BMC Public Health

RESEARCH

Open Access

Association between physical activity trajectories and successful aging in middle-aged and elderly Chinese individuals: a longitudinal study

Xing Zhang[1], Xiyan Niu[2], Mengdi Wang[1], Qiannan Li[1], Huiling Feng[1], Yanli Wang[2] and Jinghua Ma[1,3*]

Abstract

Background Physical activity (PA) varies among middle-aged and older individuals, and insufficient or excessive in activity are associated with an individual's health status. However, the associations between the trajectory of physical activity and the health status of middle-aged and older adults have been little studied. The study aims to explore the association between PA trajectories and successful aging in middle-aged and older adults.

Methods This study used data from the CHARLS in 2013 to 2020. Physical activity was measured with the IPAQ Short Form and total weekly energy expenditure was calculated for different intensities of exercise. The assessment of successful aging includes the following five aspects: the absence of major diseases, no physical impairment, high cognitive function, no depression, and active participation in social activities. Group-based trajectory modeling (GBTM) was used to identify PA trajectories and logistic regression was performed to explore the association between the trajectories of PA and the incidence of successful aging.

Results A total of 1,413 individuals participated in the follow-up study. Three PA trajectories were identified based on GBTM model: stable low, decreasing and increasing. The increasing trajectory (17.1%) had a higher prevalence of successful aging than the stable low trajectory (14.0%) and the decreasing trajectory (15.7%). The sensitivity analyses were generally consistent with the main results.

Conclusion Our study identified three PA trajectories and found that increasing PA trajectory has a higher prevalence of successful aging compared with stable low and decreasing trajectories among Chinese middle-aged and older adults. The findings underscore the importance of monitoring changes in physical activity in middle-aged and older individuals, which provides new ideas for achieving successful aging.

Keywords Physical activity, Successful aging, CHARLS, Longitudinal study

*Correspondence:
Jinghua Ma
majh_66@126.com
[1]Department of Nursing, Hebei University of Chinese Medicine, Shijiazhuang 050200, China
[2]Department of Respiratory, Hebei Provincial Hospital of Traditional Chinese Medicine, Shijiazhuang 050000, China
[3]Hebei Key Laboratory of Health Care with Traditional Chinese Medicine, Hebei University of Chinese Medicine, Shijiazhuang 050200, China

Introduction

Based on the World Health Organization (2021), the global population aged 60 years and over has reached 1 billion people in 2020, accounting for 13.2% of the total number of people in the world. The number will continue to grow in the future. It is expected to increase to about 1.4 billion people in 2030, accounting for 16.7% of the world's total population [1]. The number of aging population in China is the largest in the world. According to the China's National Bureau of Statistics (2021), the population over 60 years accounted for around 18.7% of the country's total population in 2020, and the proportion is expected to rise to about 20% by 2030 [2]. The above data show that the world has entered the age of aging, and the aging problem is more serious in China. In recent years, the average life expectancy of the older adults has also increased rapidly. Some studies have shown that the life expectancy of the elderly in China has risen from 68.6 years in 1990 to 77.3 years in 2020 [3, 4], while the healthy life expectancy in 2020 is only 69 years [4]. It indicates that the older adults are more likely to experience health problems in the nearly 8.3 years. As a result, ensuring older adult's health state maintains stability during the aging process has become critical to coping with aging.

Successful aging is defined as the absence of disease and disability, a high level of cognitive and physical functioning, and active participation in life, emphasizing that older adults keep healthier lives while living longer [5]. People who meet the criteria for successful aging can maintain both physical and mental health at the same time [6], enhancing personal and family well-being. It is an important step in coping with population aging. A systematic review and meta-analysis of successful aging reveals that roughly 24.0% of global older adults achieved successful aging. There are significant differences in the incidence of successful aging between different countries and regions, such as Asia (25.1%) having a higher incidence of successful aging than Europe (21.5%) and the Americas (20.6%) [7], which could be related to the structure of health care and the distribution of social resources in different countries. Previous studies have shown that the rate of successful aging in China is only 17.1% [8], clearly lower than the average in Asia. The data reveals that successful aging is a more significant concern in China.

In order to promote the physical health of the older adults and improve the level of successful aging, many scholars have actively explored many methods related pharmacological and non-pharmacological. Although pharmacologic therapies such as Semaglutide [9] can improve the health of older adults, the approach requires long-term monetary support. Non-pharmacological therapies such as exercise and diet have the ability to reduce oxidative stress and enhance the body's immunity, making them the first choice for promoting individual health [10–12]. Physical activity(PA) is the most widely suggested non-pharmacological therapy due to its lower cost and higher safety profile than diet.

According to recent studies, PA can reduce the risk of certain major chronic diseases like cardiovascular disease by improving cardiovascular function and regulating blood glucose levels, which promotes the health status of the individual. In a study of analyzing the relationship between PA data and mortality outcomes, Martinez et al. [13] found that despite advances in a variety of medical conditions during the past 17 years, the practice of regular PA still reduces the risk of mortality and can bring significant health benefits to individuals. The above researches suggest that PA not only prevents the occurrence of health problems but also increases life expectancy, which is the key to promoting successful aging. However, with the increase of age, the physical function of middle-aged and elderly individuals gradually declines. PA also changes when their exercise capacity gradually weakens [12]. Therefore, exploring the trajectories in PA plays an important role in promoting successful aging. Previous studies have only taken a single measure of PA, which does not clearly indicate the trajectory of changes in PA and does not provide more accurate recommendations for the realization of successful aging.

In view of this, the research objectives of this study are as follows: (1) to investigate the trajectory of PA; (2) to explore the relationship between the trajectory of PA and successful aging; (3) to analyze the association between PA from different components including the overall activity level, intensity, frequency, and volume with successful aging to find more appropriate exercise methods for middle-aged and older adults to achieve successful aging.

Materials and methods

Study population

We used the data from the second wave of the 2013 to the fifth wave of the 2020 China Health and Retirement Longitudinal Study (CHARLS) [14]. The CHARLS survey aims to collect a set of high-quality microdata representative of Chinese households and individuals aged 45 and above, which provides a scientific basis for analyzing the aging problem in China and improving the related policies of the aging population. It includes details of their demographic backgrounds, families, health status and function, body measurements, health service utilization and health insurance, etc. CHARLS has been approved by the Biomedical Ethics Review Committee of Peking University (IRB0000052-11015), and all detailed information about CHARLS can be found on the official website (https://charls.pku.edu.cn).

The inclusion and exclusion criteria for our study were as follows: (1) inclusion criteria: age ≥ 45 years; (2) exclusion criteria: (a) missing information about PA during follow-up; (b) missing information about successful aging at Wave 5; (c) lost to follow-up or death during follow-up. It is worth noting that because the average age of the CHARLS study population was 45 years or older, all populations were included in Wave 2. Ultimately, the final analysis included 1,413 eligible participants. The details are shown in the images below (Fig. 1).

Assessment of PA

The international Physical Activity Questionnaire (IPAQ) Short Form was used to measure PA of middle-aged and older adults. The reliability and validity of the questionnaire have been confirmed by previous studies [15]. Firstly, individuals were asked whether they usually engaged in different intensity of PA for at least 10 min during a week. The intensity of PA was specified as follows: (1) vigorous-intensity PA (VPA): activities such as lifting heavy objects, aerobics, fast cycling, carrying loads on a bike that make you short of breath; (2) moderate-intensity PA (MPA): activities such as lifting light objects, cycling at a regular speed, mopping the floor, playing Tai Chi that make you breathe faster than usual; (3) low-intensity PA (LPA): activities include walking at home or work, and other walking specifically for sport, exercise, recreation, or leisure. If the answer was "yes", then the frequency and duration of PA were continued to be asked. Finally, the weekly activity energy consumption of middle-aged and older adults was calculated based on the duration and frequency of PA. The calculation formula as follows: 1 week energy expenditure of PA (MET) = metabolic equivalent of corresponding PA (MET)× daily time of PA in 1 week × days of PA in 1 week, in which MET was assigned 3.3 for LPA, 4.0 for MPA and 8.0 for VPA. According to the IPAQ Working Group's rubric [16], PA levels of individuals were categorized into three levels: low (< 600 MET/week), medium (600-3,000 MET/week), and high (> 3,000 MET/week).

Furthermore, this study characterized the weekly frequency, duration, and volume of PA [17, 18]. The frequency of PA ranged from 0 to 7 d/w and was divided into four categories: sedentary, 1—2 d/w, 3—5 d/w, and 6—7 d/w. The duration of PA (min/d) was also classified into four scales: sedentary, 10–29 min/d, 30–119 min/d, and ≥ 120 min/d. The weekly volume of PA (min/w) was divided into four groups: sedentary, < 150 min/w, 150–299 min/w and ≥ 300 min/w.

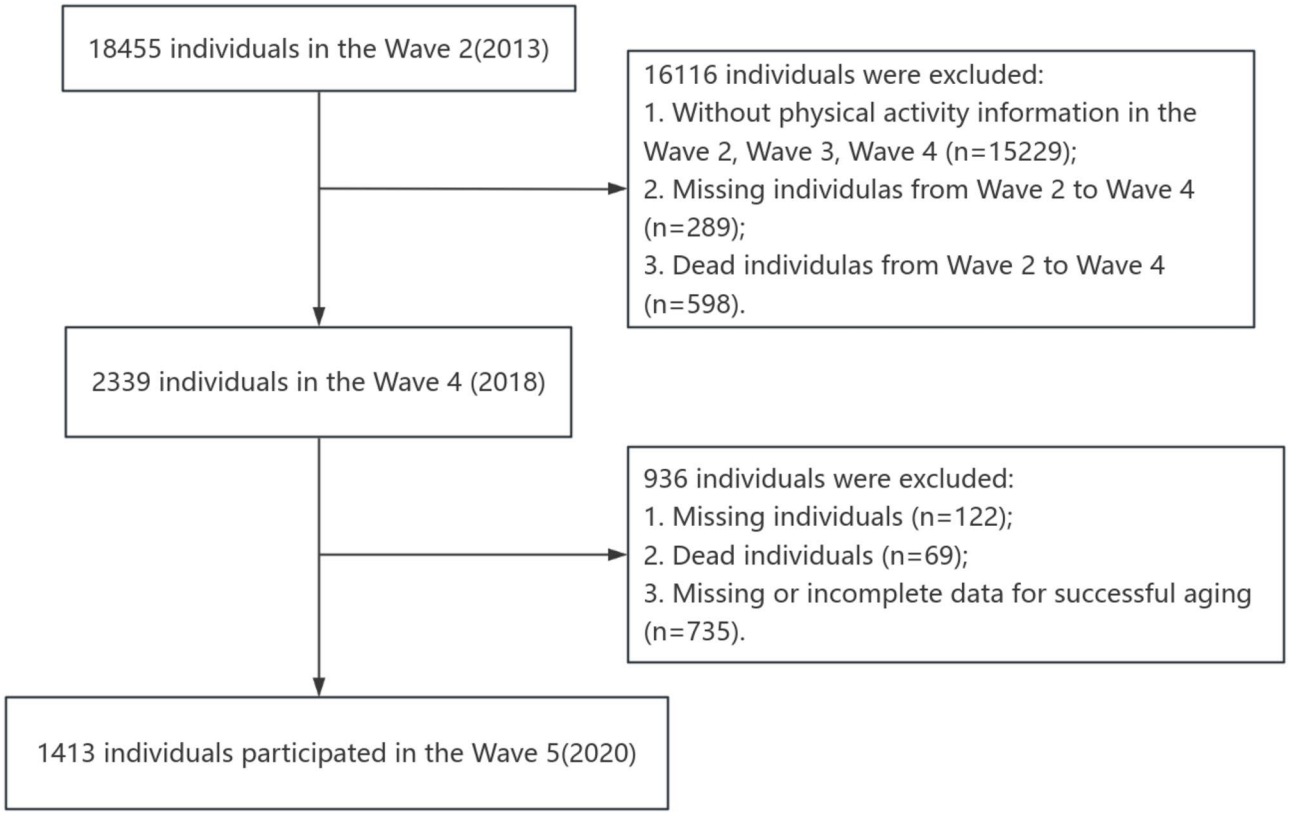

Fig. 1 Flowchart of study participants in this study

Assessment of successful aging

This study defines successful aging based on the Rowe & Kahn theoretical model. It includes five main areas: absence of major diseases, no physical impairment, high cognitive function, no depression, and active participation in social activities. Meeting the above 5 requirements can be considered to achieve successful aging [5]. The specific indicators of successful aging are defined below:

Absence of major diseases: Based on the major disease burdens in China and previous studies [19, 20], participants were asked if a doctor had told them that they have any of the following major chronic diseases including diabetes, cancer, chronic lung diseases, heart attack and stroke. The absence of any of the aforementioned diseases was considered as being free of major chronic diseases.

No physical impairment: The activities of daily living scale (ADL) was used to measure the physical function of participants. Respondents were asked about their need for assistance in performing the following activities: dressing, bathing or showering, eating, getting into or out of bed, using the toilet, and controlling urination and defecation. No physical impairment is defined as having no disability if they have no difficulty in completing the above six daily activities [21].

High Cognitive Function: Cognitive function was measured by 21 questions in four categories, including daily memory, word recall, arithmetic and drawing. Daily memory asks participants to recall today's date (year, month, day), day of the week, and season. Word recall requires participants to repeat as many of the 10 Chinese nouns that the interviewer has just read as possible. Arithmetic requires them to calculate 100 consecutive minus 7 arithmetic results (up to 5 times). For drawing, the investigator requires participants to draw the picture of two pentagons overlapped correctly. The total cognitive ability score ranges from 0 to 21, with higher scores indicating better cognitive function. This study defined a score greater than or equal to 11 as normal cognitive functioning and a score below 11 as impaired cognitive functioning [22].

No depression: CHARLS used the Center for Epidemiologic Studies Depression Scale (CES—D) to assess depressive symptoms [23]. The total CES—D score ranges from 0 to 30, with higher scores indicating more severe depression. A score < 10 was defined as having no clinically significant depressive symptoms.

Active participation in social activities: Respondents were considered to be actively involved in social activities if they had participated in one or more of these activities in the past month: (1) participating in the activities of community organizations; (2) volunteering or charity activities; (3) helping relatives, friends, and neighbors; (4) visiting homes, socializing with friends, etc. (11 items in total) [24].

Covariates

Based on previous studies [18, 25], sociodemographic characteristics and health-related factors were considered as covariates in the study. Sociodemographics characteristics included age, sex (male or female), area of residence (rural or urban), educational level (primary and below, secondary, high school and above), and marital status (married or others). Health-related factors included current smoking status (yes or no), current alcohol status (yes or no), and sleep duration (based on previous studies [26], < 6 h of sleep per night was defined as short sleep duration, 6–8 h as medium sleep duration, and > 8 h as long sleep duration).

Statistical analysis

All analyses will be performed using Stata 18.0. We employed the Group-based trajectory modeling (GBTM) to identify distinct groups that exhibit similar trajectories of PA. Firstly, the maximum number of trajectory patterns is determined by selecting a suitable model. Second, specification of the optimal trajectory shape, such as linear or quadratic. Finally, Bayesian information criteria (BIC), Entropy, and the number of participants in each trajectory (> 5% of the total participants) were used to assess model fit. Satisfactory models and trajectory classifications must meet the following criteria: (1) lower values for the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC); (2) the average posterior probabilities (AvePP) for each group more than 0.7; (3) the entropy values are close to 1.

The basic characteristics among participants with different PA trajectories were compared using the Chi-square or ANOVA test. Logistic regression models were used to analyze the multivariable adjusted odds ratio (*OR*) and 95% confidence intervals (*CIs*) for the associations between different levels of PA and successful aging in the Wave 5, with the low level of PA as the reference. Model 1 adjusted for age, sex, area of residence, education level, and marital status. Model 2 further adjusted for health-related factors, including current smoking status, current alcohol status, and sleep duration. Model 3 includes model 2 and PA level. Meanwhile, logistic regression was also used in the Wave 5 data to explore the effects of frequency, duration and volume of PA on successful aging outcomes, each VPA, MPA, and LPA used "sedentary"(no activity) as the reference group.

To verify the robustness of the results, several sensitivity analyses were conducted. First, considering that a history of hospitalization in the past year can affect successful aging, we excluded participants with hospitalized in the past year. Second, to further control confounding

Table 1 Age distribution in different waves of the survey

Age (years)	Wave 2	Wave 3	Wave 4	Wave 5
45—59	831(58.8)	730(51.6)	583(41.2)	490(34.6)
60—74	507(35.8)	621(43.9)	719(50.8)	772(54.6)
≥ 75	33(2.3)	48(3.3)	106(7.5)	147(10.4)

of health status, we restricted participants to those without hypertension. Third, having experienced a fracture in the past may influence the achieving of successful aging, so the study excluded participants with a history of fracture and re-performed the analysis. The significance level of the statistical tests was set as $P < 0.05$ (two tailed).

Results

Finally, a total of 1,413 subjects were included after screening, 17,042 people were lost, and 667 people were recorded as dead, accounting for 3.9% of the lost population. Table 1 describes the age distribution of the study population in the different survey waves. During the 7-year follow-up, 207 individuals (14.6%) met the criteria for successful aging, 784 (55.4%) reported having "absence of major chronic diseases", 1,106 (78.2%) indicated "no physical impairment", 1,001 (70.8%) reported "high cognitive function", 877 (62.0%) exhibited "no depression", and 739 (52.3%) demonstrated "active participation in social activities" (Table S1).

PA trajectories and baseline characteristics

GBTM was used to identify different patterns of PA trajectories in middle-aged and elderly individuals. The results showed that the model with three trajectories demonstrated the best fit to the data (Table S2). Therefore, we identified three optimal PA trajectories: stable low (72.5%, $n = 1{,}025$), decreasing (17.1%, $n = 242$), and increasing trajectories (10.3%, $n = 146$) (Fig. 2). The prevalence of successful aging was 14.0% ($n = 144$) in the stable low PA group, 15.7% ($n = 38$) in the decreasing group, and 17.1% ($n = 25$) in the increasing group, for an overall successful aging incidence of 14.6% (207). The incidence of successful aging was relatively highest in the PA increasing group, although the results of logistic regression analysis showed no statistically significant differences ($P = 0.543$, with the stable low trajectory as reference). The reason may be the difference in results due to insufficient sample size. Table 2 describes the basic characteristics of these individuals at baseline based on trajectories of PA. In comparison with participants in decreasing and increasing trajectories, those with a stable low trajectory were more likely to be older, female, live in urban areas, have higher levels of education, not currently smoke, not currently drink alcohol, and have medium sleep duration, all $P < 0.05$.

Association of the PA level, frequency, duration, volume and successful aging

Logistic regression analysis showed that both medium and high levels of PA significantly increased the incidence of successful aging compared to low levels of PA. In addition, among the covariates, older age, lower education level, current drinking, and less sleep duration were

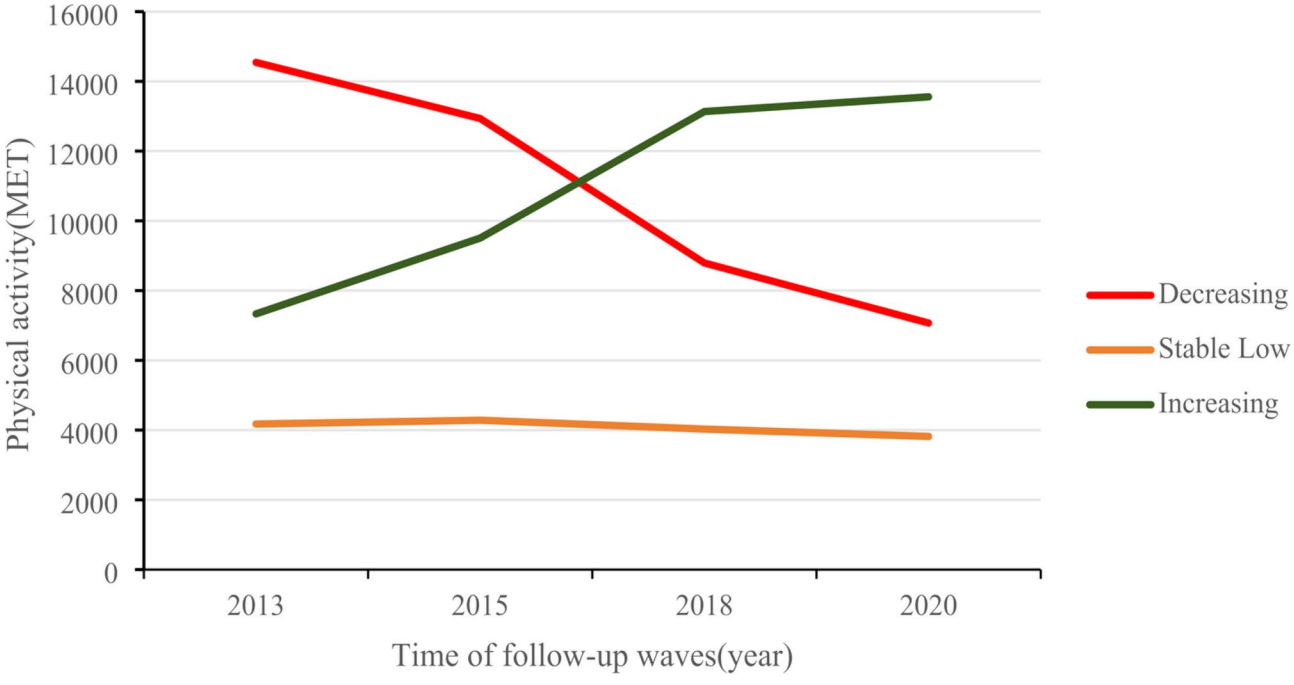

Fig. 2 Trajectory groups of Physical activity from 2013 to 2020

Table 2 Baseline characteristics of individuals in 2013

Variables	Total (*N* = 1,413)	Stable low (*N* = 1,025)	Decreasing (*N* = 242)	Increasing (*N* = 146)	*P*
Age(years)	56.95 ± 8.18	57.69 ± 8.45	54.94 ± 6.88	55.06 ± 7.32	< 0.001
Gender					< 0.001
Male	708(50.1)	477(46.5)	144(59.5)	87(59.5)	
Female	705(49.9)	548(53.4)	98(40.4)	59(40.4)	
Residential area					< 0.001
Rural	882(62.4)	581(56.6)	190(78.5)	111(76.0)	
Urban	531(37.6)	444(43.3)	52(21.4)	35(24.0)	
Education level[a]					< 0.001
≤Primary school	792(56.2)	544(53.0)	157(64.8)	91(62.3)	
Middle school	408(28.9)	300(29.2)	65(26.8)	43(29.4)	
≥high school	211(14.9)	179(17.4)	20(8.2)	12(8.2)	
Marital status[a]					0.183
Married	1,305(92.4)	938(91.5)	229(94.6)	138(94.5)	
Others	106(7.5)	85(8.2)	13(5.3)	8(5.5)	
Current smoke[a]					0.009
Yes	219(15.5)	142(13.8)	52(21.4)	25(17.1)	
No	917(64.9)	684(66.7)	144(59.5)	89(60.9)	
Current alcohol					0.007
Yes	543(38.4)	368(35.9)	109(45.0)	66(45.2)	
No	870(61.6)	657(64.0)	133(54.9)	80(54.7)	
Sleep duration[a]					< 0.001
Short sleep	421(29.8)	300(29.3)	75(31.0)	94(64.4)	
Medium sleep	899(63.6)	654(63.8)	151(62.4)	46(31.5)	
Long sleep	79(5.6)	60(5.6)	14(5.8)	5(3.4)	

[a] Missing data: education level (*n* = 2, 0.14%); marital status (*n* = 2, 0.14%); current smoke (*n* = 277, 19.60%); sleep duration (*n* = 14, 0.99%)

associated with a statistically significant difference in the reduced incidence of successful aging ($P < 0.05$) (Table 3).

Regarding PA frequency, it was found that taking a maximum of 3 ~ 5 days per week on VPA, or taking a maximum of 6 ~ 7 days per week on MPA was associated with the incidence of successful aging after adjusting for covariates. Spending ≥ 3 ~ 5 days a week on LPA tended to have a high incidence of successful aging. In terms of PA duration, our study found that taking 30 ~ 119 min/d or more on VPA and MPA was associated with the achievement of successful aging before and after adjustment. Performing at least 30 ~ 119 min/d on LPA tended to have a high incidence of successful aging. With respect to PA volume, the study noticed that taking 150 ~ 299 min/w or more on VPA, or taking ≥ 150 ~ 299 min/w on MPA was positively associated with the presence of successful aging after adjustments. Spending at least ≥ 300 min/w on LPA was associated with the occurrence of successful aging (all $P < 0.05$) (Table 4).

Sensitivity analyses

The results of sensitivity analyses are presented in Table S3-S4. Firstly, exclusion of individuals with a history of hospitalization in the past year did not change the association between the PA consumption and successful aging. Secondly, restricting participants to those with non-hypertension yielded inconsistent associations, which shows that the individual' s health status will affect the effect of PA. Thirdly, exclusion of individuals with a history of fracture produced conclusions consistent with the main results. This result strongly supports the reliability of the findings of this study.

Discussion

Main findings

As far as we know, this is the first study to examine the association between PA trajectories with successful aging. The results of this study suggest that there is a correlation between PA and successful aging and that the probability of successful aging increases with increasing activity. Additionally, our study provides appropriate exercise recommendations for middle-aged and elderly individuals. Vigorous-intensity PA (VPA) should be performed 1 ~ 2 days per week, 30 ~ 119 min each time, and 150 ~ 299 min a week. Moderate-intensity PA (MPA) should be taken 3 ~ 5 days a week, 30 ~ 119 min each time, and 300 min per week. Light-intensity PA (LPA) is best performed 3 ~ 5 days per week, 30 ~ 119 min each time, and at least 300 min a week. It is recommended that middle-aged and elderly adults should engage in varied multi-component PA at moderate or vigorous intensity on 3 or more days a week, 30 to 119 min each time and

Table 3 Association between PA levels and successful aging in 2020 based on logistic regression model analysis

Variables	Model 1		Model 2		Model 3	
	OR(95%CI)	*P*	OR(95%CI)	*P*	OR (95% CI)	*P*
Age	0.95(0.92–0.96)	< 0.001	0.95(0.93–0.97)	< 0.001	0.953(0.93–0.97)	< 0.001
Gender(male)	2.23(1.61–3.09)	< 0.001	1.29(0.85–1.94)	0.222	1.30(0.86–1.96)	0.213
Residential area(rural)	0.77(0.56–1.06)	0.114	0.82(0.58–1.14)	0.242	0.82(0.58–1.15)	0.257
Education level		0.001		0.004		0.004
≤Primary school	1.00(ref.)		1.00(ref.)		1.00(ref.)	
Middle school	1.68(1.18–2.41)	< 0.001	1.61(1.12–2.33)	0.010	1.62(1.12–2.34)	0.010
≥high school	2.02(1.32–3.08)	< 0.001	1.93(1.24–2.99)	0.003	1.95(1.26–3.04)	0.003
Marital status(married)	0.91(0.58–1.51)	0.730	0.84(0.50–1.41)	0.516	0.85(0.51–1.42)	0.535
Current smoke(yes)			0.73(0.50–1.07)	0.108	0.71(0.49–1.05)	0.087
Current alcohol(yes)			0.48(0.34–0.68)	< 0.001	0.50(0.35–0.70)	< 0.001
Sleep duration				< 0.001		< 0.001
Short sleep			0.31(0.21–0.47)	< 0.001	0.31(0.21–0.47)	< 0.001
Medium sleep			1.00(ref.)		1.00(ref.)	
Long sleep			0.59(0.28–1.24)	0.167	0.62(0.29–1.29)	0.200
PA levels						0.049
Low					1.00(ref.)	
Medium					2.16(1.10–4.28)	0.026
High					2.22(1.17–4.22)	0.015

Model 1: Age, gender, residence, education; Model 2: Model 1, Current smoking status, Current alcohol status, Sleep duration; Model 3: Model 2, PA level

gradually increase their exercise to promote successful aging. This is consistent with the recommendations for the older adults in the physical activity guidelines established by the WHO [27], indicating the reliability of the results of our study.

Comparison with other studies

Because PA varies with age, the study identified three different trajectories of PA from 2013 to 2020: stable low, decreasing, and increasing trajectories. The results observed that the increasing trajectory was related to a higher prevalence of successful aging than the other two trajectories and that medium to high levels of PA are more likely to lead to successful aging than low levels, suggesting that the more exercise an individual has, the more beneficial it is to achieve successful aging. A 9-year follow-up study of 13,714 Australian middle-aged women found that individuals in the increasing PA group had a 29% reduced risk of disability compared to the low PA group [28]. Additionally, a national longitudinal study in Sweden [29] noted that diabetic patients in the increasing PA group had a lower risk of complications, and the all-cause mortality was about 53% lower than the steady low PA group. Another study [30] in China investigating the correlation between PA levels and stroke occurrence in middle-aged and older adults indicated that medium to high levels of exercise were protective factors for stroke occurrence compared to low levels of PA. The above studies proved that increasing PA is associated with the reduction of adverse health outcomes and is beneficial to the aging outcomes of individuals, which is consistent with the findings of our study.

Besides, the study also explored the effects of the frequency, duration, and volume of PA at different intensities on successful aging, the results showed that VPA, MPA and LPA were all relevant in improving their aging outcomes. Two longitudinal studies from the United States and China [31, 32] investigating PA and cognitive dysfunction have also shown that VPA, MPA, and LPA all have a positive effect on delaying cognitive dysfunction in older adults. Another study [33] about PA and cardiovascular disease risk in 660 older adults found that daily physical activity of any intensity and avoidance of sedentary behaviour were associated with a reduced risk of cardiovascular disease. In addition, another study [34] involving 1,360 older adults from four countries found that replacing sedentary activity with either LPA or MVPA was associated with improved anxiety. However, a cross-sectional investigation [35] of PA and stroke risk found that there is no significant association between the frequency and duration of LPA and stroke risk before and after adjustment. The difference may be due to inconsistency in the reference groups: the above study used individuals without LPA as the reference group, whereas our study used sedentary individuals as the reference group. Considering that although adults who do not take LPA may also engage in other types of exercise, this may be the cause of not observing an effect of LPA in reducing the risk of stroke. Based on these results, it is clear that all three intensities of PA are associated with coping with

Table 4 Association between PA frequency, duration, volume and the incidence of successful aging

Variables	Event/participants	Successful aging	
		OR(95%CI)	Adjusted OR (95% CI)
Frequency			
VPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
1—2d/w	23/114	4.65(1.69—12.76)**	4.37(1.50—12.72)**
3—5d/w	39/202	4.40(1.67—11.56)**	4.23(1.52—11.79)**
6—7d/w	29/342	2.50(0.94—6.67)	2.44(0.87—6.83)
MPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
1—2d/w	25/153	3.59(1.32—9.73)*	2.93(1.05—8.21)*
3—5d/w	47/253	4.19(1.61—10.90)**	3.82(1.42—10.24)**
6—7d/w	66/453	3.13(1.22—8.01)*	2.90(1.10—7.64)*
LPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
1—2d/w	8/78	2.10(0.65—6.71)	1.95(0.59—6.45)
3—5d/w	42/259	3.56(1.36—9.29)**	3.24(1.20—8.75)*
6—7d/w	128/826	3.37(1.34—8.46)*	3.12(1.20—8.04)*
Duration			
VPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–29 min/d	1/31	0.61(0.69—5.46)	0.52(0.55—4.91)
30–119 min/d	30/128	5.63(2.09—15.13)**	5.07(1.76—14.54)**
≥ 120 min/d	60/399	3.25(1.27—8.35)*	3.24(1.20—8.75)*
MPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–29 min/d	19/114	3.68(1.31—10.27)*	3.25(1.12—9.42)*
30–119 min/d	59/376	3.42(1.34—8.78)*	3.10(1.17—8.23)*
≥ 120 min/d	60/369	3.57(1.39—9.16)**	3.21(1.21—8.46)*
LPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–29 min/d	19/146	2.75(0.99—7.64)	2.75(0.96—7.87)
30–119 min/d	101/608	3.66(1.45—9.24)**	3.17(1.22—8.24)*
≥ 120 min/d	58/409	3.04(1.18—7.79)*	2.95(1.11—7.79)*
Volume			
VPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–149 min/w	4/49	1.63(0.42—6.38)	1.58(0.37—6.66)
150–299 min/w	16/75	4.99(1.73—14.34)**	3.91(1.27—12.04)*
≥ 300 min/w	71/434	3.59(1.41—9.17)**	3.54(1.32—9.48)*
MPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–149 min/w	22/141	3.22(1.14—9.09)	2.91(0.99—8.50)
150–299 min/w	17/114	3.40(1.24—9.32)*	2.99(1.05—8.50)*
≥ 300 min/w	99/604	3.60(1.43—9.10)**	3.26(1.25—8.47)*
LPA			
Sedentary	5/97	1.00(ref.)	1.00(ref.)
10–149 min/w	20/155	2.73(0.98—7.52)	2.75(0.96—7.85)
150–299 min/w	14/83	3.73(1.28—10.86)*	3.23(1.06—9.79)
≥ 300 min/w	144/925	3.39(1.35—8.49)**	3.07(1.19—7.92)*

Note d/w, days/week; VPA, vigorous physical activity; MPA, moderate physical activity; LPA, light physical activity

*$p < 0.05$, **$p < 0.01$

Adjusted for age, gender, residence, education levels, marital status, current smoking status, current alcohol status, sleep duration

health problems compared with sedentary behavior and promote successful aging.

Potential mechanisms

The study's findings suggest that individuals with greater PA exertion are more likely to achieve successful aging, emphasizing the importance of exercise in improving aging outcomes in middle-aged and older adults. The potential physiological mechanisms by which exercise influences successful aging are as follows: firstly, previous research has pointed out that exercise can prevent and delay the occurrence of frailty by improving the inflammatory response of the body [36], regulating hormone levels of the body [37], and attenuating oxidative stress [38], which has a positive effect on strengthening the elderly's physical fitness and reducing the risk of various chronic diseases and disabilities. Secondly, aromatic amino acids (such as phenylalanine and tyrosine) are precursors for the synthesis of catecholamine neurotransmitters such as dopamine [39]. A lot of exercise can regulate the synthesis of aromatic amino acids [40] and promote the secretion of dopamine, leading to the development of a pleasant mood in individuals. It reduces the incidence of depression and other psychological problems. Thirdly, sports can increase an individual's opportunities to go out, promote participation in a variety of social activities and gain stronger social support. Since the absence of chronic disease, no depression and active social activities are major components of successful aging, the relationship between gradually increasing exercise and successful aging over time is clear.

The World Health Organization recommends that middle-aged and older adults engage in multi-component exercise that includes aerobic and resistance exercise [27], but does not specify an upper limit on the amount of exercise an individual can do. A review of previous research [35, 41] has found that there should be a threshold for exercise and that a sustained increase is not always beneficial. Jiang and colleagues [35] investigated the relationship between PA levels and stroke risk among Chinese adults aged 45 and over, found that the risk of stroke decreased with increasing activity, and gradually leveled off when activity reached 8,000 MET-min/w, whereas when activity exceeded 11,366 MET-min/w, the risk of stroke increased with further increases in activity. The following physiological mechanisms may explain the adverse effects of intensive exercise on health status. In the first, high-intensity activity causes an increase in cardiac output, resulting in a brief but dramatic increase in blood pressure, which may increase an individual's risk of arrhythmia or hemorrhagic stroke [41, 42]. Secondly, a systematic review [43] suggests that prolonged, intensive exercise may reduce immunity and increase an individual's risk of infection, but the exact mechanism is currently unclear. Moreover, the bone density of middle-aged and elderly adults decreases yearly, and their bones become more fragile, leading to falls easily when performing strenuous activities [44]. Hence, it is suggested that middle-aged and elderly individuals should choose a moderate form of exercise and make an exercise program under the guidance of a doctor or professional trainer.

Strengths and limitations

The strengths of this study are the high quality of a longitudinal study based on data from a national Chinese sample and conducted over a seven-year longitudinal study. Furthermore, our findings also suggested what frequency, duration, and weekly volume of PA are associated with increasing the incidence of successful aging, which is more practicable in achieving successful aging compared to previous studies that only provided information about a single PA. However, there are some limitations of this study. Firstly, instead of using objective techniques, IPAQ was utilized to collect information about PA. It has been suggested that subjective IPAQ questionnaires overestimate PA levels compared to objective measurement tools like accelerometers [45]. However, using objective tools such as accelerometers to measure an individual's daily exercise is often difficult to take in large sample studies, which is a common limitation in real-world research. Secondly, the study was unable to determine the exact weekly metabolic equivalents for individuals due to recall bias, so we did not calculate a threshold for PA to have a beneficial effect on successful aging. More research could be conducted in the future to explore the range of exercises suitable for middle-aged and elderly people to achieve successful aging. Finally, more than half of the participants in the 2013 survey (12,474 out of 18,455) were excluded because of the missing key data on exercise, which limits the sample size and generalization of the results of this study. It was advised that more studies with large sample sizes could be conducted in the future to support the reliability of the findings.

Conclusion

Our study identified three PA trajectories and found that the increasing PA trajectory group was associated with a higher incidence of successful aging compared with the stable low and decreasing PA trajectory among middle-aged and older Chinese adults. This highlights that persistent PA growth can promote successful aging. In addition, the findings emphasize the importance of monitoring dynamic changes in PA.

Abbreviations

ADL	Activities of Daily Living
CES—D	Center for Epidemiologic Studies Depression Scale
CHARLS	China Health and Retirement Longitudinal Study
CI	Confidence Intervals

GLP-1	Glucagon-like peptide-1
IPAQ	International Physical Activity Questionnaire
LPA	Light-intensity Physical Activity
MET	Metabolic equivalent
MPA	Moderate-intensity Physical Activity
OR	Odds Ratios
PA	Physical Activity
VPA	Vigorous-intensity Physical Activity

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-23021-7.

Supplementary Material 1

Acknowledgements
This research has been conducted using the China Health and Retirement Longitudinal Study (CHARLS) database. The authors are grateful to all the subjects who participated in this study.

Author contributions
X. Z. participated in the writing of the main manuscript text; Xy. N. and Yl. W. performed the implementation and feasibility analysis of the study; Md. W., Qn L. and Hl. F. performed the statistical analysis and prepared the figures; Jh. Ma. was responsible for the quality control of the article as well as for the overall responsibility and supervision of the article. All authors have read and approved the final manuscript.

Funding
This work was supported by the Key Research and Development Programme of Hebei Province (22377787D), the Construction and Research of Comprehensive Information Platform of Smart Community Nursing Service from the Perspective of Health Management (HB23SH016), and the Innovation Funding Project for Postgraduate Students of Hebei University of Chinese Medicine (XCXZZSS2025045).

Data availability
The data that support the findings of this study are available in Peking University Open Research Data at http://charls.pku.edu.cn/en/index.htm.

Declarations

Ethics approval and consent to participate
This study was approved from the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015). The written informed consent was provided by all participants.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Received: 11 March 2025 / Accepted: 2 May 2025
Published online: 16 May 2025

References

1. Zhao X, Chen S, Liu N, Hu F, Yu J. Handgrip strength is positively associated with successful aging in older adults: a national cross-sectional study in China. J Affect Disorders. 2023;333:30–7.
2. Luo Y, Su B, Zheng X. Trends and challenges for population and health during population aging - China, 2015–2050. CHINA CDC Wkly. 2021;3(28):593–8.
3. Chen X, Guo Y, Lu C, Wang Y, Wen H. Does subjective life expectancy matter in purchasing life insurance among middle-aged and older adult? Evidence from China. Front Public Health. 2024;12:1426366.
4. Liu M, Zhang M, Zhou J, Song N, Zhang L. Research on the healthy life expectancy of older adult individuals in China based on intrinsic capacity health standards and social stratification analysis. Front Public Health. 2023;11:1303467.
5. Rowe JW, Kahn RL. Successful aging. Cerontologist. 1997;37:433–40.
6. Trică A, Golu F, Sava NI, Licu M, Zanfirescu ŞA, Adam R, David I. Resilience and successful aging: a systematic review and meta-analysis. Acta Psychol. 2024;248:104357.
7. Zhou Y, Sun Y, Pan Y, Dai Y, Xiao Y, Yu Y. Prevalence of successful aging in older adults: a systematic review and meta-analysis. Arch Gerontol Geriat. 2024;128:105604.
8. Tian L, Ding P, Kuang X, Ai W, Shi H. The association between sleep duration trajectories and successful aging: a population-based cohort study. BMC Public Health. 2024;24(1):3029.
9. Ortiz GU, de Freitas EC. Semaglutide as a possible therapy for healthy aging: targeting the hallmarks of aging. Ageing Res Rev. 2024;102:102582.
10. Ye Y, Lin H, Wan M, Qiu P, Xia R, He J, Tao J, Chen L, Zheng G. The effects of aerobic exercise on oxidative stress in older adults: a systematic review and meta-analysis. Front Physiol. 2021;12.
11. Chen B, Zhao H, Li M, Zhao T, Liao R, Lu J, Zou Y, Tu J, Teng X, Huang Y, et al. Effect of multicomponent intervention on malnutrition in older adults: a multicenter randomized clinical trial. Clin Nutr Espen. 2024;60:31–40.
12. Feng C, Shi Z, Tian Y, Ma C, Sun Q. Longitudinal associations between leisure activities and subjective happiness among middle-aged and older adults people in China: national cohort study. Front Public Health. 2024;12:1441703.
13. Martinez-Gomez D, Rodriguez-Artalejo F, Ding D, Ekelund U, Cabanas-Sanchez V. Trends in the association between meeting the physical activity guidelines and risk of mortality in US adults. Prog Cardiovasc Dis. 2024;83:116–23.
14. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort profile: the China health and retirement longitudinal study (CHARLS). Int J Epidemiol. 2014;43(1):61–8.
15. Tomioka K, Iwamoto J, Saeki K, Okamoto N. Reliability and validity of the international physical activity questionnaire (IPAQ) in elderly adults: the Fujiwara-kyo study. J Epidemiol. 2011;21(6):459–65.
16. Hallal PC, Victora CG. Reliability and validity of the international physical activity questionnaire (IPAQ). Med Sci Sport Exer. 2004;36(3):556.
17. Yang D, Bian Y, Zeng Z, Cui Y, Wang Y, Yu C. Associations between intensity, frequency, duration, and volume of physical activity and the risk of stroke in middle- and older-aged Chinese people: a cross-sectional study. Int J Environ Res Public Health. 2020;17(22):8628.
18. Zhao X, Liu D, Zhang H, Shen S, Zhang N, Pan Y, Fu C, Wang W, Ren H, Pan X. Associations of physical activity intensity, frequency, duration, and volume with the incidence of sarcopenia in middle-aged and older adults: a 4-year longitudinal study in China. BMC Geriatr. 2024;24(1):258.
19. Luo H, Ren X, Li J, Wu K, Wang Y, Chen Q, Li N. Association between obesity status and successful aging among older people in China: evidence from CHARLS. BMC Public Health. 2020;20(1):767.
20. Fan ZY, Yang Y, Zhang CH, Yin RY, Tang L, Zhang F. Prevalence and patterns of comorbidity among middle-aged and elderly people in China: a cross-sectional study based on CHARLS data. Int J Gen Med. 2021;14:1449–55.
21. Zhao Y, Tang L, Zeng QW, Bu F, Zhan NN, Wang ZL, Deng XH, Lyu QY. Association between bidirectional intergenerational support and successful aging in China: evidence from CHARLS 2018. Geriatr Nurs. 2023;49:81–8.
22. Tian L, Ding P, Kuang X, Ai W, Shi H. The association between sleep duration trajectories and successful aging: a population-based cohort study. BMC Public Health. 2024;24(1).
23. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for epidemiologic studies depression scale). Am J Prev Med. 1994;10(2):77–84.
24. Chang H, Zhou J, Chen Y, Wang X, Wang Z. Developmental trajectories of successful aging among older adults in China: evidence from the China health and retirement longitudinal study. Geriatric Nurs (New York). 2023;51:258–65.
25. Zhao X, Zhang H, Yu J, Zhou Z, Wang J. Physical activity intensity, frequency, duration, volume and the risk of possible sarcopenia in middle-aged and older adults. Geroscience. 2024;46(4):3743–57.
26. Chen L, Li Q, Huang X, Li Z. Association between sleep duration and possible sarcopenia in middle-aged and elderly Chinese individuals: evidence from the China health and retirement longitudinal study. BMC Geriatr. 2024;24(1):594.
27. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput JP, Chastin S, Chou R, et al. World health organization 2020 guidelines on physical activity and sedentary behaviour. Brit J Sport Med. 2020;54(24):1451–62.

28. Nemoto Y, Brown WJ, Ding D, Nguyen B, Mielke GI. Trajectories of physical activity and chronic conditions among mid-aged women. Am J Prev Med. 2024;67(3):389–96.
29. Mavridis A, Viktorisson A, Reinholdsson M, Eliasson B, Abzhandadze T, Sunnerhagen KS. Physical activity trajectories and all-cause mortality in type 1 diabetes: a nationwide longitudinal study. Diabetes Res Clin Pr. 2024;212:111702.
30. Zhaoyin S, Weihan K, Yatao L, Yuan L, NERLICH M. Relationship between physical activity levels and stroke risk among middle-aged and older adults in China based on CHARLS data. Chin J Rehabil Theory Pract. 2024;30(04):449–53.
31. Liu D, Pan Y, Wang J, Shen S, Zhao X. Relationship between different physical activity parameters and cognitive impairment in middle-aged and older adults: insights from a 4-year longitudinal study. BMC Psychol. 2025;13(1):274.
32. Hamm JM, Parker K, Lachman ME, Mogle JA, Duggan KA, McGrath R. Increased frequency of light physical activity during midlife and old age buffers against cognitive declines. J Behav Med. 2024;47(4):622–34.
33. Länsitie M, Kangas M, Jokelainen J, Venojärvi M, Timonen M, Keinänen-Kiukaanniemi S, Korpelainen R. Cardiovascular disease risk and all-cause mortality associated with accelerometer-measured physical activity and sedentary time– a prospective population-based study in older adults. BMC Geriatr. 2022;22(1):729.
34. Tully MA, McMullan I, Blackburn NE, Wilson JJ, Bunting B, Smith L, Kee F, Deidda M, Giné-Garriga M, Coll-Planas L, et al. Sedentary behavior, physical activity, and mental health in older adults: an isotemporal substitution model. Scand J Med Sci Spor. 2020;30(10):1957–65.
35. Jiang C, Chen T, Xiang J, Pang Y. Association between physical activity levels and stroke risk among Chinese adults aged 45 and over based on CHARLS. Sci Rep-Uk. 2024;14(1):31739.
36. Safdar A, Abadi A, Akhtar M, Hettinga BP, Tarnopolsky MA. MiRNA in the regulation of skeletal muscle adaptation to acute endurance exercise in C57Bl/6J male mice. PLoS ONE. 2009;4(5):e5610.
37. Sgrò P, Romanelli F, Felici F, Sansone M, Bianchini S, Buzzachera CF, Baldari C, Guidetti L, Pigozzi F, Lenzi A, et al. Testosterone responses to standardized short-term sub-maximal and maximal endurance exercises: issues on the dynamic adaptive role of the hypothalamic-pituitary-testicular axis. J Endocrinol Invest. 2014;37(1):13–24.
38. Abruzzo PM, Esposito F, Marchionni C, di Tullio S, Belia S, Fulle S, Veicsteinas A, Marini M. Moderate exercise training induces ROS-related adaptations to skeletal muscles. Int J Sports Med. 2013;34(8):676–87.
39. Flydal MI, Martinez A. Phenylalanine hydroxylase: function, structure, and regulation. IUBMB Life. 2013;65(4):341–9.
40. Borges N, Doering TM, Murphy G, Macdonald M, Dunstan RH. Amino acid distribution in blood following high-intensity interval exercise: a preliminary study. Amino Acids. 2024;56(1):4.
41. Kubota Y, Iso H, Yamagishi K, Sawada N, Tsugane S. Daily total physical activity and incident stroke: the Japan public health center-based prospective study. Stroke. 2017;48(7):1730–6.
42. Franklin BA, Thompson PD, Al-Zaiti SS, Albert CM, Hivert MF, Levine BD, Lobelo F, Madan K, Sharrief AZ, Eijsvogels T. Exercise-related acute cardiovascular events and potential deleterious adaptations following long-term exercise training: placing the risks into perspective-an update: a scientific statement from the American Heart Association. Circulation. 2020;141(13):e705-e736.
43. Nieman DC, Wentz LM. The compelling link between physical activity and the body's defense system. J Sport Health Sci. 2019;8(3):201–17.
44. Moayyeri A. The association between physical activity and osteoporotic fractures: a review of the evidence and implications for future research. Ann Epidemiol. 2008;18(11):827–35.
45. Wijndaele K, Westgate K, Stephens SK, Blair SN, Bull FC, Chastin SF, Dunstan DW, Ekelund U, Esliger DW, Freedson PS, et al. Utilization and harmonization of adult accelerometry data: review and expert consensus. Med Sci Sport Exer. 2015;47(10):2129–39.

Publisher's note