long discussions about the insights each of us has gathered working with overseas colleagues, comparing our international research experiences and marveling at the diversity of policy and practice variation cross-nationally.

Closer to home in Australia, Colette's research focuses on healthy aging, services for older people, quality of life for older people, and behavioral and social factors in aging and chronic disease self-management. For many years she co-directed the Melbourne Longitudinal Studies on Healthy Aging program (MELSHA) with Professor Hal Kendig, himself a leading light in Australian aging research. The MELSHA 20-year longitudinal study on aging established an evidence base to inform health promotion programs for older people, a relatively novel idea when it was first established in the 1990's, as most research on aging in Australia at that time focused on the "burden of aging" and had not really embraced the personal and societal gains of increased longevity. The distance traveled in that time is evident in the UN declaration of the Decade of Healthy Aging, where we are now.

I consider Colette both a colleague and a mentor, invaluable when one is new to a place / culture / society. I joined the Australian Psychological Society very soon after arriving in Australia in 2000, and found a host of colleagues in the gerontological space, including Colette. Together we have planned symposia and supported both new and more established colleagues in their research endeavors, including getting research implemented in practice. In recognition of her many contributions to the psychology profession over time, she is a Fellow of the Australian Psychological Society (APS) as well as the APS College of Health Psychology, and is much valued by younger colleagues for her mentoring skills.

The movement of people often takes them across institutions, and Colette has held a variety of roles at several of Australia's leading universities, as well as in overseas institutions. Colette holds Honorary professorial positions at Peking University, China and the Research School of Population Health at the Australian National University in Canberra. For a time, she was the Research Director of the International Primary Health Care Research Institute, in Shenzhen, China. She was also previously the Director of the Royal District Nursing Service (RDNS) Institute, an opportunity for her to implement age-related research into practice on the ground. She has also been Director of Research and Professor of Healthy Aging in the School of Primary Health Care at Monash University. Of course, having held so many positions directing research at a high level, it was inevitable that she would rise to the level of Associate Dean Research at yet another well-regarded university for aging research, namely La Trobe University. This wealth of institutional and management experiences was personally invaluable to me, as I progressed from a largely clinical practice and research background through more managerial and higher level research positions over the course of my own career. Colette's advise on navigating the complexities of accreditation guidelines and policy (part of an important role I undertook at a national level for 5 years) was one example of her mentoring, where her experience with stakeholders with very different agendas, drivers and worldviews was invaluable to me in my development as a leader and influencer of policy in my own right.

Extensive experience in teaching and curriculum development in the areas of gerontology, research methods and psychosocial aspects of health led to her management of the Australian Corporate Public Health Postgraduate Program. This program is specifically designed for staff in the Commonwealth Department of Health and Aged Care, with a focus on policy issues in public health. As a foundational member of the national consortium that developed this national postgraduate curriculum on aging under the Public Health Education and Research program, Colette's work has touched the lives of many aspiring scholars and practitioners.

Colette has a career total of over 260 publications including well-regarded peer-reviewed papers, book chapters, and authored books making her one of the most prolific researchers in aging and public health. Her published work spans an amazing array of topics, across both primary research and policy foci. Some of her most cited work has focused on sensory impairments (1, 2), falls (3), and illness and disability (4) in later life. Implementation of research into practice is an important part of her legacy, as is cross-disciplinary research (5, 6). Her research expertise includes longitudinal and mixed methods approaches, systematic reviews, program evaluations, and randomized controlled trials. Her research on the social determinants of health (7) foreshadowed the burgeoning body of work in this area. An exciting aspect of her new work at the Health Innovation and Transformation Center at Federation University over the next 5 years, is a program of research on chronic disease prevention and management at the intersection of behavioral, genomics, and digital health interventions building on her work in Australia and China (8).

Throughout her career, Colette has taken a keen interest in how cultural aspects of older adults must inform their access to care. Whether in access to dementia services (9), management of chronic health conditions (10), or training in diversity for health and aged care workers (11), Colette's contributions in the cross-cultural space will be her most lasting contributions to women in science. I personally am extremely grateful for her friendship, collegiality, and mentoring of a transplanted American in Australia.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

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

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The association between lower socioeconomic position and functional limitations is partially mediated by obesity in older adults with symptomatic knee osteoarthritis: Findings from the English Longitudinal Study of Ageing

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Objective: To assess the longitudinal associations of socioeconomic position (SEP) with functional limitations and knee joint replacement surgery (JRS) in people with symptomatic knee osteoarthritis (OA), and whether body mass index (BMI) mediated these relationships.

Methods: Data came from the English Longitudinal Study of Ageing, a national longitudinal panel study of adults aged ≥50 years. A total of 1,499 participants (62.3% female; mean age 66.5 (standard deviation (SD) 9.4) years; 47.4% obese) self-reporting an OA diagnosis and knee pain, with at least one BMI measurement were included. Mixed effect models estimated longitudinal associations of each SEP variable (education, occupation, income, wealth and deprivation index) and obesity (BMI ≥30.0 kg/m^2) with repeated measures of functional limitations. Cox regression analyses estimated associations between SEP indicators and obesity at baseline and risk of knee JRS at follow-up. Structural equation modeling estimated any mediating effects of BMI on these relationships.

Results: Lower SEP and obesity at baseline were associated with increased odds of functional limitations in people with knee OA [e.g., difficulty walking 100 yards: no qualification vs. degree adjOR 4.33 (95% CI 2.20, 8.55) and obesity vs. no obesity adjOR 3.06 (95% CI 2.14, 4.37); similar associations were found for the other SEP indicators]. A small proportion of the association between

lower SEP and functional limitations could be explained by BMI (6.2–12.5%). Those with lower income, lower wealth and higher deprivation were less likely to have knee JRS [e.g., adjHR most vs. least deprived 0.37 (95% CI 0.19, 0.73)]; however, no clear association was found for education and occupation. Obesity was associated with increased hazards of having knee JRS [adjHR 1.87 (95% CI 1.32, 2.66)]. As the direction of the associations for SEP and obesity with knee JRS were in opposite directions, no mediation analyses were performed.

Conclusions: Lower SEP was associated with increased odds of functional limitations but lower hazards of knee JRS among people with knee OA, potentially indicating underutilization of JRS in those with lower SEP. Obesity partially mediated the relationship between lower SEP and increased odds of functional limitations, suggesting adiposity as a potential interventional target.

KEYWORDS

socioeconomic position (SEP), obesity, functional limitations, joint replacement surgery, cohort study, ageing

Introduction

Globally, osteoarthritis (OA) is one of the leading causes of years lived with disability (1). Evidence has shown that there is a "discordance" between joint damage (measured through imaging) and symptomatic progression (measured through pain and disability questionnaires) in OA (2). Functional limitations, rather than structural changes, capture the impact of the disease on the day-to-day lives of people with OA (3). In addition, functional disability is an important predictor for mortality in people with OA (4).

There is currently no cure for OA. Therefore, the mainstay of treatment combines management of symptoms with pain relief, physiotherapy and, in end stage disease, joint replacement surgery (JRS) (5). Although JRS improves pain, function, and quality of life (6), joint replacements have a finite life expectancy and revision surgery may carry risks, such as infections (5). Understanding risk factors for functional limitations and JRS in people with OA is important as it allows physicians to monitor closely patients who are at increased risk for these adverse outcomes and identify factors that may modify this risk early in the disease process.

Socioeconomic position (SEP) refers to an individual's economic and social position within a society (7). Those with lower SEP have increased risk for OA (8) and a number of cross-sectional studies have found lower SEP to be associated with worse pain and function in people with OA (9, 10). However, recent research indicates that OA patients with lower SEP are less likely to undergo JRS than OA patients with higher SEP, even in tax-based healthcare systems where medical care is free at the point of use for everyone (11–13). This indicates that there may be an unmet need for JRS among those with lower SEP.

The relationship between lower SEP and worse disease progression may be mediated by obesity. Obesity is a well-known risk factor for the development of OA (14), and a recent prospective study indicated that body mass index (BMI) mediates the relationship between lower SEP and incident OA at any site (15). Although there is conflicting evidence about the relationship between obesity and radiographic progression of knee OA (16–18), recent systematic reviews indicated a strong association between BMI and symptomatic progression measured by pain and function (18), and weight loss resulted in symptomatic improvements (i.e., pain and function) in people with knee OA (19). Obese knee OA patients also have a higher need for knee JRS (20) and at a younger age (21) than non-obese knee OA patients. As the association between SEP and obesity is gender specific (22), the mediating effect of obesity for the relationship between SEP and OA disease progression may also differ by gender. Longitudinal studies are needed to understand how SEP and obesity interact in the progression of OA over time. This could be useful for risk stratification and to target obesity interventions to those who might benefit most.

Therefore, this study aimed to understand the relationships between SEP, obesity and symptomatic OA progression. The main research questions were (1) What are the longitudinal associations between SEP and functional limitations and knee JRS in people with symptomatic knee OA, and do they differ by gender or obesity status?; (2) What are the longitudinal associations between obesity and functional limitations and knee JRS in people with symptomatic knee OA, and do they differ by gender?; (3) Does BMI mediate the associations between a lower SEP and progression of symptomatic knee OA, and do they differ by gender?

Methods

Participants and study design

This study used data from the English Longitudinal Study of Ageing (ELSA), a national longitudinal panel study recording the health, social and economic circumstances of adults aged ≥50 years and their partners, living in private households in England (23). Data collection cycles (referred to as "waves") occur every 2 years with data currently available for analysis for nine waves between 2002 and 2019. With consent an additional nurse visit was offered at waves 2, 4, 6, and 8 where a series of measurements (e.g., blood pressure, blood tests, anthropometric measurements) took place (24). Each wave aims to reassess all members of ELSA (regardless of how long they have been in the study), and collects data on newly recruited participants drawn from the Health Survey of England (HSE). The HSE is an annual cross-sectional study aiming to monitor the health of a representative sample of the English population. Written informed consent was obtained from all participants and ethical approval was acquired from the NHS Research Ethics Committees under the National Research and Ethics Service. The UK Data Service provided anonymized data for this study.

Symptomatic knee OA was defined using two questions asked at each wave. First, participants were asked "Has a doctor ever told you that you have (or had) any of the following conditions on this card?". If "Arthritis" was chosen, they could indicate the type of arthritis (osteoarthritis, rheumatoid arthritis or some other kind of arthritis). A second question was used to specifically classify a patient as having knee OA: "Do you feel knee pain?" (does not specify a timeframe). If participants answered "yes" to this question in the same or a previous wave of the self-reported OA diagnosis, they were classified as having knee OA. Participants with at least one BMI measurement were included. Prevalent OA cases from wave 1 were excluded as we could not ascertain the self-reported date of diagnosis. Baseline assessment was defined as the first time participants reported having OA during waves 2–8. Supplementary Figure 1 shows the flowchart of sample selection for this study.

Measurements/instruments

Exposure variables: Socioeconomic position and obesity at baseline

SEP was only assessed at baseline. The following categorical variables were used as indicators of SEP: highest qualification of education obtained (no qualifications, foreign/other; National Vocational Qualification (NVQ) 1/Certificate of Secondary Education (CSE) or other grade equivalent; NVQ2/General Certificate of Education (GCE) O-level equivalent (qualification normally obtained at age 16 in the UK); NVQ3/GCE A-level equivalent (qualification normally obtained at age 18 in the UK); higher education/below degree; NVQ4/NVQ5/degree or equivalent), current or most recent occupation classified using the UK National Statistics Socioeconomic Classification (NS-SEC)5 (25) (semi-routine occupations; lower supervisory and technical occupations; small employers and own account workers; intermediate occupations; managerial and professional occupations), household equivalised income fifths, household wealth fifths (includes non-housing and primary housing wealth minus debts) and relative deprivation fifths of small areas in England [based on the Index of Multiple Deprivation (IMD)] (26). The IMD is a measurement of relative deprivation of small areas in England based on seven categories of deprivation (income; employment; education, skills and training; health deprivation and disability; crime; barriers to housing and services; and living environment). The reference category for all socioeconomic indicators was the category representing the highest SEP group [i.e., having a degree, managerial and professional occupations, highest income fifth, highest wealth fifth and lowest (least deprived) IMD fifth].

Weight and height were measured by nurses in waves 2, 4, and 6 and by trained interviewers in wave 8. The BMI measurement closest to self-reported OA diagnosis was used. Obesity was defined as a BMI of 30 kg/m^2 or higher. In the regression models, obesity (BMI ≥30.0 kg/m^2) was compared with non-obesity (BMI <30.0 kg/m^2).

Outcome variables: Functional limitations and joint replacement surgery

The first outcome was functional limitations, measured through five self-reported mobility indicators and the Activities of Daily Living (ADL), a self-reported physical capability questionnaire (27), at baseline and follow-up assessments. The five self-reported mobility indicators were recorded as binary variables (ability to perform the activity, yes/no), including: (1) walking 100 yards, (2) getting up from a chair after sitting for long periods, (3) climbing several flights of stairs without resting, (4) climbing one flight of stairs without resting, and (5) stooping, kneeling or crouching. Unlike ADL, which creates a validated score (27), the mobility indicators were not summed to avoid loss of information on specific mobility indicators. ADL comprises six activities, including dressing, walking across a room, bathing/showering, eating, getting in or out of bed and using the toilet. For each ADL, participants answered the question "because of a health or memory problem, do you have difficulty doing any of the activities on this card? Exclude any difficulties that you expect to last <3 months", where participants could respond with yes or no. For this study, a continuous indicator of the number of ADLs where a participants reported "yes" was used. This resulted in a score from 0 to 6, where 0 is no difficulties and 6 is all difficulties present.

The second outcome measure was the first self-reported knee JRS due to arthritis at follow-up (waves 3–9). If participants answered "yes" to the question "whether right/left knee joint was replaced", they were further asked what the reason for the knee replacement was (arthritis, fracture, other reason). If the answer was "arthritis", it was recorded as knee JRS due to arthritis.

Covariates/additional variables

Data on covariates were collected at the baseline wave for each participant and were self-reported, including: gender (male, female), age (in years, continuous variable), ethnicity (white, non-white), smoking status (never smoked, ex-smoker, current smoker), and physical activity based on the classification used in the Allied Dunbar Survey of Fitness (28) (sedentary, low, moderate, high).

An adapted version of the Rheumatic Disease Comorbidity Index (RDCI) (29) was used to account for comorbid illness. All comorbid diseases comprising the RDCI were used [i.e., lung disease, cardiovascular disease, fracture, depression and cancer (all self-reported)], except for stomach ulcers, which are not recorded in ELSA. This resulted in a score from 0 to 8 (where 0 is no comorbidities and 8 the highest comorbidity score). NHS diabetes guidelines indicate that blood sugar levels need to be stable prior to performing surgery as peri-operative complications are more common in people with high blood sugar levels (30). Hence, it was decided to account for time-varying glycated hemoglobin (HbA1c) levels. HbA1c values were measured using nurse-collected blood samples in waves 2, 4, 6, and 8.

Statistical analysis

Descriptive and longitudinal analysis

Baseline characteristics of the study sample were reported for categorical and continuous data using frequencies (%) and means with standard deviation (SD), respectively.

Linear mixed models (LMM) for continuous outcomes and generalized LMM for binary outcomes were used to estimate longitudinal associations between each SEP variable and repeated measures of functional limitations (adjusted for age and gender) and between obesity and repeated measures of functional limitations (adjusting for age, gender, SEP and RDCI). The association between SEP and functional limitations were only adjusted for age and gender as we did not want to adjust for any potential mediators. Mixed effects models take into account the within-person correlation across each participants' repeated measures.

Cox proportional hazards regression analyses estimated associations between each SEP variable and hazards of knee JRS (adjusting for age and gender) and for obesity and hazards of knee JRS (adjusting for age, gender, SEP, RDCI and time-varying HbA1C). Participants contributed person-time from baseline to either (a) date of the wave of knee JRS (the outcome), (b) loss to follow-up (including non-response and death), (c) end of follow-up (wave 9), whichever came first. As severe obesity (BMI >35) may be a contraindication for JRS, this association was tested for non-linearity using multivariable fractional polynomials (MFP). The proportional hazards assumption was tested using the Schoenfeld residuals test, where a p-value of < 0.05 indicates violation of the assumption. The assumption was fulfilled for all analyses.

To investigate whether the aforementioned associations differed by gender (or by SEP for the obesity analyses), interaction terms between obesity/SEP and gender and obesity and SEP were included in the models. If an interaction term was statistically significant ($p \leq 0.05$), stratified analyses were performed.

Missing data were all <3.2%, except for wealth and income, which had 5.8% of missing values from the primary baseline sample of 1,499 (Table 1). The missing data was assumed to be missing at random (MAR). All independent variables with missing data were imputed using multiple imputations using chained equations (MICE) with 10 cycles. Analyses were performed in Stata v14 (StataCorp, College Station, TX).

As a sensitivity analysis, the aforementioned analyses were repeated in a larger sample that also included people with knee OA without a BMI measurement ($n = 305$). Using MICE, BMI was imputed in this sample at the time of OA diagnosis.

Mediation analysis

Structural equation modeling (SEM) using the Lavaan package in R was used to estimate the mediating effect of BMI on the relationship between SEP and functional limitations. The total effect of SEP on functional limitations can be divided into the indirect effect (i.e., effect mediated by BMI) and direct effect (i.e., effect independent of BMI).

Using confirmatory factor analysis, SEP was defined as a latent variable with education, occupation, wealth and income as observed indicators (the factor loading of IMD was non-significant ($p < 0.05$) and was therefore not included as an indicator). Mobility was defined as a latent variable with the five different indicators mentioned previously. Due to the unbalanced nature of our dataset (i.e., different number of time points for each observation), we were not able to use repeated measures in the SEM; therefore, average scores of both mobility and ADL were calculated.

Fit indices were used to assess the fit of the model, including comparative fit index (CFI) (≥0.95 indicates good fit), root mean square error of approximation (RMSEA) (≤0.08 indicates good fit) and standardized root mean square residual (SRMSR) (≤0.08 indicates good fit). The diagonally weighted least squares estimator (called 'WLSMV' in Lavaan) was used as the SEP indicators were non-normally distributed ordinal variables

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TABLE 1 Baseline characteristics of the primary sample ($n = 1,499$) stratified by obesity status.

Characteristics	With obesity ($n = 711$)		Without obesity ($n = 788$)	
	Frequencies (%)/mean (SD)	Missing	Frequencies (%)/mean (SD)	Missing
Age, years	65.3 (8.8)	4 (0.6%)	67.7 (9.8)	8 (1.0%)
Gender, female	467 (65.7%)	0 (0.0%)	467 (59.3%)	0 (0.0%)
Ethnicity, white	682 (95.9%)	0 (0.0%)	759 (96.3%)	0 (0.0%)
Education		5 (0.7%)		4 (0.5%)
No qualification	267 (37.6%)		261 (33.1%)	
Other	75 (10.5%)		93 (11.8%)	
CSE/NVQ1	40 (5.6%)		34 (4.3%)	
O-level/NVQ2/GCE	139 (19.5%)		126 (16.0%)	
A-level/NVQ3	53 (7.5%)		58 (7.4%)	
Higher education/<degree	72 (10.1%)		107 (13.6%)	
Degree/NVQ4/5	60 (8.4%)		105 (13.3%)	
Occupation		23 (3.2%)		21 (2.7%)
Semi-routine	303 (42.6%)		260 (33.0%)	
Lower supervisory/technical	90 (12.7%)		75 (9.5%)	
Small employers	65 (9.1%)		102 (12.9%)	
Intermediate	87 (12.2%)		100 (12.7%)	
Managerial/professional	143 (20.1%)		230 (29.2%)	
Income fifths		34 (4.8%)		53 (6.7%)
1: Lowest	168 (23.6%)		159 (20.2%)	
2	155 (21.8%)		178 (22.6%)	
3	149 (21.0%)		141 (17.9%)	
4	111 (15.6%)		141 (17.9%)	
5: Highest	94 (13.2%)		116 (14.7%)	
Wealth fifths		34 (4.8%)		53 (6.7%)
1: Lowest	210 (29.5%)		159 (20.2%)	
2	152 (21.4%)		158 (20.1%)	
3	128 (18.0%)		137 (17.4%)	
4	117 (16.5%)		140 (17.8%)	
5: Highest	70 (9.8%)		141 (17.9%)	
Area-level deprivation fifths		2 (0.3%)		3 (0.4%)
1: Most deprived	145 (20.4%)		121 (15.4%)	
2	152 (21.4%)		161 (20.4%)	
3	145 (20.4%)		164 (20.8%)	
4	140 (19.7%)		183 (23.2%)	
5: Least deprived	127 (17.9%)		156 (19.8%)	
Smoking status		1 (0.1%)		3 (0.4%)
Never smoked	248 (31.5%)		278 (35.3%)	
Ex-smoker	372 (47.2%)		382 (48.5%)	
Current smoker	90 (11.4%)		125 (15.9%)	
Physical activity		2 (0.3%)		0 (0.0%)
Sedentary	46 (6.5%)		46 (5.8%)	
Low	303 (42.6%)		236 (29.9%)	
Medium	281 (39.5%)		373 (47.3%)	
High	79 (11.1%)		133 (16.9%)	
RDCI comorbidities, two or more	353 (49.6%)	0 (0.0%)	350 (45.4%)	1 (0.0%)

CSE, Certificate of Secondary Education; GCE, General Certificate of Education; kg, kilograms; m, meters; NVQ, National Vocational Qualification; RDCI, rheumatic disease comorbidity index; SD, standard deviation.

(31). Confidence intervals around the indirect effects and the proportion mediated were calculated through bootstrapping. The analyses were adjusted for age, gender and number of follow-up waves. Analyses were also stratified by gender (adjusting for age and number of follow-up waves), as the association between SEP and obesity is gender specific (22).

Results

Description of the cohort

A total of 3,851 participants reported incident OA cases in waves 2–8 of ELSA. Of these, 1,804 (46.8%) reported knee pain on or before their OA diagnosis and were subsequently classified as having symptomatic knee OA. Of these, 1,499 (83.0%) had at least one BMI measurement; these participants comprised the primary baseline sample (Supplementary Figure 1). Of the primary sample, 711 (47.4%) were obese. The participants with obesity were slightly younger and had lower SEP (in terms of education, occupation, income, wealth and deprivation) compared with the participants without obesity (Table 1).

The associations between socioeconomic indicators and functional limitations and knee joint replacement surgery in people with symptomatic knee OA

Functional limitations

A lower SEP (education, occupation, income, wealth and area-level deprivation) was associated with limitations in

TABLE 2 Generalized linear mixed model for the relationships of socioeconomic indicators and obesity with difficulties in mobility.

Predictors	OR (95% CI) of reporting difficulty with each of the specified physical tasks									
	Walking 100 yards		Getting up from chair		Climbing several stairs		Climbing one stair		Stooping, kneeling, crouching	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Education										
No qualification	6.06 (3.04, 12.07)	4.33 (2.20, 8.55)†	3.02 (2.01, 4.53)	3.07 (2.04,	8.37 (4.89, 14.34)	6.84 (4.01, 11.67)†‡	9.28 (5.35, 16.09)	6.69 (3.90, 11.49)‡	3.19 (2.01, 5.05)	2.91 (1.83, 4.63)†‡
4.63)†‡	1.51 (0.65, 3.52)	1.29 (0.56, 2.97)†	1.93 (1.18, 3.16)	1.94 (1.19, 3.18)†	3.21 (1.68, 6.16)	2.93 (1.54, 5.57)†‡	3.10 (1.60, 5.98)	2.57 (1.35, 4.89)	1.97 (1.12, 3.45)	1.89 (1.08, 3.32)†‡
Other										
CSE/NVQ1	3.42 (1.19, 9.83)	2.66 (0.94, 7.52)†	2.95 (1.57, 5.56)	3.00 (1.58, 5.63)†	4.15 (1.80, 9.55)	3.55 (1.56, 8.11)†‡	3.27 (1.43, 7.50)	2.75 (1.22, 6.21)‡	2.33 (1.13, 4.82)	2.16 (1.05, 4.47)†‡
O-level/NVQ2/GCE	1.76 (0.82, 3.77)	1.72 (0.81, 3.63)†	2.33 (1.49, 3.64)	2.33 (1.49, 3.65)†	3.03 (1.69, 5.45)	3.00 (1.69, 5.35)†‡	2.65 (1.45, 4.83)	2.51 (1.40, 4.51)‡	1.93 (1.16, 3.20)	1.91 (1.15, 3.17)†‡
A-level/NVQ3	1.25 (0.49, 3.22)	1.39 (0.55, 3.53)†	1.88 (1.08, 3.26)	1.88 (1.08, 3.25)†	2.27 (1.10, 4.68)	2.34 (1.15, 4.78)†‡	1.94 (0.93, 4.05)	2.08 (1.01, 4.26)‡	1.28 (0.69, 2.38)	1.30 (0.70, 2.41)†‡
Higher education/<degree	0.96 (0.42, 2.21)	0.92 (0.41, 2.09)†	1.73 (1.07, 2.80)	1.73 (1.07, 2.80)†	2.10 (1.12, 3.94)	2.02 (1.09, 3.76)†‡	1.37 (0.71, 2.63)	2.49)‡	1.52 (0.88, 2.61)	1.49 (0.87, 2.57)†‡
Degree/NVQ4/5	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Occupation										
Semi-routine	4.44 (2.66, 7.43)	4.54 (2.74, 7.51)	2.00 (1.48, 2.70)	1.95 (1.44, 2.63)	3.37 (2.22, 5.10)	3.36 (2.23, 5.04)†	5.47 (3.65, 8.19)	5.29 (3.57, 7.84)	2.23 (1.58, 3.16)	2.14 (1.51, 3.03)
Lower supervisory/technical	3.39 (1.70, 6.80)	3.13 (1.59, 6.15)	1.57 (1.04, 2.38)	1.60 (1.05, 2.42)	1.95 (1.10, 3.45)	1.89 (1.08, 3.30)†	3.27 (1.89, 5.64)	3.25 (1.92, 5.50)	2.35 (1.43, 3.84)	2.38 (1.46, 3.90)
Small employers	2.46 (1.21, 5.00)	2.11 (1.05, 4.24)	1.63 (1.07, 2.49)	1.63 (1.07, 2.49)	2.06 (1.17, 3.64)	1.97 (1.12, 3.44)†	2.40 (1.39, 4.15)	2.21 (1.30, 3.75)	1.86 (1.15, 3.03)	1.84 (1.13, 2.98)
Intermediate	1.05 (0.52, 2.13)	1.13 (0.56, 2.28)	1.07 (0.72, 1.60)	1.02 (0.68, 1.53)	2.01 (1.18, 3.43)	2.05 (1.21, 3.45)†	1.88 (1.10, 3.19)	1.77 (1.05, 2.99)	1.44 (0.91, 2.28)	1.32 (0.83, 2.11)
Managerial/professional	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Income fifths										
1: Lowest	8.92 (4.44, 17.93)	7.37 (3.70, 14.68)	2.25 (1.52, 3.33)	2.26 (1.53, 3.34)†	3.94 (2.32,6.67)	3.45 (2.04, 5.81)†‡	7.88 (4.61, 13.47)	6.39 (3.79, 10.78)	1.87 (1.19, 2.94)	1.71 (1.08, 2.69)‡
2	9.23 (4.61, 18.50)	6.34 (3.20, 12.57)	2.01 (1.37, 2.96)	2.02 (1.37, 3.00)†	5.09 (2.98, 8.69)	(2.35, 6.80)†‡	8.65 (5.10, 14.65)	6.40 (3.83, 10.70)	2.31 (1.46, 3.66)	2.09 (1.31, 3.31)‡
3	7.40 (3.57, 15.37)	5.32 (2.60, 10.91)	1.98 (1.31, 2.99)	1.99 (1.31, 3.01)†	3.48 (2.01, 6.00)	2.86 (1.66, 4.92)†‡	6.19 (3.57, 10.73)	4.64 (2.71, 7.93)	2.25 (1.40, 3.60)	2.04 (1.27, 3.27)‡
4	2.26 (1.08, 4.76)	1.94 (0.93, 4.03)	1.41 (0.93, 2.14)	1.41 (0.93, 2.15)†	1.77 (1.03, 3.07)	2.80)†‡	2.46 (1.41, 4.29)	2.21 (1.29, 3.81)	1.34 (0.82, 2.19)	1.30 (0.80, (0.80, 2.11)‡
5: Highest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Wealth fifths										
1: Lowest	36.11 (18.07, 72.15)	36.50 (18.60, 71.63)†	3.81 (2.60, 5.60)	3.79 (2.58, 5.56)	11.96 20.33)	12.05 (7.17, 20.25)†‡	21.74 (12.82, 36.86)	21.63 (13.01, 35.96)	4.43 (2.81, 6.97)	4.38 (2.79, 6.87)
2	15.64 (7.78, 31.45)	14.93 (7.57, 29.44)†	2.35 (1.60, 3.45)	2.33 (1.59, 3.42)	5.12 (3.02, 8.66)	4.95 (2.97, 8.27)†‡	8.07 (4.76, 13.68)	7.51 (4.52, 12.45)	2.92 (1.86, 4.58)	2.85 (1.83, 4.45)
3	5.06 (2.45, 10.45)	4.48 (2.21, 9.07)†	1.73 (1.16, 2.57)	1.71 (1.15, 2.54)	2.87 (1.68, 4.91)	2.64 (1.56, 4.48)†‡	4.06 (2.36, 6.98)	3.61 (2.14, 6.08)	1.92 (1.20, 3.07)	1.83 (1.14, 2.91)
4	3.43 (1.64, 7.15)	3.20 (1.58, 6.54)†	1.37 (0.91, 2.04)	1.35 (0.90, 2.02)	2.25 (1.30, 3.88)	3.67)†‡	2.58 (1.48, 4.51)	2.38 (1.39, 4.07)	1.80 (1.12, 2.90)	1.74 (1.09, (1.09, 2.78)
5: Highest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Area-level deprivation fifths										
5: Most deprived	8.44 (4.42, 16.13)	11.55 (6.11, 21.82)†	2.42 (1.65, 3.56)	2.48 (1.69, 3.65)	3.31 (1.94, 5.65)	4.00 (2.34, 6.73)†‡	6.33 (3.81, 10.50)	8.20 (5.00, 13.43)†‡	2.52 (1.59, 3.99)	2.78 (1.76, 4.40)
4	3.86 (2.08, 7.19)	4.83 (2.63, 8.86)†	1.65 (1.15, 2.37)	1.69 (1.17, 2.43)	1.80 (1.09, 2.98)	2.05 (1.25, 3.35)†‡	3.56 (2.19, 5.79)	4.28 (2.67, 6.86)†‡	1.33 (0.87, 2.03)	1.44 (0.94, 2.20)

(Continued)

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TABLE 2 (Continued)

Predictors	OR (95% CI) of reporting difficulty with each of the specified physical tasks									
	Walking 100 yards		Getting up from chair		Climbing several stairs		Climbing one stair		Stooping, kneeling, crouching	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
3	1.45 (0.77, 2.73)	1.62 (0.89, 2.99)†	1.04 (0.72, 1.49)	1.05 (0.73, 1.51)	1.18 (0.72, 1.94)	1.25 (0.77, 2.04)†‡	1.75 (1.07, 2.86)	1.92 (1.20, 3.09)†‡	1.19 (0.78, 1.83)	1.25 (0.82, 1.90)
2	1.76 (0.95, 3.27)	1.93 (1.06, 3.52)†	1.31 (0.91, 1.87)	1.32 (0.92, 1.89)	1.46 (0.89, 2.40)	1.54 (0.95, 2.50)†‡	2.14 (1.32, 3.46)	2.31 (1.45, 3.68)†‡	1.45 (0.95, 2.20)	1.50 (0.98, 2.27)
1: Least deprived	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Obesity										
Obesity	3.51 (2.37, 5.20)	3.06 (2.14, 4.37)	2.06 (1.63, 2.59)	1.74 (1.39, 2.19)	3.92 (2.86, 5.37)	3.21 (2.40, 4.28)	3.18 (2.35, 4.31)	2.68 (2.05, 3.52)	2.77 (2.11, 3.63)	2.39 (1.83, 3.12)
Non-obesity	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
BMI per 1 kg/m^2 increment	1.14 (1.10, 1.17)	1.13 (1.09, 1.16)	1.08 (1.06, 1.10)	1.06 (1.04, 1.08)	1.56 (1.12, 1.19)	1.14 (1.11, 1.16)	1.12 (1.09, 1.14)	1.11 (1.08, 1.13)	1.12 (1.10, 1.15)	1.11 (1.08, 1.14)

BMI, body mass index; CI, confidence interval; NVQ, National Vocational Qualification; OR, odds ratio; RDCI, rheumatic disease comorbidity index; ref, reference category. SEP indicators adjusted for age and gender. Obesity/BMI adjusted for age, gender, SEP and RDCI.
† Significant interaction with gender (0.001>p<0.05); therefore these estimates were only adjusted for age.
‡ Significant interaction between SEP and obesity (0.01>p<0.05). Stratified analyses for gender and obesity are shown in Supplementary Tables 2, 3. No evidence of interaction between obesity and gender (0.09 > *p* < 0.87).

mobility (Table 2) and worse ADL scores (Table 3). For example, those with no qualification were more likely to have difficulties with walking 100 yards [adjOR 4.33 (95% CI 2.20, 8.55)] and had worse daily function based on ADL scores [adj regression-coefficient 0.31 (95% CI 0.11, 0.48)] compared with those with a degree.

For the mobility indicators, stratified analyses showed that the associations were generally stronger for men compared with women (Supplementary Table 2) and for non-obese compared to obese people with OA (Supplementary Table 3). For ADL scores, the associations between lower education, higher deprivation index and more limitations in ADL were stronger for men than women (Supplementary Table 4).

Similar results were found for the sensitivity analyses with imputed data for missing BMI (Supplementary Tables 5, 6).

Knee joint replacement surgery

Over a mean follow-up of 4.7 years (SD 2.8), 144 (9.6%) people with symptomatic knee OA reported having at least one knee JRS (8,427 person-years). Education and occupation were not associated with undergoing knee JRS (Table 4). However, those with the lowest income, lowest wealth and highest deprivation index were less likely to undergo knee JRS compared with the highest income, highest wealth and lowest deprivation index [adjusted hazard ratios (adjHRs) 0.64 (95% CI 0.38, 1.06), 0.55 (95% CI 0.33, 0.93), and 0.37 (95% CI 0.19, 0.73), respectively].

The interaction terms indicated that the relationships of education and occupation with knee JRS differed by gender. Stratified analyses indicated opposite effect sizes for men and women; for example, adjHRs no qualification vs. degree were 2.00 (95% CI 0.65, 6.14) for men and 0.39 (95% CI 0.19, 0.79) for women (Supplementary Table 7). There was no interaction between obesity and SEP indicators for knee JRS. The results were in line with those of the sensitivity analyses (Supplementary Table 8).

The associations between obesity and functional limitations and knee joint replacement surgery in people with symptomatic knee OA

Functional limitations

Overall, those with obesity had increased risks for limitations in mobility [e.g., for walking 100 yards: adjOR 3.06 (95% CI 2.14, 4.37)] and daily function based on higher ADL scores [adj regression-coefficient 0.16 (95% CI 0.06, 0.27)] compared with those without obesity (Tables 2, 3). There were no gender differences for this association. Similar results were found for the sensitivity analyses (Supplementary Tables 5, 6).

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TABLE 3 Linear mixed effects models for the relationships of socioeconomic indicators and obesity with difficulties in activities in daily living score (0–6, 0 = no difficulties).

Predictors	Regression coefficient* (95% CI)	
	Unadjusted	Adjusted
Education		
No qualification	0.36 (−0.17, 0.54)	0.31 (0.11, 0.48)†
Other	0.06 (−0.17, 0.28)	0.03 (−0.20, 0.25)†
CSE/NVQ1	0.23 (−0.07, 0.52)	0.18 (−0.11, 0.47)†
O-level/NVQ2/GCE	0.14 (−0.07, 0.35)	0.14 (−0.07, 0.34)†
A-level/NVQ3	0.03 (−0.23, 0.28)	0.05 (−0.21, 0.30)†
Higher education/<degree	−0.14 (−0.36, 0.09)	−0.15 (−0.37, 0.08)†
Degree/NVQ4/5	Ref	Ref
Occupation		
Semi-routine	0.44 (0.30, 0.58)	0.45 (0.31, 0.60)
Lower supervisory/technical	0.32 (0.12, 0.51)	0.30 (0.10, 0.49)
Small employers	0.38 (0.19, 0.58)	0.36 (0.17, 0.56)
Intermediate	0.16 (−0.03, 0.35)	0.19 (−0.00, 0.38)
Managerial/professional	Ref	Ref
Income fifths		
1: Lowest	0.42 (0.24, 0.60)	0.39 (0.21, 0.56)
2	0.50 (0.32, 0.69)	0.43 (0.25, 0.62)
3	0.34 (0.15, 0.53)	0.28 (0.09, 0.47)
4	0.08 (−0.11, 0.27)	0.05 (−0.14, 0.25)
5: Highest	Ref	Ref
Wealth fifths		
1: Lowest	0.75 (0.58, 0.92)	0.75 (0.58, 0.92)
2	0.52 (0.34, 0.70)	0.51 (0.33, 0.69)
3	0.21 (0.03, 0.40)	0.19 (0.01, 0.38)
4	0.17 (−0.02, 0.36)	0.16 (−0.02, 0.35)
5: Highest	Ref	Ref
Area-level deprivation fifths		
5: Most deprived	0.60 (0.42, 0.77)	0.65 (0.48, 0.83)†
4	0.37 (0.20, 0.54)	0.41 (0.25, 0.58)†
3	0.14 (−0.03, 0.31)	0.16 (−0.01, 0.33)†
2	0.21 (0.04, 0.38)	0.22 (0.06, 0.39)†
1: Least deprived	Ref	Ref
Obesity		
Obesity	0.21 (0.10, 0.32)	0.16 (0.06, 0.27)
Non-obesity	Ref	Ref
BMI per 1 kg/m^2 increment	0.02 (0.01, 0.03)	0.02 (0.01, 0.03)

BMI, body mass index; CI, confidence interval; CSE, certificate of secondary education; NVQ, National Vocational Qualification; OR, odds ratio; RDCI, rheumatic disease comorbidity index; ref, reference category. SEP indicators adjusted for age and gender. Obesity/BMI adjusted for age, gender, SEP and RDCI. No evidence of interactions ($0.08 > p < 0.83$), except for education and gender ($p = 0.001$) and IMD and gender ($p = 0.008$).
*Regression coefficient is interpreted as: for every one unit increase in the predictors, the outcome will increase/decrease by the regression coefficient.
†As interaction terms between education/area-level deprivation and gender were statistically significant, these estimates are not adjusted for gender; instead, stratified analyses for these are shown in Supplementary Table 4.

TABLE 4 Cox proportional hazard regression for the relationships of socioeconomic indicators and obesity with knee joint replacement surgery.

Predictors	Unadjusted HR (95% CI)	Adjusted HR (95% CI)
Education		
No qualification	0.77 (0.43, 1.37)	0.71 (0.39, 1.28)
Other	1.42 (0.76, 2.68)	1.34 (0.71, 2.55)
NVQ1/CSE	1.23 (0.53, 2.84)	1.17 (0.51, 2.73)
O-level/NVQ2/GCE	0.91 (0.49, 1.70)	0.90 (0.48, 1.68)
A-level/NVQ3	1.05 (0.50, 2.20)	1.06 (0.51, 2.22)
Higher education/<degree	1.28 (0.69, 2.39)	1.25 (0.67, 2.34)
Degree/NVQ4/5	Ref	Ref
Occupation		
Semi-routine	0.69 (0.45, 1.05)	0.69 (0.45, 1.06)
Lower supervisory/technical	1.07 (0.63, 1.84)	1.07 (0.62, 1.83)
Small employers	1.03 (0.60, 1.79)	1.03 (0.60, 1.79)
Intermediate	0.80 (0.46, 1.39)	0.79 (0.45, 1.39)
Managerial/professional	Ref	Ref
Income fifths		
1: Lowest	0.66 (0.40, 1.09)	0.64 (0.38, 1.06)
2	0.65 (0.39, 1.07)	0.60 (0.36, 1.00)
3	0.74 (0.44, 1.25)	0.70 (0.41, 1.19)
4	0.73 (0.44, 1.23)	0.72 (0.43, 1.21)
5: Highest	Ref	Ref
Wealth fifths		
1: Lowest	0.54 (0.32, 0.91)	0.55 (0.33, 0.93)
2	0.52 (0.30, 0.89)	0.52 (0.30, 0.89)
3	0.95 (0.58, 1.56)	0.95 (0.58, 1.55)
4	0.74 (0.44, 1.24)	0.74 (0.44, 1.24)
5: Highest	Ref	Ref
Index of multiple deprivation fifths		
5: Most deprived	0.36 (0.18, 0.70)	0.37 (0.19, 0.73)
4	0.80 (0.50, 1.30)	0.83 (0.51, 1.34)
3	0.80 (0.49, 1.30)	0.81 (0.49, 1.31)
2	0.88 (0.56, 1.40)	0.89 (0.56, 1.41)
1: Least deprived	Ref	Ref
Obesity		
Obesity	1.56 (1.12, 2.17)	1.87 (1.32, 2.66)
Non-obesity	Ref	Ref
BMI per 1 kg/m^2 increment	1.05 (1.02, 1.07)	1.07 (1.04, 1.10)

BMI, body mass index; CI, confidence interval; HR, hazard ratio; NVQ, National Vocational Qualification; RDCI, rheumatic disease comorbidity index; ref, reference category. SEP indicators adjusted for age and gender. Obesity/BMI adjusted for age, gender, SEP, RDCI and time-varying HbA1c.
Some indication of interaction for education and gender ($p = 0.06$) and occupation and gender ($p = 0.07$), but not for other SEP indicators ($p > 0.32$). Stratified analyses by gender for education and occupation are shown in Supplementary Table 7. No evidence of interactions between obesity and gender ($p = 0.961$) and SEP indicators ($p > 0.081$).

Knee joint replacement surgery

Obese people with symptomatic knee OA were more likely to report knee JRS than the non-obese people with OA [adjHR 1.87 (95% CI 1.32, 2.66)] (Table 4). The MFP analysis indicated a linear relationship between BMI and knee JRS fit the data best: the higher the BMI, the higher the hazards for knee JRS [adjHR 1.07 (95% CI 1.04, 1.10)]. There were no gender differences for this association. The results did not differ in the sensitivity analyses (Supplementary Table 8).

Mediation of obesity for the relationship between lower socioeconomic position and functional limitations

The fit indices of the confirmatory factor analyses and SEMs are shown in Supplementary Table 9. A small proportion of the association between lower SEP and functional limitations was mediated by obesity: 12.5% (95% CI 8.3%, 17.3%) for mobility and 6.2% (95% CI 2.2%, 11.7%) for ADL (Table 5 and Figure 1). Stratified analyses by gender indicated that the proportion mediated by obesity was higher among women [19.4% (95% CI 11.0%, 29.4%) for mobility and 11.7% (95% CI 4.8%, 22.9%) for ADL] compared with men [5.5% (95% CI 1.6%, 10.9%) for mobility and no indirect effect for ADL] (Table 5). As there was no clear association between lower SEP and increased hazards of knee JRS, no mediation analyses were performed for knee JRS as an outcome.

Discussion

This study indicates that both lower SEP and obesity at baseline were associated with greater odds of functional limitations, measured by mobility and ADL, in people with symptomatic knee OA participating in a large national longitudinal panel study of adults aged ≥50 years in England. A small proportion of the association between lower SEP and functional limitations could be explained by obesity (6.2% for ADL and 12.5% for mobility). Despite this, those with a lower income, lower wealth and higher deprivation were less likely to undergo knee JRS.

In our study among those with symptomatic knee OA a range of SEP indicators were associated with more functional limitations over time. Our findings are consistent with research suggesting that lower SEP is associated with functional limitations in knee and hip OA (9, 10, 32, 33); however, most of these studies were cross-sectional (9, 10, 32) making it difficult to determine the temporal nature of the association. Although the mechanisms are unclear, in our study obesity contributed in part to the association between a lower SEP and functional limitations. However, other factors may also contribute, such as a higher prevalence of comorbidities, lifestyle factors (e.g., physical activity) (34) and local factors (e.g., access to primary care services and less safe places to exercise in deprived areas) (35). There may also be inequalities regarding delivery of care. For example, research has indicated that people with OA with a lower education were less likely to receive advice on exercise compared to those with a higher education (36). Whether these factors mediate the rest of the association between lower SEP and adverse outcomes in symptomatic knee OA should be investigated in future studies.

Similar to our findings, obesity has also been associated with increased functional limitations in people with OA in both cross-sectional (37) and longitudinal studies (38, 39). In general, the relationship between a lower SEP and mobility was stronger for men vs. women; however, a larger proportion of this association was mediated by BMI for women vs. men. This indicates that obesity may be a more important factor leading to mobility limitations for women with lower SEP than men. This might be driven by the relationship between a lower SEP and obesity, which generally appears to be stronger for women than men (22). For men, other factors may play a role, such as occupational exposures: previous studies have found that occupational exposures (i.e., pollution and physically demanding jobs) explained the association between SEP and functional limitations in men but not for women (40). To our knowledge, gender differences for this relationship in OA populations have not been assessed previously.

Although the rates of knee JRS among different educational and occupational groups were similar, the relationships appeared to be gender dependent. In lower educational and occupational groups, women were less likely to have knee JRS and men were more likely to have knee JRS compared to higher educational and occupational groups. For income, wealth and deprivation, the lower fifths were less likely to undergo knee JRS compared to the higher fifths and there were no gender differences observed. Other studies in England (11), Sweden (12) and Denmark (13) also found that there was either an inverse (i.e., those with a lower SEP are less likely to undergo knee JRS) or no relationship between SEP and knee JRS. In general, gender differences have been found previously, where women undergo less knee JRS compared with men despite their potentially greater need (41). Our study adds that the gender differences may be more marked in lower SEP groups.

Given the association between a lower SEP and functional limitations, this may indicate underutilisation of knee JRS in lower SEP groups and specifically in women. Despite free medical care at the point of use in England, there are still socioeconomic inequalities in healthcare (42). Reasons may include that those with lower SEP are less likely to be referred to specialists care (43), fewer clinics and public transport to access clinical appointments and surgery are present in deprived communities (35), and less social support among the lower SEP potentially impacting the willingness to undergo surgery (13). Those with lower SEP may also not be able to take time off

TABLE 5 The total, direct and indirect effect *via* BMI of socioeconomic position as a latent variable on functional limitations (as indicated by difficulties in mobility and activities of daily living) in people with knee OA, adjusted for age and gender.

	Total		Direct		Indirect		Proportion mediated (95% CI)*
	β-coefficient (95% CI)	*p*-value	β-coefficient (95% CI)	*p*-value	β-coefficient (95% CI)	*p*-value	
Mobility							
Total	0.483 (0.394, 0.572)	$p < 0.001$	0.423 (0.336, 0.509)	$p < 0.001$	0.061 (0.038, 0.083)	$p < 0.001$	12.5% (8.3, 17.3%)
Men	0.609 (0.460, 0.758)	$p < 0.001$	0.576 (0.428, 0.723)	$p < 0.001$	0.034 (0.009, 0.058)	$p = 0.008$	5.5% (1.6, 10.9%)
Women	0.400 (0.289, 0.511)	$p < 0.001$	0.322 (0.216, 0.428)	$p < 0.001$	0.078 (0.043, 0.122)	$p < 0.001$	19.4% (11.0, 29.4%)
Activities of daily living							
Total	0.224 (0.171, 0.277)	<0.001	0.210 (0.157, 0.264)	<0.001	0.014 (0.004, 0.024)	0.006	6.2% (2.2, 11.7%)
Men	0.292 (0.207, 0.377)	<0.001	0.287 (0.200, 0.374)	<0.001	0.005 (-0.009, 0.019)	0.476	–
Women	0.177 (0.112, 0.243)	<0.001	0.157 (0.091, 0.222)	<0.001	0.021 (0.006, 0.035)	0.007	11.7% (4.8, 22.9%)

CI, confidence interval.
*Calculated by indirect effect/total effect*100%.
95% CI estimated with bootstrapping.
For ADL in men, there was no indirect effect so the proportion mediated was not calculated.

work to accommodate the surgery and recovery. Reasons for gender differences have been attributed to women being less willing to undergo surgery (more willing to accept functional decline, less willing to accept the risk of surgery) and specialists are more likely to recommend surgery to men than women (41). Moreover, in line with previous studies (20, 44, 45), our study confirmed the association between obesity and a higher risk of knee JRS. What our study added was that there was no interaction between obesity and SEP indicators for knee JRS; however, this may be because the two factors cancel each other out, i.e., lower SEP associated with lower rates of surgery and obesity with increased rates of surgery.

Strengths of the study include the fact that it was based on a national population sample and included data on serial assessments for up to 16 years. It also included detailed information concerning a range of SEP indicators including education, occupation, income, wealth and area-level deprivation. However, there are a number of limitations that need to be considered in interpreting the findings. The occurrence of OA was based on self-report and therefore subject to errors of recall and potential misclassification. Data from a systematic review including 11 studies comparing OA self-report (at any site) with medical records or American College of Rheumatology criteria, suggest a sensitivity of 0.75 and specificity of 0.89 for self-report (46). We attempted to minimize misclassification by including a requirement for both self-reported diagnosis and self-reported knee pain; however, this does not exclude it. Therefore, caution is required in interpreting the frequency of OA; however, any misclassification is more likely to reduce the chance of finding significant biological associations (bias toward the null). Moreover, the prevalence of self-reported knee OA in our sample was 12.7% (1,804 out of an eligible sample of ELSA of 14,228 in waves 2–8); this is in line with previously reported symptomatic knee OA prevalence estimates in the US of similar age groups [16.7% of people aged ≥45 years in the Johnston County OA project (47); 12.1% of people aged ≥60 years in NHANES III (48)]. Selection bias may have occurred by only including those with a BMI measurement in the main analyses; however, sensitivity analyses where BMI measurements were imputed did not change our findings. Data concerning JRS was also obtained based on self-report, though given the nature of the procedure it seems less likely that this would be subject to errors of recall. Furthermore, JRS data were obtained relatively contemporaneously to the procedure. ADLs and level of mobility are subject to variation over time and possibly prone to recall bias, although our use of data over multiple time points provides a more robust indicator of functional ability over time. In our study, we did not have any information concerning the severity of the underlying OA or its treatment which may have influenced outcome. It is possible, for example, that those with lower SEP may have had more severe disease or were less likely to have therapy and this may in part explain their more severe disability. Finally, our findings were based on a predominantly white English population and caution is needed in generalizing the findings beyond this setting.

Functional limitations are associated with impaired quality of life (49), work productivity (50) and mortality (4) in people with OA. Weight reduction and physical therapy interventions are effective in reducing functional limitations in OA, though there are few data concerning the impact of such interventions in disadvantaged groups for which further research is indicated (51). JRS is effective in relieving pain and improving function in those with knee OA and the lower frequency of surgery in those with lower wealth and living in deprived areas is of concern particularly given the higher levels of disability in these areas. Mediation studies are needed to understand the reasons

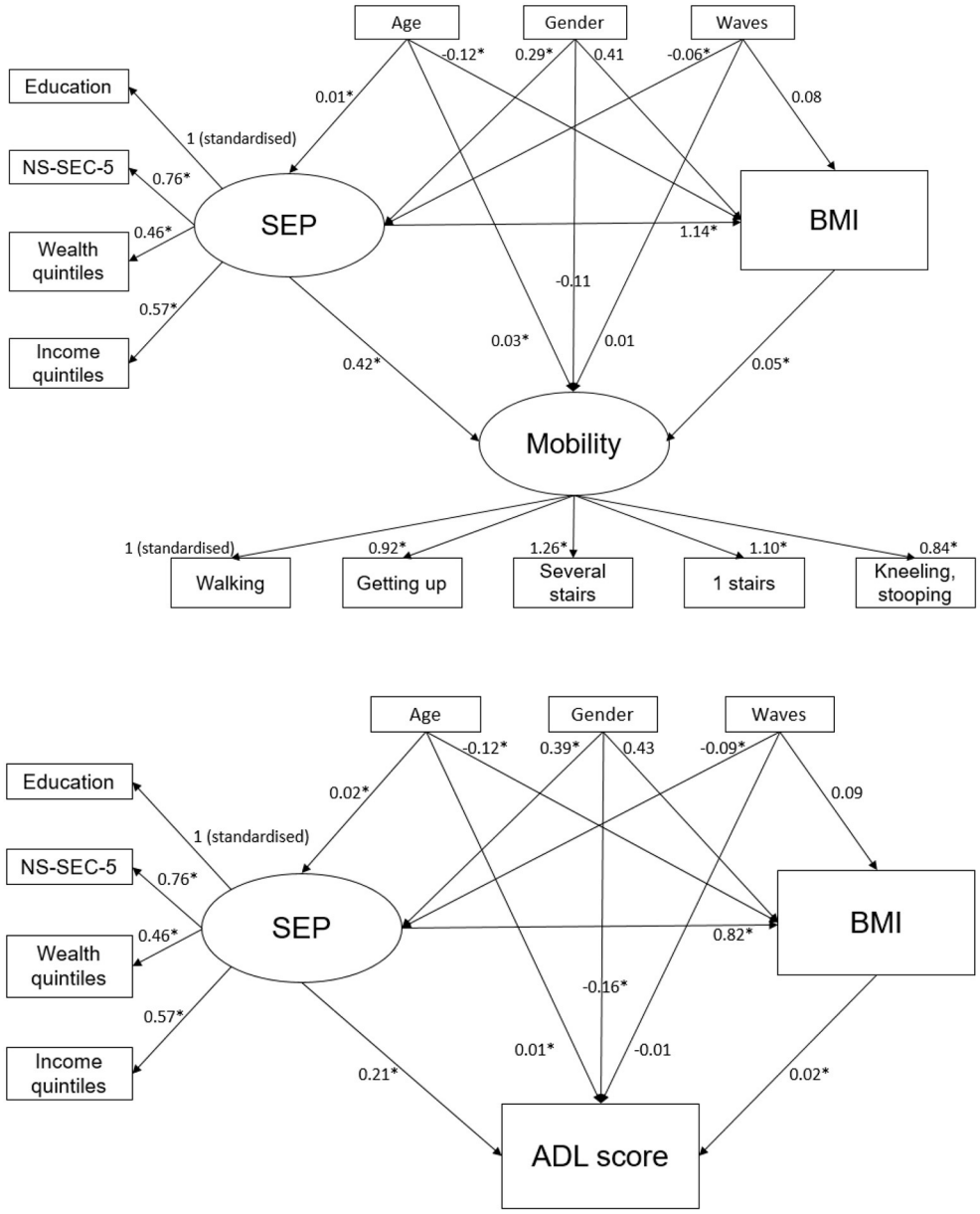

FIGURE 1
The structural equation models for the relationships between socioeconomic position, BMI and mobility/ADL score, adjusted for age, gender and number of waves attended. *Statistically significant ($p < 0.05$). ADL, activities of daily living; BMI, body mass index; NS-SEC, national statistics socioeconomic classification; SEP, socioeconomic position.

why those with a lower SEP, and particularly women, are less likely to have JRS even though they appear to have higher disability levels.

To conclude, knee OA in England is expected to rise due to an increase in the number of people with obesity coupled with population ageing. It is important for public health policy to identify predictors of disability and knee JRS. Our results showed that among those with symptomatic knee OA, lower SEP is associated with increased functional limitations and a reduced likelihood of receiving JRS. The increased functional limitations may in part be due to levels of obesity. Further research is required to understand the mechanisms linking lower SEP and adverse outcomes in knee OA and also the reduced likelihood of JRS.

Data availability statement

Publicly available datasets were analyzed in this study. This anonymized data can be found at: The UK Data Service.

Ethics statement

Written informed consent was obtained from all participants and ethical approval was acquired from the NHS Research Ethics Committees under the National Research and Ethics Service. The UK Data Service provided anonymized data for this study.

Author contributions

RW: conception and design, analysis and interpretation of the data, drafting of the article, and final approval of the article. SV, JG, and JH: conception and design, interpretation of the data, critical revision of the article for important intellectual content, final approval of the article, statistical expertise, and obtaining of funding. MC, TO'N, and RC: conception and design, interpretation of the data, critical revision of the article for important intellectual content, and final approval of the article. SV and JH take responsibility for the integrity of the work as a whole, from inception to finished article. 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

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Prescribing tailored home exercise program to older adults in the community using a tailored self-modeled video: A pre-post study

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Background: Community rehabilitation for older people after hospital discharge is necessary to regain functional ability and independence. However, poor adherence to exercise programs continues to hinder achieving positive health outcomes in older people. This study aimed to evaluate the effectiveness of prescribing a tailored video self-modeled DVD-HEP for 6 weeks, on functional mobility, physical activity, exercise self-efficacy, and health-related quality of life, in a sample of frail older adults.

Materials and methods: A pre- and post-test intervention study design was conducted, with each participant acting as their own control. A convergent, parallel, mixed-methods approach involving quantitative, and qualitative data collection was used. Participants received an individualized assessment at baseline and subsequently were provided with a 30-min tailored 6-week self-modeled DVD-HEP that showed the physiotherapist instructing the participant. The physiotherapist phoned participants fortnightly to encourage engagement in the program and explore responses to it. Outcomes evaluated included functional mobility, balance, gait speed, and exercise self-efficacy.

Results: Participants (n = 15) showed clinically meaningful improvements at follow-up compared to baseline in functional mobility (TUG_{MCID} = 3.4–3.5 s, $3\text{-}MWT_{MCID}$ = 0.1–0.2 m/s) and gait speed ($3\text{-}MWT_{MCID}$ = 0.1–0.2 m/s). There were also significant improvements in balance and self-efficacy for exercise and a 2.5- and a 1.3-fold increase in moderate and light physical activity participation at follow-up compared to baseline. The deductive themes were: (i) Enjoyment, self-efficacy, and wellbeing; (ii) Achieving life goals; (iii) Background music as a motivator to adherence; and (iv) Enhanced motor performance and learning: Task goal mastery, multimodal feedback, autonomy to self-regulate learning. The new inductive theme was (v) Preference for in-person support for exercise.

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Conclusion: Future studies are warranted to compare a tailored self-modeled video HEP to face-to-face programs and other digital health modalities to evaluate older adults' adherence levels and functional improvement.

KEYWORDS

aging, audiovisual demonstration, exercise therapy, frail elderly, functional decline, patient discharge, rehabilitation

1. Background

Aging is not only associated with an increased risk of chronic disease and functional and cognitive decline (1) but also significant health service utilization (2). For example, in 2019–2020, hospitalization rates in Australians aged 65 years and over per 1,000 ranged from 981 to 1,469 per 1,000 person-years, compared with 84 to 598 per 1,000 person-years in persons aged <65 years (3). Between 30 and 60% of older patients experience functional decline after hospitalization, resulting in reduced health-related quality of life and autonomy (4, 5).

Community rehabilitation of older people post-discharge is one of the fundamental approaches to reversing functional decline and improving independence. Exercise and physical activity are established strategies for healthy aging (6, 7). Exercise improves functional mobility, including strength and balance, and positively impacts participation in activities of daily living (1, 8–10).

Self-directed home exercise programs (HEP) are often prescribed to maximize recovery and ensure the maintenance of therapeutic gains produced during supervised treatment (11). The findings of a large randomized controlled trial in older people discharged from hospital rehabilitation wards suggest that tailored health professional education alone is insufficient to drive behavior change, with participants reporting several social and health care barriers to functional recovery and engagement in exercise (12, 13). Furthermore, poor adherence to a HEP continues to significantly hinder the achievement of favorable health outcomes in older people (14). Systematic reviews suggest that the proportion of older adults completing group exercise programs ranged from 65 to 86%, the proportion of sessions attended ranged from 58 to 77%, and the average number of HEP sessions completed ranged from 1.5 to 3 times/week (15, 16). Older people need responsive programs in their local community with wrap-around support (12, 13). Also, for older people to be engaged in exercise, the program needs to be fun and meaningful (17), with exercises tailored to target the individual's needs, preferences, interests, and learning styles (18, 19).

There is emerging evidence supporting the role of digital health technologies as safe and effective models of exercise delivery in older people with multimorbidity (20). Technologies like telephone and videoconferencing are expensive and time-consuming as they need synchronous contact with a health professional (21). While smartphones or online applications can reduce healthcare costs by automating processes (prescription and monitoring progress), older people may face limited uptake due to unfamiliarity and the absence of human engagement (22). A mixed-method study exploring older people's preferences about desired modes to receive HEP found that most selected the video delivery over the combined video and paper formats and the paper-only form (23). The video HEP was chosen for its visual appeal and easy-to-follow instructions. Typically, generic video modeling—with peers or others was used. The combination of video and paper enabled a more comprehensive understanding of HEP—with the video footage showing participants *how* to practice an exercise, and written instructions helped them understand the *why* and remember the *how* (23).

Video self-modeling is a form of observational learning in which individuals observe themselves performing a targeted behavior successfully on video and subsequently imitate the behavior (24). Video self-modeling allows individuals to view themselves as successful, acting appropriately, or performing new tasks. Video self-modeling has been successfully used in professions outside of healthcare. For example, within the sporting context, video self-modeling has been shown to improve tactical skill and knowledge more quickly than coaching (25, 26) and enable deeper self-reflection and learning in structured clinical settings (27). There is, however, limited evidence to support the effect of a tailored self-modeled video HEP for older adults (28, 29).

We previously conducted a small feasibility study using a convenience sample of four older people and provided a 5-week tailored video self-modeled DVD-HEP (30). Participants showed a high adherence to the DVD-HEP over the 5-week intervention. Adherence was enhanced by physical improvement, positive self-reflection about the DVD-HEP, and increased self-efficacy (30). The study concluded that tailored self-modeling videos might be feasible to promote adherence to HEP in community-dwelling older patients post-hip fracture (30). We built on this prior work (30) to assess the impact of a tailored self-modeled DVD-HEP in improving functional outcomes in a larger sample of frail older adults

relative to their baseline scores. The current study aimed to evaluate the effectiveness of prescribing a tailored self-modeled DVD-HEP for 6-weeks on functional mobility, physical activity, exercise self-efficacy, and health-related quality of life. The secondary aim of the study was to evaluate adherence to the tailored self-modeled DVD-HEP throughout the 6-week intervention.

2. Trial registration

The study was registered with the Australian New Zealand Clinical Trials Registry with the registration number: Trial Id: ACTRN12616000946415.

3. Materials and methods

3.1. Design

A pre- and post-test intervention study was conducted, with each participant acting as their own control. A convergent, parallel, mixed-methods approach was used, involving quantitative and qualitative data collection (31).

3.2. Participants and setting

A convenience sample was identified from older adults who sustained a fracture necessitating hospital admission or who experienced functional decline following hospital admission, illness, or a scheduled medical check-up at an outpatient clinic. Recruitment took place from an outpatient aged-care rehabilitation clinic attached to a secondary hospital in metropolitan Perth, Western Australia (WA). All potential participants visited their geriatrician for a scheduled medical check-up or follow-up after hospital discharge and had completed either an inpatient or outpatient rehabilitation program, including follow-up therapy.

Eligibility criteria for inclusion included: (i) aged between 60 and 95 years; (ii) able to speak and understand English; (iii) cognitive ability to engage in a self-directed program [eligible if mini-mental state examination score (MMSE) > 23/30] (32); (iv) not currently participating or completing an exercise program; (v) history of prior completion of a rehabilitation program *via* an outpatient rehabilitation clinic or private therapy clinic; (vi) assessed by the hospital geriatrician to be medically stable; and (vii) below their pre-morbid functional level of activity.

Participants were excluded if they demonstrated: (i) sensory deficits (audio or visual) that could not be overcome with correction (e.g., glasses or hearing aids); or (ii) a known medical diagnosis that either predisposed them to a high risk of falls or precluded them from safely and independently following a HEP. These included patients diagnosed with Parkinson's disease, a recent history of stroke, or postural hypotension. On reviewing a participant's medical records, if there were queries about their safety in using a HEP, the research team consulted with the hospital geriatrician to decide eligibility.

3.3. Intervention

The intervention comprised a 6-week structured HEP, delivered *via* a 30-min video recording on a DVD—henceforth referred to as a DVD-HEP. A JVC camcorder (model no: GZ-HM670BAA) was used to record the video of each customized training routine provided by the therapist, which consisted of a combination of widescreen and close shots of each participant that emphasized key points. The recording was undertaken by a research assistant, who received training from the university's media team to ensure quality control. It took ∼1–1.5 h to record each HEP and ∼3 h of production and editing time to convert it to DVD format. Details about the software and editing can be found in Supplementary material 1.

Each DVD-HEP included a tailored introduction to the exercise program provided by the same physiotherapist, followed by video footage of the participant performing the tailored exercises. The therapist also provided personalized feedback on how the participant executed each exercise. The physiotherapist also appeared in the video and provided the participant with brief, timely, and explicit guidance to facilitate the correct execution of techniques. Feedback included instructions on improving movement accuracy, suggestions on compensatory movements to avoid or contraindications to consider, reminders, encouragement, and visual cues. Although intervention intensity varied across participants, given that 80% of our sample had sustained a fall in the past year, evidence-based intervention components to reduce falls were included in the videos—focusing on lower extremities strength, balance, postural control, and walking (33).

Factors considered while designing the DVD-HEP to ensure fidelity and feasibility are attached in Supplementary material 1 (30). Exercises were designed to be completed with materials readily available at home, including a chair, wall, or bench for handholds. In addition, in line with neuroscience evidence on the benefits of background music for brain plasticity and as a motivator for exercise (34, 35), participants were asked to provide the physiotherapist with their favorite motivational instrumental music track, which was played in the background. The volume of the background music was adjusted to ensure that it did not overpower or clash with verbal cues. Instrumental music was selected to minimize participant distraction or unintended attention to voices and sung lyrics.

3.4. Data collection

3.4.1. Demographics

Demographic data were collected for all participants, including age, gender, the highest level of education, living arrangement, and environment, the number of falls in the last 12 months and whether they sustained a fracture and type of fracture sustained, BMI level and the use of walking aid at home.

3.4.2. Outcomes

3.4.2.1. Primary outcomes

Functional mobility was assessed using Timed Up and Go (TUG) (36), gait speed was assessed using the 3-Meter Walking Test (3-MWT) (37), and balance was measured using the Step Test (38). These outcome measures are validated tools for evaluating community-dwelling older adults' physical function (39, 40).

3.4.2.2. Physical activity

Engagement in physical activity was measured using the Community Healthy Activities Model Program for Seniors (CHAMPS) (41). The measure is suitable for older Australian adults if adequate assistance is provided during administration (42).

3.4.2.3. Exercise self-efficacy

Self-perceived exercise ability and motivation were measured using the Outcome Expectancy for Exercise-2 test (OEE-2) (43), and self-efficacy for exercise was measured using an adapted version of the Self-Efficacy for Exercise scale (SEE) (44, 45). The 13-item OEE-2 was used to rate adults' responses against statements (9-positive items, POEE and 4-negative, NOEE) about the benefits of exercising, using a 5-point Likert scale (0 = strongly agree and 5 = strongly disagree) (46). The SEE scale used in this study rated older adults' confidence about exercise barriers (using an 11-item scale ranging from 0 = not confident to 10 = very confident, with a total score of 110). A sample item includes, "Would you exercise if you felt tired during or after?"

3.4.3. Secondary outcomes

3.4.3.1. Health-related quality of life

Participant perceived health-related Quality of Life (HRQoL) was measured using European Quality of Life-5 Dimensions (EQ-5D-5L) (47).

3.4.3.2. Exercise adherence

Exercise adherence was measured using a daily exercise diary provided at baseline. Participants were asked to complete the log each time they completed an exercise session and, every week, record any reflections about their exercises in the diary.

3.4.3.3. Qualitative

Qualitative feedback from participants about their perceptions and beliefs about completing a HEP using the DVD was explored by reviewing their exercise diaries, fortnightly (3 in total) semi-structured telephone interviews conducted by the physiotherapist and final comments from participants noted down verbatim by the research assistant at the final assessment. Please refer to Supplementary material 2 for an overview of the semi-structured interview schedule.

3.5. Procedure

A face-to-face detailed physiotherapy assessment occurred at baseline. Participants' personal and functional goals and expectations were discussed during this session. The physiotherapist demonstrated each exercise included in the HEP and requested the participant to practice it a few times—until the participant could independently execute each exercise using the correct techniques. At the end of the baseline session, participants were given a tailored paper-based copy of the suggested HEP until they received the DVD-HEP copy in the post. Participants were also given an exercise diary to document their HEP participation, thoughts, and feelings. They were advised to practice 30-min of the HEP at least three times a week over six consecutive weeks (a total of 1.5 h a week). Post-test data collection was conducted by the same physiotherapist and occurred 7-weeks after the baseline session to accommodate a week for DVD-HEP production and delivery.

Over the course of 6-weeks, each participant received three phone calls from the therapist to encourage adherence, discuss progress, and provide technical and clinical support. A semi-structured protocol was followed to minimize subjectivity and safeguard data collection fidelity (30). The topic guide followed a framework of participants' use of the DVD, their feelings about the DVD-HEP, and their response to it (Refer to Supplementary material 2: Interview guide). The phone interview allowed participants a convenient and confidential way to discuss their experiences openly and honestly (48).

Each phone call lasted between 20 and 30 min. The first phone call occurred a week after the initial baseline session and coincided with the check-up that the DVD had arrived and could be used by participants. The second and third calls were 2- and 4 weeks post-DVD arrival, respectively. During the last phone call, the physiotherapist arranged the post-test assessment and reminded participants to bring their exercise diaries to the post-test appointment. The therapist made detailed notes from the phone calls, reflected and summarized them immediately afterward, and then performed member checking with participants at the last appointment.

TABLE 1 Demographic characteristics of participants*.

Age (mean, SD)	80.4 (7.2)
Sex (*n*, %)	
Female	12 (80)
Male	4 (20)
Living arrangements (*n*, %)	
Alone	10 (63)
With partner	4 (25)
With family members	2 (13)
Education (*n*, %)	
Up to year 10	4 (25)
Completed year 12	6 (38)
Apprenticeship or diploma	4 (25)
University degree	2 (12)
Number of falls in the last 12 months (*n*, %)	
None	3 (19)
One	7 (44)
More than one	6 (38)
Diagnosis (*n*, %)	
Functional decline in last 12 months	7 (56)
Fracture, hip	7 (31)
Fracture, other	2 (13)
Duration since the last hospital discharge (*n*, %)	
<3 months	2 (13)
>3 months	9 (56)
Functional decline identified at the out-patient clinic	5 (31)
Used a mobility aid (*n*, %)	
No	10 (63)
Walking stick	3 (19)
Elbow crutch	1 (6)
Four-wheel walker	2 (13)
BMI (*n*, %)	
Healthy weight	8 (50)
Overweight	3 (19)
Obese	5 (31)

*Total percentages may not add due to rounding.

3.6. Analysis

Quantitative data were analyzed using SPSS Version 25 for Windows (49). Participants' demographic profile was summarized using descriptive statistics (Table 1). Primary outcome measures of functional mobility (TUG) (36), gait speed (3-MWT) (37), and balance (Step Test) (38) were recorded as raw scores. CHAMPS activity data levels were categorized into four metabolic equivalents of task (MET) levels as either: very light < 2 METS, light > 2 but < 3 METS, moderate > 3 but <6 METS, or vigorous > 6 METS (41). Each completed activity's mean hours per week were recorded and cross-referenced against its corresponding MET level (41). Mean scores were computed to represent self-efficacy and expected outcome scores (SEE) (45, 46) and OEE scores (44). Additionally, positive and negative OEE-2 scale items were computed to represent respective expectations for exercise (46). Quality of life (EQ-5D-5L) was treated using the Dolan method, which allows a single score to be reliably generated for the categorical items that reflect the overall HRQoL and the visual analog scale (VAS) score (47).

Given our sample size ($n = 15$), we used the Shapiro-Wilk test to assess normality. Given that all outcomes except the CHAMPS were normally distributed, the differences between baseline and post-intervention performance measures were analyzed using a paired-sample *t*-test. Due to the skewed distribution of CHAMPS scores, the Wilcoxon Signed-Rank test was used to assess change in CHAMPS scores. Additionally, changes in the four CHAMPS activity levels over time were determined using mixed models assuming a negative binomial distribution and treating time (intervention) as a fixed effect and participant and activity levels as random effects. Interaction terms between the time points and activity levels were also included in the model.

Qualitative data were analyzed using inductive and deductive thematic approaches (50). The deductive approach was modeled on the framework used in our earlier feasibility study (30). This framework had been identified as wellness, life goals, and positive impact, with a central theme of the DVD format providing self-efficacy and physical improvements, which promoted adherence to the exercise (30). Participants' anonymized diaries, phone call data, and research assistant notes were independently read by two researchers (JAH, AMH) several times to understand the data. Subsequently, each researcher independently organized codes under the main themes using a stepwise categorization process. They later discussed codes and themes until a consensus was reached (50). An inductive approach was used to analyze unanticipated themes in the data—this involved independent open coding and categorization by the same researchers (JAH, AMH). Finally, a third researcher (JC) was invited to review each reviewer's final codes and themes, followed by discussions by all reviewers until a consensus was reached. An audit trail was maintained to connect the sources (50). Representative exemplary quotes are presented in the results (51).

3.7. Ethical considerations

Ethics clearance for the study was obtained from the University of Notre Dame Human Research Ethics Committee (HREC) (Reference number: 015146F) and the South

Metropolitan Health Service (SMHS) HREC (Reference Number: 15–190). All participants provided written informed consent to be included in the study.

4. Results

Recruitment took place between September 2016 and October 2017. The physiotherapist assessed twenty-five potential participants for eligibility over the phone; 20 met the criteria for inclusion, and four were lost to follow-up after enrolment. Of the 16 participants who completed baseline assessments, one could not attend follow-up assessments, and another did not provide physical activity data. Participants' demographic profile is presented in Table 1. Participants' average age was 80.4 years (Standard deviation, $SD = 7.2$ years). Most participants (80%) were female, and two-thirds ($n = 10$) reported living alone in the community. Eleven participants (69%) had a history of hospitalization the year before the study commenced. Only two of the eleven (19%) reported being discharged from the hospital within 3 months of recruitment. Just under 40% ($n = 6$) used a mobility aid at baseline.

4.1. *Post-hoc* sample size justification

Due to hospital changes within the local area health service, the original sample size was reduced to what was expected. Hence a *post-hoc* power calculation was conducted. Our sample size of $n = 14$ in a paired means study design assuming a mean baseline TUG of 17.6 and a standard deviation of the change score of 4.02 had 90% power at alpha 0.05 to detect a minimum change score of 3.8 s. The TUG's minimal clinical important difference (MCID) is between 3.4 and 3.5 s (52, 53). Had the change in TUG scores had been 3.4 s, we would have required a sample of $n = 17$ to detect a clinically meaningful change (alpha $= 0.05$).

4.2. Changes in functional mobility, gait speed, balance, exercise self-efficacy, and health-related quality of life (follow-up vs. baseline)

Changes in outcomes are presented in Table 2. Participants demonstrated statistically significant improvements in functional mobility, balance, self-efficacy for exercise, and health-related quality of life at follow-up compared to baseline measurements. Changes in functional mobility and gait speed each exceeded the minimal clinical important difference (MCID) of the measures (TUG_{MCID} = 3.4–3.5 s, $3\text{-}MWT_{MCID}$ = 0.1–0.2 m/s) (40, 52–54).

4.3. Changes in physical activity scores (follow-up vs. baseline)

Changes in physical activity are presented in Figure 1. After accounting for within-subject correlations averaged over the two data collection points, participants most frequently engaged in very light activities [22.2 h (95% CI, 11.3–33.1)] followed by light [8.4 h (95% CI, 4.2–12.6)], moderate [1.8 h (95% CI, 0.8–2.8)] and vigorous types [0.4 h (95% CI, 0.1–0.8)]. When a change in the total CHAMPS scores was compared over time (follow-up vs. baseline) using the Wilcoxon signed-rank test, a significant increase in activity levels over the DVD intervention was documented ($z = 2.638$; $p = 0.008$). Mixed regression models predicted a 24% increase in overall activity post-intervention [Incidence rate ratio, IRR 1.240 (95% CI, 1.038–1.481); $z = 2.38$, $p = 0.017$]. Further examination of time-activity interactions in the regression model revealed that the overall increase in activity post-intervention was mostly due to the 2.5 times increase in moderate activity [IRR 2.49, (95% CI, 1.42–4.3), $p = 0.001$]. When a participant with a large baseline outlier measure for light activity was removed, light activity levels increased [IRR 1.6 (95% CI, 1.2–2.1), $p = 0.003$]. There were no significant increases in very light or vigorous exercise.

4.4. Adherence to the DVD-HEP

High adherence was confirmed by documentation in participants' exercise diaries, telephone calls, and follow-up visit. As presented in Figure 2, on average, participants reported completing between 3 and 5.1 h of weekly DVD-HEP practice, which was 2–3.5 times the suggested level of exercise frequency prescribed (30-min of the HEP at least three times/week or a total of 1.5 h/week). Further, participants reported performing on average 2.6–4 h of additional weekly physical activity (Figures 2, 3)—with walking being the most frequently reported activity ($n = 14$), followed by attendance at a physiotherapy session ($n = 5$) and gardening ($n = 5$).

4.5. Qualitative feedback on the DVD-HEP

A total of 48 phone calls were made to 16 participants (average duration of 25 min) over the course of 6 weeks. The qualitative feedback identified five main themes. The deductive themes were: (i) Enjoyment, self-efficacy, and wellbeing; (ii) Achieving life goals; (iii) Background music as a motivator to adherence; and (iv) Enhanced motor performance and learning: Task goal mastery, multimodal feedback, autonomy to self-regulate learning. The new inductive theme was (v) Preference for in-person support for exercise.

TABLE 2 Changes in participants' functional outcome measures between baseline and follow-up.

Outcomes	Baseline, mean (SD)	Follow-up (7 weeks) mean (SD)	Mean raw score difference (95% CI)	Statistical change score difference
TUG test[a]	17.56 (7.70)	13.32 (4.90)	−4.25 (−6.47, −2.02)	$t_{(14)} = -4.08, p = 0.001$
3-MWT[b]	0.83 (0.25)	0.95 (0.34)	0.12 (0.08, 0.16)	$t_{(14)} = 1.87, p = 0.083$
Step L leg[c]	7.20 (3.21)	8.93 (3.83)	1.73 (0.50, 2.96)	$t_{(14)} = 3.03, p = 0.009$
Step R leg[c]	7.73 (2.31)	9.27 (3.65)	1.53 (0.15, 2.92)	$t_{(14)} = 2.37, p = 0.033$
OEE-2				
NOEE[d]	2.52 (0.78)	2.13 (0.74)	−0.38 (−0.78, 0.01)	$t_{(14)} = -2.07, p = 0.058$
POEEe[e]	4.03 (0.43)	4.22 (0.58)	0.19 (−0.02, 0.0.40)	$t_{(14)} = 1.96, p = 0.071$
SEE[f]	7.52 (1.28)	8.50 (0.97)	0.97 (0.33, 1.62)	$t_{(14)} = 3.27, p = 0.006$
EQ-5D-5L[g]	0.72 (0.20)	0.83 (0.13)	0.11 (0.02, 0.19)	$t_{(14)} = 2.73, p = 0.016$
EQ-5D-VAS[h]	72.33 (18.98)	81.53 (12.14)	9.20 (2.03, 16.37)	$t_{(14)} = 2.75, p = 0.016$

CI, Confidence interval.
[a]TUG measured in seconds; less time indicates better functional mobility.
[b]3MWT measured in meters/second; faster time shows better gait speed.
[c]Number of steps completed in 15 s for the right and left leg; a higher score indicates better balance.
[d]NOTE, Negative outcome expectancy for exercise, the maximum score possible = 8; a lower score indicates better outcome expectancy.
[e]POEE, Positive outcome expectancy for training, the top score possible = 5; a higher score indicates better outcome expectancy.
[f]Self-efficacy for exercise, top score possible = 11; a higher score indicates better self-efficacy.
[g]Dolan score range 0 = 1; a higher score indicates a better health-related quality of life.
[h]Visual analog scale 0–100, where 0 is the worst health state and 100 is the best.

4.5.1. Theme 1: Enjoyment, self-efficacy, and wellbeing

Thirteen participants were strongly positive in describing their DVD-HEP experience and used phrases like, *"Love my DVD, love the music, it makes me feel good... watched it sometimes three times/day and twice on ten days* (P2); *"Very relaxing .... exercising is enjoyable"* (P3 and P4); *"Very good overall"* (P5); *"Very useful"* (P15). Some elaborated further to explain how the DVD-HEP positively impacted their lives. For example, five reported that watching themselves execute the exercise sequels uplifted their mood, *"Viewing the DVD made me feel good"* (P2). Others discussed the boost in confidence and overall sense of wellbeing—which motivated them to continue to practice the techniques as the week progressed (flow and habit formation). Quotes to reflect these sentiments included, *"...The DVD-HEP increased my confidence. I felt so much better after the first week. It was a lack of confidence that made me frightened. Now, I feel good about it; I don't worry even when I walk crooked* (P3)*...Having the DVD motivates me...I wouldn't have bothered otherwise* (P5)*."* Two others were so impressed with the DVD and print versions of the HEP that they showed them to their family and friends and encouraged them to consult with a physiotherapist to develop a personalized video HEP.

4.5.2. Theme 2: Achieving life goals

Five participants identified that they were achieving more of their own life goals with subthemes of (independence and daily activities) because of improved confidence and physical ability. Sub-themes were overcoming barriers and improved participation. Participants described a sense of achievement in overcoming previously existing barriers, saying, *"Exercises assist with getting up the chair better"* (P9). They also spoke about their improved independence and participation in meaningful daily activities. "*It helps me to go out and about*" (P4).... "*Yes, it has been much better after doing the exercises. I drive more, didn't notice any pain down (in my) knees*" (P5).

4.5.3. Theme 3: Background music as a motivator to adherence

The *background music* was a source of motivation for some—making exercising at home a *"joyful and fun experience"*—and offered a few participants a *"feel-good factor"* to embed the DVD-HEP into their routine. For example, one participant described her experience as *"....song by my favorite artist—Love the music with my exercise"* (P1). This participant also said she had *"Advised all older people to try to do their exercises using a video of themselves."* (P2)

4.5.4. Theme 4: Enhanced motor performance and learning: Task goal mastery, multimodal feedback, autonomy to self-regulate learning

Motor learning was enabled by watching oneself successfully execute each technique (focus on performance technique

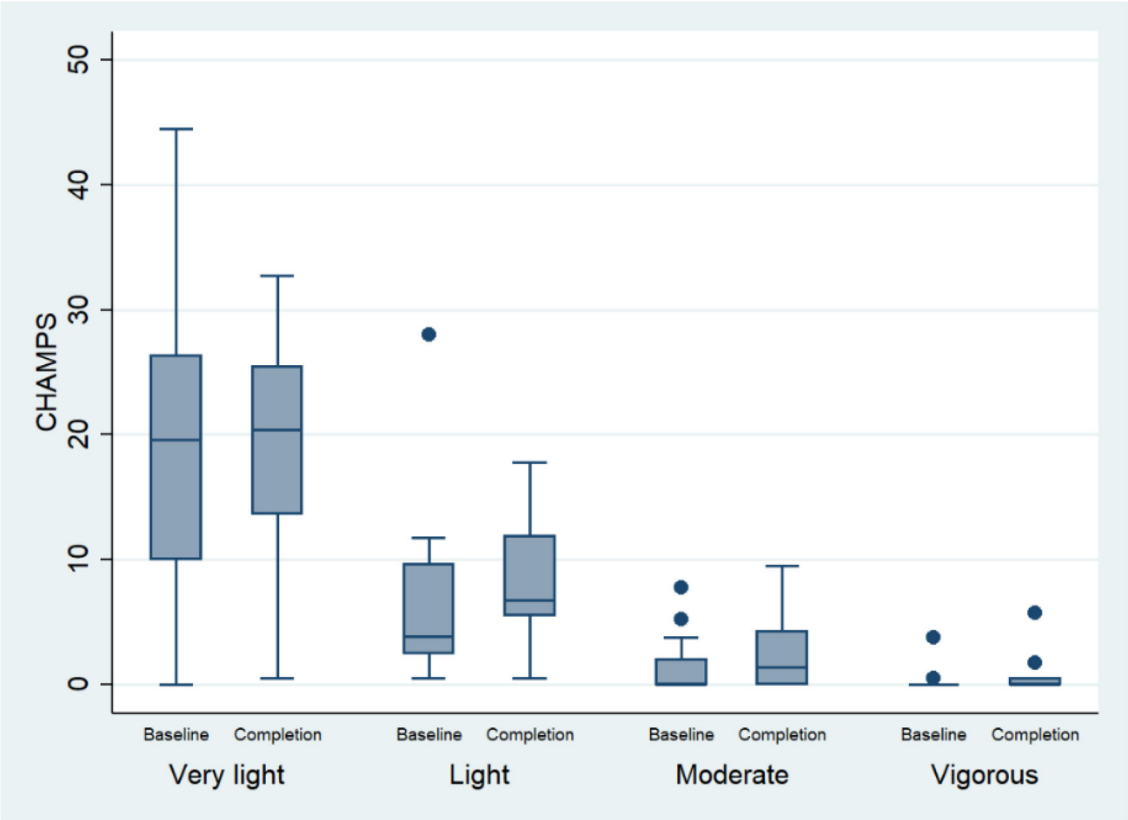


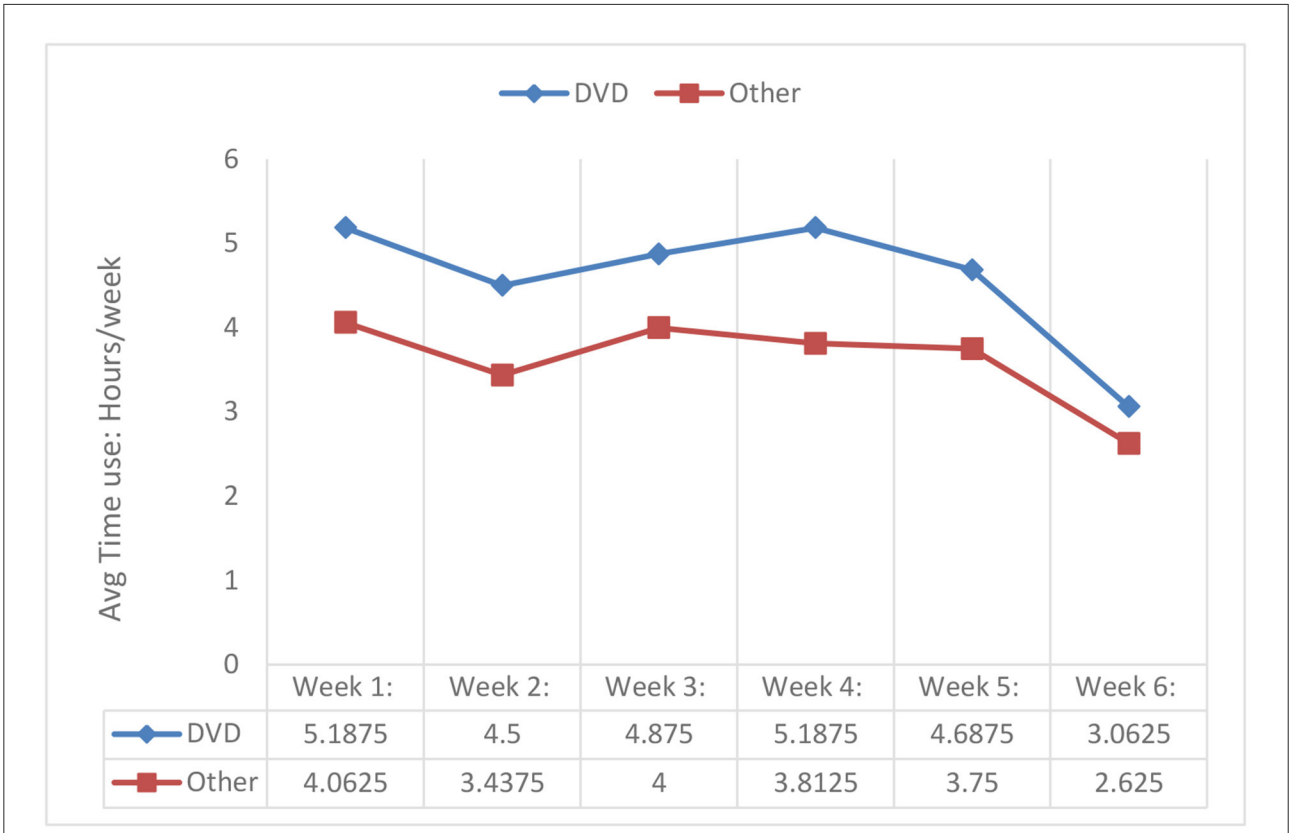
FIGURE 1
Change in physical activity performance (measured using the CHAMPS) between baseline and follow-up.

and task mastery) in conjunction with timely auditory, visual, and proprioceptive feedback provided by the therapist. This included recommendations on correcting techniques or avoiding compensatory movements (voice-over instructions and proprioceptive feedback with the person's own body used as a frame of reference). Thus, multimodal feedback and a sense of task and mastery performance enhanced participants' confidence and motivation to practice the suggested exercise techniques more often—and enabled them to *stretch their learning* as the weeks progressed. Quotes from three participants eloquently articulate this learning experience *"… Good reminder of how to correctly do the techniques...Toward the end, I watched the DVD more—I learned a little each time... As a result, I see techniques a bit better* (P14)...*Therapist feedback on what to do and why to do it helped me understand how to do the exercise correctly"* (P2).

The relative of a participant with comorbid memory problems reflected on the benefit of the video recording to cue the participant to correctly perform the movement technique saying, *"DVD helps her with exercise—seeing herself do it makes her happy. She loves watching the DVD. She was doing it completely wrong without the DVD due to (sic incorrectly) memory for exercises"* (P4). *Another participant commented that watching the DVD reminded her "....to slow down"* (P6). Further, a participant with chronic hip and knee pain and restricted movements (P12) commented on the benefit of rewinding the DVD a few times to revisit detailed steps involved in some exercise techniques—*"...to ensure that she correctly followed the therapist's recommendations."* Although this participant commented that the DVD-HEP did not *"cure her long-standing chronic pain problems,"*—she rated the DVD-HEP experience as being *"absolutely brilliant"* (P12).

4.5.5. Theme 5: Preference for in-person support for exercise

Three participants felt that the DVD format did not provide any benefit over the handwritten HEP. The first offered neutral feedback, saying, *"(exercise) was not bad"* (P14), and the second reflected, *"Quite good, don't need to put the DVD every time. Handwritten instructions given by physio were useful reminders"* (P7). The third participant, who had chronic pain and bronchitis, felt in-the-moment monitoring and in-person advice from a physiotherapist would have led to quicker



	Week 1:	Week 2:	Week 3:	Week 4:	Week 5:	Week 6:
DVD	5.1875	4.5	4.875	5.1875	4.6875	3.0625
Other	4.0625	3.4375	4	3.8125	3.75	2.625

FIGURE 2
Adherence to the DVD-HEP and other activities ($n = 14$)*. *Data from two participants were missing.

progress, as captured in the quote, *"Enjoyed the exercise initially but not after....need feedback on how to progress rather than do correctly...DVD does not tell me whether I am doing right or not"* (P8).

5. Discussion

The study aimed to evaluate the effectiveness of prescribing a tailored video self-modeled DVD-HEP for 6 weeks, on functional mobility, physical activity, exercise self-efficacy, and health-related quality of life, in a sample of frail older adults relative to their baseline scores. Participants demonstrated clinically meaningful improvements in functional mobility and gait speed between baseline and follow-up at seven weeks. The minimal clinical important difference (MCID) of the TUG test is approximately between 3.4 and 3.5 s (52, 53), and the MCID of gait speed (3-MWT) is between 0.1 and 0.2 m/s (54). Clinically meaningful improvements are important as they indicate that the therapy intensity has led to meaningful changes in participants' outcomes (54). Although both these measurements improved from baseline to follow-up, TUG and 3-MWT scores were still below normative values for community-dwelling older adults (40), suggesting our participants' would benefit from continued exercise to improve their ability to function independently in the community. Gait speed is considered such an essential measurement of function that it is referred to as the 6th vital sign (55).

Participants also demonstrated significant improvement in balance, exercise self-efficacy, and health-related quality of life at the 6-week follow-up compared to their baseline scores. Qualitative interviews revealed that the tailored DVD-HEP boosted participants' self-efficacy in successfully performing the exercises and motivated them to practice the advised exercises diligently as the weeks progressed, thus stretching their learning experiences. They reported improved wellbeing and perceived that the DVD-HEP positively impacted their lives. CHAMPS data revealed a 2.5-fold increase in engagement in moderate activities like walking, housework, gardening, and dancing and a 1.3-fold increase in light activity participation over time. Undertaking daily physical activity can augment the gains in a structured exercise program and increase participation in daily activities like shopping or walking, thereby providing positive reinforcement. It is known that exercise after hospitalization can improve functional ability (9, 10). However, older people have low adherence and enjoyment

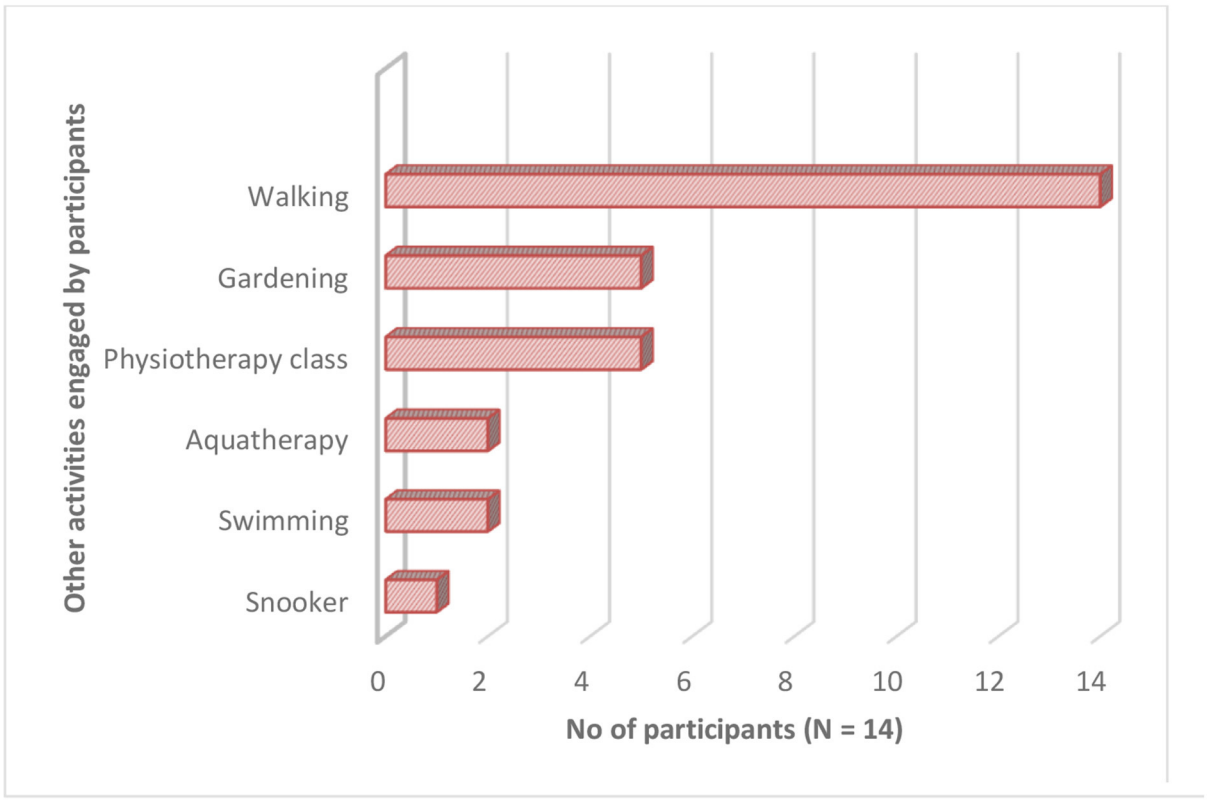


FIGURE 3
Overview of other activities engaged by participants ($n = 14$)*.

of exercise (12) and report multiple problems in recovery after hospital discharge, including engaging in exercise (13). The functional decline after hospitalization is a significant problem for older people, with multiple studies identifying that older people find it challenging to adapt to daily life after discharge due to difficulties in performing their daily activities and that even after 12 months, they continue to experience a functional decline (5, 56, 57). Programs for older people after hospital discharge that focus on providing support and rehabilitation have been identified as an urgent priority (58, 59). Innovative programs that encourage self-directed learning are needed.

Each DVD-HEP was informed by an initial face-to-face assessment by an experienced physiotherapist and was based on validated performance measures, participant goals, and functional needs. As part of the tailoring process, we included a personalized introduction to the HEP, evidence-based exercise components to address individual goals, visual cues (gestures), and specific instructions that each participant should look out for (contraindications and compensatory movements) while practicing the HEP. This was designed to simulate the experience of a face-to-face physiotherapy session.

The COVID-19 pandemic has highlighted the value of innovative strategies, including telehealth exercise programs, for preventing functional decline among older people during periods of social distancing and quarantine (60). Emerging evidence suggests that digital health modalities such as telephone calls or videoconferencing, which depend on synchronous contact with a health professional (20) and voice-controlled intelligent personal assistants (VIPAs, using Amazon Alexa), are feasible in older people. However, several barriers to adherence to the latter have been reported (namely, poor internet connectivity, voice recognition inaccuracy, and privacy issues) (61). Importantly, these modalities do not provide personalized exercise prescriptions with hands-on feedback as in our novel, tailored, self-modeled video HEP. Video self-modeling might be a novel way to improve the telehealth model by arranging an initial face-to-face "hands-on" session with the physiotherapist.

Given the amount of time and resources devoted to the creation of a tailored DVD for each participant and the suggestion that these may need to be adjusted as the individual's physical fitness changes, it is essential to acknowledge that a self-modeled audio-visual approach comes with additional demands on clinician time and workload. Technological

advances, including software options for collating videos, have significantly developed. Almost all modern computers, tablets, and even smartphones come preloaded with advanced video editing software. It is also relatively easy to upload videos online to YouTube and other platforms or embed them into streaming platforms equipped with robust governance structures. For the 27–49% of Australians aged 75 and over, who do not access the Internet (62), making a high-quality video and converting it to portable hardware is quick, economical, feasible, and requires little technical expertise. The current study's findings call for further investigation into the adherence and maintenance of longer, tailored, self-modeled video HEP and how therapists could use such modalities more routinely in clinical practice, like the possibility of a video-delivery HEP as a substitute for some face-to-face treatment sessions. Future studies comparing the impact, sustainability, and cost-effectiveness of different modalities of self-modeled video-based digital HEP are desirable to ensure that all older people have access to safe, efficient, and high-quality care aligned to their needs, preferences, and learning styles.

We can draw on several learning theories, including the cognitive theory of learning (63), and the Optimizing Performance Through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory of motor learning (64), to explain the current study's findings. Cognitive theorists would argue that it was likely that our tailored self-modeled DVD-HEP was designed to be situated within each individual's *"zone of proximal development"* (63). Accordingly, each participant was motivated to self-critique, create personal learning points while watching the video, and engage in more self-regulated learning experiences (65). According to the OPTIMAL theory of motor performance, the DVD-HEP facilitated motor performance and learning by encouraging practice conditions that promoted enhanced expectancies, autonomy, and external focus of attention (66) and motivated participants to practice and adhere to the physiotherapist's advice, thereby facilitating the consolidation of motor memories (67). Applied to the current study, watching oneself successfully execute exercises on the video footage could have encouraged participants to focus their attention on task goal mastery, thereby enhancing their expectations of performance and challenging their negative exercise expectations grounded in fear and perceptions of task difficulty (30, 68). Consequently, participants' negative outcome expectancy of exercise scores—objectively measured using the OEE-2 scale (in terms of avoiding exercise because of shortness of breath, pain, fear of falling or getting hurt, and stress on the heart) reduced after the 6-week DVD-HEP intervention.

The DVD-HEP was designed to allow participants to choose their exercise-free days and the frequency of repetitions and sets, which could have given participants a sense of agency or control (69) and encouraged self-determination of when, how often, and how intensely they exercised (70). Such practice conditions could have influenced participants' motivation to practice (71) and enhanced their self-efficacy in successfully executing the exercise routine shown in the video (72). Also, the inclusion of specific and targeted audio-visual and proprioceptive instructions and encouragement by the physiotherapist in the video recording alongside participant-selected background music was reported by participants to transform the DVD-HEP exercise routine into a *"joyful and fun experience"* and offered a few participants a *"feel-good factor."* This, in turn, motivated most participants to engage with the DVD-HEP routinely—thus suggesting why there was high adherence to the intervention in our current sample. The current trial adds to the growing evidence base on the potential efficacy of self-modeling videos of task mastery on improved motor performance in frail older adults in the community (64).

Given that our sample improved relative to their baseline scores over a relatively short 6-week period, a follow-up visit to modify the exercises and re-video might be necessary for sustained programs. While the DVD-HEP was considered favorably by most, three of the 16 participants felt the medium did not allow for in-the-moment in-person monitoring of progress that an in-person physiotherapy session would allow. This suggests that self-modeled video-HEP may not suit all older adults. Our findings validate those of a recent observation study (23) and highlight the benefits of consultation with individual patients to explore their preferences and collaboratively design tailored programs aligned to each individual's needs, preferences, and interests and deliver them using mediums that are congruent to the person's learning preference, style, and digital literacy (17, 73).

6. Strengths and limitations

All participants were made aware of the health benefits of including exercise in their daily routine and were provided personalized guidance on avoiding and managing potential risk situations while exercising (e.g., fatigue, postural hypotension). However, at the time of enrolment, all participants were not engaged in any exercise or physical activity program at home or in the community. Changes in primary and secondary outcomes were measurable and clinically significant, therefore, may be a result of participation in the DVD-HEP intervention and changes in participants' lifestyles during the intervention, but the chance of natural improvement cannot be eliminated.

Some limitations of this study must be acknowledged when interpreting the findings. We originally planned to enroll more participants; however, the trial coincided with a change in patient flow through services at the participating hospital due to the opening a new hospital. Further attempts to scale up the DVD-HEP model could be considered. This

could involve following up with participants after 6-weeks, enrolling more participants in an outpatient setting, or incorporating video prescriptions as part of the usual care. We used a single group and a sample of convenience. The design and sample size were initially designed to evaluate the intervention with a control group. However, we did not have a non-intervention control group to assess time-dependent changes and explore the contribution of factors on outcomes (e.g., sex, comorbidity, level of frailty). Also, DVD-HEP adherence was self-reported *via* a daily diary, which may be susceptible to overestimation bias. In addition, we did not objectively measure exercise fidelity. Future studies could use objective measurements of adherence, such as self-monitoring activity devices or videoconference monitoring of exercise, and use dynamometers to measure changes in physical function. Future studies could explore the influence of several confounders—such as the level of comorbidity or frailty and how sociodemographic variables such as education levels and sex influenced adherence and outcomes. A genuine rapport was built between the treating physiotherapist and our study's participants, encouraging them to feel safe sharing their views (50). While it could be considered a limitation not to have a separate interview, it was considered that the physiotherapist was their trusted clinician, and participants would feel comfortable responding over the phone. This may have been a limitation as some may have felt reluctant to respond negatively to the therapist (74). We acknowledge potential assessor bias as post-test assessments were completed by the same physiotherapist who did the baseline assessment and follow-up telephone calls. We tried to lessen assessor bias by using standardized, validated objective outcome measurements sensitive to change.

7. Conclusion

Older adults who were prescribed a tailored self-modeled DVD-HEP (which involved one face-to-face session with a physiotherapist and three follow-up phone calls) demonstrated functional improvement compared to their baseline assessment after 6 weeks of completing the program independently at home. Their adherence to the exercise program exceeded the recommended levels—suggesting participants were intrinsically motivated to use the DVD-HEP. Given advances in digital technology, future comparative studies on the efficacy of tailored self-modeled video HEP to other formats are needed to serve older adults optimally. Future healthcare systems will expect older adults to assume a more dominant role in their health and rehabilitation care. With appropriate professional guidance, based on the current study's findings, tailored self-modeled digital HEP could provide a new and novel avenue to evaluate how to provide sustainable, high-quality health professional input alongside independent exercise. This study suggests that tailored self-modeled digital HEPs may stimulate self-management and facilitate motivation, a sense of responsibility, and confidence to practice. This, in turn, can optimize functional outcomes and improve long-term health behaviors in older adults.

Data availability statement

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

Ethics statement

Ethics clearance for the study was obtained from the University of Notre Dame Human Research Ethics Committee (HREC) (Reference Number: 015146F) and the South Metropolitan Health Service (SMHS) HREC (Reference Number: 15-190). All participants provided written informed consent to be included in the study.

Author contributions

A-MH, JC, and DB conceived and designed the study. DB led site procedures. A-MH led the data collection with assistance from J-AH. A-MH, J-AH, JC, DB, KS, and SV contributed to the data collection, analysis, and interpretation. SV, A-MH, and J-AH drafted the manuscript with assistance from JC. All authors provided feedback on the manuscript drafts, read, and approved the final manuscript submitted.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.974512/full#supplementary-material

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Suicidality among older Australian adults

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Background: Vulnerability to suicidality is a concern among older adults, particularly as this proportion of the population is growing. Determining what factors contribute to suicidality will help to create a framework for understanding and assessing suicidal risk among older adults and developing effective treatments. This study examined suicidality among older Australian adults.

Methods: This study forms part of a larger study to trial a survey to collect cross-sectional data on the mental and physical health of older Australian adults across time. One hundred and fourteen Australian residents aged 65 years and over completed an anonymous survey online or by returning a paper-and-pencil version of the survey by post. The survey took approximately 25 min to complete and comprised of (1) sociodemographic questions (e.g., age, gender, education), (2) validated questionnaires measuring depression, general anxiety, psychological distress, insomnia, substance dependence, problem gambling, and stress, and (3) mental and physical health and wellbeing items (e.g., religiosity, assistance with daily tasks, and mental health service usage in the last 12-months). The dependent variable, suicidality, was measured by asking participants whether they had ever seriously thought about committing suicide.

Results: Associations with suicidality were analyzed using Chi-squares and independent samples *t*-tests. The results found suicidality to be significantly associated with lower levels of satisfaction with the frequency of seeing and/or communicating with friends, and inadequate levels of community engagement.

Conclusion: The results of this survey reinforce the importance of social connectedness as a central and significant protective factor against suicidality among older adults.

KEYWORDS

suicidality, older adults, social connection, community engagement, risk factors, mental health, physical health

Introduction

The Australian population is aging rapidly. In 20 years (2000–2020) the proportion of people aged 65 years and over increased by 3.9%, from 12.4 to 16.3% (1). In 2020, suicide was the 10th leading cause of death for men and 22nd leading cause of death for women (2). The highest age-specific suicide rate was recorded for men aged 85 years

and older (36.2 deaths per 100,000 persons). Comparatively for women, the age-specific suicide rate for those aged 85 years and over was 6.2 per 100,000 persons.

A systematic literature review (3) identified that suicidal behavior among older adults aged 65 years and over was associated with functional disability and a variety of conditions (e.g., malignant diseases, neurological disorders, pain, liver disease, arthritis). The review included 59 quantitative studies across four continents. A further six qualitative studies from three continents unpacked the results of the quantitative studies finding common themes of illness, disability, pain, feelings of being a burden, lack of dignity, independence and sense of usefulness, and lack of pleasure with living to be common themes precipitating suicidal thoughts, attempts and completed suicides. Furthermore, mental health conditions (i.e., dementia, depression, anxiety) have been positively correlated with the prevalence of suicide among older adults (4). In addition, there is also a tendency for health professionals not to routinely assess for mental health conditions amongst older adults and this can result in the under-identification and under-reporting of actual rates (5), potentially increasing the risk of suicide.

Suicidality among older adults has also been associated with a range of other mental health issues, such as insomnia (6), substance abuse (7), and gambling (8), Determining what factors contribute to suicidality will help to create a framework for understanding and assessing suicidal risk among older adults, and ultimately developing and administering effective treatments.

The aim of this study was to conduct a survey of older Australian adults (aged 65 years and over) to examine suicidality across sociodemographic variables, depression, anxiety, psychological distress, insomnia, substance dependence, problem gambling, stress, and mental health and physical well-being items.

Methods

Procedure and participants

This paper reports on data collected as part of a larger study to trial a survey to collect cross-sectional data on the mental and physical health of older Australian adults across multiple timepoints. Recruitment for this study was conducted nationally, with all Australian residents aged 65 years and older eligible to take part by completing an anonymous survey online or returning a paper-and-pencil version of the survey by post. Following ethics approval, the study was advertised *via* social and printed media, flyers on community notice boards, and in aged care residential facilities. The survey took approximately 25 min to complete. A total of 168 older adults consented to take part in the study, six participants were ineligible as they resided outside of Australia and were removed from the sample for analysis. A further 48 participants failed to complete an essential question for analysis (whether they had ever seriously thought about committing suicide) and were subsequently also removed from analysis. This left a total sample size of 114. Participant characteristics of this sample are presented in Table 1.

Measures

The survey included sociodemographic items, validated measures, and items relating to the mental and physical health and well-being of the participants.

Sociodemographic information collected included age, gender, highest level of education completed, gross income per annum, country of residence and birth, living setting, relationship status, and whether the participant had been sexually active in the last 12 months.

Patient Health Questionnaire - 9 [PHQ-9; (9)]. The PHQ-9 is a nine-item depression subscale of the Patient Health Questionnaire (10). The questionnaire is based on the diagnostic criteria from the Diagnostic and Statistical Manual, fourth edition (11). Questions are based on symptoms experienced in the previous 2 weeks, with questions answered on a four-point scale from 0 = "Not at all" to 3 = "Nearly every day" and then summed to obtain a score from 0–27.

Generalized Anxiety Disorder - 7 [GAD-7; (12)]. The GAD-7 is a seven-item screening tool for GAD. Questions are based on symptoms experienced in the previous two weeks with items answered on a four-point scale from 0 = "Not at all" to 3 = "Nearly every day". Items are summed to obtain a score from 0–21.

Kessler 6 [K6; (13)]. The K6, an abridged version of the K10, is a six-item screening tool to provide a general measure of psychological distress. Questions ask about depressive- and anxiety-related symptomology during the previous 30 days. For the Australian version of the K6, symptoms are rated on a five-point scale from 1 = "None of the time" to 5 = "All of time" with scores summed to obtain a score from 6–30.

Insomnia Severity Index [ISI; (14)]. The ISI is a seven-item measure assessing the nature, severity, and impact of both nighttime and daytime components of insomnia. Questions are based on sleep-related behaviors across the prior 2 weeks. Each question is answered on a five-point Likert scale from 0 = "None" to 4 = "Very severe" for the first three questions, (1) difficulty falling asleep, (2) difficulty staying awake, and (3) problems waking up too early; 0 = "Very satisfied" to 4 = "Very dissatisfied" for (4) satisfaction with current sleep pattern; 0 = "Not noticeable" to 4 = "Very much noticeable" for (5) noticeability of sleep problem to others; 0 = "Not worried" to 4 = "Very much worried" for (6) degree of worry/distress about current sleep problem; and 0 = "Not interfering" to 4 = "Very much interfering" for (7) extent that sleep problem interferes with daily functioning. Responses to the seven-items

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TABLE 1 Participant characteristics.

Variables ($N = 114$)	n (%)	Mean (SD)
Age		71.59 (5.33)
Gender identity		
Male	43 (37.7)	
Female	71 (62.3)	
Highest level of education completed		
Year 12 or lower	32 (28.1)	
TAFE	32 (28.1)	
University	50 (43.9)	
Gross annual income		
$0–19,999	22 (19.3)	
$20,000–39,999	51 (44.7)	
$40,000–79,000	33 (28.9)	
$80,000+	8 (7.0)	
Country of birth		
Australia	72 (63.2)	
Overseas	41 (36.0)	
Not answered	1 (0.9)	
Relationship status		
Separated/divorced/widowed/single	46 (40.4)	
Married/partnered	68 (59.6)	
Living setting		
Aged care facility/Retirement village	14 (12.3)	
Community (independently, with partner or other family member/s)	100 (87.7)	
Sexually Active (last 12 months)		
No	56 (49.1)	
Yes	41 (36.0)	
Prefer not to say/Not answered	17 (14.9)	
Have you *ever* seriously thought about committing suicide?		
No	92 (80.7)	
Yes	22 (19.3)	
Have you seriously thought about committing suicide at any time in the past 12 months?*		
No	16 (72.7)	
Yes	6 (27.3)	
Have you *ever* made a plan for committing suicide?*		
No	8 (36.4)	
Yes	7 (31.8)	
No response	7 (31.8)	
Have you made a plan for committing suicide in the past 12 months?*		
No	4 (18.2)	

(Continued)

TABLE 1 (Continued)

Variables ($N = 114$)	n(%)	Mean (SD)
Yes	3 (13.6)	
No response	15 (68.2)	
Have you *ever* attempted suicide?*		
No	11 (50.0%)	
Yes	3 (13.6%)	
No response	8 (36.4%)	

*Only participants (N = 22) who responded "Yes" to the question "Have you ever seriously thought about committing suicide" were asked these questions.

are summed to obtain a total score from 0–28, with scores interpreted as: 0–7 = No clinically significant insomnia, 8–14 = Subthreshold insomnia, 15–21 = Clinical insomnia (moderate severity), and 22–28 = Clinical insomnia (severe).

CAGE Adapted to Include Drugs [CAGE-AID; (15)]. The CAGE-AID is a four-item tool adapted from the CAGE to screen for alcohol and other drug problems. Each question is given a "yes" or "no" response, with one or more "yes" responses considered an indication of possible substance use or abuse.

Problem Gambling Severity Index [PGSI; (16)]. The PGSI is a nine-item measure of common signs for risk of problem gambling. Questions are based on the prior 12 months and answered on a four-point scale from 0 = "Never" to 3 = "Almost always", with scores summed to obtain a total score from 0–27. The total score is interpreted as: 0 = Non-problem gambler, 1–2 = Low-risk gambler, 3–7 = Moderate-risk gambler, and 8 or above = Problem gambler.

The Social Readjustment Rating Scale [SRRS; (17)]. The SRRS measures the amount of stress experienced over the prior 12 months and the risk of future illness. Participants are presented with a list of major stressful life events and asked to state whether they experienced that event within the last 12 months. Each event has been designated a score of up to 100 points, for example, death of a spouse or child = 100 points, marriage = 50 points, and children leaving home = 29 points. The scores for endorsed items are summed to obtain a total score where 0–150 = a low susceptibility to stress-induced health breakdown, 150–300 = a 50% (moderate) chance of health breakdown in the next 2 years, and 300 or more = an 80% (high) chance of health breakdown in the next 2 years.

Participants were asked to answer a series of questions related to their mental health and physical well-being. Questions included: (a) whether they had ever seriously thought about dying by suicide (yes/no); (b) whether they had ever been a smoker (yes/no); (c) how religious they are (1 = not at all religious to 11 = extremely religious); how satisfied they were with the frequency of seeing and communicating with (d) family and (e) friends (1 = No nearly enough to 11 = Very satisfied with how often); (f) their satisfaction with level of community engagement (1 = Not at all, to 5 = Very much); overall satisfaction with (g) physical health, (h) mental health, and (i) quality of life (1 = Excellent to 5 = poor); whether they had experienced symptomatology relating to (j) social phobia, (k) specific phobia, (l) post-traumatic stress disorder (PTSD), (m) obsessive-compulsive disorder (OCD), (n) panic disorder (1 = yes, 2 = sometimes, 3 = not now, but used too, 4 = no, never have); (o) whether they needed assistance with daily tasks because of physical illness or disability (1 = yes, 2 = sometimes, 3 = no); whether they (p) had ever experienced a direct blow to the head, and (q) were physically hit/smacked as a child (1 = no, never, 2 = yes, but only brief exposure, 3 = yes, prolonged exposure); (r) whether they had experienced any physical conditions from a provided list (i.e., hypertension, diabetes, osteoporosis); and (s) whether they had accessed any services from a provided list (i.e., psychologist, pharmacist, telephone service) in the past 12 months for a mental health condition.

Results

All analyses were performed using IBM SPSS (v.28). The dependent variable was suicidality, specifically, whether the participant had seriously considered suicide at any point in their lifetime. Suicidality was examined against socio-demographics, validated measures, and mental and physical health and well-being items using Chi-squares and independent samples *t*-tests, corresponding to categorical and continuous/interval variables respectively. The *p*-value was set conservatively at 0.01 due to the number of analyses conducted. The results are presented in Table 2.

The results indicate that two variables were significant at the 0.01 level with suicidality associated with lower levels of satisfaction with the frequency of seeing and/or communicating with friends, and suicidality more than three times higher among participants who reported inadequate levels of community

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TABLE 2 Suicidality by sociodemographic, validated measures, and mental and physical health and well-being items.

Variables ($N = 114$)	Suicidality		p-value
	No	Yes	
Sociodemographics			
Age, mean (SD)[a]	71.90 (5.52)	70.27 (4.30)	0.20
Gender identity			
Male	33 (76.7)	10 (23.3)	
Female	59 (83.1)	12 (16.9)	0.40
Highest level of education completed			
Year 12 or lower	24 (75.0)	8 (25.0)	
TAFE	26 (81.3)	6 (18.8)	
University	42 (84.0)	8 (16.0)	0.60
Gross annual income			
$0–19,999	20 (90.9)	2 (9.1)	
$20,000–39,999	38 (74.5)	13 (25.5)	
$40,000–79,000	27 (81.8)	6 (18.2)	
$80,000+	7 (87.5)	1 (12.5)	0.39
Country of birth			
Australia	61 (84.7)	11 (15.3)	
Overseas	31 (75.6)	10 (24.4)	0.23
Relationship status			
Separated/divorced/widowed/single	36 (78.3)	10 (21.7)	
Married/partnered	56 (82.4)	12 (17.6)	0.59
Living setting			
Aged care/Retirement village	12 (85.7)	2 (14.3)	
Community (independently or with family)	80 (80.0)	20 (20.0)	0.61
Sexually active (last 12 months)			
No	41 (73.2)	15 (26.8)	
Yes	36 (87.8)	5 (12.2)	0.08
Validated questionnaires			
PHQ-9 (depression), mean (SD)[a]	3.39 (4.29)	4.18 (4.24)	0.44
GAD-7 (general anxiety), mean (SD)[a]	2.43 (3.54)	2.55 (3.14)	0.89
K6 (psychological distress), mean (SD)[a]	8.40 (4.56)	10.23 (5.84)	0.11
ISI (insomnia), mean (SD)[a]	7.04 (4.83)	8.00 (3.99)	0.44
CAGE-AID (substance dependence)			
No	46 (88.5)	6 (11.5)	
Yes	24 (70.6)	10 (29.4)	0.04
PGSI (problem gambling)			
Low risk gambler	2 (66.6)	1 (33.4)	
Moderate risk gambler	2 (100.0)	0 (0.0)	0.39
SRRS (stress)			
Low susceptibility	91 (81.8)	18 (18.2)	

(Continued)

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TABLE 2 (Continued)

Variables ($N = 114$)	Suicidality		p-value
	No	Yes	
Moderate susceptibility	10 (71.4)	4 (28.6)	0.36
Mental health and physical well-being			
Smoker (current or past)			
No	58 (86.6)	9 (13.4)	
Yes	33 (71.7)	13 (28.3)	0.05
Religiosity, mean (*SD*)[a]	4.79 (3.35)	4.09 (3.74)	0.39
Satisfaction with seeing/communicating with family, mean (*SD*)	6.87 (3.12)	5.76 (3.71)	0.16
Satisfaction with seeing/communicating with friends, mean (*SD*)	7.78 (2.83)	5.24 (3.36)	0.00
Satisfaction with community engagement			
Inadequate (not at all/a little)	9 (52.9)	8 (47.1)	
Adequate (somewhat/much/very much)	83 (85.6)	14 (14.4)	0.00
Overall satisfaction with physical health			
Unsatisfactory (poor/fair)	20 (76.9)	6 (23.1)	
Satisfactory (good/very good/excellent)	71 (81.6)	16 (18.4)	0.60
Overall satisfaction with mental health			
Unsatisfactory (poor/fair)	9 (60.0)	6 (40.0)	
Satisfactory (good/very good/excellent)	83 (83.8)	16 (16.2)	0.03
Overall satisfaction with quality of life			
Unsatisfactory (poor/fair)	10 (76.9)	3 (23.1)	
Satisfactory (good/very good/excellent)	82 (81.2)	19 (18.8)	0.71
Social phobia			
No	70 (84.3)	13 (15.7)	
Yes	22 (71.0)	9 (29.0)	0.11
Specific phobia			
No	51 (75.0)	17 (25.0)	
Yes	41 (89.1)	5 (10.9)	0.06
PTSD			
No	65 (82.3)	14 (17.7)	
Yes	26 (78.8)	7 (21.2)	0.67
OCD			
No	74 (82.2)	16 (17.8)	
Yes	18 (75.0)	6 (25.0)	0.43
Panic disorder			
No	82 (80.4)	20 (19.6)	
Yes	10 (83.3)	2 (16.7)	0.81
Assistance with daily tasks			
No	75 (82.4)	16 (17.6)	
Yes (yes/sometimes)	12 (66.7)	6 (33.3)	0.13

(Continued)

TABLE 2 (Continued)

Variables ($N = 114$)	Suicidality		p-value
	No	Yes	
Direct blow to the head			
No	61 (82.4)	13 (17.6)	
Yes (brief or prolonged exposure)	25 (75.8)	8 (24.2)	0.42
Physically hit/smacked as a child			
No	30 (85.7)	5 (14.3)	
Yes (brief or prolonged exposure)	56 (77.8)	16 (22.2)	0.33
Physical illness			
None	25 (89.3)	3 (10.7)	
1–2 conditions	36 (78.3)	10 (21.7)	
≥3 conditions	31 (77.5)	9 (22.5)	0.41
Access to mental health services (last 12 months)			
No	45 (86.5)	7 (13.5)	
Yes	40 (74.1)	14 (25.9)	0.11

[a]t-test-based p-values, the remaining p-values are based on Chi-square statistics.

engagement compared to those who reported adequate levels of engagement.

Discussion

This study explored what variables were associated with suicidality among older Australian adults. Suicidality was examined across a series of sociodemographic variables, validated questionnaires, and mental and physical health and well-being items. Suicidality was found to be significantly associated with a dissatisfaction with the frequency of seeing and/or communicating with friends, and inadequate levels of community engagement.

The two variables highlight the importance of social connection where suicidality is concerned, the impact of which is emphasized within the Interpersonal Theory of Suicide (18). This theory posits that suicide will only occur if an individual has both the desire to die by suicide and the ability to do so. The desire to die is comprised of two psychological states, a low sense of belonginess or social isolation, and a perceived burdensomeness. In contrast, strong social support may have a protective effect against stressors in later life that increase one's vulnerability to suicidal risk factors [e.g., (19, 20)].

It could be argued that dissatisfaction with the frequency of seeing and/or communicating with family should similarly be significant. However, the nature of an obligatory relationship with family members and voluntary relationship with friends may have a differential effect on one's mental health and well-being. For example, Huxhold and Miche (21) found social activities with friends may become more important as one ages and creates a buffer against the negative effects of aging. Furthermore, Gallant and Spitze (22) found that in comparison to family members, social networks had more positive than negative influences over the management of chronic illness among older adults, such as disease management, decision-making about chronic illness, and psychosocial coping. Consequently, family members may play a more moderate role in suicidal risk among older adults than that of friends.

It was surprising that there were no further significant associations with suicidality. However, the results for the questionnaires measuring depression, general anxiety, psychological distress, insomnia, and stress suggest this was a relatively healthy cohort of older Australian adults. Although suicidality among our sample was above the worldwide range, 19.3 vs. 2.6–17%; (23). The results of the study may therefore not provide a good reflection of the general populace of older adults. Indeed, in comparison to Australian population data, our sample is comprised of a greater proportion of females [62.3 vs. 53%; (24)], a higher proportion of individuals living in cared accommodation (12.3 vs. 5.2%) and is more highly educated [43.9 vs. 12% had completed a bachelor's degree or higher, (24, 25)]. Consequently, the data should be viewed with caution. The results of the study are also limited by the small sample size and the likely impact this had on the statistical power of the analyses to detect significant results. The sample size also limited the capacity to conduct more sophisticated analyses to examine the relationship between the dependent and independent

variables. Furthermore, given the target sample, we may have been better served administering the Geriatric Depression Scale (26) over the PHQ9 to measure depression. Nonetheless, the results underscore the importance of social connection as a potential protective factor against suicidality among older Australian adults.

Going forward, as part of the larger project intended to create a database of cross-sectional data on the mental and physical health and well-being of older Australian adults, we will seek to collaborate with experts in population health, geriatrics, and biostatistics. We will aim to develop a framework protocol to incorporate how best to refine the survey, identify potential short- and longer-term research questions, analyze the data, recruit a larger more representative sample, and report the findings.

Data availability statement

The datasets presented in this article are not readily available because the unidentified raw data supporting the conclusions of this study will be made available upon reasonable request to the corresponding author and following Federation University HREC ethical approval to do so. Requests to access the datasets should be directed to BK, b.klein@federation.edu.au.

Ethics statement

The studies involving human participants were reviewed and approved by Federation University Human Research Ethics Committee. Informed consent for participation was obtained for this study in accordance with the National Legislation and the Institutional Requirements.

Author contributions

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

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Conflict of interest

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

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How long can Chinese women work after retirement based on health level: Evidence from the CHARLS

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Objective: To further enhance the understanding of factors impacting female participation in the workforce based on health levels and to measure the excess work capacity of middle-aged and older female groups by residence and educational level.

Methods: Data of women aged 45–74 were accessed from the China Health and Retirement Longitudinal Study (CHARLS) from 2011, 2013, 2015, to 2018. The health status of women was comprehensively evaluated by single health variables and frailty index. A Probit model was used to measure the excess working capacity of women by region (rural/urban) and educational level, taking all women aged 45–49, rural women aged 45–49, and rural (illiterate) women in all age groups as the benchmark, respectively.

Results: The excess capacity of all Chinese women aged 50–64 is 1.9 years, and that of women aged 50–74 is 5.1 years. The excess work capacity of women in urban and rural areas and with different educational levels is heterogeneous. The excess working capacity of urban women aged 50–64 is 6.1–7.8 years, and that of urban women aged 50–74 is 9.8–14.9 years. The excess working capacity of urban women aged 50–64 is about 6 times that of rural women. The excess work capacity of highly educated women was 3 times higher than that of illiterate women.

Conclusion: The potential work capacity of Chinese women remains to be exploited, especially for urban and highly educated middle-aged and older women with better conditions of health, whose potential is more significant. A rational retirement policy for women and the progressive implementation of an equal retirement age for men and women will contribute to further advancement of gender equality and healthy aging in the workplace in China.

KEYWORDS

delayed retirement, women's health, labor participation, Chinese, work capacity

1. Introduction

With decreasing birth rate and increasing life expectancy, numerous countries have initiated reforms attempting to raise the normal retirement age (NRA) in response to tremendous pressure on pension funds (1). China is facing a more severe situation due to early sex ratio imbalance and population expansion. China began to implement the one-child policy in the 1980s, which was continued for nearly 30 years. The long-term one-child policy has led to a persistent low fertility rate, resulting in the formation of hundreds of millions of inverted pyramidal one-child families, which will accelerate China's labor shortage (2).

Additionally, according to the World Health Organization, when the aging rate exceeds 7, 14, and 21% it is called "an aging society", "an aged society," and "a super-aged society," respectively. The "aging rate" refers to the proportion of people over 65 years old in a society (3). As China's aging population continues to grow, it is expected that China will become a "super-aged society" by 2035 (4). This labor shortage and aging increase will directly aggravate the pension payment crisis (5). According to statistics, the accumulated amount of China's existing pension fund will be in deficit by the middle of the 21st century without any reform program (6). This suggests that the current pension fund cannot protect the future older population completely. The future sustainability of pension funds will still require government financial support, which will strongly impact China's fiscal sustainability (7). Consequently, in the face of rapid aging and pressure on pension fund payments, raising the normal retirement age is urgent for China.

The retirement age in China is stipulated as 60 for men and 50 for blue-collar women (8). In 1955, the State Council of China promulgated a document raising the retirement age for white-collar women to 55. This gender-specific age policy has been in place ever since (9). The average normal retirement age in Organization of Economic Cooperation and Development (OECD) countries in 2018 was 64.2 years for men and 63.5 years for women (10). Compared with the retirement age regulations of OECD countries, China's retirement age is significantly lower, especially for women. At the same time, more than half of OECD countries have the same retirement age for men and women, and even if the remaining countries adopt the policy of different retirement age for men and women, the retirement age gap between men and women is relatively low. For example, the retirement age gap between men and women in Slovenia is only 0.3 years (11). In contrast, the gap between men and women for retirement age in China is 5 years (for men and white-collar women) or 10 years (for men and blue-collar women)—significantly higher than in OECD countries. Contradictions exist between the relatively elevated life expectancy of Chinese women and the relatively early retirement age. The average life expectancy of Chinese women in 2020 was 79.43 years, while that of men was 73.64 years, according to the *National Bureau of Statistics of China*. Although life expectancy cannot be regarded as an accurate indicator forecasting women's health, it still remains of some indicative significance (12). Although the Chinese government's policies regarding retirement at different ages for men and women were originally intended to protect women's rights, it is undeniable that with China's rapid development and women's increased health and education, these policies have shortened women's careers and hindered their professional development (13).

Under these circumstances, there is still no definite proposal for delaying retirement, even though China initiated research on the formulation and promotion of a delayed retirement policy as early as 2013, but these results are still limited to the academic community (14). Prolonging the retirement age of women may not yield the expected results, not all the older women are capable of working, especially for those burdened by physical or psychosocial health limitations. Simply prolonging the retirement age while disregarding heterogeneity among older women may lead to increased inequality between healthy and unhealthy individuals, further impairing the lives of older women in general (15). Consequently, one of the criteria for determining the delay in retirement age should be whether the older women is able to cope, and for how long, with the excess work (16).

It is well-known that retirement desire increases with age (17). Physical condition of middle-aged and older women tends to decline with age, thus poor physical condition is often cited to explain early retirement (18). As a consequence of the phenomenon, scholars have subsequently introduced other ideas such as economic factors and social security (19, 20). Some scholars believe the impact of health on retirement cannot be ignored even though it is more economical to keep working (21, 22). While numbers of scholars concur with the importance of health as a factor influencing retirement in middle and old age, there are still different arguments on the metrics of health. In studies related to health and retirement, self-rated health was first used as a proxy variable for health (23, 24). However, the endogenous side effects of self-assessed health cannot be avoided, such as the tendency of the unhealthy population to exaggerate their health conditions and retire early on the grounds of illness (25). Thus, objective health indicators have gradually been adopted by scholars to avoid these biases. Mortality, for example, is more serious and has a greater impact on labor force participation behavior (26). Several articles investigate the impacts of specific illnesses on retirement decisions, like chronic disease (27) and disability (28). However, fully objective health measures, although avoiding endogeneity problems, have three drawbacks. First, the dimensionality is single and answers are usually dichotomous variables that do not provide a comprehensive description of the condition (29). Second, the association between objective health status and labor supply is dependent on the individual's occupation, e.g., arthritis affects painters more than white-collar workers (30). Finally, geographical or cultural differences, e.g., the United States and the Netherlands have different criteria for disability (31). Thus, objective ratings of health are prone to measurement bias. To avoid endogeneity problems and measurement bias, Stern combined the two using objective health indicators as instrumental variables for self-rated health (32). Poterba, Venti, and Wise (PVW) combined self-rated health with objective health indicators using principal component analysis to construct a composite health index to comprehensively assess the health of older adults. This index has several important attributes, it has a strong stability over time. It strongly correlates with mortality and is a good predictor of future health events, such as the onset of cancer or diabetes (33, 34). This index has been used in excess work capacity studies in several countries (35–38).

There are two principal approaches to health-level flexible retirement age measurements. First, based on mortality, Wise estimates excess work capacity by comparing decline in mortality in the long-term group (as a proxy for health improvement) with variations in labor participation among the older population, but this does not provide a reasonable explanation for the rising trend in female employment rates over time (39). The second approach by Cutler, Meara, and Richards-Shubik (CMR) is based on comprehensive health status, which associates employment rate with health status by using the regression coefficient of the middle-aged group to calculate the expected labor participation rate of the older group. The difference between the expected rate and the actual rate referred to the excess working capacity (40), the

approach has been widely adopted in countries such as Spain (38), Japan (41), and Denmark (36).

From a health perspective, to what age can Chinese women delay retirement? Since China has not formally implemented a delayed retirement policy, answering this question can help promote the delayed retirement policy (13). Therefore, this paper uses the CMR health measurement model, combined with the PVW comprehensive health index, to measure women's excess work capacity based on their health level, and to a certain extent, to simulate and evaluate whether Chinese women have the health capacity to support their delayed retirement. This paper further enriches the measurement of retirement age, and provides theoretical support for the delayed retirement policy.

2. Materials and methods

2.1. Data

Data for this study were collected from four periods of the China Health and Retirement Longitudinal Study (CHARLS) in 2011, 2013, 2015, and 2018. CHARLS is a nationwide questionnaire survey conducted in 150 counties among 28 provinces (autonomous regions and municipalities) in China (42), created by the National Development Research Institute of Peking University. The CHARLS baseline survey was chosen because it contains a large number of health status measures, and it focuses on the Chinese population over the age of 45, which matches the required sample age for this study. Basic information such as health status and function, health care and insurance, and work retirement pension from the CHARLS questionnaire were involved in this study. Women aged 45–74 were selected as subjects, those missing critical variables were excluded. Eventually, a valid sample of 31 937 cases was obtained, including 19 524 cases in the labor participation group and 12,413 cases in the non-labor participation group. As one person may appear in multiple waves, standard errors were clustered at the individual level.

2.2. Variables

2.2.1. Labor participation

In this study, labor participation is defined as the dependent variable and is a binary dummy variable. If labor participation behaviors exist, it was recorded as 1, and if not, as 0. Labor participation in CHARLS consists of being engaged in agricultural production activities for more than 10 days during the past year, being engaged in paid work for at least 1-h last week, and being currently on leave or training status. Those who had never worked in their lifetime were excluded from this study ($n = 1996$).

2.2.2. Women's health

In this paper, two main forms of health expressions are adopted, the first one is the inclusion of single health variables, including subjective ratings and objective measures. The subjective assessment is the self-assessment of health status, which is divided into five levels: very good, good, fair, poor, and very poor. Objective measures include the depression (CESD-10) score, limitations on activities of daily living (ADLs), instrumental activities of daily living (IADLs), disabilities, psychiatric conditions, eyesight, hearing, chronic falls, fractures, smoking, and drinking. In CHARLS, depression was assessed using the Center for Epidemiologic Studies Depression Scale (CESD-10), ADLs are measured using a 6-item summary assessed with an ADL scale that includes eating, dressing, transferring, bathing, using the toilet, and continence, IADLs cover telephone, housework, cooking, medication, shopping, and financial management, with four different options for each measure: "no difficulty, difficulty but can still do it, difficulty needing help, and unable to do it" (42). In this study, having any ADL limitation was identified as an ADL disability, and IADL was classified in the same way. The second is the use of a composite health index instead of a series of health indicators, drawing primarily from Poterba, Venti, and Wise's composite health index (hereafter referred to as the PVW index) (34). This health index was constructed based on 19 questions, including self-rated health, functional limitations, hospital admissions, and other health indicators. The first principal component of the indicator set is used first and is ranked in percentile order based on principal component scores, so that the index is a percentile scale from 1 to 100, with higher scores associated with better health. The weights of the components in constructing the PVW index are shown in Appendix Table A1.

2.2.3. Control variables

Sociodemographic characteristics constituted the control variables for this study. The main ones included age, place of residence, marital status, educational attainment, and health insurance. Age was transformed into a categorical variable according to the needs of the study, and age 45–74 years was assigned as a group every 5 years, for a total of 6 groups. Marital status was a dummy variable, coded as 1 and 0, representing in marriage and not in marriage, respectively. Considering the differences in educational background over time, an education of junior high school and above was considered as higher education (43). Therefore, education level was divided into illiterate, elementary school, middle school, and above. Health insurance coverage was a dichotomous indicator of whether the participant reported having any type of health insurance. See Appendix Table A2 for variable definitions and codes.

2.3. Statistical analysis

2.3.1. Benchmark group setting

The key to the CMR estimation method is to assume that different age groups in the same health state have the same working capacity. Therefore, a younger group was selected in the study as reference for calculating the excess work capacity of the older group in the same health state. Women in this age group are farther away from retirement and retirement decisions tend to be independent of the pension system during this time, thus the effect of health characteristics on labor participation could be accurately assessed. However, there is a natural benchmark group in China, unlike in

developed countries, namely, Chinese rural women. More than 90% of the older people in rural China are primarily engaged in agricultural activities and do not require a clear retirement age as in urban employment (44). They usually do not choose to retire as long as they are physically able to continue working (13). There is a natural advantage in using this benchmark group as comparison to the younger group. Consequently, three benchmark groups are established in this paper: first, all women aged 45–49 years to predict the excess work capacity of all women aged 50–74 with rural and urban subgroups; second, rural women aged 45–49 to predict the capacity of urban women aged over 50 years; and third, rural women aged 50–54, 55–59, 60–64, 65–69, and 70–74 to predict the capacity of urban women with the same age.

This paper estimates the excess working capacity of older women through two steps. In the first step, a Probit model was used to estimate the relationship between health and labor participation in the benchmark group to obtain coefficients. In the second step, the coefficients obtained in the first step were combined with actual health characteristics of the post-retirement age group to predict the proportion of older workers (women aged 50–64 and women aged 50–74) working, and then to calculate their excess working capacity against the actual working proportion. In this sense, the excess work capacity defined in this paper refers to the ability to work that is determined by physical health.

Benchmark regression models of this paper were set as follows.

$$Work_i = \beta_0 + \beta_1 Health_{ij} + \beta_2 X_{ik} + \varepsilon_i \quad (1)$$

In model 1, $Work_i$ represents individual labor participation status. $Health_{ij}$(j = 1, 2…8) represents individual health characteristics, including a series of health indicators like self-assessment of health, chronic diseases, and disability; X_k (k = 1, 2, 3, 4) represents control variables; β_0 is a constant term, β_1 is a health coefficient, and ε_i is a random disturbance term.

$$Work_i = \beta_0 + \beta_1 PVW_i + \beta_2 X_{ik} + \varepsilon_i \quad (2)$$

In model 2, the health index was not regressed on multiple sets of health indicators but rather a percentile ranking after converting all health indicators of an individual into a PVW index, which is done to corroborate the validity of model 1. Higher index is associated with better health, which means that the health coefficient can be interpreted as the effect of a one percentage point change in the health distribution on the probability of labor participation. Stata (version 16.0, Stata, Computer Resource Center, College Station, TX, USA) was used for data analysis.

2.3.2. Years of labor participation

For converting the excess labor participation rate into excess years of labor participation, Milligan and Wise measured the delayable retirement age for middle-aged and older Americans based on mortality rates, and demonstrated that the sum of the excess labor participation rates at each age group was equal to their delayable years of retirement. Excess years of work could be obtained by multiplying the additional labor participation rate for each age group by the age interval, according to Milligan and Wise's formula (45). Therefore, this method was used to convert the excess work rate of women into years.

2.3.3. Critical assumptions

Several assumptions exist in application of the CMR health measurement method. To ensure the scientific precision of the study, four items were summarized based on differences in background as follows. First, it is assumed that health status has been completely included and there are no missing or omitted health variables. With increasing age and poorer health, it is easy to overestimate the additional work capacity of older women, therefore multi-dimensional health behaviors, including smoking, are included in this paper to ensure that health status is completely assessed as much as possible. Second, it is assumed that health status has an equal motivational effect on women aged 45–49 with women aged 50 and above. Third, it is assumed that all non-labor participating women aged 45–49 are influenced by health factors to exit the labor market, and the effects of other non-health factors, such as institutional factors like pensions, are not considered. If present, they are prone to underestimate excess work capacity. Given that the highest legal retirement age for Chinese women is 55 (8), women in the 45–49 age group were selected for this study in order to avoid the influence of non-health factors as much as possible. However, it has been pointed out that early retirement is widespread in China (46), and although a sample from the younger pre-retirement group was used in this study to reduce this error, the excess work capacity obtained is likely to be underestimated due to the presence of early retirement. However, in terms of delayed retirement, this underestimation does not bring a fundamental change to the conclusions of this paper. Fourth, health and employment endogeneity issues, like the reverse effect of labor participation on health, are not considered.

3. Results

3.1. Descriptive statistics

The labor participation rates, individual characteristics, and prevalence of disease among urban and rural women by age group are described in Table 1. Labor participation rate generally decreases with age. The rate is lower in urban women than in rural women and shows a significant downward trend at the age of 55, while the rate of rural women decreases more smoothly, from 84.1% at the age of 45–49 to 42.2% at the age of 70–74, with a total decrease of 41.9%. The rate of urban women plunges to 59.7% just after 55. With regards to health, it was found that PVW health index along with extremely good and relatively good self-rated health are gradually decreased with age, while the proportion of fair, bad, and extremely bad increased, so did most of the remaining health indicators. And the health status of urban women was generally higher than rural women. However, depression trended oppositely as depression levels decreased with age, which is consistent with the observation that subjective wellbeing or psychological health usually improves at older ages. The proportion of women aged 45–54 with secondary specialized education and above is relatively high, and there is an obvious downward trend after the age of 54, with the educational level of urban women being significantly higher than that of rural women, which is consistent with different generations of Chinese. The proportion of divorce and widowhood

TABLE 1 Labor participation rates, individual characteristics and prevalence of disease by age group.

		Rural women age group						Urban women age group					
		45–49	50–54	55–59	60–64	65–69	70–74	45–49	50–54	55–59	60–64	65–69	70–74
Work		0.841	0.772	0.735	0.685	0.605	0.422	0.678	0.483	0.286	0.217	0.126	0.081
PVW index		58.493	55.453	51.565	47.774	41.789	36.789	65.857	62.736	55.915	52.140	48.362	47.194
SRH	Very good	0.046	0.072	0.068	0.062	0.063	0.051	0.049	0.093	0.078	0.058	0.082	0.059
	Good	0.106	0.093	0.099	0.095	0.093	0.112	0.152	0.131	0.118	0.129	0.075	0.121
	Fair	0.543	0.498	0.484	0.465	0.437	0.413	0.582	0.577	0.568	0.556	0.579	0.562
	Poor	0.269	0.292	0.305	0.327	0.353	0.367	0.203	0.173	0.203	0.229	0.222	0.230
	Very poor	0.036	0.045	0.044	0.052	0.054	0.057	0.014	0.026	0.033	0.029	0.042	0.028
CESDscore		9.656	10.080	10.250	10.750	10.850	10.810	8.125	7.847	8.156	8.263	8.121	7.684
Physical limits	one	0.144	0.142	0.176	0.192	0.205	0.216	0.089	0.094	0.130	0.162	0.171	0.174
	Many	0.060	0.089	0.120	0.147	0.230	0.309	0.027	0.039	0.078	0.088	0.121	0.135
ADL: Any		0.029	0.033	0.045	0.071	0.092	0.132	0.014	0.016	0.041	0.036	0.070	0.068
IADL: Any		0.103	0.123	0.155	0.195	0.237	0.274	0.043	0.059	0.094	0.104	0.139	0.130
Chronicdisease	One	0.297	0.287	0.294	0.286	0.259	0.242	0.330	0.286	0.266	0.230	0.219	0.187
	Many	0.372	0.426	0.472	0.519	0.569	0.580	0.379	0.445	0.524	0.614	0.674	0.668
Disability		0.022	0.035	0.036	0.043	0.057	0.057	0.030	0.036	0.027	0.037	0.041	0.037
Psychiatric condition		0.031	0.032	0.034	0.044	0.052	0.051	0.019	0.030	0.029	0.040	0.048	0.025
Eyesight poor		0.046	0.059	0.060	0.085	0.123	0.138	0.032	0.039	0.054	0.077	0.088	0.064
Hearing poor		0.051	0.069	0.072	0.098	0.125	0.173	0.049	0.053	0.068	0.081	0.112	0.121
Falldown		0.162	0.174	0.197	0.236	0.253	0.276	0.167	0.174	0.220	0.192	0.224	0.214
Fracture		0.008	0.010	0.015	0.017	0.017	0.024	0.009	0.009	0.014	0.005	0.013	0.018
Smoke		0.056	0.063	0.073	0.106	0.109	0.141	0.035	0.065	0.049	0.076	0.066	0.126
Drink		0.075	0.075	0.076	0.074	0.099	0.087	0.083	0.077	0.079	0.069	0.077	0.066
Married		0.970	0.949	0.914	0.871	0.782	0.641	0.937	0.926	0.883	0.847	0.795	0.607
Education:	Illiteracy	0.214	0.273	0.444	0.518	0.514	0.615	0.037	0.059	0.113	0.158	0.203	0.195
	Elementary	0.515	0.426	0.369	0.399	0.431	0.333	0.238	0.236	0.261	0.367	0.402	0.434
	Middle and Above	0.271	0.301	0.187	0.082	0.054	0.052	0.726	0.705	0.627	0.476	0.395	0.372
Health Insurance		0.921	0.908	0.926	0.915	0.922	0.900	0.896	0.919	0.916	0.907	0.945	0.916
Observation		4,003	4,716	4,772	4,975	3,753	3,448	791	1,085	1,209	1,211	997	977

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increases as age increases, so the proportion of non-married women gradually increases.

3.2. Regression analysis of women's health and labor participation

3.2.1. Regression analysis of women's health and labor participation: Women aged 45–74

Considering that women aged 45–49 have not reached retirement age and may not reflect the association between health and labor participation well, a regression was first conducted for all women aged 45–74. Table 2 demonstrates the results of the Probit regression between labor participation and health for women aged 45–74 based on all health variables in Model 1. The majority of health indicators were associated with labor participation. Worse health, one or more physical limits, numbers of ADL or IADL limitations equal to or above 1, multiple chronic conditions, disabilities, psychiatric conditions, and smoking were all associated with lower labor participation. However, CESD score, number of falls, and the consumption of alcohol were positively associated with labor participation, which could be due to a multiple covariance phenomenon caused by entering excessive health indicators simultaneously. To avoid such problems, health indicators were excluded in the baseline regressions of Table 3, which used the PVW index instead of a series of health indicators. Women who married, with rural residence, and with health insurance have higher labor participation, but the phenomenon worth noting is that highly educated women are associated with lower labor participation.

TABLE 2 Regression of women's health and labor participation (N = 31,937).

Variable		45–74 women	
		Coef.	S.E.
SRH	Good	0.1775***	(0.0387)
	Fair	0.0671*	(0.0325)
	Poor	−0.0439	(0.0352)
	Very poor	−0.1989***	(0.0493)
CESDscore		0.0173***	(0.0013)
Physical limits	One	−0.1802***	(0.0209)
	Two and more	−0.5819***	(0.0252)
ADL	Yes	−0.3319***	(0.0351)
IADL	Yes	−0.1987***	(0.0231)
Chronicdisease	One	−0.0418	(0.0220)
	Two and more	−0.2541***	(0.0206)
Disability	Yes	−0.1149**	(0.0400)
Psychiatric condition	Yes	−0.1488***	(0.0402)
Eyesight poor	Yes	−0.0212	(0.0292)
Hearing poor	Yes	0.0116	(0.0271)
Falldown	Yes	0.1197***	(0.0192)
Fracture	Yes	−0.1345*	(0.0635)
Smoke	Yes	−0.2161***	(0.0270)
Drink	Yes	0.3784***	(0.0299)
Married	Yes	0.4327***	(0.0217)
Education	Elementary	−0.0087	(0.0177)
Middle school and above	−0.0249***	(0.0221)	
Health Insurance	Yes	0.1333***	(0.0270)
Residence	Rural	1.0970***	(0.0209)

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

3.2.2. Benchmark regression: Women aged 45–49

In this study, three benchmark groups were introduced, the first one utilizes the Cutler traditional approach of including all women aged 45–49 as a benchmark. Column A in Table 3 demonstrates the relationships between labor participation and health among all women aged 45–49, indicating a positive relationship between health indicators and labor participation. Marriage and educational status were not statistically significant stratifiers in the younger age group.

3.2.3. Benchmark regression: Rural women aged 45–49

The second benchmark group of this paper is rural women aged 45–49, which is used to predict the excess work capacity of urban women. Column B of Table 3 reports the health and labor participation regression results of rural women aged 45–49. As can be seen, the PVW coefficient of 0.0078 is lower than that of all women in the 45–49 age group. The PVW index is a 0–100 percentile, with larger representing better health, so the regression coefficient of the PVW index for rural women aged 45–49 is lower than that of all women in the same age group, implying that rural women Chinese rural women's work decisions are less responsive to health levels. As expected, rural women have a higher labor participation rate, but their health level is worse, and therefore have lower PVW coefficients.

3.2.4. Benchmark regression: Rural women by age group

The previous two benchmark groups used young cohorts. It is expected that, although the results can be more sensitive when using young cohorts as the benchmark, it is more likely to exaggerate capacity to work than when using women of the same age group as the benchmark. Columns C-G in Table 3 demonstrate the relationship between labor participation and health among every age group of rural women. Horizontally, PVW coefficients of rural women aged 45–59 gradually decreased, indicating that as rural women grew older, declining health had no significant impact on labor force participation, which proves that rural women tend to continue working as long as their health allows. The PVW coefficients of rural women aged 60–74 gradually increased, indicating that as rural women age further, and the relationship

TABLE 3 Benchmark regression of women's health and labor participation (PVW Index).

Variable	45–49	Rural women age group					
	All women	45–49	50–54	55–59	60–64	65–69	70–74
	A	B	C	D	E	F	G
PVW Index	0.0088***	0.0078***	0.0069***	0.0068***	0.0074***	0.0092***	0.0091***
	(0.0008)	(0.0009)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Married							
Yes	−0.0441	−0.031	0.2344**	−0.0326	0.1383*	0.3768***	0.2571***
	(0.1120)	(0.1378)	(0.0880)	(0.0715)	(0.0550)	(0.0507)	(0.0459)
Education							
Elementary	0.1458*	0.0959	−0.077	−0.1449**	−0.1405***	−0.0643	−0.0357
	(0.0590)	(0.0611)	(0.0507)	(0.0443)	(0.0395)	(0.0437)	(0.0469)
Middle school and above	0.0759	0.0621	−0.1872***	−0.2834***	−0.2660***	−0.4937***	−0.3993***
	(0.0650)	(0.0698)	(0.0544)	(0.0538)	(0.0690)	(0.0949)	(0.1037)
Health Insurance							
Yes	0.3397***	0.3709***	0.0571	0.4426***	0.0258	0.1875*	0.0722
	(0.0718)	(0.0818)	(0.0706)	(0.0709)	(0.0665)	(0.0785)	(0.0738)
Residence							
Rural	0.6094***	–	–	–	–	–	–
	(0.0580)	–	–	–	–	–	–
Observations	4,794	4,003	4,716	4,772	4,975	3,753	3,448

Standard errors in parentheses, *p < 0.05, **p < 0.01, ***p < 0.001.

between labor force participation and health status becomes more sensitive. Longitudinally, marriage and education level are statistically significant stratifiers in rural women of higher age groups. Unmarried or highly educated women are often associated with lower labor participation, so it is necessary to conduct further analysis of educational heterogeneity.

3.3. Measurement of excess labor participation rate

3.3.1. All (urban and rural) women: Benchmark of women aged 45–49

The results of the two-model measures of predicted work capacity and delayable work capacity for women in each age group were summarized in Table 4. Based on the regression results of the women aged 45–49 in Table 3, further predictions were conducted for women aged 50–74, on the subsequent measure of excess work capacity. The results of model 1 are still given in order to compare the two models. Actual labor participation rates of women aged 50–74 were high in all age groups, with 34.64% still working in women aged 70–74, however, the actual labor participation rate of urban women aged 70–74 is only 8.09%. As rural women account for nearly 80% of this study, the larger sample resulted in a higher labor participation rate for all women and a lower ability to excess work. Therefore, further measurements were conducted to stratify urban and rural women. It was found in model 1 that the excess labor participation rates of rural women aged 50–54, 55–59, 60–64, 65–69, and 70–74 were 4.34, 7.19, 11.12, 17.98, and 34.61%, respectively, while the rates of urban women in the same age group were 30.69, 50.19, 56.55, 64.50, and 67.19%, respectively, about 2–3 times higher than those of rural women.

3.3.2. Urban women: Rural women as benchmark

The predicted results based on rural women aged 45–49 are displayed in Table 5, and the excess work capacity predicted based on rural women aged 45–49 is higher compared to that based on all women aged 45–49. The capacity of model 1 shows an increase from 32.51 to 36.94%. The capacity increases from 55.46 to 55.05% for urban women aged 50–54, and the capacity of model 2 is higher than that of model 1 by about 3% for all age groups.

3.3.3. Urban women: Rural women of different age groups as benchmarks

Benchmarking exclusively on high labor participation rates of rural women aged 45–49 may overestimate the capacity of urban women. The second part of Table 5 compares the capacity of rural women with urban women at the same age and finds more conservative results for urban women, whose excess work capacity no longer increases with age, but decreases after reaching a peak of 45.95% at age 60–64.

TABLE 4 Calculation of excess work capacity (%): all 45–49 women as benchmark.

	Age group	Obs	Actual working	Model 1: All health variables		Model 2: PVW index	
				Predicted working	Excess working capacity	Predicted working	Excess working capacity
All	50–54	5,801	71.82	78.47	6.65	78.69	6.87
	55–59	5,981	64.44	76.86	12.42	77.43	12.99
	60–64	6,186	59.36	75.84	16.48	76.58	17.22
	65–69	4,750	50.44	74.08	23.64	75.28	24.84
	70–74	4,425	34.64	71.70	37.06	73.86	39.22
Urban	50–54	1,085	45.70	78.21	32.51	78.98	33.28
	55–59	1,209	25.90	77.36	51.46	78.81	52.91
	60–64	1,211	19.50	77.77	58.27	78.27	58.77
	65–69	997	13.14	77.65	64.51	77.14	64.00
	70–74	977	8.33	77.60	69.27	75.28	66.95
Rural	50–54	4,716	77.23	81.41	4.18	81.57	4.34
	55–59	4,772	73.51	80.20	6.69	80.70	7.19
	60–64	4,975	68.52	79.04	10.52	79.64	11.12
	65–69	3,753	60.48	77.47	16.99	78.46	17.98
	70–74	3,448	42.17	74.86	32.69	76.78	34.61

TABLE 5 Calculation of excess work capacity (%): different benchmark.

Age group	Obs	Actual working	Model 1: All health variables		Model 2: PVW index	
			Predicted working	Excess working capacity	Predicted working	Excess working capacity
50–54	1,085	45.70	82.64	36.94	83.11	37.41
55–59	1,209	25.90	80.95	55.05	82.15	56.25
60–64	1,211	19.50	80.28	60.78	81.82	62.32
65–69	997	13.14	79.03	65.89	81.66	68.52
70–74	977	8.33	78.34	70.01	81.77	73.44
50–54	1,085	45.70	75.49	29.79	75.8	30.10
55–59	1,209	25.90	70.72	44.82	71.35	45.45
60–64	1,211	19.50	65.45	45.95	65.82	46.32
65–69	997	13.14	54.81	41.67	55.82	42.68
70–74	977	8.33	38.81	30.48	39.36	31.03

3.4. Heterogeneity analysis of educational level

Delayable labor participation rates among women of different educational levels by age group are reported in Table 6. The largest capacity was obtained from the benchmark group of rural women aged 45–49, and the most conservative result was obtained from the benchmark group of illiterate women of all ages. In terms of the actual participation rate, women with higher educational levels tend to have lower labor participation rates, with the labor participation rates of women aged 50–54, 55–59, 60–64, 65–69, and 70–74 in secondary specialized education and above being 64.27, 48.65, 33.85, 20.53, and 12.57%, respectively. The participation rate of illiterate women aged 70–74 was at 41.82%. As for estimated labor participation rates, differences among women with different educational levels were not significant, all around 60–80%. However, when comparing excess work capacity, illiterate women tend to be lower, while women with secondary specialized education and above tend to increase more distinctly with age. The excess labor participation rates calculated from all women, urban and rural women, and women with different educational levels, show the results of the PVW score model are similar with those of the full health variable model, indicating good statistical stability.

TABLE 6 Excess work capacity of women with different education levels (%).

Age group	Education	Obs	Actual working	Benchmark: Women 45–49		Benchmark: Rural women 45–49		Benchmark: By education	
				Predicted working	Excess working capacity	Predicted working	Excess working capacity	Predicted working	Excess working capacity
50–54									
	Illiteracy	1,351	77.94	80.26	2.32	80.98	3.04	78.16	0.22
	Elementary	2,267	74.06	79.47	5.41	82.80	8.74	77.35	3.29
Middle school and above		2,183	65.69	77.46	11.77	82.31	16.62	75.62	9.93
55–59									
	Illiteracy	2,256	74.16	79.38	5.22	80.61	6.45	77.37	3.21
	Elementary	2,074	66.68	78.14	11.46	82.40	15.72	75.94	9.26
Middle school and above		1,651	48.33	74.59	26.26	81.76	33.43	72.48	24.15
60–64									
	Illiteracy	2,769	68.51	77.82	9.31	79.62	11.11	75.68	7.17
	Elementary	2,431	58.86	77.07	18.21	82.00	23.14	74.81	15.95
Middle school and above		986	34.89	71.80	36.91	81.39	46.50	69.48	34.59
65–69									
	Illiteracy	2,133	58.23	76.53	18.30	79.31	21.08	75.00	16.77
	Elementary	2,019	50.72	75.29	24.57	81.21	30.49	73.30	22.58
Middle school and above		598	21.74	69.07	47.33	80.86	59.12	66.87	45.13
70–74									
	Illiteracy	2,312	40.53	75.51	34.98	78.57	38.04	74.42	33.89
	Elementary	1,572	33.59	73.41	39.82	80.76	47.17	71.84	38.25
Middle school and above		541	12.57	68.62	56.05	80.24	67.67	66.38	53.81

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TABLE 7 Years of excess work for women (Years).

	All	Residence		Education		
		Urban	Rural	Illiteracy	Elementary	Middle school and above
Benchmark: Women 45–49						
50–64	1.9	7.2	1.1	0.8	1.8	3.7
50–74	5.1	13.8	3.8	3.5	5.0	8.9
Benchmark: Rural women 45–49						
50–64	–	7.8	–	1.0	2.4	4.8
50–74	–	14.9	–	4.0	6.3	11.2
Benchmark: Age specific rural women age group						
50–64	–	6.1	–	–	–	–
50–74	–	9.8	–	–	–	–
Benchmark: By education						
50–64	–	–	–	0.5	1.4	3.4
50–74	–	–	–	3.1	4.5	8.4

3.5. Measurement of excess work capacity years

Table 7 reports the measurement results of the PVW index model of women's excess working years. When urban and rural areas are not stratified, it is found that the excess working capacity of all women aged 50–64 is only 2 years, and that of all women aged 50–74 is 5.1 years, therefore excess working capacity is not obvious. It may be that there are more rural women in the study, which leads to an increase of the "endless labor" sample, so the predicted excess working capacity is small. Subsequently, urban and rural women were calculated separately, and it can be seen that when taking all women from 45 to 49 as the benchmark, the excess working years in urban and rural areas from 50 to 64 are 7.2 and 1.1 years, respectively, and the excess working years in age group from 50 to 74 are 13.8 and 3.8 years, respectively. The excess working capacity of urban women is huge. Therefore, to further measure the excess working ability of urban women, different rural women groups were taken as the benchmark group. When using rural women aged 45–49 as the benchmark, the excess working ability of urban women aged 50–64 and 50–74 is 7.8 and 14.9 years, respectively. This was done to avoid overestimating the excess working ability of urban women. As expected, the benchmark for rural women in the same age group gives a more conservative result of 6.1 and 9.8 years of extra work for urban women aged 50–64 and 50–74, respectively.

When measured separately in terms of educational level, it was found that the excess years of work were increased with increasing educational level. The increase was 3.5–4.8 years for women aged 50–64 with middle school and above, and 8.4–11.2 years for women aged 50–74, which illustrates that older women with higher educational level tend to possess higher work potential.

4. Discussion

The current policy reform on delayed retirement in China has not yet been implemented, and there are few studies on excess work capacity based on health perspective in China. The excess work capacity of Chinese women was estimated using a Probit model by comprehensively assessing women's health status using a variety of single health variables and PVW health coefficients. There is one study closely related by Cutler et al. who estimated the excess work capacity of the older workforce using data from 12 countries participating in the *International Social Security Project* (ISS), including the UK, Japan, Germany, and Italy, which conducted an international comparison (40). Unlike previous studies, this paper includes two new benchmark groups, young rural women in China and rural women in the same age group. Compared to Cutler et al. who took a single young cohort as the baseline group for their study, China, a developing country, has a special study context with urban-rural background differences and rural women with endless labor behavior (13, 47, 48). Rural women in China tend not to have a clear concept of retirement and will work if their health allows. Therefore, the use of the same age group of rural women as the benchmark group, ensures more accurate results than using a younger cohort and is less likely to have results that exaggerate the excess work capacity of older adults.

Health level is associated with labor force participation among older adults. Older women with better health tend to remain in the labor force, which is consistent with previous research (49, 50). The effect of health on labor participation is not only manifested in self-rated health, but objective health measures such as chronic illness, ADL and IADL are significantly associated with labor participation (27). It is important to note that Chinese rural women generally have lower health levels than urban women. Previous studies have also demonstrated that rural Chinese women are far less susceptible to retirement due to health issues than urban women (47). In other words, rural women are more likely to continue working as long as their health allows until their health deteriorates (15). This phenomenon is common in China, but this idea often leads rural women with health problems to remain in the labor market and thus experience health deterioration, exacerbating urban-rural health inequalities (51). Given the gap between rural and urban areas, the government should provide appropriate assistance to

middle-aged and older women who continue to work in agriculture due to economic factors and improve social welfare policies for middle-aged and older rural women to narrow the health gap between urban and rural women. The retirement age should also be set to maintain proper consideration of women's health levels and implement a flexible retirement policy (52).

The results of this study also suggest there is an urban-rural heterogeneity in the excess work capacity of older women. Urban women have significantly higher excess capacity to work than rural women, but urban women with better health have much lower actual labor participation rates than rural women. This suggests that urban women have health levels to support delayed retirement, but it does not mean that urban women are willing to continue working after retirement or support delayed retirement policies. Many scholars have investigated women's willingness to delay retirement and found that most urban women workers oppose delaying retirement (53). It is mainly due to two reasons, one is that urban women have better social security resources, they can get access to better social security services and benefits (54). In addition, the three-child policy is currently being advocated in China (55), due to China's strong traditional intergenerational ties and the inadequacy of the current childcare system (56, 57), more and more women prefer to retire to care for their grandchildren to reduce the pressure on their children (58, 59). In the absence of social support, many women are physically and psychologically exhausted by family (60). Therefore, in the formulation of delayed retirement policies, urban-rural differences should be considered according to health status. For urban women, a corresponding retirement incentive should be established to encourage women in better health to remain in the labor market and provide certain subsidies (61), while supporting policies such as infant and childcare services should also be implemented one after another. The public welfare services for childcare to some extent can weaken the grandparenting responsibility and intensity of the older women and in turn can enable them to remain in the labor market and prolong their working life (62).

Finally, educational heterogeneity was found in the excess work capacity of older women. Excess work capacity increases with education and the predicted working rate is higher for highly educated women, but the actual labor participation rate is lower. However, in developed countries such as Denmark, the extra work capacity of highly educated women is instead lower than that of less educated women (63). This shows there is currently a huge labor potential for highly educated older women of China. Along with Chinese women's education levels significantly rising (43), women's initial age of entry into the labor market has been delayed, while the retirement age has remained the same implying that women are working fewer years (64). Furthermore, women with higher education are generally in better health, especially the older people (65), thus, women with more education are more capable of delaying retirement (66). Therefore, considering the characteristics of knowledgeable women with long years of education, high starting age for employment, abundant human capital stock, and generally better health, it is possible to take the lead in implementing a delayed retirement policy in medical, scientific research, and higher education sectors where knowledgeable women are concentrated (67), so as to make reasonable use of human resources of highly educated female and gradually narrow the retirement age gap between males and women (52).

5. Limitations

This paper also has some limitations. First, this study is based on survey data from women aged 45 and above, which, although relatively representative, is the time women start to think about retirement and is not representative of the entire female population. Secondly, it is undeniable that the estimation method in this paper relies on many assumptions. For example, the endogeneity of labor force participation and health levels are not considered. Although multiple benchmark groups and different health measures were used to ensure the robustness of the findings as much as possible, given the importance of delayed retirement reform, we argue that more predictive research on the additional work capacity of the older population is still needed. Third, the delayed retirement age policy targets full-time workers, and the labor force participation behavior in this study is examined for both full-time and part-time women, and we hope that further distinctions can be made in future studies to better promote policy improvement.

6. Conclusion

China has announced a delayed retirement system, but the specific delayed retirement policy still needs to be formulated (8). As health is an essential factor affecting the employment of the older people (22), few studies in China have been conducted to explain whether the older population has sufficient health capacity to cooperate with implementing the delayed retirement policy from a health perspective. This study finds that older women in China still have some excess working capacity and room for delayed retirement based on women's health perspective, which further enriches the measurement of retirement age and provides some theoretical support for the delayed retirement policy. As the health level of older women continues to improve, if the labor potential of older women can be further explored, it will help further mitigate the adverse effects of population aging and realize the positive aging strategy (52). However, the implications of delaying retirement age reform are broad and far-reaching. In the future, there is still a need to use more detailed information on employment and health, taking into account a variety of integrated factors including health levels. A more in-depth exploration of the gender differences that exist in the retirement ages of men and women in China is needed to facilitate large-scale delayed retirement policy reform.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories

and accession number(s) can be found in the article/Supplementary material.

Ethics statement

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

Author contributions

YZ and YF conceived and designed the study and supervised the data analysis. XC and YZ wrote the paper. XC performed all statistical analyses. YZ and XC contributed to revising the paper. 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

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.987362/full#supplementary-material

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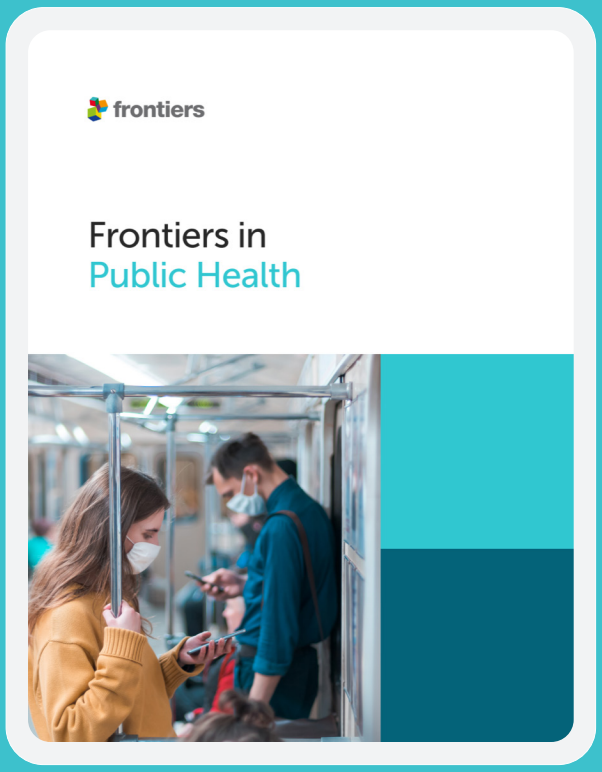

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