

# ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND SARCOPENIA AMONG MIDDLE-AGED AND OLDER ADULTS IN CHINA: A CROSS-SECTIONAL STUDY

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**Abstract.** Physical activity has been reported to be an effective method to reduce the risk of sarcopenia. In this cross-sectional study, we aimed to determine if there is a significant association between physical activity levels and the prevalence of sarcopenia among middle-aged and older adults in China in order to inform efforts to prevent and manage sarcopenia in the study population. The data used in our study were obtained retrospectively from the China Health and Retirement Longitudinal Study (CHARLS) conducted in 2015. The CHARLS assessed physical activity levels among study subjects using the International Physical Activity Questionnaire (IPAQ) asking about activity during the previous week, expressed as metabolic equivalents of task in minutes (MET-minutes) per week. Sarcopenia in our study was defined using the 2019 Asian Working Group for Sarcopenia (AWGS) criteria and classified as possible sarcopenia, sarcopenia and severe sarcopenia. Study subjects were divided into 3 groups based on their physical activity levels following IPAQ criteria as: low (<600 MET-min/week, reference group), moderate (600-3,000 MET-min/week) and high (>3,000 MET-min/week). We used multivariable logistic regression analysis and restricted cubic splines to identify significant associations between physical activity levels and sarcopenia. A total of 8,449 subjects were included in the study: 52.4% ( $n = 4,426$ ) females. The mean ( $\pm$ standard deviation (SD)) age of study subjects was 66.1 ( $\pm 8.6$ ) years (range: 45–90 years). The mean ( $\pm$ SD) body mass index (BMI) of subjects was 23.56 ( $\pm 3.70$ ) kg/m<sup>2</sup>. 1,855 subjects (22.0%) met the 2019 AWGS criteria for having possible sarcopenia and 1,346 (15.9%) met the criteria for sarcopenia and 605 (7.2%) met the criteria for severe sarcopenia. The median (interquartile range (IQR)) physical activity levels among subjects without sarcopenia, those having possible sarcopenia, sarcopenia and severe sarcopenia were: 2,562.00

(933.00-7,337.00), 1,782.00 (462.00-6,716.25), 2,032.50 (309.50-6,318.00) and 1,732.50 (462.00-5,544.00) MET-min/week, respectively. The median IQR among subjects without sarcopenia was statistically higher than among subjects in the other 3 groups ( $p$ -value  $<0.001$ ). After adjusting for age, gender, marital status, location of residence, education level, body mass index, smoking status, alcohol consumption status and retirement status, subjects in the moderate and high physical activity level groups had significantly lower odds of having possible sarcopenia than subjects in the low physical activity group (moderate activity level versus (vs) low activity level: adjusted odds ratio (aOR): 0.791; 95% confidence interval (CI): 0.683-0.915,  $p$ -value = 0.002 and high activity level vs low activity level: aOR: 0.679; 95% CI: 0.594-0.776,  $p$ -value  $<0.001$ ). Subjects in the high physical activity level had significantly lower odds of having sarcopenia than subjects in the low activity level group (aOR: 0.745; 95% CI: 0.584-0.950,  $p$ -value = 0.017). Subjects in the high physical activity level group had significantly lower odds of having severe sarcopenia than subjects in the low activity level group (aOR: 0.679; 95% CI: 0.499-0.923,  $p$ -value = 0.013). Restricted cubic spline analysis showed subjects in the high activity group had significantly lower odds of having possible sarcopenia by overall association than subjects in the low activity group ( $p$ -value  $<0.001$ ) and subjects in the high activity group had significantly lower odds of having possible sarcopenia by nonlinear association than subjects in the low physical activity group ( $p$ -value = 0.001). However, subjects in the high activity group did not have significantly lower odds of sarcopenia than subjects in the low physical activity group by overall association or nonlinear association ( $p$ -value = 0.560). For severe sarcopenia, the overall association approached significance but was not significant ( $p$ -value = 0.054). When all sarcopenia categories were combined, on restricted cubic spline analysis, subjects with high activity levels had significantly lower odds of having any kind of sarcopenia than subjects in the low physical activity group for overall association ( $p$ -value  $<0.001$ ) and nonlinear association ( $p$ -value = 0.002). Subgroup analysis revealed subjects who did not smoke and had a high activity level had lower odds of having possible sarcopenia than subjects with a high activity level who did smoke (aOR: 0.644; 95% CI: 0.553-0.750,  $p$ -value  $<0.001$ ). Subgroup analysis also showed subjects who were not retired and who had a high physical activity level had lower odds

of having possible sarcopenia than retired subjects who had a high physical activity level (aOR: 0.654; 95% CI: 0.566-0.756,  $p$ -value <0.001). No significant differences were found by sarcopenia category ( $p$ -value for interaction >0.05). In summary, subjects with higher physical activity levels had significantly lower odds of having possible sarcopenia, sarcopenia and severe sarcopenia than subjects with low physical activity levels. We conclude, moderate to high physical activity levels are recommended for subjects in the study group in order to prevent or manage sarcopenia. Further studies are needed to determine if interventions to increase physical activity are able to prevent or reduce sarcopenia in this population.

**Keywords:** sarcopenia, physical activity, middle-aged and older adults

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## INTRODUCTION

Sarcopenia, defined as a progressive loss of skeletal muscle mass and strength, is a major public health problem worldwide (Cruz-Jentoft *et al*, 2019). The prevalence of sarcopenia among older adults (aged  $\geq 60$  years) globally ranges from 10% to 27%, depending on the diagnostic criteria applied (Petermann-Rocha *et al*, 2022). China, one of the most rapidly aging countries, faces a

potential problem with increasing sarcopenia. Sarcopenia is associated with adverse health outcomes, including falls, fractures, disability, hospitalization and mortality (Steffl *et al*, 2017). A meta-analysis from China estimated the prevalence of sarcopenia among Chinese adults aged 60-69 years to be 15.7% and among those aged  $\geq 80$  years to be 45.4% (Meng *et al*, 2024). A study using data from the China Health and Retirement Longitudinal Study (CHARLS) reported the prevalences

of possible sarcopenia, sarcopenia and severe sarcopenia were 38.5%, 18.6% and 8.0%, respectively (Wu *et al*, 2021). Sarcopenia puts a substantial burden on healthcare systems and affects quality of life.

Physical activity is a modifiable factor that can affect the development or progression of sarcopenia. A systematic review and meta-analysis reported increased physical activity can prevent sarcopenia in older adults (Steffl *et al*, 2017). Another meta-analysis, which pooled both cross-sectional and longitudinal studies, reported that increased physical activity was inversely associated with sarcopenia on both cross-sectional analyses (aOR = 0.49; 95% CI: 0.37-0.62,  $p$ -value <0.001) and longitudinal analyses (aOR = 0.51; 95% CI: 0.27-0.94,  $p$ -value <0.001) (Sánchez-Sánchez *et al*, 2024). Another study reported exercise, particularly resistance training, is the most effective non-pharmacological approach for improving muscle strength and physical performance in older adults with sarcopenia (Shen *et al*, 2023).

These findings show the importance of promoting physical activity as a sarcopenia prevention strategy.

Most sarcopenia prevention studies have been conducted among Western populations. There are few studies of this type among Asian populations.

A study using CHARLS data explored factors associated with sarcopenia among older Chinese adults but did not specifically examine the dose-response relationship between physical activity levels and the presence of sarcopenia (Wu *et al*, 2021). Few studies have distinguished between “possible sarcopenia” and “sarcopenia” as defined by the 2019 Asian Working Group for Sarcopenia (AWGS) criteria (Chen *et al*, 2020). Given the trend of increasing age in the Chinese population, it is important to understand the association between physical activity and all categories of sarcopenia in the Peoples Republic of China, in order to inform efforts to prevent and manage sarcopenia in this population.

In this study, we aimed to determine if there was a significant association between physical activity levels and the prevalence and categories of sarcopenia among middle-aged and older adults in China in order to inform efforts to prevent and manage sarcopenia in the study population.

## MATERIALS AND METHODS

### Study subjects

Data for this study were obtained from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey evaluating Chinese adults aged  $\geq 45$  years. CHARLS used a multistage stratified cluster sampling method, covering 150 counties and 450 village committees across 28 provinces in the Peoples Republic of China for the study (Zhao *et al*, 2014). We used 2015 cross-sectional survey data from the CHARLS for our study. The study subject inclusion criteria were: 1) being included in the 2015 CHARLS survey and 2)

being aged  $\geq 45$  years. The study subject exclusion criteria were: 1) missing information required for sarcopenia diagnosis, 2) missing physical activity data and 3) missing covariate data.

### Assessment of sarcopenia

Sarcopenia was diagnosed using the 2019 AWGS diagnostic criteria (Chen *et al*, 2020). Muscle strength was measured in both hands using a hand dynamometer with two measurements recorded for each hand and the maximum value for each hand noted. The average of the maximum values for both hands was used as the grip strength level. Low muscle strength was defined as a grip strength  $< 28$  kg for men and  $< 18$  kg for women.

Skeletal muscle mass was assessed using the appendicular skeletal muscle mass index divided by the square of the subject height (ASM/ht<sup>2</sup>). The predicted appendicular skeletal muscle mass was calculated using the following equation (Hu *et al*, 2022):

$$\text{ASM in kilograms (kg)} = (0.193 \times \text{body weight in kg}) + (0.107 \times \text{height in centimeters (cm)}) \\ - (4.157 \times \text{sex}) - (0.037 \times \text{age in years}) - 2.631$$

where the category of sex in the equation was given as 1 for males and 0 for females. The height-adjusted index was then calculated as the ASM/height in meters (m)<sup>2</sup> (Ht<sup>2</sup>) where low skeletal muscle mass was defined as being below the 20th percentile for ASM/Ht<sup>2</sup> corresponding to <7.0 kg/m<sup>2</sup> for men and <5.7 kg/m<sup>2</sup> for women.

Physical performance was assessed using the Short Physical Performance Battery (SPPB), which consisted of three subtests, where each subtest had a possible score of 0-4 points giving a total possible score of 0-12 points. The first subgroup test of the SPPB was gait speed where each subject was asked to walk 2.5 m at a normal pace and back and the speed during this test was recorded (low was defined as <1m/s). The second subgroup test of the SPPB was the five-time chair stand test, where the time it took for the subject to stand up and sit

down again with their arms folded across their chest 5 times from a 47-cm chair was recorded (low was defined as >12 s). The third subtest was a balance test in which subjects were asked to maintain three different positions for 10 seconds each, with a possible score of 0 to 4 points for each position: 1) "side-by-side" where the subject stands with the feet side-by-side, 2) semi-tandem where the subject stands with the heel of one foot beside the big toe of the other foot, and 3) tandem where the subject stands with the heel of one foot in front of and touching the toes of the other foot (low was defined as a score of ≤9).

Subjects were classified using 2019 AWGS criteria, into 4 groups: no sarcopenia (not meeting any sarcopenia diagnostic criteria), possible sarcopenia (low muscle strength or low physical performance, but normal skeletal

muscle mass), sarcopenia (low skeletal muscle mass combined with either low muscle strength or low physical performance) and severe sarcopenia (low skeletal muscle mass combined with both low muscle strength and low physical performance).

### Physical activity assessment

Physical activity data were obtained from the CHARLS questionnaire and adapted from the International Physical Activity Questionnaire (IPAQ). Subjects were asked to report the frequency, in days/week, and duration of physical activity at 3 intensity levels during the previous week: vigorous activity (*eg*, heavy lifting, digging), moderate activity (*eg*, cycling, dancing) and light activity (*eg*, walking). Activity duration was recorded and categorized into one of the following activity duration groups: 0, 10-29, 30-119, 120-239, and  $\geq 240$  minutes/week). The midpoint values of the time intervals were used for duration calculations, with a fixed MET value

of 8.0, 4.0, and 3.0 METs assigned to vigorous, moderate, and light activity, respectively (Ainsworth *et al*, 2011; Tian and Shi, 2022). Total weekly physical activity was calculated as the sum of MET-min/week across all activity types using the formula (Mou *et al*, 2025): MET value  $\times$  duration (minutes)  $\times$  frequency (days/week).

Physical activity levels were classified into three categories (Macfarlane *et al*, 2011): low (<600 MET-min/week), moderate (600-3,000 MET-min/week) and high (>3,000 MET-min/week).

### Statistical analysis

Continuous variables with normal distribution are expressed as means and standard deviations and continuous variables with skewed distribution are expressed as medians and interquartile ranges (IQR). Categorical variables are expressed as frequencies and percentages. Baseline characteristics were compared among the 4 sarcopenia groups (no sarcopenia, possible sarcopenia,

sarcopenia and severe sarcopenia). Between-group differences in continuous variables were assessed using analysis of variance (ANOVA) for normally distributed variables and the Kruskal-Wallis test for skewed variables and between-group differences in categorical variables were assessed using chi-square tests.

We used multivariable logistic regression analysis to assess the association between physical activity levels and having sarcopenia. Using the low physical activity level group as the reference group, 3 models were constructed and evaluated. Model 1 was unadjusted; Model 2 adjusted for subject age group, body mass index (BMI) and gender; and Model 3 adjusted for age, gender, BMI, education level, marital status, residence, retirement status, smoking status, drinking status, presence of hypertension and presence of diabetes. Possible sarcopenia and sarcopenia and severe sarcopenia were analyzed independently using no sarcopenia as the reference outcome. The

results are expressed as odds ratios (ORs) with 95% confidence intervals (CI).

We used restricted cubic spline analysis, based on the fully adjusted logistic regression analysis model, to explore the dose-response relationship between total physical activity level in metabolic equivalents and the presence of sarcopenia. Knots were placed at the 10th, 50th and 90th percentiles to better capture potential nonlinear features of the exposure-outcome relationship.

We conducted subgroup analyses to explore heterogeneity in associations between physical activity and selected variables. These variables were age (<65 years/ $\geq$ 65 years), gender (male/female), residence (urban/rural), smoking status (no/yes), alcohol consumption status (no/yes), education level (junior high school and below/senior high school and above) and retirement status (not retired/retired). The effect of modification was assessed using the

likelihood ratio test by including a product interaction term between physical activity level and the subgroup variable in the fully adjusted model.

All statistical analyses were performed using R software (version 4.5.2) (R Foundation for Statistical Computing, Vienna, Austria). All hypothesis tests were two-sided and a *p*-value <0.05 was considered statistically significant.

### **Ethical approval**

The CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (approval number: IRB00001052-11015). This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. All subjects gave written informed consent prior to being included in the study. The present study was a secondary analysis based on publicly available CHARLS data so no additional ethical approval was requested for our study.

## **RESULTS**

A total of 8,449 subjects were included in the study: 52.4% (*n* = 4,426) females. 4,643 (55.0%) had no sarcopenia, 1,855 (22.0%) had possible sarcopenia, 1,346 (15.9%) had sarcopenia and 605 (7.2%) had severe sarcopenia (Table 1). The mean ( $\pm$ SD) age of study subjects was 66.1 ( $\pm$ 8.6) (range: 45-90) years. Subjects with sarcopenia had a significantly higher mean ( $\pm$ SD) age (71.03  $\pm$  8.02 years) than subjects with no sarcopenia (64.55  $\pm$  7.03 years; *p*-value <0.001) and subjects with possible sarcopenia (64.46  $\pm$  10.35 years; *p*-value <0.001). There was no significant difference (*p*-value >0.05) in the mean ( $\pm$ SD) age between subjects with sarcopenia (71.03  $\pm$  8.02 years) and subjects with severe sarcopenia (71.29  $\pm$  8.34 years). There was also no significant difference (*p*-value >0.05) in mean ( $\pm$ SD) age between subjects with no sarcopenia (64.55  $\pm$  7.03 years) and subjects with possible sarcopenia (64.46  $\pm$  10.35 years).

The mean ( $\pm$ SD) body mass

Table 1  
Baseline characteristics of study subjects by sarcopenia status

Characteristics	Overall	No sarcopenia	Possible sarcopenia	Sarcopenia	Severe sarcopenia	<i>p</i> -value
Number of subjects	8,449	4,643	1,855	1,346	605	
Age in years, mean ± SD	66.05 ± 8.58	64.55 ± 7.03	64.46 ± 10.35	71.03 ± 8.02	71.29 ± 8.34	<0.001
BMI in kg/m <sup>2</sup> , mean ± SD	23.56 ± 3.70	24.72 ± 3.27	24.87 ± 3.16	19.55 ± 1.77	19.49 ± 1.78	<0.001
Total MET, median [IQR]	2,160.00 [462.00, 6,772.50]	2,562.00 [933.00, 7,337.00]	1,782.00 [462.00, 6,716.25]	2,032.50 [309.50, 6,318.00]	1,732.50 [462.00, 5,544.00]	<0.001
Age group, <i>n</i> (%)						
<65 years	3,844 (45.5)	2,471 (53.2)	932 (50.2)	309 (23.0)	132 (21.8)	<0.001
≥65 years	4,605 (54.5)	2,172 (46.8)	923 (49.8)	1,037 (77.0)	473 (78.2)	
Gender, <i>n</i> (%)						
Female	4,426 (52.4)	2,351 (50.6)	1,011 (54.5)	732 (54.4)	332 (54.9)	0.005
Male	4,023 (47.6)	2,292 (49.4)	844 (45.5)	614 (45.6)	273 (45.1)	
Education, <i>n</i> (%)						
Middle school or below	6,566 (77.7)	3,372 (72.6)	1,483 (79.9)	1,185 (88.0)	526 (86.9)	<0.001
High school or above	1,883 (22.3)	1,271 (27.4)	372 (20.1)	161 (12.0)	79 (13.1)	

Table 1 (cont)

Characteristics	Overall	No sarcopenia	Possible sarcopenia	Sarcopenia	Severe sarcopenia	<i>p</i> -value
Marital status, <i>n</i> (%)						
Unmarried	1,543 (18.3)	642 (13.8)	356 (19.2)	366 (27.2)	179 (29.6)	<0.001
Married	6,906 (81.7)	4,001 (86.2)	1,499 (80.8)	980 (72.8)	426 (70.4)	
Residence, <i>n</i> (%)						
Urban	3,156 (37.4)	2,009 (43.3)	631 (34.0)	329 (24.4)	187 (30.9)	<0.001
Rural	5,293 (62.6)	2,634 (56.7)	1,224 (66.0)	1,017 (75.6)	418 (69.1)	
Retirement status, <i>n</i> (%)						
Not retired	6,990 (82.7)	3,616 (77.9)	1,625 (87.6)	1,205 (89.5)	544 (89.9)	<0.001
Retired	1,459 (17.3)	1,027 (22.1)	230 (12.4)	141 (10.5)	61 (10.1)	
Smoking status, <i>n</i> (%)						
No	6,174 (73.1)	3,399 (73.2)	1,441 (77.7)	914 (67.9)	420 (69.4)	<0.001
Yes	2,275 (26.9)	1,244 (26.8)	414 (22.3)	432 (32.1)	185 (30.6)	
Alcohol drinking status, <i>n</i> (%)						
No	5,724 (67.7)	3,026 (65.2)	1,332 (71.8)	947 (70.4)	419 (69.3)	<0.001
Yes	2,725 (32.3)	1,617 (34.8)	523 (28.2)	399 (29.6)	186 (30.7)	

Table 1 (cont)

Characteristics	Overall	No sarcopenia	Possible sarcopenia	Sarcopenia	Severe sarcopenia	<i>p</i> -value
Physical activity level, <i>n</i> (%)						
Low (<600 MET-min/week)	2,258 (26.7)	1,080 (23.3)	552 (29.8)	430 (31.9)	196 (32.4)	<0.001
Moderate (600-3,000 MET-min/week)	2,422 (28.7)	1,350 (29.1)	526 (28.4)	369 (27.5)	177 (29.3)	
High (>3,000 MET-min/week)	3,769 (44.6)	2,213 (47.6)	777 (41.8)	547 (40.6)	232 (38.3)	

BMI: body mass index; IQR: interquartile range; kg/m<sup>2</sup>: kilograms per square meter; MET-min/week: metabolic equivalents in minutes per week; SD: standard deviation

indices (BMI) of subjects with sarcopenia ( $19.55 \pm 1.77 \text{ kg/m}^2$ ) and severe sarcopenia ( $19.49 \pm 1.78 \text{ kg/m}^2$ ) were significantly lower than subjects with no sarcopenia ( $24.72 \pm 3.27 \text{ kg/m}^2$ ;  $p$ -value  $<0.001$ ) and subjects with possible sarcopenia ( $24.87 \pm 3.16 \text{ kg/m}^2$ ;  $p$ -value  $<0.001$ ).

No significant difference in BMI was observed between subjects with no sarcopenia and subjects with possible sarcopenia ( $p$ -value  $>0.05$ ).

The median (IQR) total MET of subjects overall was 2,160 (462-6,773) MET-min/week. The median (IQR) total MET of subjects with severe sarcopenia (1,733 (462-5,544) MET-min/week) was lower than the median (IQR) total MET among subjects with no sarcopenia (2,562 (933-7,337) MET-min/week;  $p$ -value  $<0.001$ ). No significant difference in the median (IQR) total MET-min/week was observed between subjects with sarcopenia (2,033 (310-6,318) MET-min/week) and subjects with severe sarcopenia (1,733 (462-5,544) MET-min/week) ( $p$ -value  $>0.05$ ).

Among subjects with severe sarcopenia 32.4% had a low physical activity level and among subjects with no sarcopenia, 23.3% had a low physical activity level ( $p$ -value  $<0.001$ ). Among subjects with severe sarcopenia 38.3% had a high physical activity level and among subjects with no sarcopenia, 47.7% had a high physical activity level.

Significantly more ( $p$ -value  $<0.001$ ) subjects with sarcopenia were aged  $\geq 65$  years (77.0%) than subjects with possible sarcopenia (49.8%) and significantly more ( $p$ -value  $<0.001$ ) subjects with sarcopenia were aged  $\geq 65$  years than subjects with no sarcopenia (46.8%). There was no significant difference in the proportion of subjects aged  $\geq 65$  years between subjects with sarcopenia (77.0%) and subjects with severe sarcopenia (78.2%) ( $p$ -value = 0.578). There was no significant difference ( $p$ -value = 0.096) in the proportions of subjects with no sarcopenia and possible sarcopenia who were aged  $\geq 65$  years.

Significantly more ( $p$ -value

<0.001) subjects with sarcopenia had a middle school or lower education level (88.0%) than subjects with no sarcopenia (72.6%) and significantly more subjects with sarcopenia had a middle school or lower education level than subjects with possible sarcopenia (79.9%) ( $p$ -value <0.001). There was no significant difference in the proportion of subjects with a middle school or lower education level between subjects with sarcopenia (88.0%) and subjects with severe sarcopenia (86.9%) ( $p$ -value = 0.495).

Significant differences among all 4 groups (no sarcopenia, possible sarcopenia, sarcopenia and severe sarcopenia) were seen by gender ( $p$ -value = 0.005), marital status ( $p$ -value <0.001), location of residence ( $p$ -value <0.001), retirement status ( $p$ -value  $p$  <0.001), smoking status ( $p$ -value <0.001) and alcohol drinking status ( $p$ -value <0.001).

Logistic regression analysis showed physical activity levels were inversely associated with the odds of having sarcopenia (Table 2).

In the non-adjusted model (Model 1), subjects with a high level of physical activity had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (crude odds ratio (cOR): 0.683; 95%CI: 0.599-0.779,  $p$ -value <0.001) and subjects with a moderate physical activity level had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (cOR: 0.755; 95%CI: 0.654-0.872,  $p$ -value <0.001).

In the model adjusted for age, BMI and gender (Model 2), subjects with a high physical activity level had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (aOR: 0.687; 95%CI: 0.602-0.784,  $p$ -value <0.001) and subjects with a moderate physical activity level had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (aOR: 0.757; 95%CI: 0.602-0.784,  $p$ -value <0.001).

In the fully adjusted model (Model 3), subjects with a high

Table 2  
Odds ratios for the association between physical activity levels and odds of having sarcopenia

Physical activity level	Model 1		Model 2		Model 3	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
No sarcopenia <i>vs</i> possible sarcopenia						
Low (<600 MET-min/week)	Reference	Reference	Reference	Reference	Reference	Reference
Moderate (600-3,000 MET-min/week)	0.755 (0.654-0.872)	<0.001	0.757 (0.656-0.875)	<0.001	0.791 (0.683-0.915)	0.002
High (>3,000 MET-min/week)	0.683 (0.599-0.779)	<0.001	0.687 (0.602-0.784)	<0.001	0.679 (0.594-0.776)	<0.001
No sarcopenia <i>vs</i> severe sarcopenia						
Low (<600 MET-min/week)	Reference	Reference	Reference	Reference	Reference	Reference
Moderate (600-3,000 MET-min/week)	0.679 (0.578-0.797)	<0.001	0.681 (0.521-0.888)	0.005	0.730 (0.556-0.959)	0.024
High (>3,000 MET-min/week)	0.616 (0.533-0.713)	<0.001	0.767 (0.604-0.973)	0.029	0.745 (0.584-0.950)	0.017
No sarcopenia <i>vs</i> severe sarcopenia						
Low (<600 MET-min/week)	Reference	Reference	Reference	Reference	Reference	Reference
Moderate (600-3,000 MET-min/week)	0.734 (0.590-0.913)	0.005	0.750 (0.540-1.042)	0.087	0.819 (0.587-1.144)	0.242
High (>3,000 MET-min/week)	0.581 (0.474-0.713)	<0.001	0.697 (0.515-0.943)	0.019	0.679 (0.499-0.923)	0.013

Model 1: unadjusted; Model 2: adjusted for age and gender; Model 3: adjusted for age, gender, BMI, marital status, residence, education, smoking status, alcohol drinking status, and retirement status. Low physical activity (<600 MET-min/week) served as the reference group.

BMI: body mass index; CI: confidence interval; OR: odds ratio; MET-min/week: metabolic equivalents in minutes per week

physical activity level had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (aOR: 0.757; 95%CI: 0.656-0.875,  $p$ -value <0.001) and subjects with a moderate physical activity level had significantly lower odds of having possible sarcopenia than subjects with a low physical activity level (aOR: 0.791; 95%CI: 0.683-0.915,  $p$ -value = 0.002).

In Model 1, subjects with a high physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level (cOR: 0.616; 95%CI: 0.533-0.713,  $p$ -value <0.001) and subjects with a moderate physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level (cOR: 0.679; 95%CI: 0.578-0.797,  $p$ -value <0.001).

In Model 2, subjects with a high physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level

(aOR: 0.767; 95%CI: 0.604-0.973,  $p$ -value = 0.029) and subjects with a moderate physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level (aOR: 0.681; 95%CI: 0.521-0.888,  $p$ -value = 0.005).

In Model 3, subjects with a high physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level (aOR: 0.745; 95%CI: 0.584-0.950,  $p$ -value = 0.017) and subjects with a moderate physical activity level had significantly lower odds of having sarcopenia than subjects with a low physical activity level (aOR: 0.730; 95%CI: 0.556-0.959,  $p$ -value = 0.024).

In Model 1, subjects with a high physical activity level had significantly lower odds of having severe sarcopenia than subjects with a low physical activity level (cOR: 0.581; 95%CI: 0.474-0.713,  $p$ -value <0.001) and subjects with a moderate physical activity level had significantly lower odds of having

severe sarcopenia than subjects with a low physical activity level (cOR: 0.734; 95%CI: 0.590-0.913,  $p$ -value = 0.005).

In Model 2, subjects with a high physical activity level had significantly lower odds of having severe sarcopenia than subjects with a low physical activity level (aOR: 0.697; 95%CI: 0.515-0.943,  $p$ -value = 0.019); however, there was no significant difference in the odds of having severe sarcopenia between subjects with a moderate physical activity level and subjects with a low physical activity level (aOR: 0.750; 95%CI: 0.540-1.042,  $p$ -value = 0.087).

In Model 3, subjects with a high physical activity level had significantly lower odds of having severe sarcopenia than subjects with a low physical activity level (aOR: 0.679; 95%CI: 0.499-0.923,  $p$ -value = 0.013); however, there was no difference in the odds of having severe sarcopenia between subjects a moderate physical activity level and subjects with a low physical activity level (aOR: 0.819; 95%CI:

0.587-1.144,  $p$ -value = 0.242).

Restricted cubic spline analysis showed a significant overall association between physical activity and the odds of having possible sarcopenia ( $p$ -value <0.001) (Fig 1A). The curve showed a significant inverse nonlinear association between physical activity level and odds of having possible sarcopenia ( $p$ -value = 0.001). We found no significant overall association between physical activity and sarcopenia ( $p$ -value = 0.560) and we found no significant nonlinear association between physical activity and sarcopenia ( $p$ -value = 0.782) (Fig 1B). We also found no significant overall association between physical activity and severe sarcopenia ( $p$ -value = 0.054) and we found no significant nonlinear association between physical activity and severe sarcopenia ( $p$ -value = 0.095) (Fig 1C). However, we did find a significant overall association between physical activity and any sarcopenia ( $p$ -value <0.001) and we found a significant

non-linear association between physical activity and any sarcopenia ( $p$ -value = 0.002) (Fig 1D).

A high physical activity level was significantly associated with lower odds of having possible sarcopenia for both age groups (<65 years: aOR: 0.693; 95%CI: 0.573-0.837,  $p$ -value  $p$  <0.001;  $\geq$ 65 years: aOR: 0.672; 95%CI: 0.554-0.815,  $p$ -value <0.001) and both genders (males: aOR: 0.643; 95% CI: 0.536-0.771,  $p$ -value <0.001; females: aOR: 0.728, 95% CI: 0.596-0.890,  $p$ -value = 0.002).

Among non-smokers, moderate (aOR: 0.775; 95%CI: 0.657-0.915,  $p$ -value = 0.003) and high (aOR: 0.644, 95%CI: 0.553-0.750,  $p$ -value <0.001) physical activity levels were significantly associated with lower odds of having possible sarcopenia; however, no such significant associations were found with smokers.

A high level of physical activity was significantly associated with lower odds of having possible sarcopenia by both residence locations (urban: aOR: 0.688; 95%CI:

0.549-0.862,  $p$ -value = 0.001; rural: aOR: 0.686; 95%CI: 0.581-0.811,  $p$ -value <0.001).

A high level of physical activity was significantly associated with lower odds of having possible sarcopenia for both alcohol drinking status groups (non-drinker: aOR: 0.669; 95%CI: 0.571-0.785,  $p$ -value <0.001, drinker: aOR: 0.713; 95%CI: 0.555-0.916,  $p$ -value = 0.008).

A high level of physical activity was significantly associated with lower odds of having possible sarcopenia for both education level groups (middle school or lower: aOR: 0.680; 95%CI: 0.585-0.790,  $p$ -value <0.001, high school or above: aOR: 0.691; 95%CI: 0.515-0.929,  $p$ -value = 0.014).

Among non-retired subjects, a moderate level of physical activity (aOR = 0.782; 95% CI: 0.667-0.917,  $p$ -value = 0.002) and a high physical activity level (aOR = 0.654; 95% CI: 0.566-0.756,  $p$ -value <0.001) were significantly associated with lower odds of having possible sarcopenia but among retired subjects there were no significant associations

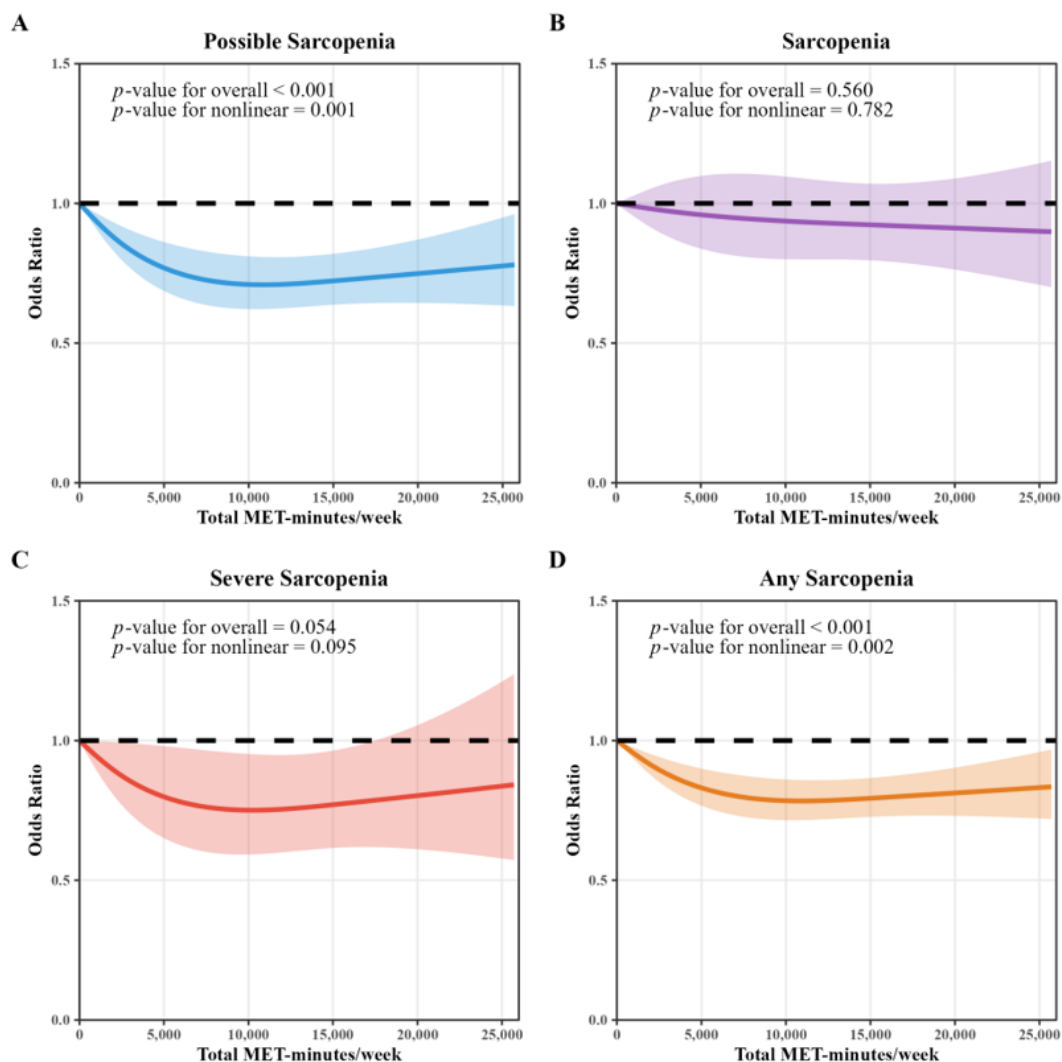


Fig 1 - Dose-response relationship between total physical activity and odds of having sarcopenia using restricted cubic splines

Physical activity levels were categorized as low (<600 MET-min/week), moderate (600-3,000 MET-min/week) and high (>3,000 MET-min/week), with low serving as the reference group. All analyses were adjusted for age, gender, marital status, residence, education, smoking status, alcohol consumption, and retirement status.

CI: confidence interval; MET-min/week: metabolic equivalents in minutes per week

between moderate and high-level physical activity levels and possible sarcopenia (Fig 2A).

Among subjects aged <65 years, a moderate physical activity level was significantly associated with lower odds of having sarcopenia (aOR: 0.481; 95%CI: 0.296-0.781,  $p$ -value = 0.003) and a high physical activity level was also significantly associated with lower odds of having sarcopenia (aOR: 0.608; 95%CI: 0.405-0.912,  $p$ -value = 0.016); however, no such significant associations were found among subjects aged  $\geq 65$  years.

Among females, a high physical activity level was significantly associated with lower odds of having sarcopenia (aOR: 0.665; 95%CI: 0.461-0.959,  $p$ -value = 0.029); however, no such significant association was found among males.

Among rural residents, a moderate physical activity level was significantly associated with lower odds of having sarcopenia (aOR: 0.667; 95%CI: 0.478-0.931,  $p$ -value = 0.017); however,

no such significant association was found among urban residents. Among alcohol non-drinkers, a moderate level of physical activity was significantly associated with lower odds of having sarcopenia (aOR: 0.690; 95%CI: 0.496-0.961,  $p$ -value = 0.028).

Among subjects with a high school or greater education level, a moderate physical activity level was significantly associated with lower odds of having sarcopenia (aOR: 0.461; 95%CI: 0.240-0.888,  $p$ -value = 0.020).

Among non-retired subjects, a high physical activity level was significantly associated with lower odds of having sarcopenia (aOR: 0.711; 95%CI: 0.547-0.924,  $p$ -value = 0.011) but among retired subjects there were no significant associations between physical activity levels and sarcopenia. We found no significant associations between any of the subgroups and sarcopenia ( $p$ -value  $> 0.05$ ) (Fig 2B).

Among subjects aged  $\geq 65$  years, a high level of physical activity was significantly associated with lower

odds of having severe sarcopenia (aOR: 0.645; 95%CI: 0.453-0.918,  $p$ -value = 0.015); however, we found no such association among subjects aged <65 years.

Among females, a high level of physical activity was significantly associated with lower odds of having severe sarcopenia (aOR: 0.624; 95%CI: 0.390-0.998,  $p$ -value = 0.049); however, no such association was found among males.

Among urban residents, a high level of physical activity was significantly associated with lower odds of having severe sarcopenia (aOR: 0.495; 95%CI: 0.283-0.867,  $p$ -value = 0.014); however, no such association was found among rural residents.

Among non-smokers, a high level of physical activity was significantly associated with lower odds of having severe sarcopenia (aOR: 0.677; 95%CI: 0.470-0.976,  $p$ -value = 0.036); however, no such association was found among smokers.

Among alcohol non-drinkers, a

high level of physical activity was significantly associated with lower odds of having severe sarcopenia (aOR: 0.650; 95%CI: 0.446-0.949,  $p$ -value = 0.026); however, no such association was found among alcohol drinkers.

Among non-retired subjects, a high level of physical activity was significantly associated with lower odds of having severe sarcopenia (aOR: 0.644; 95%CI: 0.463-0.895,  $p$ -value = 0.009); however, no such association was found among retired subjects. We found no significant associations between any of the subgroups and severe sarcopenia ( $p$ -value >0.05) (Fig 2C).

## DISCUSSION

In our study, overall, we found higher physical activity levels were significantly associated with lower odds of having possible sarcopenia, sarcopenia or severe sarcopenia. These findings are consistent with those of previous large-scale observational studies (Beaudart *et al*, 2017; Sánchez-Sánchez *et al*, 2024). A comprehensive meta-

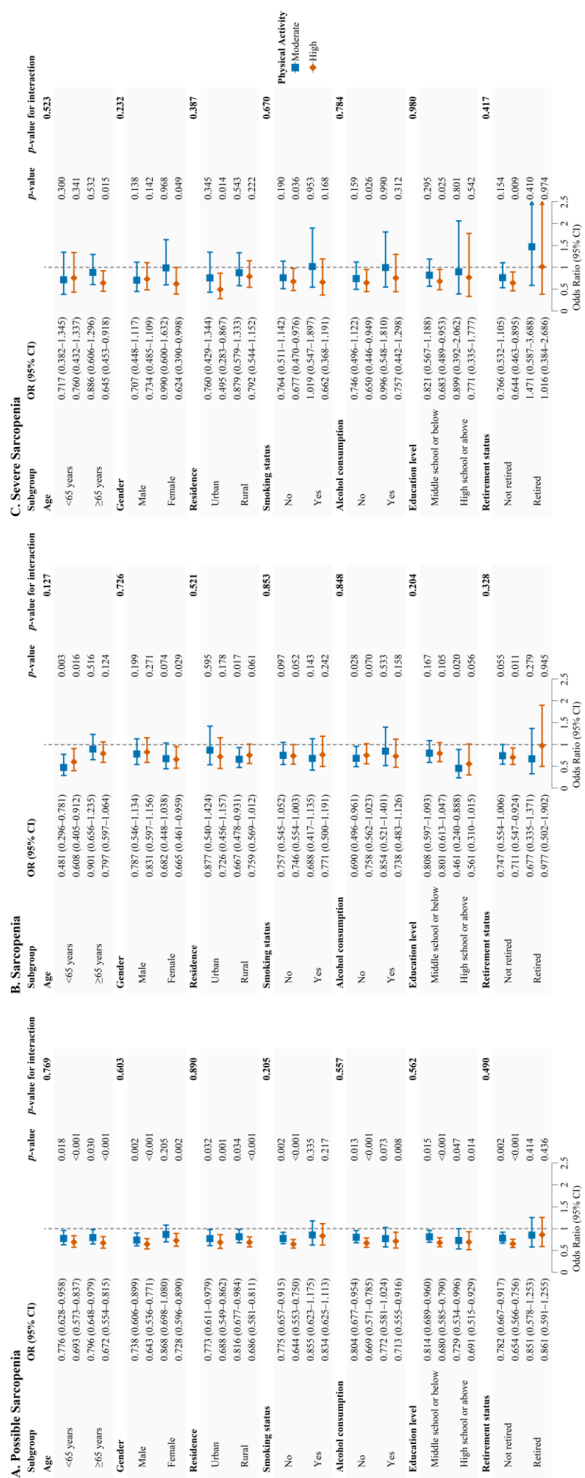


Fig 2 - Subgroup analyses of the association between physical activity and odds of having sarcopenia. Physical activity levels were categorized as low, (<600 MET-min/week), moderate (600-3,000 MET-min/week) and high (>3,000 MET-min/week), with low serving as the reference group. All analyses were adjusted for age, gender, marital status, residence, education, smoking status, alcohol consumption, and retirement status.

CI: confidence interval; MET-min/week: metabolic equivalents in minutes per week; OR: odds ratio

analysis of 124 studies having 230,174 older adult subjects reported higher levels of physical activity were associated with 50% lower odds of having sarcopenia (Sánchez-Sánchez *et al*, 2024). A systematic review also reported finding a significant association between physical activity and sarcopenia (Beaudart *et al*, 2017).

In our study, the inverse association between physical activity and possible sarcopenia was stronger than for the inverse association between physical activity and sarcopenia and severe sarcopenia. The biological mechanisms underlying the association between physical activity and levels of sarcopenia are likely multifaceted. A previous study reported muscle strengthening is more readily influenced by physical activity through neural adaptation, but maintenance of muscle mass is affected by multiple other factors, such as nutritional status, hormonal levels and genetic factors (Aslam *et al*, 2023). Physical activity promotes muscle protein synthesis

through activation of the IGF-1/PI3K/Akt/mTOR signaling pathway, while simultaneously inhibiting muscle protein degradation by suppressing FoxO-mediated proteolytic pathways (Marzetti *et al*, 2017; Yoon, 2017). Regular exercise promotes mitochondrial biogenesis through activation of Adenosine 5'-monophosphate (AMP)-activated protein kinase (AMPK), reduces chronic low-grade systemic inflammation, and enhances neuromuscular junction function (Ziaaldini *et al*, 2017). These mechanisms may act synergistically and may underlie the dose-dependent association seen in our study.

In our study, subgroup analyses showed no significant associations between physical activity and sarcopenia ( $p$ -value  $>0.05$ ). However, a moderate physical activity level was significantly associated with lower odds of sarcopenia among subjects aged  $<65$  years but not among those aged  $\geq 65$  years. The lack of a significant association between

physical activity and sarcopenia among older adults may be related to age-related anabolic resistance, whereby older adults exhibit an attenuated muscle protein synthesis response to exercise (Burd *et al*, 2013). This suggests physical activity interventions for sarcopenia prevention may need to be tailored by age.

A moderate physical activity level was significantly associated with lower odds of sarcopenia among rural residents but not among urban residents. This difference in the association between physical activity and sarcopenia by residential setting may be attributable to the greater muscular exertion required for agricultural labor among rural residents, whereas urban subjects may lead a more sedentary lifestyle, potentially attenuating this association (Prado *et al*, 2024). This suggests that promoting physical activity among urban residents may require targeted strategies to increase their uptake of exercise.

Among non-retired subjects, both moderate and high levels of physical activity were significantly associated with lower odds of sarcopenia, but no significant associations were found among retired subjects. This difference in the association between physical activity and sarcopenia by retirement status may reflect the contribution of occupational physical activity, as continued engagement in work-related activities provides regular muscular stimulation. This suggests that retired individuals may benefit from structured physical activity programs to compensate for the loss of occupational activity. No significant associations were observed between physical activity and sarcopenia by gender, smoking status, alcohol drinking status, or education level subgroups.

Our study had several limitations. Physical activity was assessed using a self-reported questionnaire, which may be subject to recall bias. Skeletal muscle mass was estimated using an anthropometric prediction equation

rather than directly measured by dual-energy x-ray absorptiometry, which may introduce measurement error. The cross-sectional study design prevents determining causation. It cannot be presumed decreased physical activity caused the sarcopenia since sarcopenia can cause decreased physical activity. Although we adjusted for multiple covariates, other potentially confounding factors, such diet or medication use were not taken into consideration. Finally, the study population consisted of middle-aged and older Chinese adults living in the Peoples Republic of China, so our results cannot be applied to other populations.

In summary, we found higher physical activity levels were significantly associated with lower odds of possible sarcopenia, sarcopenia and severe sarcopenia. We found an inverse association between physical activity and sarcopenia and severe sarcopenia among subjects living in rural areas and among those not yet retired. We conclude the proportion study

subjects with sarcopenia was relatively high and promoting increased physical activity warrants prospective investigation to determine if it can prevent or manage sarcopenia among elderly Chinese in the Peoples Republic of China.

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#### CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflicts of interest related to the content of this article. No financial or personal relationships with other individuals or organizations have inappropriately influenced this work.

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