BMC Public Health

RESEARCH

Open Access

The impact of chronic diseases on the health-related quality of life of middle-aged and older adults: the role of physical activity and degree of digitization

Yining Hu[1], Yuke Yang[1], Yan Gao[1*], Liangyu Zhao[1], Lu Chen[1], Wenze Sui[1] and Jingquan Hu[1]

Abstract

Background The incidence of chronic diseases is on the rise worldwide, with a high mortality rate in China, posing a serious threat to the health-related quality of life (HRQoL) of middle-aged and older adults. This study explores the association between chronic diseases and the HRQoL of middle-aged and older adults, as well as the role of physical activity (PA) and degree of digitization in this relationship.

Methods The data used in this study was obtained from the 2018 China Health and Retirement Longitudinal Study (CHARLS), which included 13,620 middle-aged and older Chinese adults (≥ 45 years). The study utilized correlation analysis, and bootstrapping to investigate the mediating role of PA and the moderating influence of the degree of digitization. Data analysis was conducted using SPSS 26.0.

Results The study findings indicate that the severity of chronic disease has a significant negative predictive effect on HRQoL (PCS, physical component summary; MCS, mental component summary) (PCS: $\beta = -2.515$, $p < 0.01$, MCS: $\beta = -0.735$, $p < 0.01$). Further analysis revealed that PA plays a mediating and masking role in the impact of chronic disease on PCS and MCS. Additionally, the degree of digitization moderates the relationship between chronic disease and PA, chronic disease and PCS, and PA and PCS.

Conclusion For middle-aged and older persons, chronic diseases have a detrimental effect on their HRQoL; nevertheless, PA can help. Furthermore, proper internet usage can help older individuals to some extent in mitigating the negative impact of chronic diseases. Therefore, it is encouraged to promote PA among the elderly with chronic diseases to improve their physical health, as well as to guide them in the proper use of the Internet to establish healthy behaviors.

Keywords Chronic disease, Health-related quality of life, Physical activity, Degree of digitization, Middle-aged and older adults

*Correspondence:
Yan Gao
gaoyanluck@sdu.edu.cn
[1]School of Physical Education, Shandong University, No. 17923, Jingshi Road, Lixia District, Jinan City 250061, Shandong Province, People's Republic of China

Introduction

Chronic non-communicable diseases, such as hypertension, hyperlipidemia, hyperglycemia, hyperuricemia, and obesity, are the most common. According to World Health Statistics, four major chronic diseases, including diabetes, caused about 33.3 million deaths globally in 2019 alone, representing a 28% increase compared to 2000 [1]. In China, the probability of dying from the four major non-communicable diseases, namely cardiovascular disease, cancer, diabetes, and chronic respiratory disease, between the ages of 30 and 70 is 15.9% [1]. Moreover, as of the end of 2022, the elderly demographic in China, aged 60 and above, has surpassed 280 million. Projections indicate that by 2040, the population of individuals over 60 will reach an estimated 402 million [2]. With the rapid economic and social development in China and the exacerbation of the aging trend, chronic diseases have become a serious public health issue that threatens the lives and health of the people.

Additionally, many people with chronic diseases do not suffer from a single ailment but rather have two or more chronic diseases [3]. This not only leads to treatment challenges, increased medication usage, and a heavier disease burden but also significantly affects the quality of life of the patients [4]. Studies have shown that comorbidity or multiple chronic conditions have a significant negative impact on the quality of life [5], and patients with multiple chronic conditions have more severe pain and a higher risk of depression compared to those with fewer chronic diseases [6]. Furthermore, several studies have confirmed that chronic diseases restrict their physical functioning and deteriorate patients' overall health, subsequently affecting their quality of life [7–9].

Health-related quality of life (HRQoL) is a broad multidimensional concept that usually refers to the perceived physical and mental health status of an individual or a group over time, and it includes both physical health summary (PCS) and mental health summary (MCS) [10]. HRQoL reflects the overall impact of medical or therapeutic interventions on patients, particularly those with chronic diseases [11]. It is widely believed that HRQoL is a complex construct that encompasses three distinct areas: physical, psychological, and social functioning [9]. Research has shown that chronic diseases and multimorbidity are consistently associated with declining HRQoL across different age groups [12, 13]. Individuals with at least one or five common chronic diseases are even more likely to have lower HRQoL [14]. Therefore, it is assumed that chronic diseases have a negative impact on the HRQoL of middle-aged and older adults.

Chronic Inflammation and most chronic diseases can benefit from physical activity (PA). Engaging in regular PA can provide benefits for physical and mental health [15–18]. Some elderly adults diagnosed with chronic diseases may believe that PA could exacerbate their symptoms, leading to deterioration of their conditions, and ultimately reducing their PA levels [19]. Furthermore, research has confirmed that the presence of chronic diseases to some extent limits physical functioning, leading to reduced PA among elderly adults with chronic diseases [20, 21]. A decrease in PA levels may lead to increased disease risks, deterioration of mental health, increased prevalence of depression, and a closely related decline in HRQoL [22–24]. Conversely, regular moderate-to-high-intensity exercise can induce beneficial cardiac metabolic effects, prevent cardiovascular diseases, and reduce the association between sedentary time and the risk of mortality [25, 26]. Health ecology theory suggests that an individual's health behaviors are influenced by the interaction of several factors, including personal factors, the social environment, and behavioral characteristics. According to this theory, the level of participation in PA can be considered a health behavior, and the health status of older people is influenced by PA and its interactions [27]. Hence, we hypothesize that chronic disease can influence the HRQoL of middle-aged and older adults through PA.

In addition, the utilization of the internet is also seen as a significant determinant of the well-being of middle-aged and elderly adults [28]. The Internet, as an essential communication tool in current life, has been shown to potentially have a positive impact on the cognitive reserve of older adults, which has a non-negligible positive effect on active aging [29]. As internet usage rates continue to rise, concerns about its impact on health have also grown. According to the Social Cognitive Theory, older people can learn about various health issues through the use of the Internet in an observational learning manner, which motivates them to take part in physical activities and thus better maintain their health [30]. Numerous studies suggest that using the Internet is beneficial for physical health [31]. For instance, internet technology has been widely utilized in the healthcare field [32, 33]; patients can use the Internet to access health information [34, 35], engage in Internet intervention for PA [16], and participate in telemedicine [36], among other uses. A longitudinal study has identified a specific association between the daily usage of the Internet by middle-aged and older persons in China and a steady decrease in the occurrence of several chronic diseases [32]. Additionally, research has demonstrated that internet technology promotes social engagement, which can help the elderly strengthen their social connections and alleviate feelings of loneliness, thus contributing to the psychological well-being of middle-aged and older adults [37, 38]. However, a significant body of research also holds the opposite view. While internet use may increase PA, excessive time spent online can lead to increased sedentary behavior,

reduced social interactions, and, ultimately, impairments to physical and mental health [39]. Previous studies have found that the higher the frequency of internet use, the more severe the impact on sleep duration [40, 41], and excessive internet use can also contribute to feelings of depression and anxiety [42]. Women with high internet usage are at an increased risk of future depression [43]. Therefore, with the widespread use of the internet among middle-aged and older adults, studying whether internet use among elderly adults with chronic diseases is beneficial to their HRQoL is a focal point of this research. Thus, we hypothesize that the degree of digitization plays a moderating role in the relationship between chronic disease, PA, and HRQoL.

Although related research has demonstrated the association between PA, degree of digitization, and chronic disease, the interconnections between chronic disease, HRQoL, PA, and the degree of digitization remain largely unexplored. Therefore, this study aims to explore the mediating role of PA in the relationship between chronic disease and HRQoL in middle-aged and older adults. Additionally, we investigate the moderating effect of the degree of digitization on the mediated relationship between PA and chronic disease in relation to the HRQoL of middle-aged and older adults. To achieve this, we propose three hypotheses and construct a theoretical model as depicted in Fig. 1.

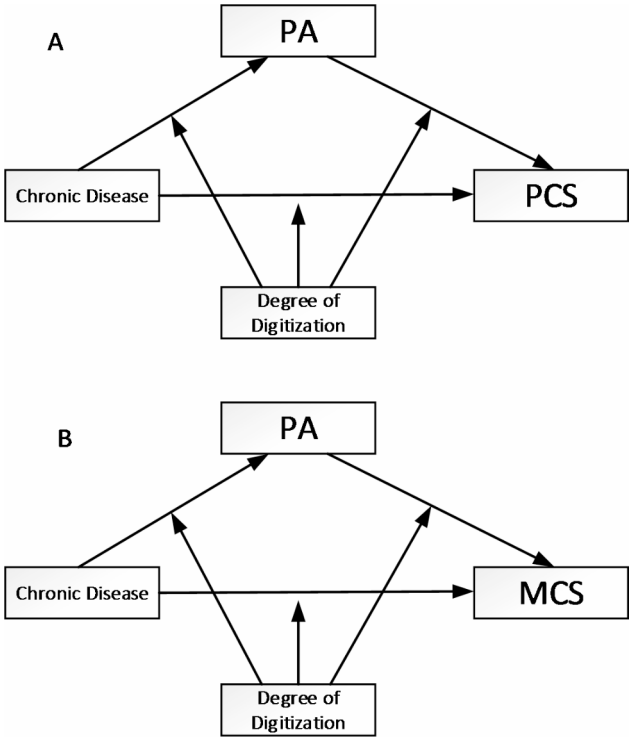

Fig. 1 Hypothetical Models: (**A**) Hypothetical Model between Chronic disease and PCS; (**B**) Hypothetical Model between Chronic disease and MCS. PA, Physical activity; PCS, Physical component summary; MCS, Mental component summary

Methods

Participants

The study participants were selected from the China Health and Retirement Longitudinal Study (CHARLS), which is a nationally representative survey performed by the National Development Institute of Peking University. CHARLS is a high-quality, household-based, longitudinal survey. The survey covers 28 provinces in China and aims to collect demographic information and basic health status of individuals aged 45 and above. CHARLS has received approval from the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants have given their informed consent.

The World Health Organization (WHO) criteria for categorizing a population's age are: 45–59 years old for middle-aged people and 60 years old and above for older people [44]. Therefore, this study used participants of CHARLS 2018 as our study population (n=19,816) and included people aged 45 years and older as study participants. Exclusion criteria included: (1) Adults aged 45 and below or with missing age information in the 2018 CHARLS survey (n=424); (2) Individuals for whom information on gender, age, residence, education level, marital status and chronic disease was not provided in the 2018 CHARLS survey (n=5279); (3) Those for whom information on PA, PCS, or MCS was unavailable in the 2018 CHARLS (n=493). Ultimately, the final sample consisted of 13,620 persons overall, comprising 6,507 males and 7,113 females. Figure 2 shows the detailed process for including and excluding study participants.

Measurement

Chronic diseases

In the CHARLS 2018 survey, we extracted data on "health status and functioning." The presence of chronic diseases was assessed by inquiring, "Has a doctor ever told you that you have any of the following?" CHARLS covers the following 14 chronic diseases: hypertension, dyslipidemia, diabetes, cancer or malignant tumor, liver disease, heart problems (heart attack, coronary heart disease, angina, and congestive heart failure), stroke, kidney disease, stomach or other digestive diseases, emotional, nervous, or psychiatric issues, memory-related diseases (such as dementia, cerebral atrophy, and Parkinson's disease), arthritis or rheumatic disease, and asthma. A value of "1" was assigned if the participant had the disease; otherwise, it was "0." A score of 0 to 14 is the total number of chronic diseases for each respondent, which indicates the severity of the chronic diseases, with a higher number of chronic diseases representing greater severity.

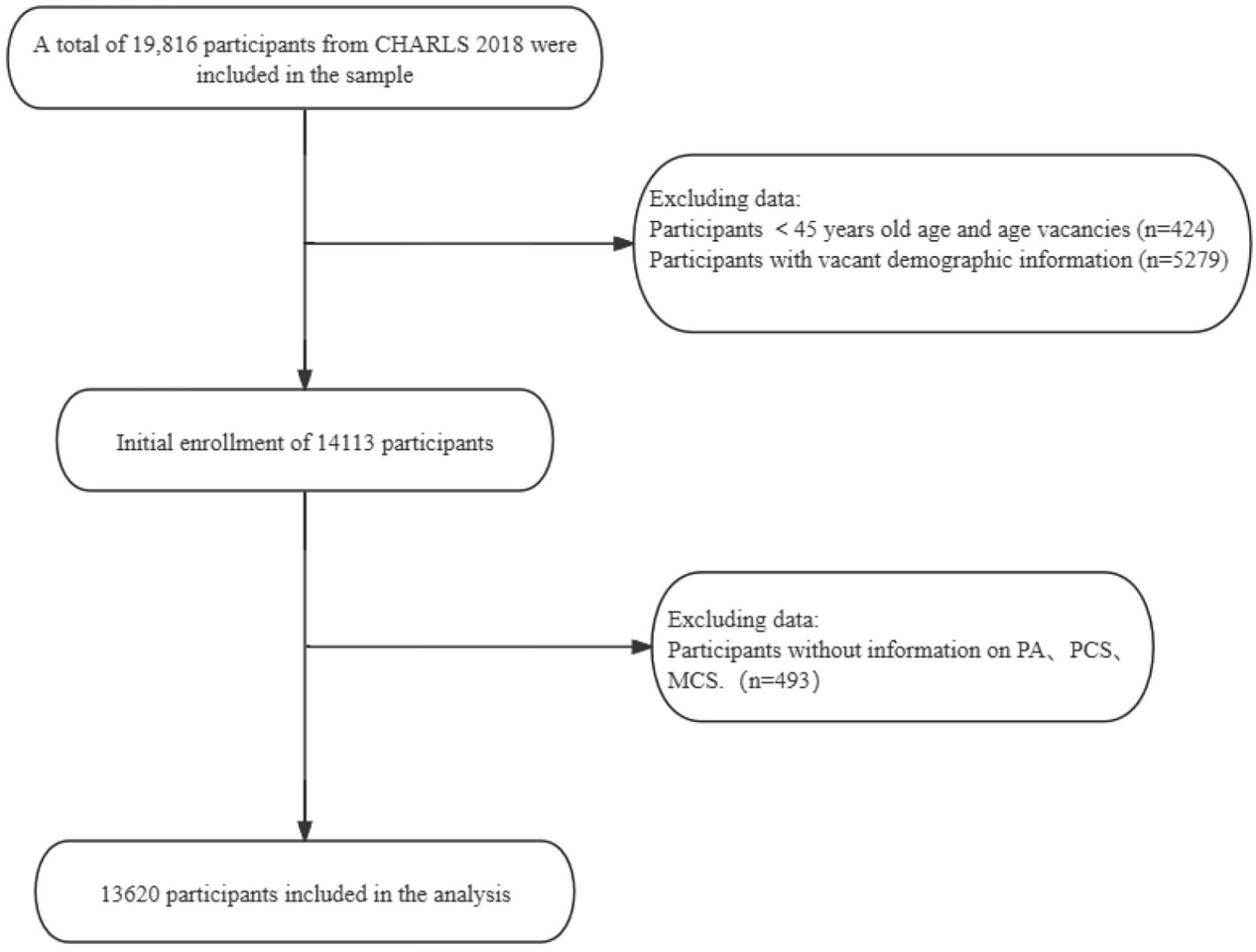

Fig. 2 Flowchart of the selection and analysis of the study sample. CHARLS, The China Health and Retirement Longitudinal Survey. PA, Physical activity; PCS, Physical component summary; MCS, Mental component summary

Health-related quality of life (HRQoL)

The HRQoL of individuals was measured using a new scale that was developed based on the Short Form 36 (SF-36) and CHARLS questionnaire variables. The SF-36 is a self-administered questionnaire used to assess general HRQoL. It consists of 36 items that measure eight different dimensions of HRQoL [45]. The construction of the new scale is based on the 8 dimensions of the SF-36 and selects corresponding CHARLS variables to assess the following 8 dimensions: physical functioning (PF), role-physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role-emotional (RE), and mental health (MH). Based on the conceptual model of the SF-36, the scores of the 8 dimensions were aggregated into 2 total scores, PCS and MCS, respectively [46]. Physical functioning, physical role, physical pain, and general health were calculated as PCS, and mental health, vitality, emotional role, and social functioning were calculated as MCS. In the study, the Cronbach's alpha of the scale was 0.781. Scores for the 8 dimensions are calculated by summing category scores and then converting the raw scores to a 0 to 100-point scale to provide an overall measure of physical and mental functioning, where higher values indicate better functioning. The questionnaire has been determined to be valid in Chinese populations and has been used in related studies [47].

Physical activity (PA)

This study used five questions from the CHARLS 2018 questionnaire to measure respondents' PA. In the CHARLS survey, PA types are classified into three categories: vigorous activities with strong energy expenditure, moderate-intensity physical activities, and light physical activities such as walking. Participants were asked if they engaged in each activity type for at least ten minutes continuously each week (yes=1, no=0). If the answer was "yes," they were then asked about the number of days per week they engaged in each type of PA for at least ten minutes (from 1 to 7 days, corresponding to 1–7 points); for those days when they engaged in each type of

PA, they were asked about the amount of time spent each day (≥10 min and <30 min, ≥30 min and <2 h, ≥2 h and <4 h, and ≥4 h). According to Liang Deqing's principle of PA calculation [48], each activity type's time, frequency, and intensity were multiplied to calculate the PA scores of different types, which were summed to give a total score, with higher values indicating more PA.

Degree of digitization

In the CHARLS 2018 questionnaire, the degree of digitization was measured using five questions. Participants were asked if they had used the internet in the previous month (yes=1, no=0). If the answer was affirmative, they were then asked about the frequency of their internet use in the previous month (almost every day=3, almost every week=2, not often=1). Additionally, they were asked the following: Do you use mobile payment platforms such as Ali-pay or We-chat Pay? (yes=1, no=0), Do you use We-chat? (use=1, do not use=0), Do you post updates on We-chat Moments? (post=1, do not post=0). The Cronbach's alpha for the five items was 0.874, which was higher than the minimum of 0.6, and is therefore reliable for measuring degree of digitization. The scores for the five questions were summed up, with a score range of 0 to 7, where a higher score indicates a higher degree of digitization. This study focused on the use of the Internet, especially mobile payments, and social media applications (e.g., We-chat), which cover important aspects of digital life. The questionnaire has been used in a related study [49].

Socio-demographic variables

Several demographic variables were controlled for in this study, including age, gender, education level, marriage, and living environment. Gender was encoded as a dummy variable (1=male, 2=female). Age was measured in years. Education was measured by the highest level of education obtained (excluding adult education). Marriage refers to their current marital status (married and living together, married but separated for work, separate (married couple), divorcee, widowed, never married). The living environment measure was constructed based on living arrangements (categorized as family residence, retirement institution, hospital) and residential location (rural or urban).

Study methods

This study utilized a cross-sectional design, and statistical analysis was primarily conducted using IBM SPSS Statistics version 26 (IBM SPSS Inc., Chicago, USA). Descriptive statistical analyses were initially performed for the variables and control variables in the study. Pearson's correlation test was used to analyze the correlation between chronic disease, PCS, MCS, HRQoL, and PA. The mediation effect of PA in the relationship between chronic disease and HRQoL was examined using the PROCESS macro model 4 in SPSS. A bias-corrected Bootstrap percentile method was utilized for mediation effect testing, where a significant mediation effect was indicated if the path coefficient fell within the 95% CI and did not include 0. Finally, the PROCESS model 59 was employed to test the moderating effect of degree of digitization level in the mediation model. In the examination of mediation and moderation effects, demographic variables (gender, age, education, marital status, residence) were controlled for.

Results

Descriptive analysis

The variable descriptive statistics are shown in Table 1. A total of 13,620 participants were included in this study with a mean age of 61.81. Of these, slightly more females (52.22%) than males (47.78%) were enrolled. Most of them had low levels of education, of which 20.37% indicated that they had no formal education and 41.72% had completed only primary education. The majority (87.55%) were currently married and their spouses were still alive.

Correlation analysis

Table 2 presents the mean values, standard deviations, and correlation coefficients of the study variables. The results of Pearson correlation analysis indicate that the degree of chronic disease is negatively correlated with PCS (r=-0.262, p<0.01), positively correlated with MCS (r=0.088, p<0.01), and negatively correlated with PA (r=-0.058, p<0.01). There is a significant positive correlation between PA and PCS (r=0.183, p<0.01), and a significant negative correlation with MCS (r=-0.039, p<0.01). Furthermore, the degree of digitization is positively correlated with PCS (r=0.160, p<0.01) and MCS (r=0.247, p<0.01), and also positively associated with PA (r=0.023, p<0.01). These preliminary results provide support for subsequent regression analysis (see Table 2).

.

Mediating role

The PROCESS model 4 was used to test the mediating effect of PA on the relationship between chronic disease and PCS. The results of the mediating effect are shown in Table 3. Firstly, chronic disease significantly negatively predicted PCS (β=-2.515, p<0.01). Secondly, it was found that chronic disease significantly negatively predicted PA (β=-0.576, p<0.01), and PA significantly positively predicted PCS (β=0.071, p<0.01). Finally, in order to determine whether PA has a full or partial mediating effect when PA was simultaneously included in the regression equation, the strength of the relationship between

Table 1 Descriptive statistics of the sample ($n = 13,620$)

Variables	Definition	Frequency	Percentage (%)	Mean	SD
Age	45–59	6075	44.6	61.81	10.05
	60–69	4538	33.3		
	≥ 70	3007	22.1		
Gender	Male	6507	47.78	1.52	0.5
	Female	7113	52.22		
Residence	Town	2753	20.21	1.8	0.402
	Village	10,867	79.79		
Educational level	No formal education	2774	20.37	2.2	0.782
	Primary school	5682	41.72		
	Middle school	4853	35.63		
	High School or above	311	2.28		
Marriage	Married and living together	10,844	79.62	1.61	1.358
	Married but separated for work	878	6.45		
	Separate (married couple)	50	0.37		
	Divorcee	152	1.12		
	Widowed	1635	12		
	Never married	61	0.45		
Chronic diease	Continuous variable(0–14)	13,620		0.72	1.051
HRQoL	Continuous variable	13,620		53.35	10.254
PCS	Continuous variable	13,620		34.97	4.603
MCS	Continuous variable	13,620		18.38	8.203
PA	Continuous variable	13,620		26.35	18.495
Degree of Digitization	Continuous variable	13,620		0.89	2.179

PCS: Physical component summary; MCS: Mental component summary; PA: Physical activity.

Table 2 Correlation analysis of chronic disease level, HRQOL, PA

	1	2	3	4	5	6
1Chronic disease	1					
2PCS	-0.262**	1				
3MCS	-0.088**	0.205**	1			
4HRQoL	-0.240**	0.844**	0.698**	1		
5PA	-0.058**	0.183**	-0.039**	0.113**	1	

* $p < 0.05$ ** $p < 0.01$.

1Chronic disease, Chronic disease; 2PCS, Physical component summary; 3MCS, Mental component summary; 4HRQoL, Health-related quality of life; 5PA, Physical activity.

Table 3 Results of the analysis of the mediating role of PA on the relationship between chronic disease and PCS

	PCS		PA		PCS	
	β	SE	β	SE	β	SE
Constant	88.020**	0.997	51.962**	1.764	84.330**	1.021
Gender	-3.556**	0.185	-1.411**	0.327	-3.456**	0.183
Age	-0.219**	0.01	-0.450**	0.017	-0.187**	0.01
Residence	-1.055**	0.226	3.882**	0.399	-1.331**	0.225
Highest level of education	1.883**	0.128	-0.664**	0.227	1.930**	0.127
Marriage	-0.350**	0.068	-0.461**	0.12	-0.317**	0.067
Chronic disease	-2.515**	0.082	-0.576**	0.146	-2.474**	0.082
PA					0.071**	0.005
R^2	0.191		0.074		0.204	
F	535.488**		180.816**		497.472**	

* $p < 0.05$, ** $p < 0.01$. SE, standard error. PCS, Physical component summary; PA, Physical activity.

Table 4 Results of the analysis of the mediating role of PA on the relationship between chronic disease and MCS

	MCS		PA		MCS	
	β	SE	β	SE	β	SE
Constant	25.242**	0.892	51.962**	1.764	25.878**	0.834
Gender	-1.305**	0.208	-1.411**	0.327	-1.322**	0.15
Age	0.066**	0.008	-0.450**	0.017	0.060**	0.008
Residence	-2.153**	0.183	3.882**	0.399	-2.105**	0.183
Highest level of education	1.237**	0.104	-0.664**	0.227	1.229**	0.104
Marriage	-0.098	0.055	-0.461**	0.12	-0.104	0.055
Chronic disease	-0.735**	0.067	-0.576**	0.146	-0.742**	0.067
PA					-0.012**	0.004
R^2	0.05		0.074		0.051	
F	120.222**		180.816**		104.496**	

* $p<0.05$, ** $p<0.01$. SE, standard error. MCS, Mental component summary; PA, Physical activity.

Table 5 Moderating effect of degree of digitization

	PCS		PA		MCS		PA	
	β	*SE*	*β*	*SE*	*β*	*SE*	*β*	*SE*
Constant	83.15**	1.033	52.785**	1.786	22.572**	0.828	52.785**	1.786
Chronic disease	-2.71**	0.088	-0.704**	0.157	-0.746**	0.07	-0.704**	0.157
Degree of digitization	0.403**	0.084	-0.312**	0.09	0.84**	0.067	-0.312**	0.09
Chronic disease*Degree of digitization	0.274**	0.038	0.156*	0.068	-0.022	0.03	0.156*	0.068
Gender	-3.43**	0.183	-1.406**	0.326	-1.307**	0.146	-1.406**	0.326
Age	-0.175**	0.01	-0.459**	0.017	0.099**	0.008	-0.459**	0.017
Residence	-1.054**	0.227	3.713**	0.405	-1.339**	0.182	3.713**	0.405
Highest level of education	1.754**	0.13	-0.53**	0.233	0.661**	0.104	-0.53**	0.233
Marriage	-0.316**	0.067	-0.454*	0.12	-0.129*	0.054	-0.454*	0.12
PA	0.08**	0.005			-0.011**	0.004		
PA*Degree of digitization	-0.013**	0.002			0.002	0.002		
R^2	0.21		0.075		0.093		0.075	
F	362.607**		137.247**		140.323**		137.247**	

* $p<0.05$, ** $p<0.01$. SE, standard error; PCS, Physical component summary; MCS, Mental component summary, PA, Physical activity.

chronic disease and PCS decreased but remained significant (β=-2.474, $p<0.01$), as shown in Table 3. Moreover, the 95% BootCI did not include the number 0 [-0.006 ~ -0.001]. The results indicate that PA partially mediates the relationship between chronic disease and PCS, with an indirect effect value of -0.041, accounting for 1.627% of the total effect (-2.515).

Using the same method, we tested the mediating effect of PA on the association between chronic disease and MCS. We found that chronic disease significantly negatively predicted MCS (β=-0.735, $p<0.01$), chronic disease significantly negatively predicted PA (β=-0.576, $p<0.01$), and PA significantly negatively predicted MCS (β=-0.012, $p<0.01$). Finally, when PA was simultaneously included in the regression equation, we found that the relationship between chronic disease and MCS remained significant and the strength increased (β=-0.742, $p<0.01$), as shown in Table 4. Due to the opposite signs of the direct and indirect effects, the total effect was masked. Therefore, there is a masking effect of PA on the relationship between chronic disease and MCS, with the indirect effect accounting for 0.946% of the direct effect.

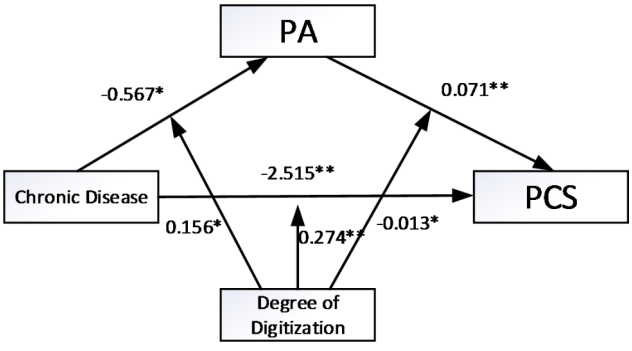

Fig. 3 Reconciling the results of the mediation model. PA, Physical activity; PCS, Physical component summary

Moderator effects

Next, the moderation effect of degree of digitization level was tested using Model 59 in the SPSS macro, and the results are shown in Table 5; Fig. 3. The results indicate that the product of chronic disease and degree of digitization significantly predicted PCS and PA (β=0.274, $p<0.01$) (β=0.156, $p<0.01$). Additionally, the product of PA and degree of digitization significantly predicted PCS

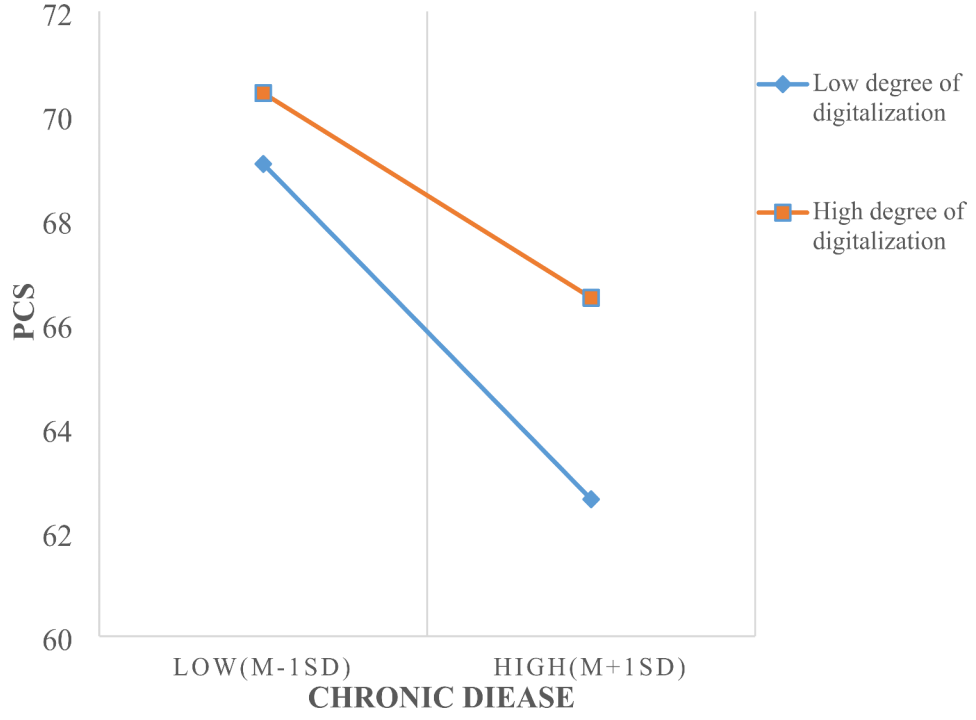

Fig. 4 Simple slope analysis. The blue line indicates a low level of digitization and the orange line indicates a high level of digitization. PCS, Physical component summary

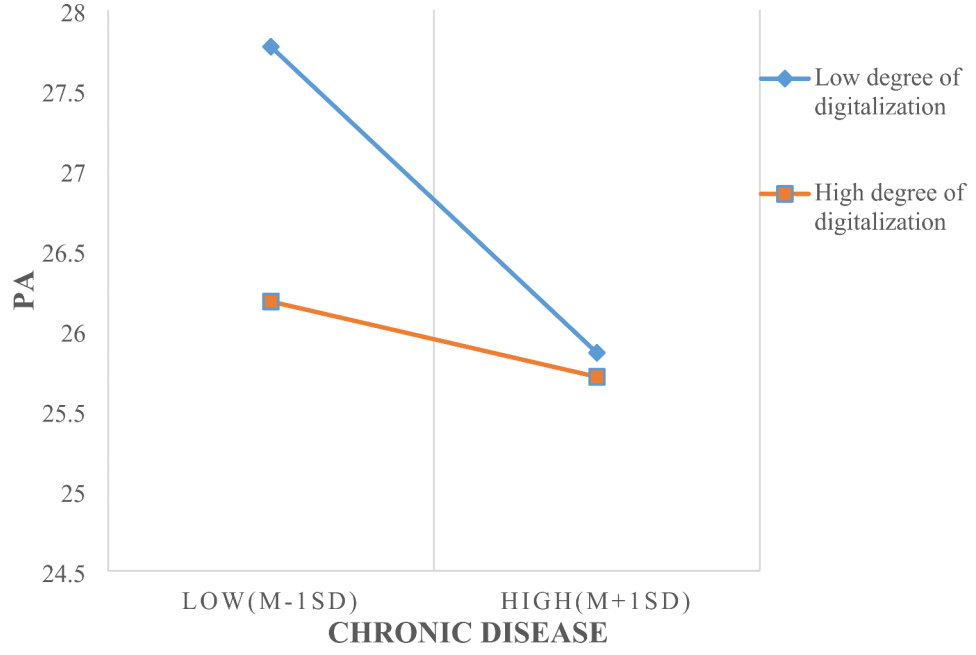

Fig. 5 Simple slope analysis. The blue line indicates a low level of digitization and the orange line indicates a high level of digitization. PA, Physical activity

(β=-0.013, p<0.01), indicating that the impact of chronic disease on PCS through PA is moderated by the degree of digitization.

We further examine the association between chronic disease and PCS, as well as the relationship between PA and PCS, using simple slope analysis at different levels of digitization. As shown in Figs. 4 and 5, the relationship between chronic disease and PCS, as well as PA, is significant in situations with lower levels of digitization. However, this relationship is much weaker in situations with higher levels of digitization, indicating that the predictive effect of chronic disease on PCS and PA decreases with

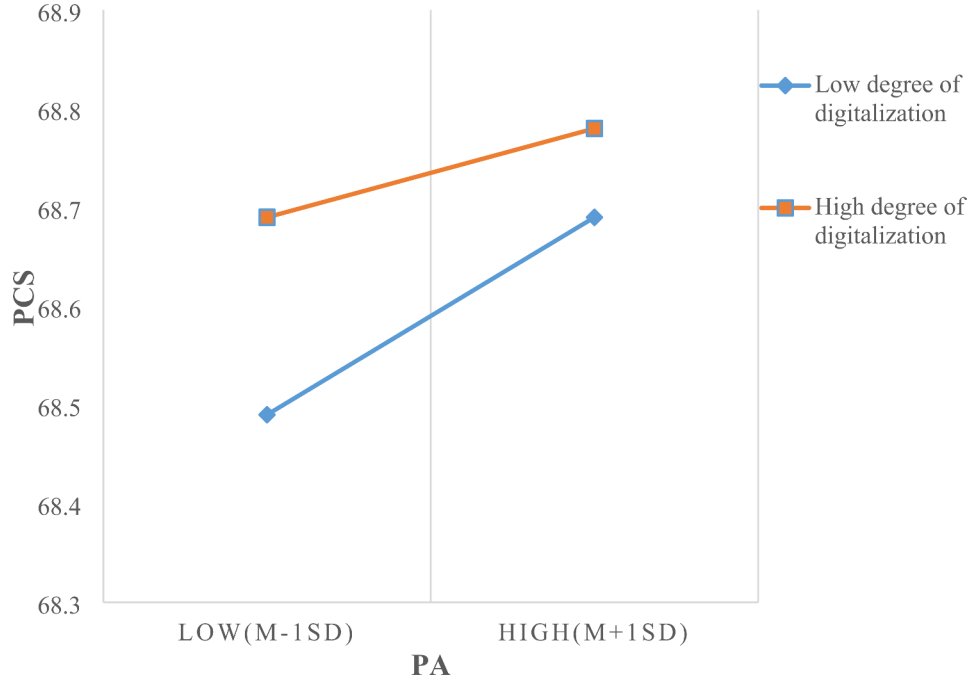

Fig. 6 Simple slope analysis. The blue line indicates a low level of digitization and the orange line indicates a high level of digitization. PCS, Physical component summary; PA, Physical activity

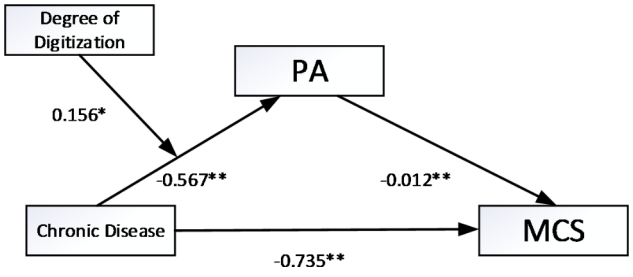

Fig. 7 Results of the moderated mediator model. PA, Physical activity. MCS, Mental component summary

increasing levels of digitization. The results of the simple slope analysis for the moderating effect of digitization on the relationship between PA and PCS are shown in Fig. 6. We found that regardless of the degree of digitization, PA positively predicts PCS, and the relationship between PA and PCS is more significant in situations with lower levels of digitization.

Subsequently, we utilized Model 59 in the Process procedure of SPSS to test the moderating effect of digitization on the relationship between chronic disease and MCS. The results, as shown in Table 5; Fig. 7, indicate that the product of chronic disease and digitization significantly predicts PA ($\beta=0.156$, $p<0.01$), demonstrating that digitization has a moderating effect on the relationship between chronic disease and PA.

Discussion

In this study, we investigated the correlations among chronic disease, PA, HRQoL, and digitization, with a particular focus on examining the mediating role of PA in the relationship between chronic disease and HRQoL, as well as the moderating effect of digitization. The results of our study demonstrate that the severity of chronic disease significantly negatively predicts PCS and MCS. The degree of chronic diseases has a negative impact on PA, and the impact of PA on PCS and MCS differs. Our findings confirm that PA partially mediates the relationship between chronic disease and PCS, while it masks the relationship between chronic disease and MCS. Moreover, digitization significantly moderates the predictive effect of chronic disease on PA and PCS, as well as the predictive effect of PA on PCS.

Common chronic diseases can cause varying degrees of impairment in HRQoL for patients [50, 51]. This not only affects their physical well-being but also has an impact on their mental health. In our study, the number of chronic diseases in older adults is significantly negatively correlated with PCS, which is consistent with previous research. Previous studies have shown that the presence of chronic diseases in older adults increases their likelihood of developing Activities of Daily Living (ADLs) disabilities [52]. In China, cancer survivors over the age of 45 have lower HRQoL compared to their peers without cancer [53]. The findings suggest that older individuals who have a greater number of chronic illnesses experience lower levels of physical well-being. This may

be due to the possibility that treating one disease may have adverse effects on another existing disease, leading to further reductions in HRQoL [54]. There is also research demonstrating the association between chronic diseases and adverse mental health conditions [22, 55]. A study of older adults aged 65 and above in Canada found a positive correlation between chronic diseases and psychological distress, as well as a negative correlation with positive mental health [56]. For patients with systemic low-grade inflammation, the likelihood of experiencing depression is higher compared to healthy individuals [57]. These findings support our results: middle-aged and older adults with one or more chronic diseases experience a decline in MCS as the number of their diseases increases. However, findings from a survey in South Australia show an inconsistency with our study, as the number of chronic diseases in adults was not negatively correlated with MCS [58]. One possible explanation is that while individuals' physical function may be significantly affected by chronic diseases and advanced age, their mental health can still remain at relatively high and stable levels [59].

Our findings also confirm the mediating role of PA in the relationship between chronic disease and HRQOL. As an important component of a healthy lifestyle, PA has been associated not only with enhanced physical fitness and reduced risk of disease but has also been shown to be related to improved HRQOL in older adults [60, 61]. However, many patients with chronic diseases have physical impairments, which adversely affect their daily life and activities, resulting in a decline in their HRQoL [6]. Canadian adults with multiple conditions spend significantly less time on sports activities and more time sedentary on a daily basis [62]. Previous research has indicated that there is a correlation between elevated levels of systemic inflammation and impaired left ventricular function with decreased PA in patients with chronic obstructive pulmonary disease (COPD) [63]. Based on this research, we investigated the mediating role of PA in this association and found that chronic diseases indirectly affect PCS through the mediating role of PA, indicating that chronic diseases limit certain physical activities, which in turn affects PCS. This result also confirms previous research, demonstrating that chronic diseases affect HRQoL by increasing deficits in physical function and activity [7]. This suggests that middle-aged and older adults with one or more chronic diseases can promote the recovery of chronic diseases and improve the PCS by engaging in PA and establishing healthy behaviors.

On the other hand, existing studies have confirmed the positive effects of PA on mental health [55]. In a nationally representative cohort of older adults, it was found that older adults with low-grade systemic inflammation had lower levels of PA, which was associated with subsequently increased depressive symptoms [57]. However, engaging in moderate to vigorous physical activities can weaken the link between multiple chronic diseases and adverse mental health. James A found that exercise training may effectively reduce depressive symptoms in heart failure patients [64], emphasizing the importance of PA in improving mental health. Interestingly, our results differ from other studies: PA has a significant negative predictive effect on the mental component and plays a certain masking role in the relationship between chronic diseases and MCS. For older adults with chronic diseases, reducing PA may be more favorable for MCS. A study by Underwood et al. also found that a moderate-intensity exercise intervention for nursing home residents did not reduce depressive symptoms. This study also indicates that this strategy is not beneficial for improving mental symptoms in this physically frail population [65]. This provides some support for our research results.

Finally, our study found that higher levels of digitization in older adults with chronic diseases alleviate the negative predictive effects of chronic diseases on PCS and PA. On one hand, many studies have shown that using the internet is beneficial for the health of older adults. This may be attributed to the provision of online medical services, which improves the medical efficiency of chronic disease patients and may enhance their HRQOL [66]. Older adults can search for health information online based on their own physical condition, reducing their reliance on formal care systems [67]. It has even been confirmed that Internet use increases older people's confidence in using digital technology, which in turn improves their cognitive abilities and increases their independence and autonomy [68]. This also confirms our research. A survey in Japan found that internet users with cancer and those with depression and anxiety disorders were more likely to seek health information online compared to internet users without these conditions [69]. The internet is now used as a method to provide various health interventions [70], and internet-based cognitive behavioral therapy can effectively reduce depressive symptoms and increase PA. This shows that the use of the internet may increase health behaviors and PA in the elderly from different perspectives, thereby considering encouraging older adults with chronic diseases to use the internet to increase their PA and therefore improve their health status.

On the other hand, we found that the degree of digitization negatively moderates the positive correlation between PA and PCS. This is consistent with previous research findings, which may be due to the fact that the use of the Internet occupies the social and outdoor activity time of the elderly, leading to sedentary behavior and reduced outdoor activities, forming unhealthy habits that are detrimental to the physical health of the elderly

[71–73]. At the same time, the increase in Internet use intensity often accompanies staying up late. Elderly adults with high Internet usage frequency may spend longer time online before sleep, increasing the time spent staying up late [73], which is not conducive to their sleep quality. Nevertheless, multiple studies have demonstrated a positive correlation between the; degree of Internet use and an increase in PA [74], which is generally beneficial for health. Therefore, we believe that Internet use may reduce the risk of certain chronic diseases, but it is essential to use the Internet in a healthy manner, particularly to avoid prolonged sedentary behavior [32].

Moreover, this research has specific constraints. This is a cross-sectional study that does not establish the precise causal association between the number of chronic diseases, HRQoL, PA, and level of digitization. Moreover, the data in this study were collected in the form of self-reporting, and relying solely on this method may lead to biases and other issues, affecting the validity and reliability of the study results due to the influence of recall and social expectations. Therefore, future research can adopt longitudinal data to examine the interaction of variables in order to better understand the causal relationships between variables. Using multiple sources of information to collect data can also enhance the reliability of the study results.

Conclusion

In conclusion, this study examined the relationship between chronic diseases, PA, degree of digitization, and the HRQoL of chronic disease patients. The study provides cross-sectional evidence demonstrating that chronic disease can impact the physical and mental components of HRQoL in middle-aged and older adults through PA. Furthermore, the degree of digitization has a moderating effect on the negative impact of chronic diseases on body composition and PA. This study emphasizes that certain chronic disease patients can improve their functional and physical health status through PA. Additionally, the correct use of the Internet can help elderly adults mitigate the negative effects of chronic diseases to a certain extent, thus this study encourages the elderly to utilize the Internet correctly to cultivate healthy behavioral habits. The results of this study can aid in the creation of intervention tactics centered around chronic illnesses, with the goal of enhancing HRQoL for older individuals.

Abbreviations

BP	Bodily pain
CHARLS	China health and retirement longitudinal study
CI	Confidence interval
GH	General health
HRQoL	Health-related quality of life
MCS	Mental component summary
MH	Mental health
PA	Physical activity
PCS	Physical component summary
PF	Physical functioning
QoL	Quality of life
RE	Role emotional
RP	Role physical
SD	Standard deviation
SF	Social functioning
VT	Vitality

Acknowledgements

We would like to extend our appreciation to Shandong University for providing us with scientific research support, and thanks to Peking University for providing open data.

Author contributions

Y.H.: conceptualization, methodology, writing original draft, project administration. Y.Y.: writing original draft, visualization. L.Z.: data analysis. L.C.: conceptualization. W.S.: formal analysis. J.H.: visualization. Y.G.: writing-review and editing, supervision, and funding acquisition. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by the National Social Science Foundation of China (grant number: 21BTY054).

Data availability

The datasets analyzed during the current study are available from the CHARLS repository [http://charls.pku.edu.cn].

Declarations

Ethics approval and consent to participate

All participants joined CHARLS voluntarily and signed a informed consent form before participation. The original CHARLS was approved by the Ethical Review Committee (IRB) at Peking University in June 2008 (IRB00001052–11015), and the study protocol complies with the ethical guidelines of the 1975 Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 28 November 2023 / Accepted: 20 August 2024
Published online: 28 August 2024

References

1. World Health Statistics. 2022. https://www.who.int/news/item/20-05-2022-world-health-statistics-2022. Accessed 29 Jul 2024.
2. Ageing. and health. https://www.who.int/china/zh/health-topics/ageing. Accessed 2 Nov 2023.
3. About Chronic Diseases | CDC. 2022. https://www.cdc.gov/chronicdisease/about/index.htm. Accessed 2 Nov 2023.
4. Fan Z-Y, Yang Y, Zhang C-H, Yin R-Y, Tang L, Zhang F. Prevalence and patterns of Comorbidity among Middle-aged and Elderly people in China: a cross-sectional study based on CHARLS Data. Int J Gen Med. 2021;14:1449–55.
5. Fortin M, Lapointe L, Hudon C, Vanasse A, Ntetu AL, Maltais D. Multimorbidity and quality of life in primary care: a systematic review. Health Qual Life Outcomes. 2004;2:51.
6. Ma Y, Xiang Q, Yan C, Liao H, Wang J. Relationship between chronic diseases and depression: the mediating effect of pain. BMC Psychiatry. 2021;21:436.
7. Sexton E, King-Kallimanis BL, Layte R, Hickey A. CASP-19 special section: how does chronic disease status affect CASP quality of life at older ages? Examining the WHO ICF disability domains as mediators of this relationship. Aging Ment Health. 2015;19:622–33.
8. Jeong S, Cho S. Acceptance and patient functioning in chronic pain: the mediating role of physical activity. Qual Life Res. 2017;26:903–11.

9. Preto O, Amaral O, Duarte J, Chaves C, Coutinho E, Nelas P. Quality of life and chronic disease in patients receiving primary health care. European Proceedings of Social and Behavioural Sciences. 2016;Health&Health Psychology-icH&Hpsy 2016.
10. CDC. Centers for Disease Control and Prevention. 2024. https://www.cdc.gov/index.html. Accessed 29 Jul 2024.
11. Vartiainen P, Mäntyselkä P, Heiskanen T, Hagelberg N, Mustola S, Forssell H, et al. Validation of EQ-5D and 15D in the assessment of health-related quality of life in chronic pain. Pain. 2017;158:1577.
12. Ge L, Ong R, Yap CW, Heng BH. Effects of chronic diseases on health-related quality of life and self-rated health among three adult age groups. Nurs Health Sci. 2019;21:214–22.
13. Gallegos-Carrillo K, García-Peña C, Mudgal J, Romero X, Durán-Arenas L, Salmerón J. Role of depressive symptoms and comorbid chronic disease on health-related quality of life among community-dwelling older adults. J Psychosom Res. 2009;66:127–35.
14. Havens E. Comorbid Arthritis is Associated with Lower Health-Related Quality of Life in older adults with other chronic conditions, United States, 2013–2014. Prev Chronic Dis. 2017;14.
15. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. Can Med Assoc J. 2006;174:801–9.
16. Broekhuizen K, de Gelder J, Wijsman CA, Wijsman LW, Westendorp RG, Verhagen E, et al. An internet-based physical activity intervention to improve quality of life of inactive older adults: a Randomized Controlled Trial. J Med Internet Res. 2016;18:e4335.
17. Wong MYC, Ou K, Chung PK, Chui KYK, Zhang C. The relationship between physical activity, physical health, and mental health among older Chinese adults: a scoping review. Front Public Health. 2023;10.
18. Optimising the effects of physical activity on mental health and wellbeing. A joint consensus statement from Sports Medicine Australia and the Australian Psychological Society. J Sci Med Sport. 2023;26:132–9.
19. Zhou P, Hughes AK, Grady SC, Fang L. Physical activity and chronic diseases among older people in a mid-size city in China: a longitudinal investigation of bipolar effects. BMC Public Health. 2018;18:486.
20. Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H. Extrapulmonary effects of Chronic Obstructive Pulmonary Disease on Physical Activity A cross-sectional study. Am J Respir Crit Care Med. 2008;177:743–51.
21. Barbour KE. Vital signs: Prevalence of Doctor-diagnosed arthritis and arthritis-attributable activity limitation — United States, 2013–2015. MMWR Morb Mortal Wkly Rep. 2017;66.
22. Arokiasamy P, Uttamacharya U, Jain K, Biritwum RB, Yawson AE, Wu F, et al. The impact of multimorbidity on adult physical and mental health in low- and middle-income countries: what does the study on global ageing and adult health (SAGE) reveal? BMC Med. 2015;13:1–16.
23. Öztürk A, Şimşek TT, Yümin ET, Sertel M, Yümin M. The relationship between physical, functional capacity and quality of life (QoL) among elderly people with a chronic disease. Arch Gerontol Geriatr. 2011;53:278–83.
24. Maynou L, Hernández-Pizarro HM, Errea Rodríguez M. The Association of Physical (in)activity with Mental Health. Differences between elder and younger populations: a systematic literature review. IJERPH. 2021;18:4771.
25. Nayor M, Shah RV, Miller PE, Blodgett JB, Tanguay M, Pico AR, et al. Metabolic Architecture of Acute Exercise Response in Middle-aged adults in the community. Circulation. 2020;142:1905–24.
26. Ekelund U, Tarp J, Fagerland MW, Johannessen JS, Hansen BH, Jefferis BJ, et al. Joint associations of accelero-meter measured physical activity and sedentary time with all-cause mortality: a harmonised meta-analysis in more than 44 000 middle-aged and older individuals. Br J Sports Med. 2020;54:1499–506.
27. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. Annu Rev Public Health. 2006;27:297–322.
28. Li L, Ding H, Li Z. Does Internet Use Impact the Health Status of Middle-aged and older populations? Evidence from China Health and Retirement Longitudinal Study (CHARLS). Int J Environ Res Public Health. 2022;19:3619.
29. Ranieri J, Guerra F, Angione AL, Di Giacomo D, Passafiume D. Cognitive Reserve and Digital confidence among older adults as New Paradigm for resilient aging. Gerontol Geriatric Med. 2021;7:233372142199374.
30. Ma X, Liu Y, Zhang P, Qi R, Meng F. Understanding online health information seeking behavior of older adults: a social cognitive perspective. Front Public Health. 2023;11:1147789.
31. Yang K. Internet use, employment performance and the health of Chinese residents. Int Health. 2022;14:222–35.
32. Li P, Zhang C, Gao S, Zhang Y, Liang X, Wang C, et al. Association between Daily Internet Use and Incidence of Chronic diseases among older adults: prospective cohort study. J Med Internet Res. 2023;25:e46298.
33. Reiners F, Sturm J, Bouw LJW, Wouters EJM. Sociodemographic factors influencing the Use of eHealth in people with Chronic diseases. Int J Environ Res Public Health. 2019;16:645.
34. Burns P, Jones SC, Caputi P, Iverson D. Are older australians with chronic diseases online? Health Promotion J Australia. 2018;29:72–8.
35. Ayers SL, Kronenfeld JJ. Chronic illness and health-seeking information on the internet. Health (London). 2007;11:327–47.
36. Wilcox ME, Adhikari NK. The effect of telemedicine in critically ill patients: systematic review and meta-analysis. Crit Care. 2012;16:R127.
37. Fan S, Yang Y. How does internet use improve Mental Health among Middle-aged and Elderly people in Rural areas in China? A quasi-natural experiment based on the China Health and Retirement Longitudinal Study (CHARLS). Int J Environ Res Public Health. 2022;19:13332.
38. Cotten SR, Ford G, Ford S, Hale TM. Internet use and depression among retired older adults in the United States: a longitudinal analysis. Journals Gerontology: Ser B. 2014;69:763–71.
39. Chandrasekaran B, Ganesan TB. Sedentarism and chronic disease risk in COVID 19 lockdown – a scoping review. Scott Med J. 2021;66:3–10.
40. Kokka I, Mourikis I, Nicolaides NC, Darviri C, Chrousos GP, Kanaka-Gantenbein C, et al. Exploring the effects of Problematic Internet use on adolescent sleep: a systematic review. Int J Environ Res Public Health. 2021;18:760.
41. Billari FC, Giuntella O, Stella L. Broadband internet, digital temptations, and sleep. J Econ Behav Organ. 2018;153:58–76.
42. Sami H, Danielle L, Lihi D, Elena S. The effect of sleep disturbances and internet addiction on suicidal ideation among adolescents in the presence of depressive symptoms. Psychiatry Res. 2018;267:327–32.
43. Mars B, Gunnell D, Biddle L, Kidger J, Moran P, Winstone L, et al. Prospective associations between internet use and poor mental health: a population-based study. PLoS ONE. 2020;15:e0235889.
44. Moshkovits Y, Goldman A, Beckerman P, Tiosano S, Kaplan A, Kalstein M, et al. Baseline renal function and the risk of cancer among apparently healthy middle-aged adults. Cancer Epidemiol. 2023;86:102428.
45. Je W, Cd S. The MOS 36-item short-form health survey (SF-36). I. conceptual framework and item selection. Med Care. 1992;30.
46. Jandhyala R. Neutral theory: applicability and neutrality of using generic health-related quality of life tools in diseases or conditions where specific tools are available. BMC Med Res Methodol. 2021;21:86.
47. Hao X, Yang Y, Gao X, Dai T. Evaluating the Effectiveness of the Health Management Program for the Elderly on Health-Related Quality of Life among Elderly people in China: findings from the China Health and Retirement Longitudinal Study. Int J Environ Res Public Health. 2019;16:113.
48. Liang D-Q. Stress Levels of High School Students and their relationship with physical activity. Chin J Mental Health. 1994;5–6.
49. Zhao L, Zhang K, Gao Y, Jia Z, Han S. The relationship between gender, marital status and depression among Chinese middle-aged and older people: mediation by subjective well-being and moderation by degree of digitization. Front Psychol. 2022;13:923597.
50. Salive ME. Multimorbidity in older adults. Epidemiol Rev. 2013;35:75–83.
51. Li Y, Schoufour J, Wang DD, Dhana K, Pan A, Liu X et al. Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: prospective cohort study. BMJ. 2020;368.
52. Associations of depressive. symptoms and chronic diseases with activities of daily living among middle-aged and older population in China: A population-based cohort study. https://www.frontiersin.org/articles/10.3389/fpsyt.2022.848255/full. Accessed 12 Oct 2023.
53. Li J, Pang H, Sun Z, Zhao L, Bai C. Health status of middle-aged and older cancer survivors: a nationwide cross-sectional study from the China Health and Retirement Longitudinal Study (CHARLS). Annals Translational Med. 2020;8:183–183.
54. Mujica-mota RE, Roberts M, Abel G, Elliott M, Lyratzopoulos G, Roland M, et al. Common patterns of morbidity and multi-morbidity and their impact on health-related quality of life: evidence from a national survey. Qual Life Res. 2015;24:909–18.
55. McPhee JS, French DP, Jackson D, Nazroo J, Pendleton N, Degens H. Physical activity in older age: perspectives for healthy ageing and frailty. Biogerontology. 2016;17:567–80.
56. Yang G, D'Arcy C. Physical activity and social support mediate the relationship between chronic diseases and positive mental health in a national sample of

community-dwelling canadians 65+: a structural equation analysis. J Affect Disord. 2022;298:142–50.
57. Frank P, Kaushal A, Poole L, Lawes S, Chalder T, Cadar D. Systemic low-grade inflammation and subsequent depressive symptoms: is there a mediating role of physical activity? Brain. Behav Immun. 2019;80:688–96.
58. González-Chica DA, Hill CL, Gill TK, Hay P, Haag D, Stocks N. Individual diseases or clustering of health conditions? Association between multiple chronic diseases and health-related quality of life in adults. Health Qual Life Outcomes. 2017;15:244.
59. Hopman WM, Harrison MB, Coo H, Friedberg E, Buchanan M, VanDenKerkhof EG. Associations between chronic disease, age and physical and mental health status. Chronic Dis Can. 2009;29:108–16.
60. Oh TR, Choi HS, Suh SH, Kim CS, Bae EH, Sung S, et al. The Association between Health-Enhancing Physical Activity and Quality of Life in patients with chronic kidney disease: propensity score matching analysis. Int J Environ Res Public Health. 2022;19:1318.
61. Phillips SM, Wójcicki TR, McAuley E. Physical activity and quality of life in older adults: an 18-month panel analysis. Qual life Research: Int J Qual life Aspects Treat care Rehabilitation. 2013;22:1647–54.
62. Hains-Monfette G, Atoui S, Needham Dancause K, Bernard P. Device-assessed physical activity and sedentary behaviors in canadians with Chronic Disease(s): findings from the Canadian Health measures Survey. Sports. 2019;7:113.
63. Extrapulmonary Effects of Chronic Obstructive Pulmonary Disease on Physical Activity. A Cross-sectional Study. https://webvpn.sdu.edu.cn/https/77726476706e6973746856265737421e7e056d2372267416b0d9ab8d6562c38/docview/20888008?pq-origsite=wos&accountid=13813. Accessed 12 Oct 2023.
64. Blumenthal JA, Babyak MA, O'Connor C, Keteyian S, Landzberg J, Howlett J et al. Effects of Exercise Training on depressive symptoms in patients with Chronic Heart failure: the HF-ACTION Randomized Trial. JAMA. 2012;308.
65. Underwood M, Lamb SE, Eldridge S, Sheehan B, Slowther A-M, Spencer A, et al. Exercise for depression in elderly residents of care homes: a cluster-randomised controlled trial. Lancet. 2013;382:41–9.
66. Wen W, Zhang Y, Shi W, Li J. Association between Internet Use and Physical Health, Mental Health, and Subjective Health in Middle-aged and older adults: nationally Representative cross-sectional survey in China. J Med Internet Res. 2023;25:e40956.
67. Choi NG, DiNitto DM. The Digital divide among low-income homebound older adults: internet use patterns, eHealth literacy, and attitudes toward Computer/Internet use. J Med Internet Res. 2013;15:e2645.
68. Cilli E, Ranieri J, Guerra F, Colicchia S, Di Giacomo D. Digital Affinitiy and cognitive reserve: salience for resilient aging in pandemic. Gerontol Geriatric Med. 2023;9:233372142311627.
69. Mitsutake S, Takahashi Y, Otsuki A, Umezawa J, Yaguchi-Saito A, Saito J, et al. Chronic diseases and Sociodemographic Characteristics Associated with Online Health Information Seeking and using Social networking sites: nationally Representative cross-sectional survey in Japan. J Med Internet Res. 2023;25:e44741.
70. Marcus BH, Ciccolo JT, Sciamanna CN. Using electronic/computer interventions to promote physical activity. Br J Sports Med. 2009;43:102–5.
71. Gilleard C, Hyde M, Higgs P. Community and communication in the third age: the impact of internet and cell phone use on attachment to place in later life in England. Journals Gerontology: Ser B. 2007;62:S276–83.
72. Hamer M, Stamatakis E. Screen-based sedentary behavior, physical activity, and muscle strength in the English Longitudinal Study of Ageing. PLoS ONE. 2013;8:e66222.
73. Wang Y, Xu J, Xie T. The Association of Internet Use Intensity and Lifestyle behaviors during the COVID-19 pandemic: a cross-sectional study in Chinese adults. Front Public Health. 2022;10.
74. Sasaki S, Sato A, Tanabe Y, Matsuoka S, Adachi A, Kayano T, et al. Internet use and physical activity of older adults during the COVID-19 pandemic: a cross-sectional study in a northern Japanese. BMC Geriatr. 2022;22:688.

Publisher's note