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REVIEW

Relationship between sarcopenia and physical activity in older people: a systematic review and meta-analysis

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Abstract: Physical activity (PA) has been identified as beneficial for many diseases and health disorders, including sarcopenia. The positive influence of PA interventions on sarcopenia has been described previously on many occasions. Current reviews on the topic include studies with varied PA interventions for sarcopenia; nevertheless, no systematic review exploring the effects of PA in general on sarcopenia has been published. The main aim of this study was to explore the relationship between PA and sarcopenia in older people on the basis of cross-sectional and cohort studies. We searched PubMed, Scopus, EBSCO*host*, and ScienceDirect for articles addressing the relationship between PA and sarcopenia. Twenty-five articles were ultimately included in the qualitative and quantitative syntheses. A statistically significant association between PA and sarcopenia was documented in most of the studies, as well as the protective role of PA against sarcopenia development. Furthermore, the meta-analysis indicated that PA reduces the odds of acquiring sarcopenia in later life (odds ratio [OR] =0.45; 95% confidence interval [CI] 0.37–0.55). The results of this systematic review and meta-analysis confirm the beneficial influence of PA in general for the prevention of sarcopenia.

Keywords: aging, sarcopenia, physical activity

Introduction

Although diseases related to the aging process are problematic themselves, they rarely occur in isolation and the effects of one may spark the onset of another. As such ailments progress, the importance of physical activity (PA) remains high, with previous research confirming that regular PA is essential for healthy aging.[1] Specifically, PA plays a substantial role in lowering the risk of coronary heart disease,[2] obesity,[3] type 2 diabetes,[4] hypertension,[5] peripheral vascular disease,[6] high cholesterol,[7] osteoporosis,[8] osteoarthritis,[9] and chronic obstructive pulmonary disease.[10] Although PA may have an indirect impact on some health aspects, it has a direct impact on muscle quality and quantity.[11]

Sarcopenia, which was first described by Rosenberg in 1989[12] as the progressive decrease in muscle mass and strength during aging, is a syndrome that is directly affected by PA.[13–15] Soon after sarcopenia was defined, muscle mass assessment had been recommended as the main sarcopenia diagnosing method. Baumgartner et al[16] proposed that the appendicular skeletal muscle mass index (ASMMI) should be the main indicator, and the cutoff point was established as two standard deviations below the mean of a young reference group. Even though this measurement is always expressed in relative terms (muscle mass in kilograms divided by body

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height in meter squared, resulting in kg/m^2), many different names have been suggested, eg, appendicular lean mass index (ALMI), fat-free mass index (FFMI), relative skeletal muscle mass index (RSMI), and muscle mass index (MMI), and occasionally skeletal muscle mass (SMM) alone serves as an indicator of sarcopenia. Computed tomography (CT) and magnetic resonance imaging (MRI) are gold standards for measuring muscle mass in research. The dual-energy X-ray absorptiometry (DXA) is the preferred alternative method for research and clinical use;[17] however, bioelectrical impedance analysis (BIA) has been found as a relevant alternative.[18] Except these methods, the mid-upper arm muscle circumference (MAMC) has been proposed as an alternative tool for muscle mass estimation.[19] Later, several groups were formed for sarcopenia consensus on definition and diagnosis in Europe – the European Working Group on Sarcopenia in Older People (EWGSOP),[17] in Asia – the Asian Working Group for Sarcopenia (AWGS),[20] and except them the International Working Group on Sarcopenia (IWGS).[21] These groups recommended including muscle strength and physical performance measurement as the additional methods for sarcopenia diagnosing. Currently, the EWGSOP algorithm is the most widely used method in research and in clinical practice.

Previous research has shown that physical inactivity contributes to the development of sarcopenia,[22,23] and other studies have shown that PA increases muscle strength[24,25] and muscle mass[26,27] in older adults. Therefore, a strong link has emerged between PA and a lower prevalence of sarcopenia.[28–31] Specifically, resistance training is generally considered to be the best countermeasure for preventing sarcopenia.[11,32–38]

Although many reviews and meta-analyses have summarized the effects of individual or combined interventions (eg, resistance training and nutritional supplementation) on sarcopenia, a systematic review and meta-analysis of the effects of PA defined as general activity that requires more energy than resting metabolic rate (eg, exercising, strengthening, walking, working in the garden, and so on) on sarcopenia has not been published. Therefore, the main aim of this systematic review and meta-analysis was to describe the relationship between PA and the presence of sarcopenia.

Methods

This systematic review and meta-analysis, in accordance with the recommendations and criteria as outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[39] focused on cross-sectional and cohort studies.

Criteria for considering studies for this study

To be included in the analyses, studies had to meet the following conditions: only data from cross-sectional studies and follow-up or baseline datasets of longitudinal cohort studies were included, date of publication 1989–2017, English language, and participants have to be older than 40 years. As PA, there were considered every activity requiring increased energy output without regard of frequency and intensity, sarcopenia has to be diagnosed by some of the standard recommendation. There had to be data presented from regression models, which included PA as the independent variable and sarcopenia as the dependent variable, and odds ratio (OR) had to be used as the effect size in those regression models for the systematic review. For the meta-analysis, the raw data reporting numerically PA habits by both sarcopenic and nonsarcopenic individuals had to be presented.

Search methods for identification of studies

Appropriate articles were manually identified through searches using four electronic databases: PubMed, Scopus, EBSCO*host*, and ScienceDirect and through the reference lists of publications identified in this search. The search stream that was used in all the databases is presented in Table 1. This process was conducted by the first and third authors; the searches were done by the first and last authors independently. There was no disagreement between those coauthors during the process. The articles were collected and sorted using the software EndNote X5 for managing bibliographies.

Data collection and analysis

All abstracts were explored by the first and third authors independently with the aim of identifying relevant articles. During the first step of this process, duplicate articles and reviews were removed, then full texts of the remaining articles were systematically examined for inclusion or exclusion, and the articles lacking the required information about PA and sarcopenia were removed. Subsequently, the remaining articles were included in the synthesis. Additionally, the aforementioned protocol was completed on relevant articles that were identified within the reference lists of the articles identified through database searching.

Table 1 Search strategies used with four databases to identify articles describing the relationship between sarcopenia and physical activities

Database (yield)	Search terms	Record identified through searching
PubMed	Search (sarcopenia[Title]) AND ("physical activit*") AND (cross-sectional OR cohort)	85
Scopus	(TITLE (sarcopenia) AND TITLE-ABS-KEY ("physical activit*") AND TITLE-ABS-KEY (cross-sectional OR cohort))	54
EBSCO*host*	TI sarcopenia AND TX "physical activit*" AND TX (cross-sectional OR cohort)	182
ScienceDirect	TITLE (sarcopenia) and TITLE-ABSTR-KEY (("physical activit*") AND (cross-sectional OR cohort))	22

Note: January 4, 2017 – record identified through database searching: 343.

After collection of the relevant articles, the Newcastle-Ottawa Scale (NOS) was used to assess the quality of nonrandomized studies in meta-analyses to eliminate the risk of bias.[40] This was carried out independently by the fourth and fifth authors. There was no disagreement between them during the process.

Measures of effect sizes

The Cochran-Mantel-Haenszel statistical method[41] based on a fixed-effect model was used to calculate an effect size of PA on sarcopenia in the meta-analysis. The OR was calculated as the effect size of PA on sarcopenia. In this article, the OR estimated the odds of demonstrating sarcopenia while accounting for PA. An OR less than 1 favors PA, indicating that PA decreases the risk (odds) of sarcopenia, and an OR greater than 1 suggests that PA increases the risk (odds) of sarcopenia. A sensitivity analysis was carried out to reach the best estimation. During the sensitivity analysis, those studies that might have had an influence on heterogeneity because of publication bias were removed. Through the sensitivity analysis, the best OR estimation represented by the highest value of a test for the overall effect (Z) taking into account heterogeneity and publication bias was calculated. An index I^2, which does not depend upon the number of studies, the type of outcome data, or the choice of treatment effect, was used to quantify the impact of heterogeneity and to assess inconsistency. I^2 can be readily calculated from basic results obtained from a typical meta-analysis as $I^2=100\% \times (Q - df)/Q$, where Q is standard Cochran's heterogeneity statistic and df the degrees of freedom. A rough guide to interpretation of I^2 is as follows: 0 to 40% might not be important, 30% to 60% may represent moderate heterogeneity, 50% to 90% may represent substantial heterogeneity, and 75% to 100% represents considerable heterogeneity.[42] Funnel plots were used for visualizing biases.[43] A funnel plot is a simple scatter plot of exposing the effect estimated from individual studies against some measures of each study's size or precision.[44] Statistics were carried out using Review Manager 5.3.

Results

Description of studies and study population

Figure 1 summarizes the yield of the search process. Of 354 articles identified as potentially relevant by the database searching, 19 were included. An additional six articles identified through article reference lists were added. Excluded articles are presented in Table S1. Ultimately, 25 total studies were included in the qualitative and quantitative syntheses, comprised of 17 cross-sectional[30,31,45–59] and 8 cohort studies.[29,60–66] From these 25 articles, 20 were used in the systematic review and 14 were used in the meta-analysis: some articles were used for both, but all 25 articles were used in one way or another. Data from 40,007 individuals (21,222 males and 18,785 females) were obtained from all 25 studies. The mean age of the participants was 71.7±4.9 for nonsarcopenic males and 74.9±5.6 for sarcopenic males and 73.1±4.7 for nonsarcopenic females and 76.1±5.0 for sarcopenic females. All participants were over 60 years old apart from subjects within four studies: Beavers et al (>40 years old),[45] de Castro et al (55–68 years old),[46] Castillo et al (55–98 years old),[62] and Park et al (>50 years old).[55] The age ranged from 40 to 106 years. Participants lived in a community in 23 cases, one time in a nursing home,[50] and one time participants were recruited from a hospital.[53] PA was quantified using several different methods, but the most common was a self-report questionnaire. In most studies, PA was divided into several categories. Sarcopenia diagnostics

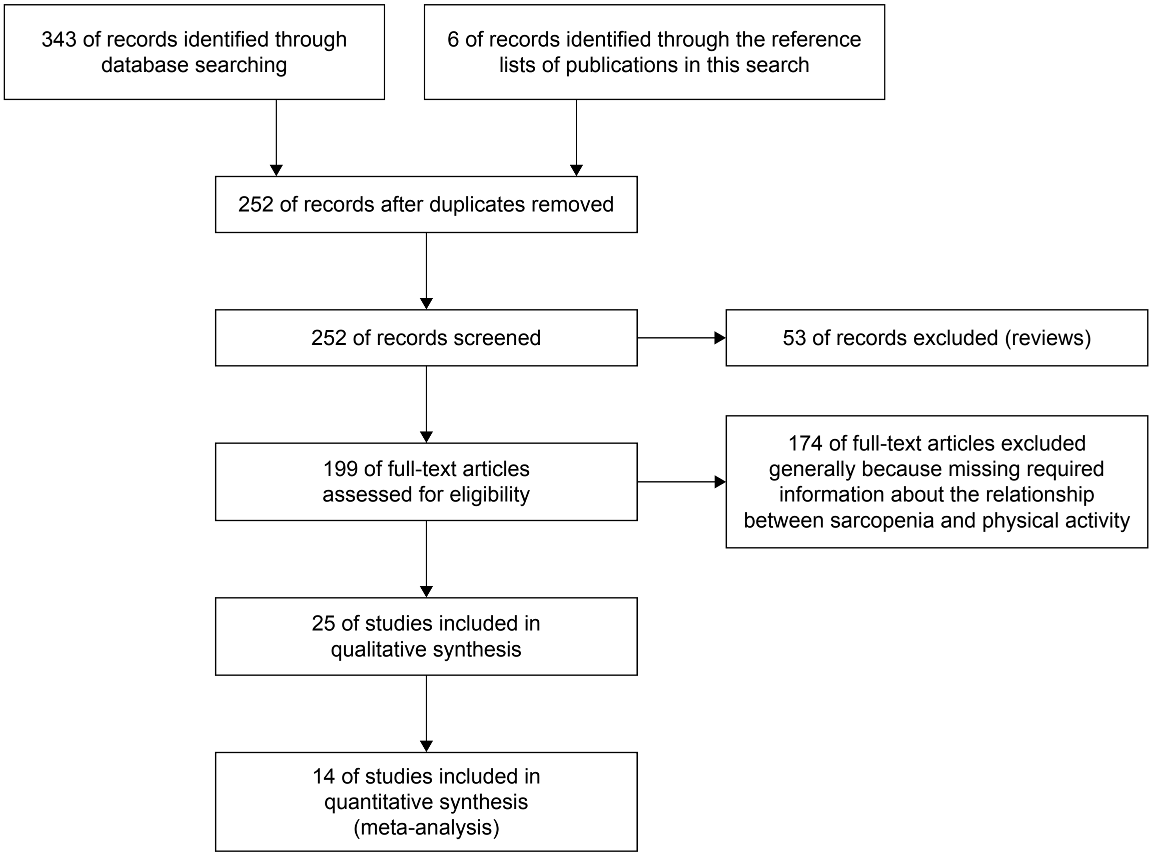

Figure 1 Flowchart showing how the reviewed articles were identified and selected.

were based on body composition measurements in most cases. The EWGSOP algorithm was used in seven studies, and AWGS criteria and IWGS criteria were each used one time (Table 2). The quality of the included studies was sufficient according to the NOS score, and no study was excluded due to that analysis (Table S2).

Systematic review

Most of the regression models suggested that PA might help preserve muscle mass because only four of 32 ORs were above 1, and only one study[49] estimated PA to be a significant risk factor for sarcopenia in females. However, 13 of 32 regression models estimated PA to be a significant protective factor against sarcopenia in older people (Table 3). Additionally, six of nine regression models estimated that physical inactivity was a significant risk factor for sarcopenia in older people (Table 4).

Meta-analysis

In all the analyses, the article by Goodman et al[49] stand out of the funnel plot that signalized the increased risk of bias and for the same reason the article by Park et al[55] was excluded during sensitivity analysis in the analysis males and females together.

For males, data from eight studies were initially included in the first analysis, with one study[49] later excluded due to publication bias, thereby resulting in acceptable heterogeneity, from I^2=73% to I^2=4%. After the exclusion of this study, the OR (95% confidence interval [CI]) for males (n=3,881) was 0.46 (0.37–0.58), Cochran Q =5.2, df=5 (P=0.390), indicating that PA reduced the odds of males suffering from sarcopenia. The test for overall effect was quite strong Z=6.50, which was statistically significant ($P<0.00001$). The forest plot is shown in Figure 2.

For females, data from seven studies were included in the first analysis, but data from Goodman et al[49] were excluded for the same reason, reducing heterogeneity from I^2=75% to an acceptable I^2=29%. After the exclusion of this study, the OR (95% CI) for females (n=6,234) was 0.65 (0.52–0.81), Cochran Q =7.8, df=5 (P=0.290) indicating that PA reduced the odds of females demonstrating sarcopenia. The test for overall effect was weaker than in males at Z=3.79; however, it was still statistically significant ($P<0.0001$). The forest plot is shown in Figure 3.

Table 2 Summary of studies describing the classification of PA and sarcopenia diagnostics

Study	Design[a]	Classification of PA Sarcopenia diagnostics
Aggio et al[60]	Cohort[b]	Physical monitoring: accelerometry EWGSOP algorithm,[17] SMM (kg) by MAMC,[72] the lowest two-fifths of the MAMC distribution
Akune et al[29]	Cohort[b]	Survey: categorization of past PA based on yes/no Survey: categorization of past current walking habit based on yes/no EWGSOP algorithm,[17] SMI (kg/m^2) by BIA; cutoff 7.0 kg/m^2 for males and 5.8 kg/m^2 for females
Atkins et al[61]	Cohort[b]	Survey: current PA classified as: inactive, occasional, light, moderate, moderately vigorous, vigorous FFMI (kg/m^2) by BIA, $<$1st quartile of the distribution of FFMI; cutoff 15.96 kg/m^2
Beavers et al[45]	Cross-sectional	Survey: current PA classified as: inactive $<$4, low 4–11, moderate 12–20, high $>$20 times per month SMM (kg) by BIA, sarcopenia class I and II of $<$1 SD, respectively, $<$2 SD of young reference group from this study
Castillo et al[62]	Cohort[b]	Survey: regular PA three or more times per week – yes/no FFM (kg) by BIA, $<$2 SD of a young reference group from Pichard et al study[73]
de Castro et al[46]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[74] ALMI (kg/m^2) by DXA, $<$1 SD of a young reference group from this study, cutoff 7.3 kg/m^2 for females
da Silva et al[47]	Cross-sectional	Survey: categorization of past PA based on yes/no SMI (kg/m^2) by BIA, cutoff 16.7 kg/m^2 adopted from Atkins et al study[75]
Domiciano et al[63]	Cohort[b]	An interviewer-mediated standardized questionnaire adapted from National Health Interview Survey Basic Questionnaire[76] RSMI (kg/m^2) by DXA, cutoff 5.45 kg/m^2 for females adopted from Baumgartner et al study[16]
Dutra et al[48]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[74,77] EWGSOP algorithm, SMI (kg/m^2) by the Lee equation,[78] cutoff 6.75 kg/m^2 for females adopted from Janssen et al study[79]
Figueiredo et al[64]	Cohort[b]	An interviewer-mediated standardized questionnaire adapted from National Health Interview Survey Basic Questionnaire[76] ASMMI (kg/m^2) by DXA, cutoff 7.26 kg/m^2 for males adopted from Baumgartner et al study[16]
Goodman et al[49]	Cross-sectional	Survey: average level of PA each day classified as: low, moderate, heavy SMI (kg/m^2) by DXA, sarcopenia class I $<$1SD of a young reference group from this study
Kim et al[30]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[77] ASMMI (kg/m^2) by DXA, $<$2 SD of a young reference group from this study, cutoff 6.52 kg/m^2 for males
Landi et al[50]	Cross-sectional	Minimum Data Set assessment form for the Nursing Home (MDS-NH)[80,81] EWGSOP algorithm, SMI (kg/m^2) by BIA, cutoff 8.87 kg/m^2 for males and 6.42 kg/m^2 for females adopted from NHANES III
Lau et al[51]	Cross-sectional	Survey: categorization of load-bearing exercise based on yes/no ASMMI (kg/m^2) by DXA, $<$2.0 SD of a young reference group from this study
Lin et al[52]	Cross-sectional	Survey: categorization of regular exercise habits based on yes/no EWGSOP algorithm, SMI (kg/m^2) by DXA, $<$2 SD of a young reference group from this study
Martinez et al[53]	Cross-sectional	Survey: categorization of PA prior admission less than 2$\times$ per week based on yes/no MMI (kg/m^2) by the Lee equation,[78] $\leq$20th percentile, cutoff 8.90 kg/m^2 for males and 6.37 kg/m^2 for females
Murphy et al[54]	Cross-sectional	Survey: PA was assessed according to kcal/wk spent by exercising in the prior week as: $<$500, 500–1,499, $>$1,500 kcal/wk ALMI (kg/m^2) by DXA, $\leq$20th percentile, cutoff 7.95 kg/m^2 for males and 6.24 kg/m^2 for females
Park et al[55]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[77] SMI (kg/m^2) by DXA, $<$2 SD of a young reference group from this study
Rolland et al[65]	Cohort[c]	Survey: categorization of recreational PA for $\geq$1 h/wk for the past month or more based on yes/no SMI (kg/m^2) by DXA, $<$2 SD of a reference population from the Rosetta Study,[82] cutoff 5.45 kg/m^2 for females

(*Continued*)

Table 2 (*Continued*)

Study	Design[a]	Classification of PA Sarcopenia diagnostics
Ryu et al[31]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[77] ASMMI (kg/m^2) by DXA, <2 SD of a young reference group from this study
Silva Alexandre et al[56]	Cross-sectional	International Physical Activity Questionnaire (IPAQ) – long version[74] EWGSOP algorithm,[17] SMI (kg/m^2) by the Lee equation,[78] ≤20th percentile, cutoff 8.90 kg/m^2 for males and 6.37 kg/m^2 for females
Tramontano et al[57]	Cross-sectional	Global Physical Activity Questionnaire (GPAQ)[83] IWGS criteria,[21] ASMMI (kg/m^2) by DXA, cutoff 7.23 kg/m^2 for males and 5.67 kg/m^2 for females
Volpato et al[58]	Cross-sectional	Survey: PA was divided as: low, moderate/high EWGSOP algorithm,[17] SMI (kg/m^2) by BIA, cutoff 8.87 kg/m^2 for males and 6.42 kg/m^2 for females according to EWGSOP[17]
Yu et al[66]	Cohort[d]	Physical Activity Scale of the Elderly (PASE)[84] EWGSOP algorithm,[17] SMI (kg/m^2) by DXA, the lowest quintile, cutoff 6.52 kg/m^2 for males and 5.44 kg/m^2 for females
Zeng et al[59]	Cross-sectional	Survey: engaging in physical exercise at least once a week and lasting for 30 min or more – yes/no AWGS criteria,[20] SMI (kg/m^2) by BIA

Notes: [a]As stated by the authors. [b]Follow-up dataset. [c]Baseline dataset. [d]Baseline to 2 years.

Abbreviations: PA, physical activity; EWGSOP, European Working Group on Sarcopenia in Older People; SMM, skeletal muscle mass; MAMC, mid-upper arm muscle circumference; SMI, skeletal muscle mass index; BIA, bioelectrical impedance analysis; FFMI, fat-free mass index; SD, standard deviation; ALMI, appendicular lean mass index; DXA, dual-energy X-ray absorptiometry; RSMI, relative skeletal muscle mass index; AWGS, Asian Working Group for Sarcopenia.

When combining males and females (nine studies), and after excluding two studies[49,55] through sensitivity analysis, data from the overall population (n=4,605) showed the strongest estimation with an OR (95% CI) of 0.45 (0.37–0.55), Cochran Q =8.1, df=6 (P=0.230) indicating that PA reduced the odds of patients suffering from sarcopenia. The test for overall effect was strong at Z=7.76 (P<0.00001), and heterogeneity was sufficiently acceptable I^2=26%. The forest plot from this analysis is presented in Figure 4.

Discussion

An emerging body of evidence shows that PA plays a preventive role against many diseases such as coronary heart disease, obesity, type 2 diabetes, hypertension, peripheral vascular disease, high cholesterol, osteoporosis, osteoarthritis, and chronic obstructive pulmonary disease. Data from our systematic review and meta-analysis, similar to that of previous authors,[14,15] also show that PA protects against sarcopenia. Our results are also in concordance with

Table 3 Relationship between sarcopenia and physical activity, according to multiple regression models

Study	N	Variable	Status	Multiple logistic regression models adjusted for	OR (95% CI)
Females					
Akune et al[29]	651	Current walking habits	Yes vs no	Age and BMI	0.75 (0.39–1.44)
		Exercise habits in middle age	Yes vs no	Age and BMI	0.55 (0.27–1.13)
Castillo et al[62]	1,006	Exercise 3+ times/wk	Yes vs no	Age, alcohol use, and current smoking status	0.51 (0.30–0.89)*
de Castro et al[46]	91	Physical activity level	–	Age, total cholesterol, LDL, HDL, diabetes, WHR, WC, CI, WHER, and BMI	0.54 (0.13–2.27)
Goodman et al[49]	374	Average level of physical activity each day	Moderate vs low	Unadjusted	1.30 (1.01–1.75)*
			Heavy vs low	Unadjusted	1.14 (0.40–4.23)
Ryu et al[31]	1,324	Physical activity level	Moderate vs low	Age	1.01 (0.65–1.57)
			High vs low	Age	0.76 (0.45–1.29)
Males					
Akune et al[29]	349	Current walking habits	Yes vs no	Age and BMI	0.60 (0.28–1.27)
		Exercise habits in middle age	Yes vs no	Age and BMI	0.48 (0.22–1.03)
Castillo et al[62]	694	Exercise 3+ times/wk	Yes vs no	Age, alcohol use, and current smoking status	0.77 (0.39–1.55)

(*Continued*)

Table 3 (*Continued*)

Study	N	Variable	Status	Multiple logistic regression models adjusted for	OR (95% CI)
Figueiredo et al[64]	399	Physical activity	Yes vs no	Age, BMI, race, smoking, and total femur bone mineral density	0.28 (0.08–0.95)*
Goodman et al[49]	551	Average level of physical activity each day	Moderate vs low	Unadjusted	0.79 (0.62–1.01)
			Heavy vs low	Unadjusted	0.57 (0.29–1.13)
Kim et al[30]	1,156	3 or more days of vigorous activity of at least 20 min per day	–	Age, BMI, smoking habit, alcohol drinking, family income, education, and protein intake	0.55 (0.23–1.31)
		5 or more days of moderate-intensity activity of at least 30 min/d	–	Age, BMI, smoking habit, alcohol drinking, family income, education, and protein intake	0.59 (0.26–1.36)
		5 or more days of walking of at least 30 min/d	–	Age, BMI, smoking habit, alcohol drinking, family income, education, and protein intake	0.49 (0.29–0.83)*
		Strength exercise: 2 or more days/wk	–	Age, BMI, smoking habit, alcohol drinking, family income, education and protein intake	0.59 (0.24–1.48)
		Flexibility exercise: 2 or more days/wk	–	Age, BMI, smoking habit, alcohol drinking, family income, education and protein intake	1.21 (0.61–2.40)
Ryu et al[31]	940	Physical activity level	Moderate vs low	Age	0.65 (0.41–1.04)
			High vs low	Age	0.29 (0.15–0.56)*
Females and males together					
Akune et al[29]	1,000	Current walking habits	Yes vs no	Age and BMI	0.69 (0.42–1.12)
		Exercise habits in middle age	Yes vs no	Age and BMI	0.53 (0.31–0.90)*
Beavers et al[45]	7,544	Physical activity level	High vs none	Age, BMI, protein intake, serum uric acid	0.80 (0.70–1.00)*
			Med vs none	Age, BMI, protein intake, serum uric acid	0.70 (0.60–1.00)*
			Low vs none	Age, BMI, protein intake, serum uric acid	0.80 (0.60–1.00)*
da Silva et al[47]	253	Past physical activity (PPA)	Yes vs no	Unclear	0.41 (0.20–0.82)*
Landi et al[50]	122	1 h or more exercises per day	Never or less than 1 h/d	Unadjusted	0.37 (0.12–0.99)*
Murphy et al[54]	2,355	Physical activity	500–1,499 vs <500 kcal/wk	Unclear	0.87 (0.70–1.06)
			>1,500 vs <500 kcal/wk	Unclear	0.77 (0.60–0.97)*
Yo et al[66]	3,142	PASE total score	–	Age, demographics, socioeconomic status, medical history, lifestyle factors, cognitive function, IADL impairments, and BMI	0.99 (0.98–0.99)*
Zeng et al[59,a]	461	Physical exercise	Yes vs no	Unclear	0.27 (0.09–0.79)*

Notes: [a]Sarcopenia was considered as low gait speed. *Statistically significant.
Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; PASE, Physical Activity Scale of the Elderly; LDL, low-density lipoproteins; HDL, high-density lipoproteins; WHR, waist-hip relation; WC, waist circumference; CI, conicity index; WHER, waist-height relation; IADL, instrumental activity of daily living.

Table 4 Relationship between sarcopenia and physical inactivity, according to multiple regression models

Study	Sex	N	Variable	Multiple logistic regression models adjusted for	Status	OR (95% CI)
Atkins et al[61]	Males	4,252	Physically inactive	Age	–	1.43 (1.15–1.76)*
Dutra et al[48]	Females	173	Sedentary	Crude	vs active	2.96 (1.23–7.12)*
Lau et al[51]	Males	262	Regular exercise	Age	No vs yes	1.51 (0.68–3.38)
	Females	265	Regular exercise	Age	No vs yes	1.10 (0.40–3.00)
Lin et al[52]	Together	761	Exercise	Crude	No vs yes	3.09 (1.98–4.82)*
			Exercise	Age, sex, marital status, regular exercise habits, comorbidity status	No vs yes	2.70 (1.66–4.41)*
Martinez et al[53]	Together	110	Physical activity less than 2× per week	Unclear		3.40 (1.10–10.90)*
Silva Alexandre et al[56]	Together	1,149	Sedentary lifestyle	Unclear	vs active lifestyle	0.66 (0.42–1.06)
Tramontano et al[57]	Together	222	Low physical activity levels	Unclear	Recommended physical activity levels	3.80 (1.30–10.90)*

Note: *Statistically significant.
Abbreviations: OR, odds ratio; CI, confidence interval.

Study or subgroup	Active events	Total	Inactive events	Total	Weight (%)	Odds ratio M–H, fixed, 95% CI	Odds ratio M–H, fixed, 95% CI
Aggio et al (2016)[60]	19	134	200	976	20.2	0.64 (0.39, 1.07)	
Akune et al (2014)[29]	22	232	26	117	15.3	0.37 (0.20, 0.68)	
Castillo et al (2003)[62]	26	514	17	180	11.7	0.51 (0.27, 0.97)	
Figueiredo et al (2014)[64]	39	349	15	50	11.4	0.29 (0.15, 0.59)	
Kim et al (2013)[30]	61	836	53	320	34.7	0.40 (0.27, 0.59)	
Lau et al (2005)[51]	20	121	12	52	6.8	0.66 (0.30, 1.47)	
Total (95% CI)		**2,186**		**1,695**	**100**	**0.46 (0.37, 0.58)**	
Total events	187		323				

Heterogeneity: χ^2=5.20, *df*=5 (*P*=0.39); I^2=4%
Test for overall effect: *Z*=6.50 (*P*<0.00001)

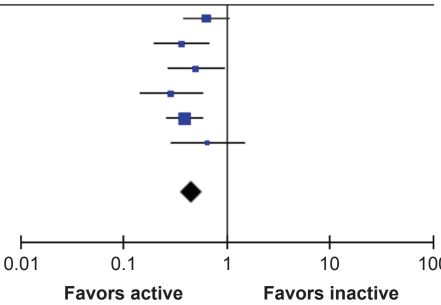

Figure 2 The forest plot of effect sizes for males.
Abbreviation: CI, confidence interval.

three recent meta-analyses: one including eight trials reporting that exercise can increase gait speed, balance, and activities of daily living in frail older adults,[67] another incorporating 19 trials that concluded that exercise has some benefits in frail older people,[68] and a third synthesizing data from 18 studies, which provided evidence that physical exercise therapy could improve mobility and physical functioning even among older patients with mobility problems and physical disability.[69] Although there is conformity among our work and these meta-analyses, it should be pointed out that the other meta-analyses were focused mostly on randomized controlled trials while our meta-analysis combined diverse studies of PA, which was typically identified by self-report. It is worth mentioning that the method of acquiring PA data largely varies among studies. In involved studies, some people performed PA such as regular housework, gardening, or did an occupational activity involving the carrying of light or heavy objects. They also occasionally walked, did slow swimming, played doubles tennis, volleyball, did vigorous exercise such as running, climbing, fast cycling, fast swimming, football, basketball, rope jumping, squash, and singles tennis. In the study of Aggio et al,[60] participants wore an accelerometer for 7 days during waking hours, which was removed only for water-based activities.

As seen in Table 2, many different methods were used to diagnose sarcopenia, which may result in increased risk of publication bias, which has been previously described.[70] For example, Goodman et al[49] used only one standard deviation below a young reference group as the cutoff value for diagnosing sarcopenia, which may have caused a large percentage of the population to be falsely identified as sarcopenic. Another weakness of our review was that we did not include subgroup analyses, as there were only a few studies for making subgroups according to sarcopenia diagnosing or several different physical activities as well as metabolic equivalent of task (MET). Therefore, we recommend that future research should unify diagnostic methods according to consensus. This may improve our knowledge of how PA plays a role in sarcopenia protection. Finally, it should be mentioned that we used only four databases and the terms "sarcopenia" and "physical activity" may not have unearthed 100% of the research in this area. However, we believe that despite this limitation, the review is beneficial, as it is the first systematic review and meta-analysis on the topic.

Study or subgroup	Active events	Total	Inactive events	Total	Weight (%)	Odds ratio M–H, fixed, 95% CI	Odds ratio M–H, fixed, 95% CI
Akune et al (2014)[29]	21	268	60	383	22.9	0.46 (0.27, 0.77)	
Castillo et al (2003)[62]	29	663	30	343	19.0	0.48 (0.28, 0.81)	
Goodman et al (2013)[49]	19	558	4	53	3.5	0.43 (0.14, 1.32)	
Lau et al (2005)[51]	11	105	8	67	4.4	0.86 (0.33, 2.27)	
Park et al (2014)[55]	48	678	189	2,333	39.7	0.86 (0.62, 1.20)	
Rolland et al (2009)[65]	10	326	26	457	10.5	0.52 (0.25, 1.10)	
Total (95% CI)		**2,598**		**3,636**	**100**	**0.65 (0.52, 0.81)**	
Total events	138		317				

Heterogeneity: χ^2=7.08, *df*=5 (*P*=0.21); I^2=29%
Test for overall effect: *Z*=3.79 (*P*=0.0001)

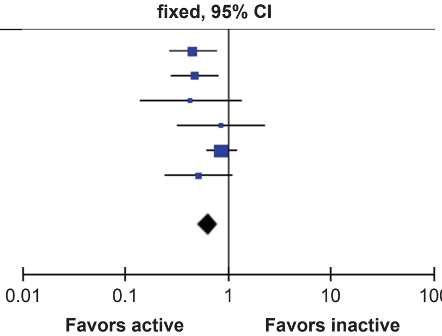

Figure 3 The forest plot of effect sizes for females.

Study or subgroup	Active events	Total	Inactive events	Total	Weight (%)	Odds ratio M–H, fixed, 95% CI
Akune et al (2014)[29]	43	500	86	500	28.4	0.45 (0.31, 0.67)
Castillo et al (2003)[62]	55	1,177	47	564	21.9	0.54 (0.36, 0.81)
Landi et al (2012)[50]	20	84	20	38	7.6	0.28 (0.13, 0.63)
Lau et al (2005)[51]	31	226	20	119	8.2	0.79 (0.43, 1.45)
Lin et al (2013)[52]	55	583	44	178	22.0	0.32 (0.20, 0.49)
Martinez et al (2015)[53]	4	34	19	64	4.2	0.32 (0.10, 1.02)
Volpato et al (2014)[58]	7	128	48	410	7.8	0.44 (0.19, 0.99)
Total (95% CI)		**2,732**		**1,873**	**100**	**0.45 (0.37, 0.55)**
Total events	215		284			

Heterogeneity: χ^2=8.05, *df*=6 (*P*=0.23); I^2=26%
Test for overall effect: *Z*=7.76 (*P*<0.00001)

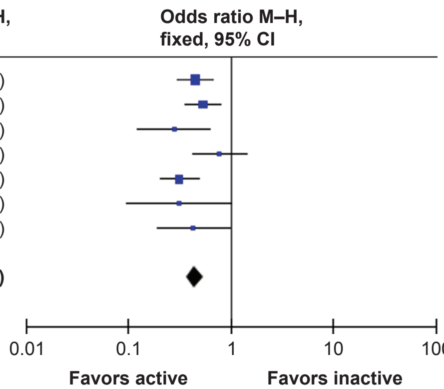

Figure 4 The forest plot of effect sizes for males and females.

In summary, when participants did at least some PA, they had better odds of avoiding sarcopenia. Our results support the recommendation of the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) that regular PA, including occupational activity, aerobic sport activity, and muscle-strengthening activity, is essential for healthy aging.[71]

Most likely, the association between PA and the protection of muscle mass is common sense. However, this is the first systematic review and meta-analysis to confirm this association on the basis of cross-sectional and cohort studies. Moreover, it seems that the type of PA that is undertaken is not important, because except for one study that showed an association between PA and worsening sarcopenia, studies including several different PA showed that PA acts as a protective factor against sarcopenia.

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Disclosure

The authors report no conflicts of interest in this work.

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