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Effects of physical exercise on subjective well-being in older adults --- is based on the analysis of multiple mediating effect models of physical and mental health

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Objective: This study examined the association between physical exercise frequency and subjective well-being among older adults in China and investigated the parallel mediating roles of self-rated health and lower depressive mood.

Methods: This cross-sectional study used data from the 2021 Chinese General Social Survey and included 1,872 adults aged 60 years or older. The outcome variable was subjective well-being, the primary explanatory variable was physical exercise frequency, and the mediators were self-rated health and lower depressive mood, with the latter measured by reverse-coding the frequency of feeling depressed or downhearted during the previous four weeks. Ordinary least squares regression was used to examine the association between exercise frequency and subjective well-being. Ordered probit regression, binary logistic regression, recoding of the primary explanatory variable, and propensity score matching were conducted as robustness checks. Bootstrap procedures were used to test parallel mediation effects, and subgroup differences by age, sex, co-residence with a spouse, and subjective household economic status were examined.

Results: After adjustment for relevant covariates, higher physical exercise frequency was significantly associated with greater subjective well-being ($\beta = 0.0526$, $p < 0.01$), and this association remained stable across robustness checks. The positive association was more pronounced among adults aged 70 years or older, men, those co-residing with a spouse, and those reporting higher subjective household economic status. The indirect effect through self-rated health was 0.0045, accounting for 7.32% of the total association (95% CI: 0.0014-0.0076), while the indirect effect through lower depressive mood was 0.0044, accounting for 7.15% (95% CI: 0.0004-0.0084). Together, the two mediating pathways accounted for 14.47% of the total association, whereas the direct association accounted for 85.53%.

Conclusion: Higher leisure-time physical exercise frequency was associated with greater subjective well-being among older adults in China, with self-rated health and lower depressive mood serving as important mediating pathways. Expanding access to safe, appropriate, and sustainable exercise opportunities, particularly for older adults with limited family support or socioeconomic resources, may contribute to improved well-being in later life.

Keywords: older adults; physical exercise; subjective well-being; healthy aging

1 Introduction

Population aging has become a major global issue affecting older adults‘ quality of life and social welfare. As one of the countries with the largest elderly population in the world, China is experiencing a rapid and sustained demographic shift. According to the Statistical Bulletin of the People’s Republic of China on the 2025 National Economic and Social Development, the population aged 60 years and above reached 323.38 million in 2025, accounting for 23.0% of the total population; among them, the population aged 65 years and above reached 223.65 million, representing 15.9% of the total population [1]. Against this backdrop, improving older adults‘ quality of life and subjective well-being has become a critical issue in healthy aging research.

Physical exercise is closely associated with higher levels of subjective well-being [2]. As an accessible, low-cost, and sustainable health promotion strategy, it not only improves older adults’ physical function and psychological state but also enhances their positive evaluations of life [3].Correspondingly, subjective well-being reflects an individual’s overall assessment of their living conditions and serves as an important indicator for measuring older adults‘ quality of life and psychological well-being. However, regular participation in physical exercise among older adults is linked not only to better physical function and self-rated health but also to improved well-being through reduced depressive symptoms and enhanced positive psychological experiences [4]. Notably, the present study focuses on subjective well-being because it more directly reflects older adults’ satisfaction with and affective experiences of their current lives, which better aligns with the “immediate feedback” characteristic of physical exercise [5]. Nevertheless, previous research has mainly concentrated on the direct association between physical exercise and subjective well-being in older adults, or has explained the relationship from only a single health dimension, while studies that simultaneously examine both physical and mental health as two potential pathways remain relatively limited.

Given that both physical health and mental health serve as important foundations for the well-being experience of older adults, this study integrates both dimensions into the analytical framework to explore the relationship between physical exercise and older adults’ subjective well-being, as well as the potential mediating roles of physical and mental health. This research holds significant theoretical and practical implications for a deeper understanding of the dual pathways through which physical exercise enhances subjective well-being in older adults and for formulating intervention strategies aimed at promoting healthy aging.

2 Literature review and research hypotheses

2.1 Physical exercise and subjective well-being among older adults

Subjective well-being is a key psychological indicator that reflects an individual‘s overall evaluation of their life situation. It encompasses both cognitive judgments of life satisfaction and affective experiences, including positive and negative emotions [6,7]. Among older adults, subjective well-being not only reflects their quality of life in later years but is also closely associated with health status, social adaptation, and the process of active aging [8]. As they age, older adults may face challenges such as declining physical function, an increased risk of chronic diseases, and changes in their social networks. Therefore, how to enhance their well-being through sustainable daily behaviors has become a key issue in healthy aging research.

physical exercise is an easily accessible and sustainable health behavior for older adults. It may enhance their subjective well-being by improving physical condition, increasing positive emotional experiences, and expanding social interaction opportunities. Existing research generally supports a positive relationship between physical

exercise and subjective well-being. For example, multiple meta-analyses have shown that leisure-time physical exercise is significantly positively correlated with positive affect and life satisfaction [2,9]. These findings suggest that physical exercise not only provides physical health benefits but may also serve as an important behavioral foundation for promoting positive life evaluations.

In the older adult population, the relationship between physical exercise and subjective well-being has also received empirical support. Stathi et al. [10] found that physical exercise participation among older adults was significantly associated with multiple dimensions of subjective well-being. Moreover, older adults with higher levels of physical exercise tend to have higher levels of well-being [11]. Studies focusing on the Chinese older adult population have also revealed that participation in physical activities such as Tai Chi, health Qigong, walking, and jogging is significantly associated with higher levels of subjective well-being [12]. A 12-week Tai Chi intervention study further confirmed this finding [13]. Overall, evidence from diverse countries, study designs, and exercise modalities consistently indicates that physical exercise is an important factor for enhancing subjective well-being in older adults.

Accordingly, we propose Hypothesis 1: physical exercise has a significant positive effect on the subjective well-being of older adults.

2.2 Heterogeneity in the effects of physical exercise on subjective well-being among older adults

The relationship between physical exercise and subjective well-being in older adults may exhibit heterogeneity depending on differences in individual demographic characteristics, family support status, and socioeconomic resources. Older adults' experience of well-being is influenced not only by their health status but is also closely linked to social relationships, life resources, and opportunities for daily participation.. Health, social relationships, and socioeconomic conditions are all important factors influencing older adults' subjective well-being. Therefore, although physical exercise is generally associated with higher levels of subjective well-being, this relationship may vary across different groups of older adults.

First, age differences may influence the relationship between physical exercise and subjective well-being. As age increases, older adults' physical function, mobility, and health needs may change, and the importance of physical exercise in maintaining physical capacity, enhancing self-efficacy, and improving psychological experience may also shift accordingly. Research has shown that participating in physical activities can effectively enhance the psychological well-being of older adults, with improvements in physical function and self-efficacy being closely associated with enhanced well-being [14]. Studies focusing on Chinese older adults have also found significant links between physical exercise and the physical, psychological, and social dimensions of subjective well-being [15]. Thus, older adults at different ages may exhibit varying degrees of association with well-being due to differences in their physical function status and exercise needs.

Second, the relationship between physical exercise and subjective well-being may exhibit gender differences. A meta-analysis based on 300 empirical studies indicated that older men and women differ to some extent in life satisfaction, well-being, self-rated health, and loneliness, yet the overall variance explained by gender is relatively limited [16]. This suggests that gender differences should not be simply attributed to biological characteristics or emotional stability, but rather to factors such as exercise modality, health limitations, family roles, and access to social resources. Related research has also found that women tend to benefit more from mind-body exercises such as yoga and dance, whereas men are more likely to enhance their well-being through competitive or more physically demanding activities such as ball games and high-intensity training [17]. Therefore, it is necessary to examine whether the relationship between physical exercise and subjective well-being differs by gender.

Third, living with a spouse may influence the relationship between physical exercise and subjective well-being in older adults. Spousal companionship provides not only emotional comfort and daily care but also encouragement, accompaniment, and behavioral supervision that help older adults maintain long-term physical exercise. Existing research has confirmed that high-quality social network quality positively predicts life satisfaction and well-being in older adults [18]. Relevant meta-analytic findings further indicate that social support is an important external factor driving older adults' participation in physical exercise, and adequate support from family and friends can effectively mobilize older adults' exercise willingness and increase their level of physical exercise engagement [19]. Therefore, older adults who live with their spouses may be more likely to receive emotional and behavioral support during physical exercise, thereby making the positive relationship between physical exercise and subjective well-being more pronounced.

Finally, household economic status may be an important resource condition for physical exercise to enhance well-being. Higher economic status generally provides older adults with more time, facilities, health services, and opportunities for social participation. However, a systematic review of physical exercise interventions for older adults indicates that socioeconomic inequalities may affect both participation in and benefits from such interventions, and that universal interventions targeting all older adults do not necessarily automatically eliminate disparities between different socioeconomic groups [20]. Thus, older adults with greater household economic resources may be better positioned to convert physical exercise into positive life experiences and well-being gains.

Furthermore, recent studies on Chinese older adults have begun to directly examine group differences in the relationship between physical exercise and subjective well-being. A study using data from the China Family Panel Studies confirmed that, among older adults, the associations between physical exercise and well-being, life satisfaction, and depressive symptoms vary across gender, urban-rural residence, and marital status [21]. This finding suggests that, beyond analyzing the overall relationship between physical exercise and subjective well-being in older adults, attention should also be given to potential differences across sociodemographic groups.

Based on the above analysis, this study proposes Hypothesis 2: The relationship between physical exercise frequency and subjective well-being in older adults exhibits group heterogeneity, meaning that this relationship varies depending on age, gender, spouse co-residence status, and household economic status.

2.3 The mediating effects of physical health status and mental health status

physical exercise may directly enhance older adults‘ subjective well-being. It may also exert an indirect effect by improving their perceived physical health and psychological emotional states. For older adults, physical and mental health are key foundations of well-being. Subjective well-being is closely linked to health status: good health not only helps maintain their ability to carry out daily activities but also contributes to a more positive evaluation of their later life.Thus, the relationship between physical exercise and subjective well-being may partly arise from the physical and mental health benefits of exercise participation.

Regarding the physical health pathway, physical exercise can help older adults maintain physical function, improve mobility, and enhance their positive perceptions of their own health status. A systematic review indicates a consistently positive relationship between physical exercise and various dimensions of older adults‘ overall quality of life, including functional ability, independence, vitality, and physical health [22]. Meanwhile, regular participation in physical exercise improves older adults' physical function, health-related quality of life, and overall well-being [23]. Self-rated health reflects older adults‘ comprehensive assessment of their physical capacity, disease burden, and daily functional status. When physical exercise leads older adults to experience better physical condition and greater mobility, their assessments of quality of life and happiness may improve accordingly. Therefore, self-rated health may serve as an important mediating pathway between physical exercise and subjective well-being in older adults.

Regarding the mental health pathway, depressive symptoms are an important psychological factor affecting older adults‘ life satisfaction and well-being and represent a relatively common health risk in this population. Research has shown that physical exercise can effectively alleviate depressive symptoms in older adults [24]. For example, different types of exercise—such as walking, aerobic exercise, yoga, health Qigong, resistance training, and Tai Chi—can reduce depressive symptoms to varying degrees [25].These findings suggest that physical exercise not only improves physical health but may also enhance older adults' subjective well-being by alleviating negative emotions and promoting positive psychological feelings.

Furthermore, a study focusing on Chinese older adults found that physical exercise is significantly correlated with subjective well-being, with both physical and mental health playing significant mediating roles in this relationship [26]. This provides direct evidence for understanding how physical exercise relates to well-being through health pathways. However, the study's sample was drawn primarily from a single city, so whether its findings can be generalized to a broader, more representative population of Chinese older adults remains to be tested. Using nationally representative survey data, the present study incorporates both self-rated health status and depressive symptoms into an analytical framework to further examine their mediating roles in the relationship between physical exercise frequency and subjective well-being in older adults.

Based on the above analysis, this study proposes Hypothesis 3: physical exercise frequency enhances subjective well-being by improving older adults' self-rated health and reducing their depressive symptoms. In other words, self-rated health status and depressive symptoms play mediating roles in the process through which physical exercise frequency affects older adults' subjective well-being. The proposed hypothesis model is illustrated in Fig. 1.

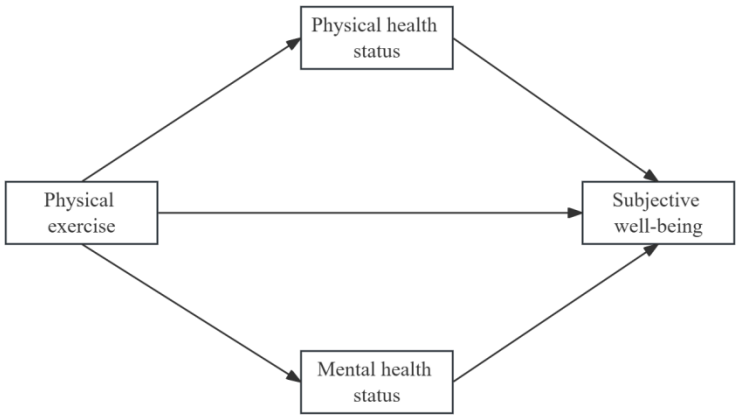

Fig. 1. Hypothetical model diagram

3 Methods

3.1 Data source

This study uses data from the 2021 wave of the Chinese General Social Survey (CGSS). The CGSS is a nationwide, continuous cross-sectional survey project targeting the adult population in mainland China, conducted by the National Survey Research Center at Renmin University of China, and has been widely used by numerous researchers [27,28]. The CGSS 2021 employed a multi-stage stratified sampling method and collected information on

individuals, families, and social life through face-to-face interviews. The original dataset contains 8,148 respondents and 700 variables.

Based on the research objectives of this study, the sample selection process was as follows: First, the study population was restricted to respondents aged 60 years and above at the time of the survey. Second, samples with complete information on subjective well-being, physical exercise frequency, self-rated health status, depressive symptoms, and control variables were retained. Finally, individuals with missing values or invalid responses on the relevant variables were excluded. After this sample selection process, a final sample of 1,872 older respondents was obtained as the analytical sample for this study.

In the final sample, 1,001 older adults (53.47%) reported having participated in physical exercise to varying degrees over the past year, while the remaining 871 (46.53%) reported no participation. Among those who participated, 124 engaged in physical exercise several times a year or less, 130 several times a month, 171 several times a week, and 576 every day.

3.2 Variable Settings

3.2.1 Dependent variable

The dependent variable in this study is subjective well-being, derived from the survey question: “Overall, do you feel that your life is happy?” Responses are coded on a scale from 1 to 5. Respondents who answered “very unhappy” are assigned a value of 1; “relatively unhappy” assigned 2; “neither happy nor unhappy” assigned 3; “relatively happy” assigned 4; and “very happy” assigned 5.

3.2.2 Core explanatory variable

The core independent variable is the frequency of physical exercise participation, based on the question: “In the past year, how often did you engage in physical exercise during your leisure time?” Responses are coded on a 5-point scale: 1 = never, 2 = several times a year or less, 3 = several times a month, 4 = several times a week, and 5 = every day.

Table 1. Variable assignment and descriptive statistics

Variable type	Variable	Sample size	Mean	SD	Min	Max
Dependent variable	Subjective well-being (SWB)	1872	4.067	0.841	1	5
Core explanatory variable	Physical exercise (PE)	1872	2.710	1.780	1	5
Control variable	Gender	1872	0.499	0.500	0	1
	Age	1872	70.263	6.891	60	99
	Educational attainment	1872	1.642	0.783	1	3
	Marital status	1872	0.622	0.485	0	1
	Hukou	1872	0.411	0.492	0	1
	Residence	1872	0.504	0.500	0	1

	Household economic status	1872	2.545	0.826	1	5
	Medical insurance participation	1872	0.943	0.392	0	1
	Pension insurance participation	1872	0.811	0.231	0	1
Mediating variable	Physical health status (PHS)	1872	3.105	1.119	1	5
	Mental health status (MHS)	1872	3.834	1.143	1	5

3.2.3 Mediating variable

In this study, "physical health status" and "mental health status" are used as mediating variables. Physical health status is measured based on older adults' self-rated health, derived from the survey question: "How would you rate your current physical health condition?" Responses range from 1 to 5, with higher scores indicating better physical health. Mental health status is assessed using the question: "During the past four weeks, how often have you felt depressed or down?" Responses also range from 1 to 5, with higher scores reflecting better mental health.

3.2.4 Control variable

Following established studies, this paper categorizes the control variables into three dimensions. The first is individual characteristics, including gender (male coded as 1, female as 0), age (coded as actual age), educational attainment (elementary school or below coded as 1, junior high school as 2, senior high school or above as 3), marital status (married and living with spouse coded as 1; divorced, widowed, never married, or married but not living with spouse coded as 0), and Hukou (non-agricultural Hukou coded as 1, agricultural Hukou coded as 0). The second dimension is family characteristics, including place of residence (urban coded as 1, rural as 0) and household economic status (far below average coded as 1, below average as 2, average as 3, above average as 4, far above average as 5). The third dimension is social characteristics, including medical insurance participation (enrolled coded as 1, not enrolled as 0) and pension insurance participation (enrolled coded as 1, not enrolled as 0).

For detailed variable assignment and descriptive statistics, see Table 1.

3.3 Empirical model

This study uses an ordinary least squares (OLS) model for regression analysis. The formula for calculating the subjective well-being of older adults is as follows:

$$SWB_i=\beta_0+\beta_1 PE_i+\beta_2 PHS_i+\beta_3 MHS_i+\beta_4 COV_i+\varepsilon_i \qquad (1)$$

where SWB_i is the dependent variable, representing the subjective well-being of individual i ; PE_i is the core explanatory variable, representing the physical exercise status of individual i ; PHS_i is the physical health status of individual i ; MHS_i is the mental health status of individual i ; COV_i is a series of control variables for individual i , covering three dimensions: individual characteristics, family characteristics, and social characteristics; and ε_i is the random error term.Building on this, the study further examines the mediating roles of self-rated health status and depressive mood in the relationship between physical exercise frequency and subjective well-being. Self-rated health status reflects older adults' perception of their physical health, whereas depressive mood captures their mental and emotional state. These two variables may thus serve as parallel pathways through which physical

exercise influences subjective well-being. Thus, following the multiple mediation analysis method proposed by Hayes [29] and Preacher [30], this study constructs a parallel multiple mediation model as follows:

$$SWB_i=a_0+a_1PE_i+\lambda COV_i+\mu_i \quad (2)$$

$$PHS_i=b_0+b_1PE_i+\Omega COV_i+v_i \quad (3)$$

$$MHS_i=c_0+c_1PE_i+\rho COV_i+u_i \quad (4)$$

The definitions of the variables in Equations (2), (3), and (4) are identical to those in the baseline model (1). Here, μ_i , v_i, and u_i are the random disturbance terms of the three models, respectively. The parameters a_1, b_1, and c_1 represent: the total effect of physical exercise on older adults' subjective well-being; the effect of physical exercise on the mediating variable of physical health status; and the effect of physical exercise on the mediating variable of mental health status, respectively. In the baseline model (1), β_1 represents the direct effect of physical exercise on the subjective well-being of older adults; $b_1\beta_2$ represents the mediating effect of physical health status in the relationship between physical exercise and subjective well-being; and $c_1\beta_3$ represents the mediating effect of mental health status in that relationship. Thus, ($b_1\beta_2+ c_1\beta_3$) is the total mediating effect. The total effect, direct effect, and mediating effects satisfy the following relationship: $a_1=\beta_1+ (b_1\beta_2+ c_1\beta_3)$.

4 Results

4.1 Basic regression analysis

Table 2 presents the estimated effects of physical exercise, physical health status, and mental health status on the subjective well-being of older adults, as derived from the OLS model.

This study adopts a stepwise approach by gradually adding different control variables to ensure the robustness of the estimation results. Specifically, Models (1) through (3) present the estimation results after sequentially adding three categories of control variables: individual characteristics, family characteristics, and social characteristics. Models (4) through (6) are based on Model (3) and further incorporate the mediating variables—first physical health status alone, then mental health status alone, and finally both simultaneously.

As variables are progressively added, the pseudo R-squared value increases. This indicates that the selection of control variables and mediating variables is both reasonable and necessary. Across all six models, the core explanatory variable—physical exercise—remains positive and significant at the 1% level. Thus, physical exercise significantly enhances the subjective well-being of older adults. Taking Model (6) as an example: a one-point increase in the frequency of physical exercise participation corresponds to a 0.0526-point increase in subjective well-being, supporting Hypothesis 1.Both physical health status and mental health status are also significant at the 1% level. A one-point increase in physical health status is associated with a 0.0676-point increase in subjective well-being, while a one-point increase in mental health status corresponds to a 0.1240-point increase. These results suggest that physical exercise may influence older adults' subjective well-being through improvements in both physical and mental health. Accordingly, physical health status and mental health status play mediating roles in the relationship between physical exercise and subjective well-being.

Regarding the control variables, age, marital status, and family economic status significantly affect older adults' subjective well-being, whereas the remaining control variables do not. Specifically, older adults of more advanced age report higher subjective well-being. Those who are married and live with their spouse also report higher subjective well-being. Likewise, higher family economic status is associated with higher subjective well-being.

Table 2. Baseline regression results (n=1872)

Variable	Subjective well-being											
	（1）		（2）		（3）		（4）		（5）		（6）	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Physical exercise	0.0751***	6.92	0.0616***	5.79	0.0615***	5.77	0.0539***	5.09	0.0562***	5.37	0.0526***	5.01
Gender	0.0491	1.29	0.0403	1.08	0.0404	1.08	0.0252	0.68	-0.0005	-0.01	-0.0026	-0.07
Age	0.0246***	8.96	0.0222***	8.12	0.0222***	8.20	0.0241***	8.81	0.0227***	8.41	0.0237***	8.74
Educational attainment	0.0461	1.68	0.0052	0.19	0.0054	0.20	0.0011	0.04	-0.0095	-0.35	-0.0096	-0.36
Marital status	0.1750***	4.26	0.1631***	4.13	0.1633***	4.14	0.1634***	4.21	0.1602***	4.16	0.1608***	4.19
Hukou	-0.0176	-0.39	-0.0523	-0.99	-0.0517	-0.98	-0.0574	-1.09	-0.0684	-1.33	-0.0690	-1.34
Residence			0.0043	-0.09	-0.0038	-0.08	-0.0169	-0.35	-0.0203	-0.42	-0.0253	-0.53
Household economic status			0.2573***	9.90	0.2573***	9.90	0.2234***	8.58	0.2075***	8.22	0.1958***	7.69
Medical insurance participation					0.0273	0.30	0.0437	0.49	0.0352	0.40	0.0436	0.50
Pension insurance participation					-.0188	-0.37	-0.0214	-0.42	-0.0219	-0.43	-0.0229	-0.45
Physical health status							0.1141***	6.19		7.80	0.0676***	3.50
Mental health status									0.1490***		0.1240***	6.13
Cons	1.9299***	8.75	1.5782***	7.31	1.5681***	6.97	1.1990***	5.11	1.1593***	5.01	1.0092***	4.28
R^2	0.0700		0.1290		0.1291		0.1498		0.1649		0.1711	

*** p<0.01， ** p<0.05， * p<0.1

4.2 Robustness tests

4.2.1 Alternative estimation methods

This study further tests the robustness of the baseline regression results using two alternative estimation methods: ordered probit and binary logit. In the binary logit model, respondents who answered “very happy” or “fairly happy” are classified as “happy” (coded as 1), while all others are classified as “unhappy” (coded as 0). Table 3 reports the estimation results from both models. The core explanatory variable—physical exercise—remains significantly positive at the 1% level in both the ordered probit and binary logit models. Similarly, the mediating variables—physical health status and mental health status—also exhibit significantly positive coefficients. These findings are consistent with the baseline regression results, confirming that the positive effect of physical exercise on the subjective well-being of older adults is robust.

Table 3. Robustness tests (n = 1872)

Variable	Subjective well-being					
	probit		logit		Construct binary variables	
	β	*t*	*β*	*t*	*β*	*t*
physical exercise	0.0795***	4.97	0.2029***	4.66	0.1206**	3.12
physical health	0.1070***	3.76	0.1637**	2.49	0.0701***	3.62
mental health	0.1634***	5.73	0.3711***	5.77	0.1252***	6.15
Control variable	**Yes**		**Yes**		**Yes**	
Pseudo R2	0.0806		0.1630		0.1649	

*** p<0.01， ** p<0.05， * p<0.1

4.2.2 Construct binary variables

In the baseline model, the core explanatory variable—physical exercise—ranges from 1 to 5. For robustness testing, this study replaces it with a binary variable. Older adults who chose “never” are classified as “not participating in physical exercise” and coded as 0, while those who chose “once a year or less,” “several times a month,” “several times a week,” or “every day” are classified as “participating in physical exercise” and coded as 1. The last column of Table 3 reports the estimation results after this reclassification. The coefficient of physical exercise remains significantly positive at the 5% level. In addition, the coefficients of the mediating variables—physical health status and mental health status—are significantly positive at the 1% level. These results are consistent with the baseline regression findings, further confirming the robustness of the conclusion that physical exercise positively affects the subjective well-being of older adults.

4.2.3 Propensity score matching

The baseline regression model shows that, in addition to the core explanatory variable (physical exercise), three control variables—age, marital status, and household economic status—significantly affect older adults’ subjective well-being. To address endogeneity and sample self-selection, this study employs propensity score matching (PSM) to estimate the net effect of physical exercise on subjective well-being.

Prior to matching, the core explanatory variable (physical exercise) is transformed into a binary variable. The main analytical framework of PSM is as follows: for each individual in the treatment group (those who participate in physical exercise), we identify a matched counterpart in the control group (those who do not participate) to create a counterfactual. The difference in the dependent variable between the two groups represents the net effect of physical exercise.This study employs three matching methods for robustness testing: K-nearest neighbor matching (K = 1), radius matching (caliper = 0.01), and kernel matching (bandwidth = 0.02). The average treatment effect on the treated (ATT) is estimated accordingly.

Table 4 presents the balancing test results under radius matching. After matching, the bias for all control variables falls below 10%. Before matching, the values for Pseudo R^2, LR chi^2, MeanBias, B, and R are 0.100, 259.57, 29.9, 78.2, and 1.20, respectively. After matching, these values become 0, 0.26, 0.5, 2.3, and 0.99, indicating good matching quality.

Table 4. Balance tests

Variable	Matching results	Mean		Bias (%)	Bias reduction (%)	t	P
		Experimental group	Control group				
Gender	Before	0.5255	0.4696	11.2	95.4	2.42	0.016
	After	0.5261	0.5286	-0.5		-0.12	0.908
Age	Before	69.713	70.896	-17.2	97.5	-3.72	0.000
	After	69.719	69.770	-0.4		-0.10	0.923
Educational attainment	Before	1.8372	1.4179	56.0	99.6	11.99	0.000
	After	1.8337	1.8353	-0.2		-0.04	0.965
Marital status	Before	0.6384	0.6028	7.3	91.3	1.58	0.113
	After	0.6373	0.6342	0.6		0.14	0.886
Hukou	Before	0.5345	0.2698	56.0	97.9	12.04	0.000
	After	0.5331	0.5276	1.2		0.25	0.806
Residence	Before	0.6274	0.3617	55.1	99.8	11.89	0.000
	After	0.6263	0.6268	-0.1		-0.02	0.980
Household economic status	Before	2.6893	2.3789	38.2	98.7	8.26	0.000
	After	2.6824	2.6863	-0.5		-0.11	0.913
Medical insurance participation	Before	0.9580	0.9265	13.5	95.7	2.95	0.003
	After	0.9579	0.9566	0.6		0.15	0.881
Pension insurance participation	Before	0.8382	0.7796	14.9	96.2	3.24	0.001
	After	0.8387	0.8409	-0.6		-0.13	0.893
Joint test			**Pseudo R^2**	**LR chi^2**	**MeanBias**	**B**	**R**
Before			0.100	259.57	29.9	78.2	1.20
After			0.000	0.26	0.5	2.3	0.99

*** p<0.01， ** p<0.05， * p<0.1

Table 5 presents the estimation results for three matching methods: K-nearest neighbor matching, radius matching, and kernel matching. Across all three methods, physical exercise consistently exerts a positive and significant effect on the subjective well-being of older adults ($p < 0.01$). These findings align with the baseline regression results, further confirming the robustness of the baseline estimates.

Table 5. Matching Results

Methods	Average Treatment Effect on the Treated
K-Nearest neighbors matching	0.1975***
Radius matching	0.1462***
Kernel matching	0.1439***

*** p<0.01， ** p<0.05， * p<0.1

4.3 Heterogeneity tests

The baseline regression and robustness test results indicate that physical exercise frequency significantly enhances the subjective well-being of older adults. However, older adults vary in age, gender, co-residence with a spouse, and household economic status, and the well-being benefits of physical exercise may not be equally

distributed. To further examine these subgroup differences, this study constructs interaction terms between physical exercise frequency and each of the following variables: age, gender, co-residence with a spouse, and household economic status. Table 6 presents the estimation results.

4.3.1 Age heterogeneity

Age-related changes in physical function, health needs, and daily activity patterns may give physical exercise different implications for the life experiences of older adults at different stages. An et al. [31] conducted a study targeting young, middle-aged, and older adult populations. After controlling for demographic characteristics, they found that higher levels of physical activity were significantly associated with higher levels of life satisfaction and well-being. Moreover, a positive curvilinear relationship was observed between age and both life satisfaction and well-being. This finding suggests that, in later stages of life, the association between physical activity and positive life evaluations may deserve particular attention.

In this study, respondents aged 60 to 69 are classified as the younger-old group, and those aged 70 and above as the middle- and older-old group, and an interaction term between physical exercise frequency and age group is constructed accordingly. The results of Model (1) in Table 6 show that the coefficient of the interaction term between physical exercise frequency and age group is positive and statistically significant at the 5% level, indicating that the enhancing effect of physical exercise frequency on subjective well-being is stronger for the middle- and older-old group than for the younger-old group. A possible explanation is that, as age increases, the maintenance of physical function, preservation of mobility, and positive life experiences become more important for the well-being of older adults; thus, physical exercise may yield more pronounced well-being benefits.

4.3.2 Gender heterogeneity

Male and female older adults may differ in their motivations for physical exercise, preferences for activity contexts, and modes of participation. A study of individuals aged 60 to 67 found significant gender differences in exercise motivation and activity environment preferences. For example, women place greater emphasis on weight loss, improving appearance, and engaging in activities with others, whereas men and women do not share identical preferences regarding exercise formats and participation settings [32]. Thus, the effect of physical exercise on subjective well-being may vary by gender.

In this study, male is coded as 1 and female as 0, and an interaction term between physical exercise frequency and gender is constructed. The results of Model (2) in Table 6 show that the coefficient of this interaction term is positive and significant. This indicates that the enhancing effect of physical exercise frequency on subjective well-being is stronger for male older adults. This finding suggests that when promoting physical exercise among older adults, full consideration should be given to gender differences in exercise content, participation styles, and activity support needs, rather than adopting identical approaches to activity organization.

4.3.3 Heterogeneity by spouse co-residence status

Living with a spouse provides older adults with stable family companionship and may offer behavioral and emotional support for sustained physical exercise. A study using longitudinal survey data of middle-aged and older adults in the United States found that both co-residence with a partner and the quality of the partner relationship are associated with physical activity levels. Specifically, respondents who transitioned from not living

with a partner to living with a partner reported higher levels of physical activity. Partner support was significantly positively associated with moderate-intensity physical activity, whereas partner conflict was significantly negatively associated with higher-intensity physical activity [33]. These findings suggest that the partner relationship is an important family condition influencing physical activity participation and positive experiences among middle-aged and older adults.

In this study, older adults who are married and living with their spouse are coded as 1; those who are unmarried, divorced, widowed, or married but not living with their spouse are coded as 0. An interaction term between physical exercise frequency and spouse co-residence status is then constructed. Model (3) in Table 6 shows that the coefficient of this interaction term is significantly positive, indicating that the enhancing effect of physical exercise frequency on subjective well-being is stronger for older adults living with their spouse. Thus, spousal companionship and family support may help older adults participate in physical exercise more consistently and derive greater well-being benefits from it.

4.3.4 Household economic status heterogeneity

Family economic status may influence older adults' participation in physical exercise by affecting access to activity venues, health services, exercise time stability, and the ability to bear associated costs. A systematic review of physical activity interventions among older adults with low socioeconomic status found that those with limited economic resources faced greater constraints, including cost, venue accessibility, activity schedules, and lack of social support [34]. For this group, reducing participation costs, providing convenient and familiar venues, and enhancing social connections are important conditions for improving the acceptability of physical activity. Thus, family economic resources may affect whether older adults can sustain physical exercise and derive positive life experiences from it.

In this study, respondents' subjective evaluation of their household economic status is used as the measure, coded from 1 (lowest) to 5 (highest). An interaction term between physical exercise frequency and family economic status is then constructed. Model (4) in Table 6 shows that the coefficient of this interaction term is significantly positive. This indicates that as family economic status improves, the enhancing effect of physical exercise frequency on older adults' subjective well-being becomes stronger. This finding suggests that the well-being benefits derived from physical exercise may be influenced by economic resources. Older adults with lower economic status may face more practical constraints in obtaining these positive benefits.

In summary, the enhancing effect of physical exercise frequency on subjective well-being varies significantly across age, gender, spouse co-residence status, and household economic status. Specifically, physical exercise has a stronger positive effect on subjective well-being for older adults who are older, male, living with a spouse, or have higher household economic status. Thus, Hypothesis 2 of this study is verified.

Table 6. Heterogeneity Tests (n = 1872)

Variable	Subjective well-being							
	（1）		（2）		（3）		（4）	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Physical exercise * Age	0.0242**	2.06						
Physical exercise * Gender			0.0456**	4.27				
Physical exercise * Spouse					0.0411**	3.24		
Physical exercise * household economic status							0.0134***	3.71
Control variable	**Yes**		**Yes**		**Yes**		**Yes**	
Pseudo R^2	0.1623		0.1649		0.1648		0.1657	

*** p<0.01， ** p<0.05， * p<0.1

4.4 Mediating effects of physical health and mental health

In the baseline regression of Section 4.1, Model (3) reports the estimation results without including physical health status and mental health status, where the estimated coefficient of the core explanatory variable—physical exercise (β_1)—is 0.0615.. After sequentially adding physical health status alone, mental health status alone, and both together, beta_1 decreases to 0.0539, 0.0562, and 0.0526, respectively. These declines suggest that physical exercise, physical health status, and mental health status all influence older adults' subjective well-being, but the effect of physical exercise weakens once the two health status variables are included. Thus, physical health status and mental health status may serve as key pathways through which physical exercise affects subjective well-being.To test these mediating effects, this study employs the bootstrap method with 1,000 replications to examine the mediating roles of physical health and mental health.

Table 7 reports the mediating effects of physical health status and mental health status estimated using the bootstrap method. The 95% confidence intervals for both mediators exclude zero, indicating that the mediating effects of physical health status and mental health status in the relationship between physical exercise and subjective well-being are significant. Thus, Hypothesis 3 is supported.

The total effect of physical exercise on subjective well-being is 0.0615. The direct effect of physical exercise is 0.0526, accounting for 85.53% of the total effect. The mediating effect of physical health status is 0.0045 (7.32%), and that of mental health status is 0.0044 (7.15%). These results indicate that the effect of physical exercise on older adults' subjective well-being is predominantly direct, with the two mediating effects being nearly equivalent.

Table 7. Bootstrap Test

Type	Path	Effect size	95% Confidence interval	Relative effect (%)
Direct effect	Physical exercise → Subjective well-being	0.0526	[0.0317，0.0734]	85.53
Mediating effect	Physical exercise → Physical health → Subjective well-being	0.0045	[0.0014，0.0076]	7.32
Mediating effect	Physical exercise → Mental health → Subjective well-being	0.0044	[0.0004，0.0084]	7.15
Total effect	Physical exercise → Subjective well-being	0.0615	[0.0404，0.0826]	100

Furthermore, this study also employs the stepwise method to test the mediating effects of physical health status and mental health status in the relationship between physical exercise and the subjective well-being of older adults. The relevant estimation results are presented in Table 8; Fig. 2. Model (1) in Table 8 reports that the coefficient of physical exercise, a_1 (Equation (2)), is 0.0615, which is positive and significant at the 1% level, indicating the presence of a total effect. Models (2) and (3) show that the coefficient of physical health status, b_1 (Equation (3)), is 0.0667, positive and significant at the 5% level, and the coefficient of mental health status, c_1 (Equation (4)), is 0.0357, also positive and significant at the 5% level, indicating that physical exercise significantly improves the physical and mental health of older adults . In Model (4), the coefficient of physical exercise, β_1 (Equation (1)), is 0.0526, positive and significant at the 1% level, demonstrating the presence of a direct effect of physical exercise on the subjective well-being of older adults. The coefficients of physical health status,β_2 (Equation (1)), and mental health status, β_3 (Equation (1)), are 0.0676 and 0.1240, respectively, both positive and significant at the 1% level, confirming the existence of mediating effects of physical health status and mental health status.

Table 8. Stepwise Test (n = 1872)

Variable	（1）Subjective well-being	（2）Physical health status	（3）Mental health status	（4）Subjective well-being
Physical exercise	0.0615***	0.0667**	0.0357**	0.0526***
Physical health status				0.0676***
Mental health status				0.1240***
Control variable	**Yes**	**Yes**	**Yes**	**Yes**
Pseudo R^2	0.1291	0.1029	0.1256	0.1711

*** p<0.01， ** p<0.05， * p<0.1

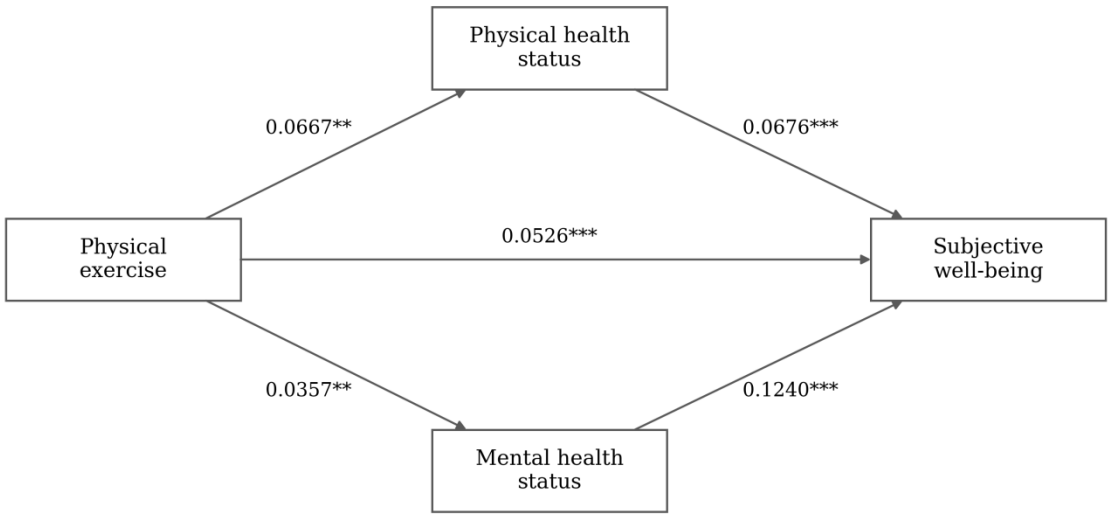

Fig.2. Path coefficients of the parallel mediation model, ** p < 0.05, *** p < 0.01

5 Discussion

This study finds a significant positive relationship between physical exercise frequency and the subjective well-being of older adults. Compared with those who rarely or never participate in physical exercise, older adults with higher exercise frequency report higher levels of well-being. The reason physical exercise is associated with the subjective well-being of older adults may lie not only in its role as a physical activity but also as a daily practice that helps maintain life rhythm, enhance the sense of self-control, and provide positive emotional experiences. Existing research has confirmed that physical activity can improve the long-term quality of life of older adults, and this relationship is associated with changes in positive emotions, self-efficacy, and self-worth experiences [35]. This suggests that, for older adults, the significance of physical exercise extends beyond physical fitness to include maintaining vitality, receiving positive feedback, and reinforcing self-identity in daily life. The findings of this study, based on a sample of Chinese older adults, are consistent with this interpretation: a higher frequency of physical exercise makes older adults more likely to develop positive life evaluations and well-being experiences.

The study further finds that self-rated health status plays a significant mediating role in the relationship between physical exercise frequency and subjective well-being. This suggests that part of the well-being benefits older adults gain from physical exercise arises from their positive evaluation of their own physical condition. In later life, individuals tend to pay greater attention to physical function, mobility, and independent living ability. Physical health not only affects actual activity scope but also influences overall judgments about quality of life in old age. The relationship between physical activity and quality of life can be explained through self-efficacy and health status, with health status serving as a key pathway linking the two [36]. Accordingly, using self-rated health status as a mediating variable reflects older adults' comprehensive perception of their physical ability and health condition during exercise. When older adults feel they are in good physical condition and can carry out daily activities more freely, their life satisfaction and well-being evaluation are also more likely to improve.

Psychological and emotional state constitutes another important mediating pathway identified in this study. The results show that older adults with higher physical exercise frequency report fewer feelings of depression or frustration, and that a more positive psychological and emotional state is further associated with higher subjective well-being. Physical exercise may help older adults reduce negative emotional experiences through regular daily routines, positive bodily experiences, attentional shifts, and emotional release gained during activity participation. A study based on the European population aged 50 and above found that physical activity, self-rated health, depression, and quality of life are closely interrelated, with self-rated health and physical activity of different intensities forming significant indirect pathways between depression and quality of life [37]. Although the direction of the variable relationships in that study differs from the present one, its results similarly suggest that among middle-aged and older adults, physical activity, health evaluation, depressive mood, and quality of life are not isolated but rather constitute an interconnected system of health-related experiences.

It is worth noting that the mediating effects of self-rated health status and psychological and emotional state identified in this study are relatively modest, with the two pathways together accounting for less than 15% of the total effect. The direct effect between physical exercise frequency and subjective well-being still constitutes the major part. This finding suggests that the relationship between physical exercise and the well-being of older adults cannot be fully explained solely by physical health and depressive mood. Physical exercise may also influence the well-being experience of older adults through pathways such as expanding social interaction, enhancing group belonging, enriching leisure life, and improving social participation ability. A study based on CGSS data on Chinese older adults found a significant positive relationship between physical exercise and mental health, with

social ability playing a mediating role between the two [38]. This finding suggests that the value of physical exercise for older adults may also manifest at the social level: participating in exercise activities can increase opportunities for interaction with others, enhance the ability to engage in public life and integrate into social networks, thereby generating well-being benefits beyond physical health and emotional improvement. From this perspective, the high proportion of direct effects found in this study does not imply that the mediation analysis is of limited significance; rather, it indicates that the process through which physical exercise affects the well-being experience of older adults is multidimensional. This finding suggests that the value of physical exercise for older adults may also manifest at the social level: participating in exercise activities can increase opportunities for interaction with others, enhance the ability to engage in public life and integrate into social networks, thereby generating well-being benefits beyond physical health and emotional improvement. From this perspective, the high proportion of direct effects found in this study does not imply that the mediation analysis is of limited significance; rather, it indicates that the process through which physical exercise affects the well-being experience of older adults is multidimensional. Future research should further incorporate variables such as social support, social participation, and social ability.

The heterogeneity analysis in this study reveals that the positive relationship between physical exercise frequency and subjective well-being is more pronounced among older adults who are older, male, living with a spouse, and have higher household economic status. For those of advanced age, physical exercise may be more directly linked to maintaining physical function, mobility, and independent living ability, thereby yielding greater well-being benefits. For those living with a spouse, physical exercise may more readily receive daily encouragement, joint participation, and emotional companionship, thereby enhancing the continuity and positivity of the exercise experience.

In contrast, the heterogeneity results regarding household economic status are particularly noteworthy. Physical exercise is often considered a low-cost, broadly accessible health behavior. However, whether older adults can participate consistently, access safe and convenient exercise environments, and obtain necessary health support may still be constrained by economic resources. Malkowski et al.[39] using data from the English Longitudinal Study of Ageing, found significant socioeconomic disparities in physical activity levels among older adults, with those from lower-resource groups exhibiting relatively lower levels of exercise participation, and that these disparities may further widen with changes in external living conditions . Consistent with these findings, the present study suggests that the positive relationship between physical exercise and subjective well-being may exhibit a degree of resource dependence. Older adults with higher family economic status are not only more likely to participate in physical exercise but may also more readily translate exercise participation into physical improvements, emotional pleasure, and positive life experiences. Therefore, promoting physical exercise among older adults should go beyond general advocacy. Attention must also be paid to practical barriers faced by relatively disadvantaged groups, including access to exercise venues, activity costs, companionship support, and health guidance.

Overall, this study makes two contributions beyond the existing literature. First, using a nationally representative survey sample, it simultaneously examines two parallel mediating pathways—self-rated health status and psychological-emotional state—demonstrating that the relationship between physical exercise and subjective well-being among older adults has both a physical health foundation and a psychological-emotional basis. Second, this study further identifies how this relationship varies across different subgroups of older adults, particularly revealing that family support and economic resources may affect the extent to which older adults derive well-being benefits from physical exercise. This finding suggests that, in the context of population aging, physical exercise is not only an important means of promoting older adult health but is also closely related to issues of welfare distribution and group disparities in later life.

This study has several limitations. Because cross-sectional data were used, the findings mainly reflect statistical relationships among physical exercise frequency, self-rated health status, psychological-emotional state, and subjective well-being; they cannot fully establish causal relationships. Furthermore, the measurements of physical exercise, physical health, and mental icators, without further distinguishing exercise intensity, duration, or specific types of physical activity. Future research could employ longitudinal data and adopt more detailed measures of physical exercise and health to further examine the relationship between physical exercise and subjective well-being among older adults.

6 Conclusions and recommendations

6.1 Conclusions

Using data from the 2021 Chinese General Social Survey (CGSS), this study examines the relationship between physical exercise frequency and subjective well-being among older adults and analyzes the mediating roles of self-rated health status and psychological-emotional state. The main conclusions are as follows:(1) Physical exercise has a significant positive effect on older adults' subjective well-being. This finding remains consistent across a series of robustness tests. (2) The relationship between physical exercise frequency and subjective well-being exhibits group heterogeneity. The positive effect is stronger among older adults who are older, male, living with a spouse, or have higher household economic status. (3) Both physical health status and mental health status play significant mediating roles in the relationship between physical exercise and subjective well-being. Nevertheless, the direct effect of physical exercise on subjective well-being remains predominant.

6.2 Recommendations

First, opportunities for physical exercise that are convenient, sustainable, and safe for older adults should be increased. The World Health Organization recommends that older adults engage in regular physical activity, including aerobic activities, muscle strength training, and balance training appropriate to their abilities [40]. In light of the findings of this study, communities and elderly service institutions can focus on forms of exercise such as walking, Tai Chi, Qigong, flexibility training, and balance training, providing accessible activity venues and basic exercise guidance, lowering participation barriers, and enhancing the sustainability of physical exercise.

Second, support should be appropriately directed toward older adults who lack companionship and have limited economic resources. Measures such as offering free or low-cost exercise programs, organizing buddy-based exercise activities, strengthening community volunteer companionship, and improving age-friendly exercise facilities can help older adults with relatively fewer resources participate in physical exercise more consistently.

Data availability

The data that support the findings of this study are available on request from the corresponding author.

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Competing interests

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