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Panna Yang, Ruilin Xu & Liujin Wu

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The Mediating Role of Physical Exercise on Subjective Wellbeing in Older Adults

Panna Yang ¹, Ruilin Xu ², Liujin Wu ^{3*}

¹ Department of Physical Education and Health, Tongren Preschool Education College, Guizhou, 554300, China.

² School of Physical Education (Main Campus), Zhengzhou University, Zhengzhou, 450001, Henna, China.

³ Guilin Medical University, Guilin, 541004, Guangxi, China.

*Corresponding author.

Email address: liujinwu@glmc.edu.cn (Liujin Wu)

Abstract: With the global population aging, there is a growing interest in exploring the role of physical exercise in enhancing the subjective well-being of older adults. This study aims to investigate how physical exercise influences the subjective well-being of older adults through perceived social support, physical health, and mental health. Additionally, it seeks to differentiate the impacts of varying exercise intensities and genders on subjective well-being. A total of 314 valid responses were obtained from older adults aged 60 and above in Luohe City through an offline questionnaire survey. Regression analysis was conducted using SPSS 26. to examine the associations between physical exercise, perceived social support, physical and mental health, and subjective well-being. Additionally, a mediation test was performed using the Bootstrap method. The findings show that Physical exercise was positively correlated with subjective well-being ($\beta=0.196$, $p<0.01$). Perceived social support ($\beta=.094$, 95% CI [.052, .150]) and physical and mental health ($\beta=.054$, 95% CI [.024, .097]) independently mediated the relationship between physical exercise and subjective well-being. Together, they constituted a sequential mediating pathway (effect size = .015, 95% CI [.003, .039]), with the combined indirect effect explaining 60.9% of the total effect. Furthermore, the impact of moderate and high-intensity physical exercise on the subjective well-being of older individuals surpassed that of low-intensity exercise, but there is no significant difference between moderate and high-intensity. Additionally, physical exercise had a slightly stronger effect on the subjective well-being of older women compared to older men. In conclusion, this study elucidates the pathway through which physical exercise improves the subjective well-being of older individuals by bolstering perceived social support and enhancing both physical and mental health. These findings offer a theoretical foundation for promoting healthy aging.

Keywords: older adults; physical exercise; subjective well-being; perceived social support; physical and mental health

Introduction

In the context of an aging population, the physical and mental health of older adults is declining¹, for example, older adults often experience psychological problems such as anxiety² and depression³. High levels of depression and anxiety symptoms can lead to low levels of well-being⁴, and the lack of subjective well-being is further exacerbated in old age⁵. In addition, older adults who lack physical exercise are more likely to suffer from physical and mental health deterioration, resulting in higher morbidity and mortality⁶. Therefore, how to improve subjective well-being of older adults and achieve healthy aging has received widespread attention.

In order to realize healthy aging, in 2019, the China government issued the Opinions of the General Office of the State Council on Promoting the Development of Pension

Services, proposing to carry out multi-level pension services to enhance the happiness of older adults⁷. The China government mentioned in the Opinions of the CPC Central Committee and the State Council on Strengthening the Work on Aging in the New Period that sports should be listed as one of the important measures to deal with the aging problem and encourage older adults to actively participate in physical exercise and improve their health status⁸. Under the increasingly serious aging trend, physical exercise is undoubtedly one of the important means to deal with the aging problem.

Participation in physical exercise can not only improve residents' subjective well-being, but also have a significant positive impact on their physical and mental health⁹. The positive influence of physical health on subjective well-being has been widely recognized¹⁰, mental health is also considered as an important predictor of subjective well-being¹¹, and participation in physical exercise is an important factor affecting residents' physical and mental health⁹. Social support is a key determinant of positive ageing and has been identified as a major source of subjective well-being¹². High levels of perceived social support are strongly associated with good physical and mental health⁹. Based on the buffer model of social support¹³ and the extended construction theory of positive emotions¹⁴, perceived social support and physical and mental health are regarded as potential mediating pathways through which physical exercise affects subjective well-being.

Although the academic community has reached a consensus on the positive effects of physical exercise on subjective well-being^{15,16,17,18}, existing research still has obvious limitations. Firstly, most studies have focused on the relationship between physical exercise and the subjective well-being of college students or middle-aged adults¹⁹ while there are relatively few studies on the underlying and mediating mechanisms of the relationship between physical exercise and subjective well-being in older adults²⁰. Secondly, previous studies have mostly verified the direct relationships between physical exercise and perceived social support, physical and mental health, and subjective well-being²¹, rarely integrating the four variables into a comprehensive framework to examine their internal mechanisms. However, the association between exercise intensity and subjective well-being and its gender differences still lack systematic exploration among older adults. To systematically respond to the above issues, firstly, integrate perceived social support and physical and mental health into a single analytical framework to examine their independent and chain mediating effects, thereby clarifying the specific path of physical exercise on the subjective well-being of older adults. Secondly, by using analysis of variance and post hoc comparison, the group differences in subjective well-being at low, medium and high exercise intensity levels were investigated to reveal the relationship characteristics between exercise intensity and subjective well-being. Thirdly, through subgroup analysis, explore the gender differences in the association between exercise and subjective well-being, providing certain reference basis for specifically enhancing the subjective well-being of older adults and achieving active aging.

1 Literature Review

1.1 Physical exercise and subjective well-being

Subjective well-being is the subjective feeling and evaluation of individual's quality of life and satisfaction, mainly including positive emotion, negative emotion and life satisfaction²². Spirduso et al.²³ argue that subjective well-being arises from a variety of factors, particularly in ageing populations. Physical exercise is defined as conscious,

purposeful social activity²⁴ undertaken by individuals or groups to achieve physical and mental pleasure, enhance social interaction, and experience cultural life. Kim et al.²⁵ found a significant and positive association between physical exercise participation and overall well-being. Silverstein et al.²⁶ noted that regular physical exercise can significantly improve cognitive function, quality of life, and well-being in older adults. Song Shuhua et al.²⁷ found that regular exercise can effectively improve the subjective well-being of the older adults by investigating in adults aged 60-69. Several studies have demonstrated significant positive effects of physical exercise and physical exercise on subjective well-being²⁸. Therefore, based on the above analysis, this study proposes hypothesis

H1: Physical exercise is significantly positively correlated with subjective well-being of older adults.

1.2 The mediating role of perceived social support

Social support is the material or spiritual support that individuals can obtain from others through social relationships. Social support plays a vital role in providing individuals with a sense of security, belonging and self-worth, and promoting and maintaining mental health. Perceived social support refers to an individual's beliefs, expectations, and evaluations of social support available to him/her²⁹. Dai Bing et al.³⁰ conducted a questionnaire survey on older adults in Chengdu City, Sichuan Province, to study their social support and its influencing factors. The results showed that there was a positive correlation between the level of social support and physical exercise. Older adults participate in physical exercise for a long time, the frequency of communication between older adults increases, the level of support from others increases, and older adults can perceive that their quality of life has improved. The Zhang Zhanjia¹⁵ study found that social support can modulate the relationship between physical exercise and subjective well-being, and an increase in physical exercise leads to enhanced social support, which in turn contributes to higher levels of life satisfaction and positive emotion. The Dong et al.³¹ study showed that when individuals engage in physical exercise and receive support from family and friends, they can generate lasting enthusiasm and interest in physical exercise. When they experience more social support, they have a more positive description of themselves, which leads to higher self-evaluations and thus higher subjective well-being levels. Therefore, based on the above analysis, this study proposes the hypothesis

H2: Perceived social support mediates the relationship between physical exercise and subjective well-being in older adults.

1.3 The mediating role of physical and mental health

Physical exercise has long been recognized as a key component of healthy aging, and older adults who engage in moderate physical exercise have slower rates of physical decline and lower risks of chronic disease and poor mental health than older adults who do not exercise³². When residents face physical health problems and mental health problems, huge pain and psychological stress often cause a vicious circle, thus greatly affecting residents' happiness³³. Zheng Yuannan et al.¹⁵ believe that participation in physical exercise can promote the physical and mental health of older adults, enhance self-confidence, help improve the quality of life of older adults and finally obtain happiness. In the process of stable participation in physical exercise, participants can not only directly increase muscle mass³⁴, enhance cognitive performance and reduce

obesity incidence³⁵ through physical exercise, but also gain pleasure and reduce anxiety and depression, thus enhancing personal health³⁶. Physical exercise is an important means to improve individual physical and mental health, physical and mental health is an important factor to improve subjective well-being, therefore, based on the above analysis, this study proposes hypothesis

H3: Physical and mental health plays a mediating role between physical exercise and subjective well-being of older adults.

1.4 Perceived social support and the chain-mediated role of physical and mental health

Perceived social support and physical and mental health are important factors affecting physical exercise and subjective well-being of older adults, which means that perceived social support and physical and mental health may play a chain mediating role in the impact of physical exercise on subjective well-being of older adults. Physical exercise has social attributes; participation in it not only improves physical fitness, but also fosters Social networks³⁷, improving quality of life and subjective well-being³⁸. As a social situational resource, perceived social support has been shown to have a significant impact on physical functioning, mental and cognitive health³⁹ in older adults. Mo et al.'s study shows that social support mediates between mental health, physical health and subjective well-being⁴⁰. For example, the study found that the largest group of Guozhuang dance practitioners are older adults, because Guozhuang dance not only keep older adults healthy, but most importantly, it is perfectly integrated with social culture, which means that older adults have the opportunity to socialize while exercising, thus generating positive emotions and contributing to their subjective well-being⁴¹. Therefore, based on the above analysis, this study proposes hypothesis

H4: Perceived social support and physical and mental health play a chain mediating role between physical exercise and subjective well-being.

1.5 Research hypothesis model

This study constructs a test model with physical exercise as independent variable, perceived social support and physical and mental health as intermediate variables, subjective well-being as dependent variable. The model is shown in Figure 1.

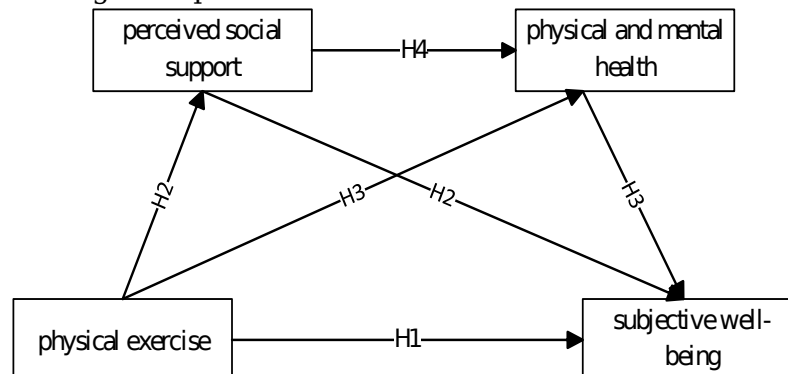


Fig. 1 Diagram of the study model

2 Materials and methods

2.1 Sample selection

This study conducted a cross-sectional survey in Luohe City from January 1 to 31, 2024 using a convenient sampling method. In order to make the samples more representative, 3 communities were randomly selected in Zhaoling District, Yuanhui District and Licheng District of Luohe City, and 339 questionnaires were distributed in total. This survey was conducted by three professionally trained investigators. They reached out to older adults in public areas such as community parks and squares within the selected community, explained the research purpose and process to them, and informed them that they could withdraw at any time. After obtaining the consent of the subjects, they carried out the questionnaire survey through offline face-to-face communication. The inclusion criteria for the subjects of this survey are as follows: (1) Age ≥ 60 years old; (2) Have resided locally for 6 months or more; (3) Clear consciousness and possess normal communication skills; (4) Sign the informed consent form. The exclusion criteria are: older adults who are unable to cooperate with the investigation due to reasons such as confusion, physical disability and inability to participate in physical exercise. After the survey, the questionnaires were recovered in time, and 25 questionnaires that were not filled in according to the specifications and missed answers were excluded. A total of 314 valid questionnaires were recovered, with an effective rate of 93%. There were 128 men and 186 women. This study received approval from the Institutional Review Board (IRB) of Tongren Preschool Education College in December 2023 (ethics approval no. TRYZ-RT-2024).

No sample size calculation was performed in this study, but the final sample size (N=314) met the requirements of multivariate analysis such as multiple regression. After post hoc validation analysis, the sample size of this study provides sufficient statistical power to detect hypothetical relationships⁴² in the medium-sized test model.

2.2 variable definitions

The questionnaire is divided into two parts, namely, basic demographic variable information (Table 1) and description and measurement of 4 variables such as physical exercise and subjective well-being.

Variables	Categories	Frequency	Percentage [%]	Variables	Categories	Frequency	Percentage [%]
Gender	Men	128	40.8	Education level	Primary and below	32	10.2
	Women	186	59.2		Junior high school	120	38.2
Ages	60-65	235	74.8	high school	111	35.4	
	66-70	45	14.3	Three-year junior college	28	8.9	
	71-75	29	9.2	Undergraduate and above	23	7.3	
	≥ 76	5	1.6	Monthly income	0-2000yuan	148	47.1
Ethnic group	Han ethnic group	305	97.1		2001-3000yuan	83	26.4
	National minority	9	2.9		3001-4000yuan	33	10.5
Marriage	Unmarried	5	1.6	4001-	13	4.1	

Married	309	98.4	5000yuan 5001 yuan and above	37	11.8
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Table 1 Basic information of valid samples*2.2.1 Physical Activity Rating Scale (PARS-3)*

This study adopted the physical exercise rating scale (PARS-3) revised by Liang, D.Q.⁴³ to measure the physical exercise grade from three angles: frequency, time and intensity. Physical exercise score = frequency × time × intensity, 3 dimensions were scored with 5-point Likert Scale. Physical exercise scale score range is [0, 100], score ≤19 is divided into low level exercise group, 19 < score ≤42 is divided into high level exercise group. The participants' levels of physical exercise were calculated by our research team using SPSS 26.0 based on the collected questionnaire data. The survey process did not involve any experimental interventions, and all participants completed the questionnaire based on their usual levels of physical exercise. This scale has been verified multiple times among different Chinese populations and has good reliability and validity. The survey was conducted by trained investigators in Mandarin. As all respondents were native Mandarin speakers from Luohe City, no additional language adaptation was required. Therefore, this scale⁴⁴ is adopted in this study. The overall Cronbach alpha coefficient of PARS-3 in this study was 0.836, indicating that the scale had good reliability.

2.2.2 Perceived social support (PSSS)

The perceived social support scale (PSSS) Chinese version compiled by Zimet et al.⁴⁵ was used in this study. This scale has been validated many times in China and has high reliability and validity⁴⁶. Therefore, this scale was used in this study. The perceived social support scale consists of three dimensions: family support, friend support, and other support. There are 12 items to evaluate the degree of support individuals feel from family, friends, and other people, such as "my friends can really help me." The scale is scored on a 5-point Likert scale from 1 (total disagreement) to 5 (total agreement), with the total score representing the overall level of social support the individual feels. The scale has good reliability and validity, and its Cronbach alpha coefficient is 0.93.

2.2.3 physical and mental health

This study draws on the research of Liu & Zhong⁴⁷, which confirmed the rationality of summing the scores of a total of 8 questions of health self-assessment, physical health, and mental health as a comprehensive indicator of physical and mental health when using CGSS data. Therefore, this study adopted the same summation scoring method to assess the physical and mental health level of older adults. The survey is conducted in Mandarin and has been standardized for use across China. The CGSS self-assessment questions are "How is your health at the moment" and measure the subject's self-assessment on a scale of 1 to 5 (1 means "very unhealthy" and 5 means "very healthy"). In terms of physical and mental health, CGSS measures how often a health problem affected a participant's work or other daily activities in the past four weeks, and how often the participant felt depressed in the past four weeks, such as "Are you energetic?" and measures the participant's physical and mental well-being on a scale of 1 to 5 (1 means "always" and 5 means "never"). As all respondents were native speakers of Mandarin in Luohe City, no language adjustment is required. This study used this as a reference and used the total score to measure the physical and mental health of the respondents. In this study, the Cronbach alpha coefficient of this scale was 0.741, indicating that the reliability of this scale was relatively high.

2.2.4 subjective well-being (WHO-5 Chinese version⁴⁸)

The Chinese version of the questionnaire comes from WHO's official website, which states that this questionnaire is a public resource with the aim of "making WHO-5 available to all interested parties in various languages." Respondents fill out a questionnaire based on their own situation in the last two weeks, a total of five questions, such as: "I feel happy and happy in the past two weeks", using a 5-point Likert scale, from 1 (always) to 5 (never), the higher the total score, the higher the subjective well-being of the individual. The scale has good internal consistency, good validity (Cronbach's $\alpha = 0.71$)⁴⁹, and easy to understand the topic, it is easy to be accepted by older adults. The Cronbach alpha coefficient of this scale in this study was 0.87, which had good reliability.

2.2.5 Statistical methods

First, SPSS 26.0 was used to calculate the mean (M) and standard deviation (SD) of each variable, and Pearson correlation analysis was performed. Secondly, one-way analysis of variance (ANOVA) was used to test the different effects of exercise intensity (low, medium and high intensity) on subjective well-being. If ANOVA results were significant ($p < 0.05$), post-hoc tests were performed to determine which specific groups were significantly different. Thirdly, in order to investigate whether the influence of physical exercise on subjective well-being varies with gender, the samples are divided into men and women groups, and linear regression analysis is carried out respectively to compare the difference of regression coefficients. Fourth, multiple linear regression analysis of physical exercise on subjective well-being of the direct effect. Finally, using the SPSS 26.0 process plug-in, 95% confidence intervals (CI) for indirect effects were calculated using Bootstrap method (5,000 samples). Independent and chain mediating effects were analyzed for perceived social support and physical and mental health. If the CI did not contain 0, the mediating effect was significant.

To enhance the transparency and reproducibility of this study, the entire research process - from sampling design and questionnaire analysis to model construction - has been thoroughly documented. Data analysis was conducted using SPSS 26.0 software, with all variables and indicators fully presented in the manuscript.

3 Results

3.1 Common methodological bias

Common method bias test Because the questionnaire was completed in anonymous paper form and subjective, there may be common method bias. Harman one-way test was used to conduct non-rotational exploratory factor analysis on 27 variable items in this study. The results showed that five of these factors had eigenvalues greater than 1, with the first factor explaining 34.86% of the variance, below the threshold of 40%. Thus, there are no significant common methodological biases for the variables involved in this study.

3.2 Descriptive statistics and correlation analysis

Descriptive analysis was performed on the four variables of physical exercise (PE), perceived social support (PS), physical and mental health (PM) and subjective well-being (SWB). The results are shown in Table 2. It can be seen that the average value of physical exercise is 1.65, which is between low intensity and medium intensity, indicating that

the overall physical exercise intensity of the respondents is not high; the average values of the three variables of perceived social support, physical and mental health and subjective well-being are all in the median. Above 3 indicates that the respondents 'perceived social support, physical and mental health and subjective well-being levels are all above average, and the overall level is high. Correlation analysis of the four variables revealed significant pairwise positive correlations (all $p < 0.01$). The significant correlation between variables laid the foundation for the follow-up test of the impact of physical exercise on subjective well-being.

Table 2 Results of descriptive and correlation analyses

Variables	PE	PS	PM	SWB
PE	1	0.234**	0.242**	0.270**
PS	0.234**	1	0.271**	0.509**
PM	0.242**	0.271**	1	0.423**
SWB	0.270**	0.509**	0.423**	1
M	1.65	3.67	3.27	3.80
SD	0.74	0.57	0.49	0.73

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

3.3 Differential analysis

In order to explore whether there is significant difference in subjective well-being of older adults with different physical exercise intensity, the subjects were divided into low intensity group (N=161), medium intensity group (N=103) and high intensity group (N=50) according to physical exercise intensity. One-way ANOVA was used to test the data. Results As shown in Table 3, ANOVA results show that there is a significant difference in subjective well-being among older adults with different physical exercise intensity ($F=20.979$, $p < 0.001$). Specifically, the mean SWB was 3.558 (SD =0.7391) for the low-intensity group (n=161), 4.103 (SD =0.6950) for the moderate-intensity group (n=103), and 3.940 (SD =0.4664) for the high-intensity group (n=50). To further clarify the details of differences between groups, post-hoc comparative analyses were performed.

Table 3 Results of one-way ANOVA

Dependent variable	Workout intensity	N	M	SD	F	P
Subjective well-being	low intensity	161	3.558	.7391	20.979	0.000
	medium intensity	103	4.103	.6950		
	high intensity	50	3.940	.4664		
	strength					

A post-hoc comparative analysis was conducted on the three older groups of low intensity, medium intensity and high intensity. As shown in Table 4, there was a significant difference in subjective well-being between older groups of low intensity group and medium intensity group ($p < 0.001$), and the well-being of the older population of medium intensity group was significantly higher than that of low intensity group. There was also significant difference in subjective well-being between low intensity group and high intensity group ($p = 0.001$), and the well-being of high intensity group was significantly higher than that of low intensity group. However, there was no

statistically significant difference in subjective well-being between the moderate-intensity group and the high-intensity group ($p=0.171$).

Table 4 Ex post facto comparative analysis of results

Intensity of exercise	Intensity of exercise	P	Comparative results
Low intensity	medium intensity	0.000***	low intensity < medium intensity
Medium intensity	high strength	0.001**	
High strength	low intensity	0.000***	low intensity < high strength
	high strength	0.171	
	low intensity	0.001**	
	medium intensity	0.171	

Note: *** $P<0.01$, ** $P<0.01$.

3.4 heterogeneity analysis

This study mainly aims at gender to study whether there are group differences in the effect of physical exercise on subjective well-being of older adults. Divide the respondents into two groups of men and women, and conduct regression analysis respectively to test whether there is any difference in the influence of physical exercise on subjective well-being between the two groups of respondents. The results are shown in Table 5. It can be seen that physical exercise has a significant positive impact on subjective well-being of men ($\beta=0.264$, $p<0.001$) and women ($\beta=0.269$, $p<0.01$) older groups, and the impact of physical exercise on subjective well-being of older women is slightly higher than that of older men.

Table 5 Results of gender heterogeneity analysis

Variables	Women	Men
Physical exercise	0.269**	0.264***
R	0.083	0.072
R2	0.278	0.262
F	0.077	0.069
	10.527	13.552

3.5 Multiple collinearity test

To avoid multicollinearity problems caused by significant correlations between all variables, resulting in unstable final results. This study decided to use subjective well-being of older adults as a dependent variable, physical exercise, perceived social support, and physical and mental health as independent variables to diagnose covariance, and to standardize each predictor variable. The results showed that the tolerance values (0.847, 0.881, 0.857) of each predictor variable were greater than 0.1, and the VIF values (1.181, 1.135, 1.167) were less than 5. Any multicollinearity problem and is suitable for further chain mediation testing.

3.6 Direct effect test

Regression analysis was performed on the variables to verify each hypothesis relationship, and the results are shown in Table 6. The results showed that physical exercise had significant positive effects on subjective well-being ($\beta=0.196$, $P<0.01$), perceived social support ($\beta=0.112$, $P<0.05$) and physical and mental health ($\beta=0.172$,

$P < 0.001$). Perceived social support significantly affected subjective well-being ($\beta = 0.436$, $P < 0.001$) and physical and mental health ($\beta = 0.171$, $P < 0.01$). Physical and mental health significantly affected subjective well-being ($\beta = 0.562$, $P < 0.001$). Therefore, hypothesis H1 is supported.

Table 6 Direct effects test

Model	β	SE	P	F	R ²	ΔR^2	Results
PE→SWB	0.266	0.054	0.000	24.489	0.073	0.070	set up
PE→PS	0.181	0.043	0.000	18.089	0.055	0.052	set up
PE→PM	0.161	0.037	0.000	19.389	0.059	0.055	set up
PS→SWB	0.648	0.062	0.000	109.016	0.259	0.257	set up
PS→PM	0.232	0.047	0.000	24.687	0.073	0.070	set up
PM→SWB	0.627	0.076	0.000	67.800	0.179	0.176	set up

3.7 Mediation effect analysis

This study mainly analyzed three aspects, one is whether perceived social support plays a mediating role between physical exercise and subjective well-being, the other is whether physical and mental health plays a mediating role between physical exercise and subjective well-being, and the third is whether perceived social support and physical and mental health play a chain mediating role between physical exercise and subjective well-being.

This study uses SPSS 26.0 process plug-in to conduct mediation effect test, and the results are shown in Table 7. First, mediation analysis yielded a total mediating effect of 0.162, accounting for 60.9% of the total effect, and the 95% confidence interval ([0.1035, 0.2034]) did not contain 0, indicating that the model perceived a range of mediating variables for social support and physical and mental health to be correct and reliable. Secondly, by adding perceived social support and physical and mental health into the relationship between physical exercise and subjective well-being, it is concluded that there are four ways in which physical exercise affects subjective well-being: path 1 The direct effect size of (physical exercise → subjective well-being) is 0.104, the effect proportion is 39.1%, and the confidence interval is 95%.([0.011, 0.1965]) does not contain zeros, indicating significant direct effects for this pathway; Path 2 The mediating effect value of (physical exercise → perceived social support → subjective well-being) was 0.094, accounting for 35.34% of the total effect with 95% confidence interval.([0.0523, 0.1496]) does not contain 0, indicating significant mediating effects for this pathway; Path 3 The mediating effect value of (physical exercise → physical and mental health → subjective well-being) is 0.054, the effect ratio is 20.3%, and the confidence interval is 95%.([0.0523, 0.1496]) does not contain 0, indicating that the mediating effect of this pathway is significant; the mediating effect value of path 4 (physical exercise → perceived social support → physical and mental health → subjective well-being) is 0.015, the effect proportion is 5.6%, and the 95% confidence interval ([0.0026~0.0386]) does not contain 0, indicating that the chain mediating effect of this

pathway is significant. To sum up, in the relationship between physical exercise and subjective well-being of older adults, H1, H2, H3 and H4 are assumed to be true. After validation, the relationship model between the four variables is shown in Figure 2.

Table 7 Mediating effects test

Effect pathway	Effect size	BootSE	BootLLC I	BootUL CI	Relative effects [%]
Total effect	0.266	0.054	0.1603	0.3720	100
direct effect	0.104	0.047	0.011	0.1965	39.10
Total indirect effect	0.162	0.033	0.1035	0.2304	60.90
PE→PS→SWB	0.094	0.025	0.0523	0.1496	35.34
PE→PM→SWB	0.054	0.018	0.0239	0.0970	20.30
PE→PS→PM→SW	0.015	0.009	0.0026	0.0386	5.6

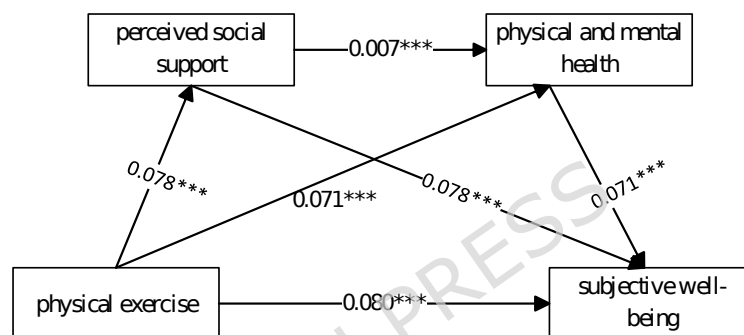


Fig. 2 Diagram of the validated research model

4 Discussion

4.1 Relationship between physical exercise and subjective well-being of older adults

Data analysis revealed that physical exercise there was a significant positive correlation between physical exercise and subjective well-being among older adults. This finding supports the study's hypothesis and is consistent with the findings of previous studies^{24,25,26,27}. As a result, hypothesis H1 holds true. Yang Jiao et al⁵⁰ also used PARS-3 scale to measure the subjective well-being of older adults, and found that physical exercise had a positive impact on the subjective well-being of older adults. These studies show a significant beneficial association between physical exercise and subjective well-being in older adults. With the increase of age, older adults will have various health problems, and then produce certain negative emotions, and the low subjective well-being has been considered to be one of the important factors leading to loneliness and depression in older adults⁴. Physical exercise, an external aid known to be effective in combating negative emotions in humans, will help reduce the risk of depression and loneliness⁵¹. For example, aerobic exercise such as tai chi⁵² has a positive effect on relieving anxiety and depression and improving subjective well-being in older adults.

This study once again verified the positive association between physical exercise and subjective well-being among older adults in Luohu City, further supporting the universality of this conclusion among older adults in different regions.

4.2 Mediating effect of perceived social support on physical exercise and subjective well-being of older adults

The finding that perceived social support partially mediates the relationship between physical exercise and subjective well-being among older adults supports Hypothesis H2, which is consistent with the results of previous studies^{17,30,31}. Physical exercise is an important way to increase individual perceived social support, and perceived social support is also a key factor affecting individual positive emotions⁵³. The buffer model of social support¹³ suggests that social support acts as a buffer between stress and health, and physical exercise can enhance individuals' perception of social support (e.g., through group activities and social interactions), thus indirectly improving subjective well-being. Taking Guozhuang dance as an example, regular exercise can produce good results on people's physical health, improve their mental state, cultivate their aesthetic taste, relieve fatigue and keep them happy⁵⁴. In addition, Gatab and Pirhayti's⁵⁵ research also shows that regular participation in social interactive physical exercise helps build good social networks, improve quality of life and subjective well-being. Active participation in physical exercise helps to expand social circle, strengthen social connection and peer support, thus effectively alleviating negative emotions and enhancing subjective well-being.

This study verified the mediating role of perceived social support in physical exercise and subjective well-being among older adults ($\beta=0.094$, 95% CI [0.052, 0.150]), further revealing that the mediating effect of social support accounted for 35.3%, significantly higher than that of the physical and mental health pathway (20.3%). This result indicates that in the process of physical exercise among older adults, perceived social support plays a more significant role than physical and mental health.

4.3 Mediating effect of physical and mental health on physical exercise and subjective well-being of older adults

The research shows that physical and mental health plays a part of mediating role between physical exercise and subjective well-being of older adults, which is consistent with the results of previous research^{15,34,35,36}, and hypothesis H3 holds true. Zhang and Li⁵⁶ show that participation in physical exercise can improve physical health and enhance mental health, thus effectively enhancing subjective well-being. According to Extended Constructional Theory, physical exercise expands cognitive resources through positive emotions (such as pleasure), and then constructs long-term physical and mental health resources, indirectly enhancing happiness¹⁴. For example, Guozhuang dance, as a collective exercise, largely meets the physical and mental health needs of older adults⁵⁷. There may be two reasons. First, the positive emotions inadvertently promoted by older adults during dance are an important source of happiness⁵⁸. Secondly, the combination of music and rhythmic exercise can promote the physical and mental health of older adults and improve subjective well-being⁵⁹.

This study verified the mediating role of physical and mental health in the relationship between physical exercise and subjective well-being among older adults, and further revealed the internal mechanism by which physical exercise enhances the subjective well-being of older adults through physical and mental pathways.

4.4 The chain mediating effects of perceived social support and physical and mental health on physical exercise and subjective well-being of older adults

The results show that physical exercise plays a chain mediating role in the influence of subjective well-being of older adults, which is consistent with the results of previous studies^{39,40,41}. Therefore, Hypothesis 4 holds true. Participating in physical exercise can not only enhance physical fitness, but also help increase the frequency of social interaction and build a strong social support network⁶⁰; it is precisely this support and encouragement from peers that enables older people to experience a strong sense of social belonging through physical exercise, thereby making them more likely to feel happy and fulfilled⁶¹. The main effect model of social support indicates⁶² that the promoting effect of social relationships on health is not related to individual stress levels, and its mechanism may be achieved through increasing positive emotions and other pathways⁶³. For example, participating in group sports such as square dance can help increase the positive emotions of middle-aged and older adults, expand interpersonal communication channels in daily life, meet the needs of social communication and emotional communication, and improve individual enthusiasm⁶⁴.

This study integrates physical exercise, perceived social support, physical and mental health, and subjective well-being into one model, expanding the existing theoretical model. Although the total effect explained by this chain mediating pathway is relatively small at 5.6%. This might be due to the fact that subjective well-being is a multi-dimensional concept and is also influenced by other factors such as medical care and family structure. Additionally, the sample size of this time (N=314) might be slightly insufficient when testing the chain mediating effect. Despite this, this finding still provides practical references for physical intervention among older adults, that is, to enhance their perceived social support and physical and mental health by participating in collective physical exercise, thereby increasing their subjective well-being.

4.5 Effects of different physical exercise intensity on subjective well-being of older adults

This research shows that older adults who engage in moderate-intensity and high-intensity physical exercise exhibit a higher correlation in their subjective well-being levels compared to those who engage in low-intensity exercise, while there is no significant difference in the subjective well-being levels between older participants in moderate-intensity and high-intensity physical exercise. This is slightly different from the research conducted by Panza et al.⁶⁵, who found that moderate-intensity physical exercise has the most significant effect on enhancing subjective well-being, while high-intensity physical exercise has an inhibitory effect instead. In this study, high-intensity physical exercise did not show an inhibitory effect on subjective well-being, but rather demonstrated a promotional effect comparable to that of moderate-intensity exercise. There may be several reasons for this. First, it can be seen from the data that the sample size of the high intensity group is relatively small (n=50). Compared with the low intensity group (n=161) and the medium intensity group (n=103), the number of subjects is insufficient, which may affect the sensitivity of the statistical test, so that the slight difference between the medium and high intensity groups fails to reach the statistical significance level. Secondly, the effect of physical exercise on happiness presents an "inverted U-shaped" relationship, that is, moderate intensity can most effectively stimulate positive emotions, promote endorphin secretion, and maintain good physical recovery, which is most significant for happiness promotion; although excessive intensity is still beneficial, it may bring physical fatigue, risk of sports injury or psychological stress, which makes happiness promotion limited, and even has the same effect as moderate intensity⁶⁶.

This research has significant guiding significance for the scientific exercise of older adults. This Study show that high-intensity physical exercise does not offer additional happiness gains beyond moderate-intensity ones, and older adults often have a higher risk of injury. Therefore, "moderate-intensity exercise" should be regarded as the most suitable intensity exercise for among older adults.

4.6 Group differences in physical exercise on subjective well-being

Research shows that there are gender differences in the promoting effect of physical exercise on subjective well-being. The association between physical exercise and subjective well-being in the order female group is slightly higher than that in the order male group. This finding is consistent with the results of previous research⁶⁷. There are several possible reasons for this: First, the improvement in emotional and social functioning (i.e., lower depression, increased self-confidence; befriending more dancers) was greater in women than in men⁶⁷ and was more in line with women's physical and psychological needs⁶⁸. Second, due to social stereotypes, adults showed heterogeneous associations between dance participation and subjective well-being. Square dancing was initially stereotypically perceived as women's leisure activities, and women remain its predominant participants⁶⁹. This stereotype may affect the willingness of older men to participate in square dancing, thereby leading to gender heterogeneity in the promoting effect of physical exercise on subjective well-being among older adults⁷⁰.

The findings of this study suggest that gender should be taken fully into account when designing physical exercise programmes for older adults, thereby enhancing the pertinence and effectiveness of interventions.

5 Limitations and future research

There are still some areas for improvement in this study: First, this is a cross-sectional study, lacking long-term follow-up of older adults, and it is difficult to infer causal relationships between variables. Alternative model directions are plausible. For example, higher well-being or better health may increase exercise participation, and greater social support may enable both higher activity and better health. Because all variables were measured at the same time point, the sequential ordering implied by the indirect-effect model cannot be confirmed. Future studies could consider longitudinal designs (e.g., cross-lagged panel models) or interventions are required to test directionality." Secondly, due to the convenience sampling survey method adopted in this study, the sample was limited to Luohe City and the sample size was relatively small, which restricted the generalizability of the findings to a wider population and other regions. There are significant differences in economic development levels, community sports facilities and other aspects among different regions. These potential confounding factors may lead to substantial differences in the physical activity levels and exercise patterns of older adults in different regions. Future research can scientifically design sampling methods, conduct investigations and studies in a wider range of regions, control confounding factors, and enhance the external validity of research conclusions. Third, the data in this study are mainly based on self-reports, which may introduce problems such as social expectation bias or recall bias, although we mitigate this problem by filling in anonymously, but it may still affect the reliability of the results. Future studies can be cross-validated with experimental or objective data. Finally, this study reveals the mediating effect and chain mediating effect of perceived social support and physical and mental health on physical exercise and subjective well-being of older adults. Because there are differences in exercise programs and habits among older

adults, future studies could consider adding moderating variables such as age, gender, education level, and exercise type (group versus individual).

6 Conclusion

Through the study we found that: (1) older adults physical exercise and subjective well-being was significantly positive correlation. (2) Perceived social support and physical and mental health mediate the relationship between physical exercise and subjective well-being of older adults. The mediating effect consists of three pathways: perceived social support alone, physical and mental health alone, and chain mediating effect of perceived social support and physical and mental health. (3) The correlation between physical exercise and subjective well-being in middle-high intensity older group is higher than that in low-intensity older group. In addition, the correlation between physical exercise and subjective well-being in older women is slightly higher than that in older men.

This study enriches the empirical research on how physical exercise promotes subjective well-being among older adults. The chain mediation indicates that to enhance the subjective well-being of older adults, it is not only necessary to encourage their participation in physical exercises, but also to consciously help them build social connections and pay attention to physical and mental health during the exercise process. In addition, attention should also be paid to the differential effects of exercise intensity and gender on subjective well-being, so as to formulate more scientific and personalized intervention plans for older adults.

Data availability

The datasets generated and analysed during the current study are available in the [Figshare] repository with the private link for peer review: [https://figshare.com/s/3a379d5524cc8ab98a98]. The data will be made publicly available upon acceptance of the manuscript.

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Author contributions

Panna Yang: Writing - original draft, Formal analysis, Data curation, Conceptualization. **Ruilin Xu:** Supervision, Methodology. **liujin Wu:** review & editing, Software, Investigation. All author shave read, revised, and approved of the final manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Conflict of interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical approval

This study received approval from the Institutional Review Board (IRB) of Tongren

Preschool Education College (ethics approval no. TRYZ-RT-2024). The IRB confirmed that all procedures complied with the institution's relevant guidelines and regulations. Written informed consent was obtained from all participants.

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