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Review Article

Effect of exercise intervention on elderly patients with sarcopenia: a meta-analysis

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Abstract: Objective: To investigate the effects of exercise on muscle mass and strength in elderly sarcopenia patients through a meta-analysis. Methods: Randomized controlled trials (RCTs) on exercise interventions for elderly patients with sarcopenia were retrieved from the Web of Science, PubMed, Cochrane Library, ProQuest, EBSCOhost, Scopus, EMBASE, China National Knowledge Infrastructure (CNKI), and Chinese Science and Technology Periodical Database (VIP) published between 2015 and 2025. The Cochrane Risk of Bias tool was used to assess the quality of studies, and the RevMan 5.3 software was applied for the meta-analysis. Subgroup analyses were performed to evaluate the effect of different exercise intervention protocols on the outcome measures. Results: A total of 15 studies involving 902 participants were included in this study, with 527 receiving exercise intervention. Meta-analysis results indicated that exercise intervention significantly improved skeletal muscle index (MD = 0.25, 95% CI: 0.13-0.39), knee extension strength (KES) (SMD = 0.64, 95% CI: 0.46-0.81), walking speed (SMD = 0.54, 95% CI: -0.10 to 1.18), TUG (MD = -1.38, 95% CI: -1.73 to -1.02), and handgrip strength (SMD = 0.52, 95% CI: 0.29 to 0.75). Subgroup analysis of the modality and frequency of exercise intervention for the measure of handgrip strength indicated that both RT and AT+RT increased handgrip strength in elderly sarcopenic patients without any significant between-group difference. Both exercise frequency of ≥ 3 times/week and < 3 times/week showed an improvement in handgrip strength. Conclusion: Exercise interventions can increase muscle mass and strength in people suffering from sarcopenia and enhance their quality of life. Nonetheless, additional research is required to confirm these results and refine specific protocols for implementation.

Keywords: Exercise, elderly, sarcopenia, meta-analysis

Introduction

Sarcopenia refers to loss of muscle mass and strength with aging or reduced energy expenditure [1]. Falls are the leading cause of injury-related hospitalization and mortality among older adults, with their prevalence increasing with age. About 29% of community-dwelling older adults experience falls, and the rate is even higher among inpatients, individuals with multiple chronic conditions, or nursing home residents [2]. Evidence indicates that exercise improves health outcomes in older adults by lowering total and abdominal fat levels, increasing limb muscle mass and bone density, thereby preventing or delaying the occurrence of sarcopenia and its complications [3]. In contrast, physical inactivity accelerates muscle loss and function decline, contributing to higher incidence and disability rates with aging. Therefore, maintaining muscle health through adequate exercise is essential [4]. However, the optimal type, duration, and intensity of exercise for preventing, delaying, or alleviating sarcopenia in older adults remain unclear. This meta-analysis aims to determine the most effective exercise interventions for older adults.

Materials and methods

Literature search

Randomized controlled trials (RCTs) on exercise interventions for sarcopenia in older adults were retrieved from the Web of Science, PubMed, Cochrane Library, ProQuest, EBSCOhost, Scopus, EMBASE, China National Knowledge Infrastructure (CNKI), and Chinese

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Science and Technology Periodical Database (VIP), covering the period from 2015 to 2025. Search strategy: (((sport OR exercise OR training OR physical activity OR physical therapy OR exercise therapy OR remedial exercise)) AND (Older OR Elder OR Aged OR Elderly)) AND (randomized controlled trial OR randomized) AND (Sarcopenia OR sarcopenias). This study was registered with PROSPERO (CRD420251182278).

Inclusion and exclusion criteria for literature

Inclusion criteria: (1) Aged ≥ 60 years; (2) Diagnosis of sarcopenia based on established criteria (assessment methods may vary) [5, 6]; (3) One or more exercise interventions in intervention groups, normal daily activities or non-exercise interventions (e.g., health education) in the control group; (4) Outcomes including skeletal muscle index (SMI), knee extension strength (KES), walking speed, timed up-and-go (TUG) test, and handgrip strength; (5) RCTs.

Exclusion criteria: (1) Conference abstracts, newspaper articles, laboratory studies, or review articles; (2) Non-RCTs; (3) Studies without available full text or with incomplete outcome data.

Data extraction

Using EndNote software, titles and abstracts were independently reviewed to decide study relevance. Full texts of potentially eligible articles were then assessed in detail. The data extracted included authors, publication year, sample size, participant age, descriptions of interventions and controls (e.g., exercise type, intensity, frequency, duration), and outcome measures.

Literature quality assessment

In line with the principles of the Cochrane Handbook, the included studies were comprehensively assessed by the two researchers independently. Any disagreement was resolved through discussion or consultation with a third reviewer. The risk of bias in each RCT was evaluated using Cochrane Risk of Bias Tool (RoB2), covering ① bias in randomization process; ② bias due to deviations from the intended intervention; ③ bias resulting from missing outcome data; ④ bias in outcome measurement; ⑤ bias from selective reporting of results. Each domain was rated as “high risk”, “low risk”, or “unclear”.

Statistical analysis

Data were analyzed using Review Manager 5.3 (RevMan, Cochrane Collaboration, http://ims.cochrane.org/revman). Heterogeneity was assessed using the I^2 statistic and the Q test. When $P \geq 0.1$ and $I^2 \leq 50\%$, heterogeneity considered insignificant, and a fixed-effects model was used; when $P < 0.1$ and $I^2 > 50\%$, a random-effects model was applied. Weighted mean difference (WMD) was used for outcomes measured with the same units; otherwise, the standardized mean difference (SMD) was used. Statistical significance was defined as $P < 0.05$, and 95% CI was reported for all effect sizes. Funnel plots were used to check publication bias.

Results

Search results

The initial search identified 1,269 studies. Of these, 132 duplicate publications were excluded, 581 were removed for other reasons, and 63 studies were selected for full-text review. Ultimately, 15 RCTs were included in this meta-analysis (**Figure 1**).

Study characteristics

A total of 15 RCTs involving a total of 902 participants were published between 2017 and 2024, of which 527 engaged in exercise interventions. The mean age of participants ranged from 63.8±3.6 to 79.9±7.2 years. Eight studies included both men and women, six focused exclusively on women, and one included only elderly male patients. Data extraction details are shown in **Table 1**.

Summary of risk of bias

All studies addressed selection bias by reporting how random sequences were generated, with 14 out of 15 trials also reporting allocation concealment [7-20]. None of the studies concealed the research purpose from participants, leading to a high risk of performance bias, which is a common challenge in RCTs of exercise intervention. Ten studies

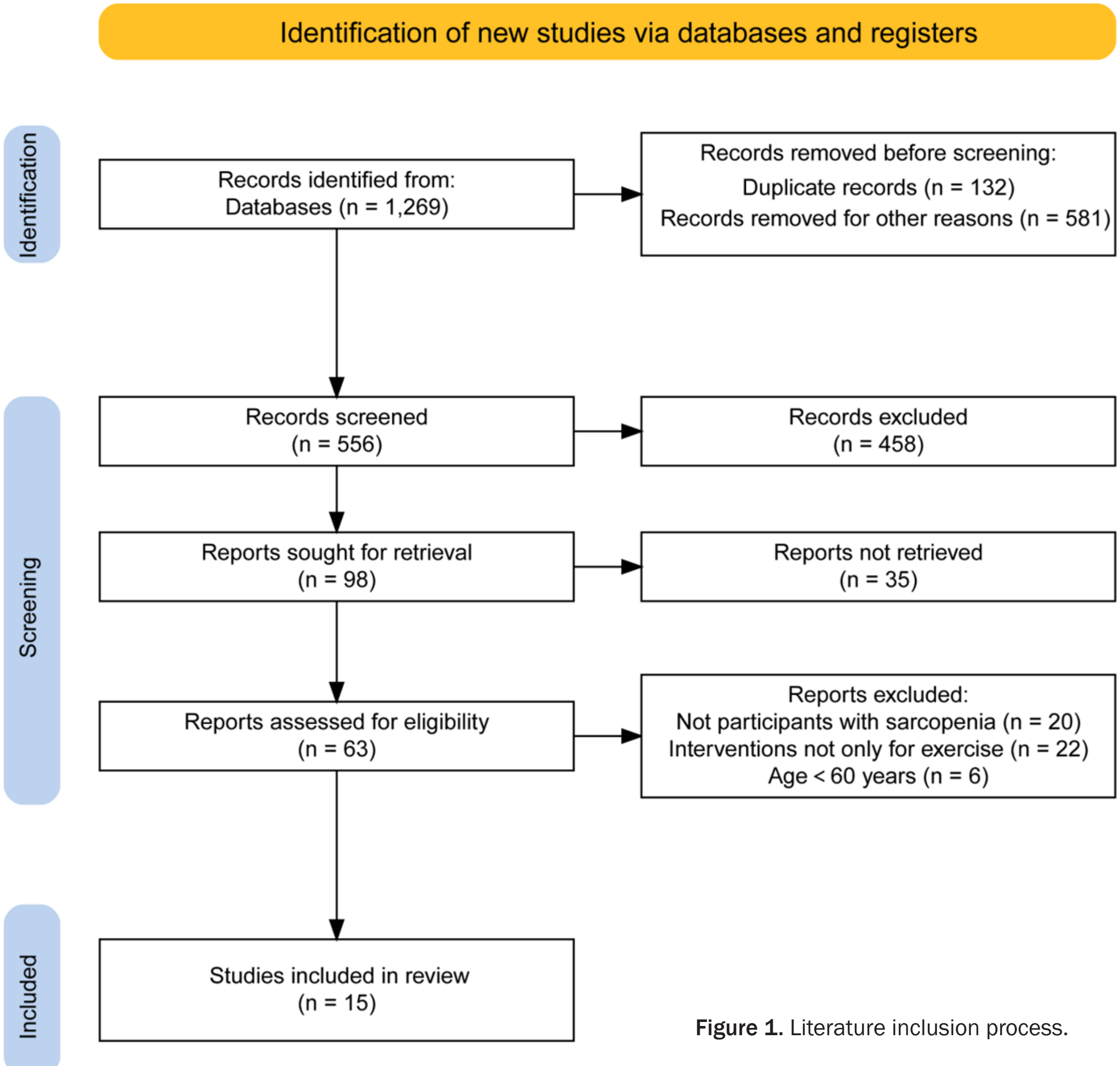

Figure 1. Literature inclusion process.

blinded participants to outcome assessments [8, 9, 12, 14, 15, 17-21], and four studies were at high risk of detection bias [10, 11, 13, 16]. Furthermore, all studies showed a low risk of reporting bias and other biases (**Figure 2A**, **2B**).

Effects of exercise on muscle function and physical performance

Handgrip strength: A total of 12 studies [7-12, 14, 16, 18-21] reported the effects of exercise on grip strength, with I^2 = 61% and P = 0.0005, thus requiring a random-effects model. Due to varying outcome measures for grip strength (dominant hand, non-dominant hand, both hands), the effect size was calculated using standardized mean difference (SMD) (SMD = 0.52, 95% CI: 0.29-0.75, P < 0.001). This confirmed that exercise interventions significantly improved grip strength (**Figure 3**).

Subgroup analyses examined differences across different exercise modalities and frequencies (**Figure 4A**, **4B**). Results showed that resistance training (RT) (MD = 2.18, 95% CI: 1.09-3.27, P < 0.001) and aerobic training in combination with resistance training (AT+RT) (MD = 1.84, 95% CI: 0.64-3.04, P < 0.001) both significantly improved grip strength in elderly sarcopenic patients. Similarly, both exercise frequency of ≥ 3 times/week (MD = 1.64, 95% CI: 0.73-2.56, P < 0.001) and < 3 times/week (MD = 2.37, 95% CI: 0.91-3.83, P = 0.001) increased grip strength in elderly patients with sarcopenia.

Table 1. General characteristics of included studies

Author	Year	Sex (male/female)		Age (years)		Exercise Program		Exercise Intensity/ Frequency	Exercise Time	Main Outcomes
		Intervention	Control	Intervention	Control	Intervention	Control			
Hongzhi Guo [18]	2024	14/19, 13/17	16/14	66.94±4.42, 66.87±3.84	65.42±3.97	TC+ST/ST	general physical activities	moderate-intensity load	24 weeks	①③
Minjing Liu [19]	2024	12/29	18/27	74.2±4.67	75.6±6.35	HT RT+AT	general physical activities	Adjusted for RPE scores and HR	12 weeks	①②③④⑤
Vanessa R. Dos Santos [17]	2024	0/20	0/20	68.4±6.9	69.3±7.4l	RT	No control	2/3 times per week	18 weeks	①⑦
Mei Zhang [20]	2024	6/5	7/3	73.15±4.22	71.25±3.15	RT	No control	high-intensity/low-load	12 weeks	②③④
Cristina Flor-Rufino [15]	2023	0/20	0/18	79.9±7.2	79.6±7.7	RT	general physical activities	high-intensity 2 times per week	24 weeks	⑥⑦
Pablo Valdés-Badilla [16]	2023	0/21, 0/19	0/40	73.91±8.27, 72.85±8.67	73.26±8.35	RT/group-based dance	general physical activities	3 times per week	12 weeks	①④⑤
Yuta Otsuka [14]	2022	8/8,8/9	9/8	63.6±8.1, 63.5±8.3	63.5±8.5	RT	general physical activities	3 times per week	24 weeks	①⑦
Myong-Won Seo [21]	2021	0/12	0/10	70.3±5.38	72.9±4.75	RT	general physical activities	3 times per week	16 weeks	①③④⑤
Wolfgang Kemmler [13]	2020	19/0	22/0	77.8±3.6	79.2±4.7	RT	general physical activities	Personalized Customization	8-12 weeks	②③
Sanna Vikberg [11]	2019	16/20	16/18	70.9±0.28	70.0±0.29	RT	general physical activities	Moderate to high RT	10 weeks	①④⑤
LiuYing Zhu [12]	2019	8/29, 11/29	7/29	72.2±6.6, 74.5±7.1	74.8±6.9	AT+RT	maintain daily lifestyle	2 times per week	12 weeks	①②③④
S. Tsuzuku [10]	2018	25/17	26/18	72.5±2.1	73.2±2.1	SRT-BW	general physical activities	15 min per day	12 weeks	①②
Chun-De Liao [9]	2018	0/33	0/23	66.67±4.54	68.32±6.05	RT	general physical activities	3 times per week	12 weeks	①②④⑤⑥
Hung-Ting Chen [7]	2017	3/12, 1/14, 4/11	2/13	68.9±4.4, 69.3±3.0, 68.5±2.7	68.6±3.1	RT/AT/RT+AT	general physical activities	2 times per week	8 weeks	①②
Chun-De Liao [8]	2017	0/25	0/21	66.39±4.49	68.42±5.86	Progressive RT	general physical activities	3 times per week	12 weeks	①③④⑤

Note: AT: aerobic training; RT: resistance training; ET: endurance training; ST: strength training; HT: home therapeutic exercise; TC: tai chi; RPE: rating of perceived exertion; SRT-BW: slow movement resistance training using body weight as a load. Outcomes: ① Handgrip strength; ② Knee extension strength; ③ Skeletal Muscle Index; ④ Walking speed; ⑤ Timed Up and Go Test; ⑥ Quality of life; ⑦ Muscle mass.

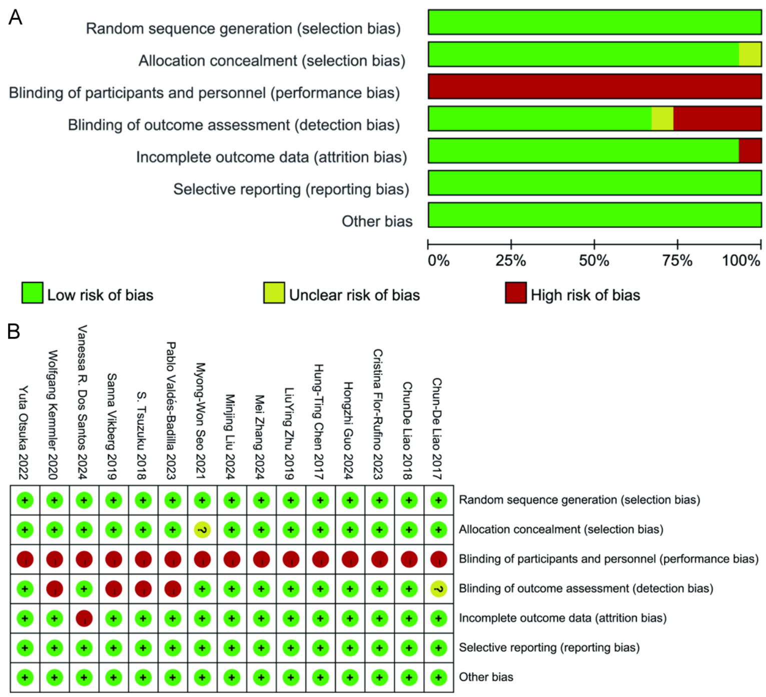

Figure 2. Quality assessment of included studies. A: Weighted Risk of Bias Evaluation; B: Summary of Bias. Note: Green shows low risk of bias, yellow indicates unclear risk, and red signifies high risk of bias.

KES: Seven studies [7, 9, 10, 12, 13, 19, 20] reported the effects of exercise on KES. Heterogeneity was low, with I^2 = 21% and P = 0.25, thus, a fixed-effects model was adopted. Since KES was reported in different units (e.g., Nm, kg), the SMD was used to determine the effect size (SMD = 0.64, 95% CI: 0.46-0.81, P < 0.001), indicating that exercise interventions effectively improved knee muscle strength (**Figure 5**).

SMI: A total of 7 studies [7, 12, 13, 18-21] reported the effects of exercise on skeletal muscle index. With I^2 = 32% and P = 0.16, a fixed-effects model was used. The pooled effect size (MD = 0.25, 95% CI: 0.13-0.39, P < 0.001) showed that exercise intervention effectively increased the SMI (**Figure 6**).

Walking speed: A total of 8 studies [8, 9, 11, 12, 16, 19-21] reported the effects of exercise on walking speed. With I^2 = 91% and P < 0.001, a random-effects model was used. Due to differences in gait speed measurement endpoints (e.g., 3-meter test, 6-meter test), the SMD was applied to calculate effect size (SMD = 0.54, 95% CI: -0.10 to 1.18, P = 0.10), suggesting that exercise interventions had a limited effect on gait speed in elderly patients with sarcopenia (**Figure 7**).

A sensitivity analysis of walking speed was further conducted. After excluding two studies using a 6-meter walk test [12, 19] and one study using two 4-meter fast-walk test without sprinting [16], heterogeneity decreased markedly (I^2 = 0%, P = 0.51). The pooled effect size demonstrated that exercise intervention effectively improved walking speed in elderly patients with sarcopenia (SMD = 1.57, 95% CI: 1.26-1.89, P < 0.001) (**Figure 8**).

TUG test: A total of 6 studies [8, 9, 11, 16, 19, 21] reported the effects of exercise on TUG test. Low heterogeneity (I^2 = 12% and P = 0.34) supported the adoption of a fixed-effects model. The pooled effect size suggested that exercise intervention effectively shortened the duration of the TUG test (MD = -1.38, 95% CI: -1.73 to 1.02, P < 0.001) (**Figure 9**).

Publication bias

Funnel plots were generated for SMI, KES, walking speed, TUG test, and grip strength (**Figure 10A-E**). The results showed partial asymmetry in the walking speed funnel plot (**Figure 10C**), indicating possible publication bias. The other funnel plots appeared nearly symmetric, suggesting a relatively low likelihood of publication bias.

Discussion

In this meta-analysis, 16 RCTs evaluating the effects of various exercise programs on muscle strength and physical performance in older adults with sarcopenia were analyzed. The results demonstrated that exercise significantly improved SMI, grip strength, and overall functional performance.

At present, multiple diagnostic criteria for sarcopenia are available. Many organizations,

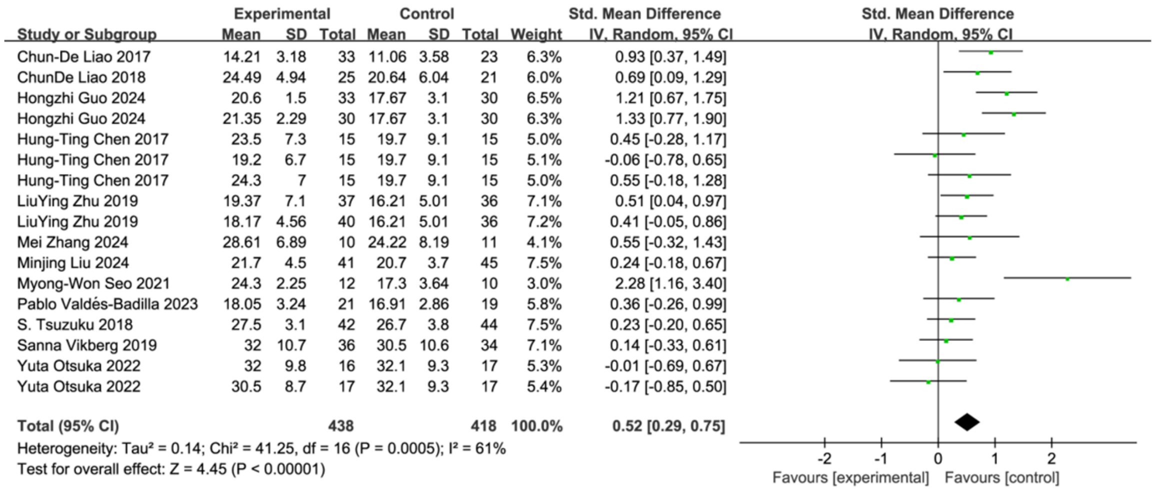

Figure 3. Forest plot illustrating the effects of various exercise intervention programs on handgrip strength.

including the Asian Sarcopenia Working Group [6], the European Working Group on Sarcopenia in Older People [22], and the International Sarcopenia Working Group [23] have defined and established diagnostic criteria for sarcopenia. Although no unified consensus has been reached yet, these organizations consistently recognize muscle mass, muscle strength, and physical function as core diagnostic components of sarcopenia [24].

Currently, muscle strength is considered the most valid measure of muscle function, with grip strength being one of the defining measures. Over the past few decades, the conceptualization of sarcopenia has shifted from assessment of muscle mass to the evaluation of muscle strength and physical function [25]. It is important to note that muscle strength declines faster than muscle mass with advancement in age. Consequently, grip strength has emerged as a strong predictor of various adverse outcomes. In this study, all exercise interventions produced significant improvement in grip strength when compared to the control group. Further subgroup analysis of exercise modalities revealed that both resistance training alone and combined resistance-aerobic training significantly enhanced patients' grip strength. This discrepancy may stem from aerobic exercise's limited effect on grip strength enhancement. Earlier research indicates that resistance training significantly improves grip strength [26]; meanwhile, another study has shown that grip strength is enhanced after a combination of resistance and aerobic training in elderly patients with sarcopenia [16]. This study found that patients' grip strength improved significantly regardless of exercise frequency, whether ≥ 3 times per week or < 3 times per week. This shows that more research and development of effective exercise programs to improve grip strength in the elderly are warranted.

KES is an important indicator of lower limb muscle strength and is related to performance and fall risk [27]. According to our results, we found that exercise interventions significantly improved KES. This finding supported earlier evidence that resistance and aerobic training are effective for enhancing KES [28]. Differences in characteristics of the population explain the various findings. Compared to younger people, older people may respond more slowly to resistance training due to their physiological processes [29]. The balance of protein synthesis and breakdown determines the rate of muscle mass gain [30]. In older individuals, a decrease in physical activity levels is accompanied by a slower metabolism of muscle cells along with reduced protein synthesis and metabolism. Moreover, many patterned diseases, like inflammatory disease, respiratory diseases, endocrine disease, and other chronic diseases, also lower protein synthesis rate in elderly people [31]. As stated before, older adults with sarcopenia tend to have decreased physical function and lower tolerance for high-intensity exercise [32]. Moreover,

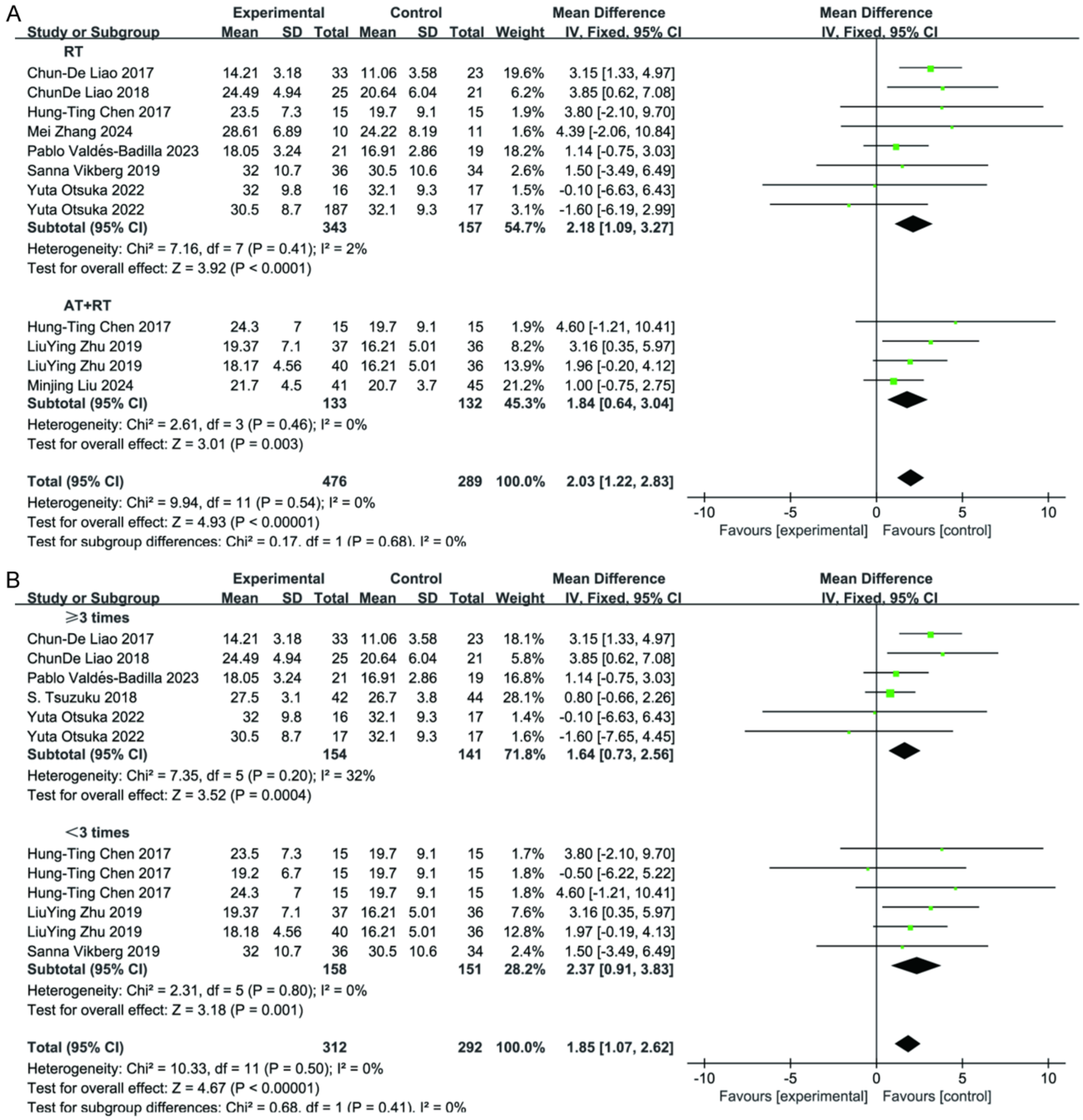

Figure 4. Subgroup analysis of grip strength. A: Various Exercise Intervention Programs; B: Different Exercise Frequencies.

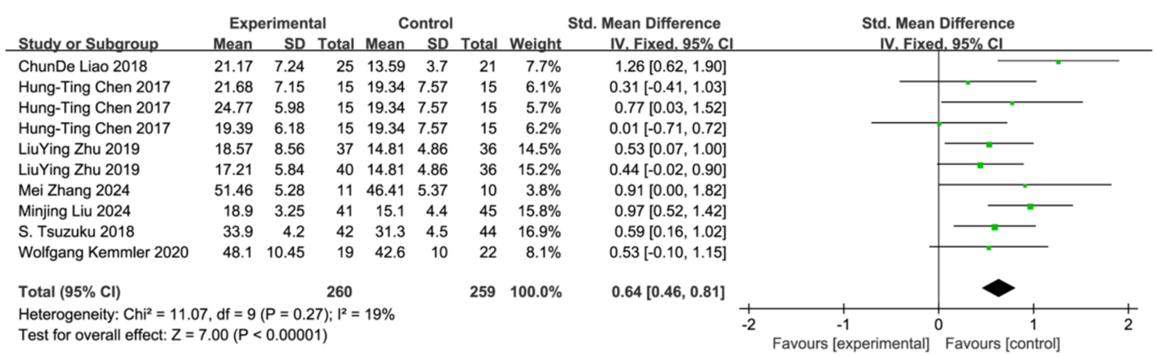

Figure 5. Forest plot illustrating the effects of various exercise intervention programs on KES. Notes: KES: knee extension strength.

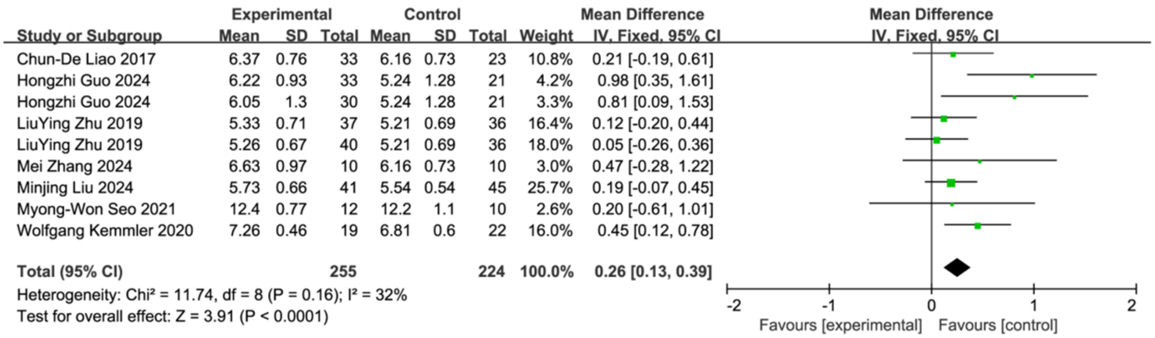

Figure 6. Forest plot displaying the effects of various exercise intervention programs on SMI. Notes: SMI: skeletal muscle index.

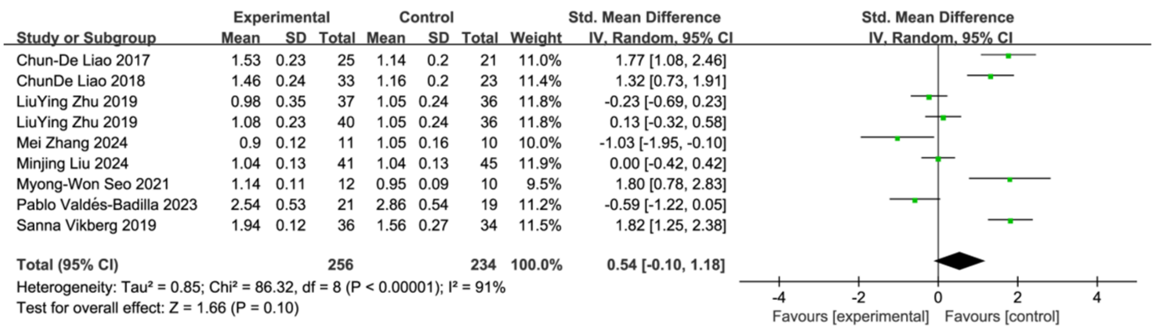

Figure 7. Forest plot displaying the effects of various exercise intervention programs on walking speed.

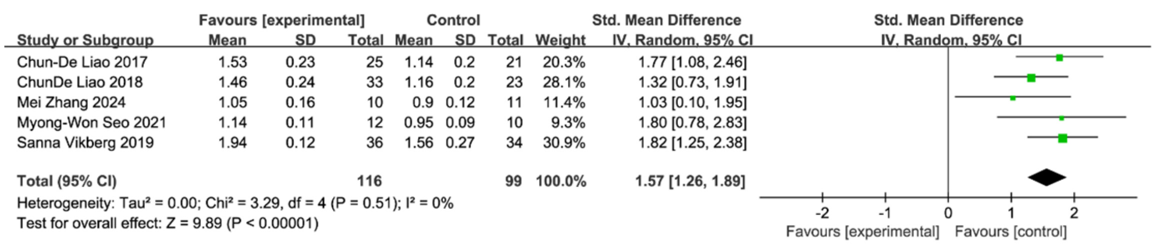

Figure 8. Sensitivity analysis of walking speed.

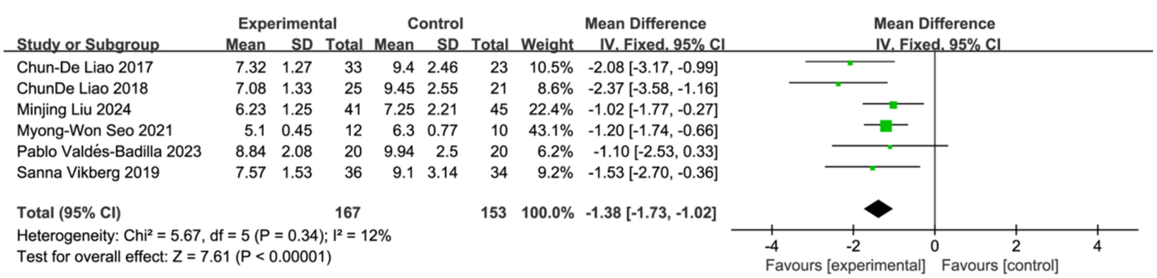

Figure 9. Forest plot showing the effects of different exercise intervention programs on the TUG test. Notes: TUG: timed up and go.

there is substantial evidence that the intensity of exercise affects the muscle protein synthesis [33]. This impact determines the muscle mass gain amounts in sarcopenic older adults.

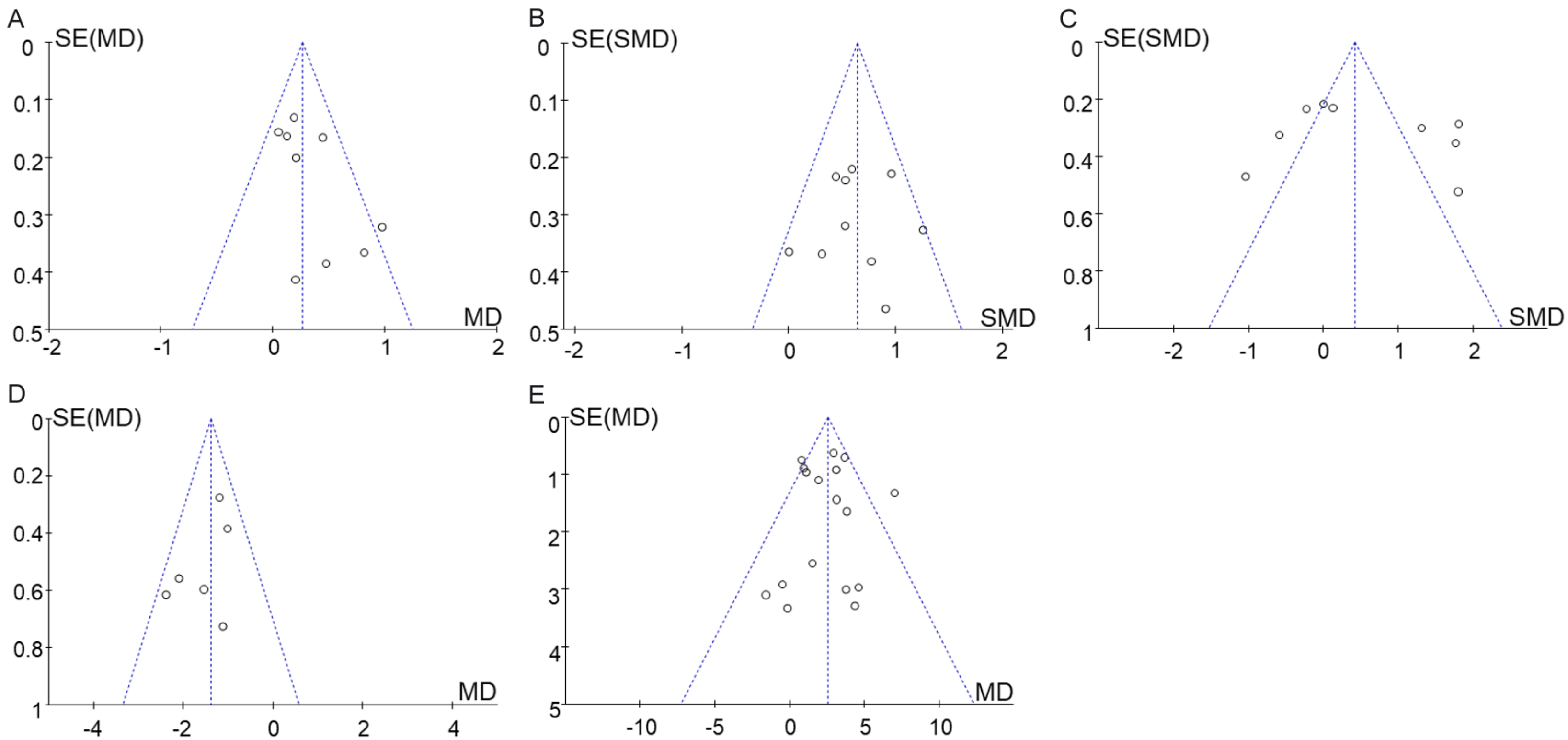

Figure 10. Funnel chart. A: SMI; B: KES; C: Walking speed; D: TUG; E: Handgrip strength. Notes: SMI: skeletal muscle index; KES: knee extension strength; TUG: timed up and go.

According to various guidelines, gait speed is an essential measure of physical function that should be included in all consensus guidelines for sarcopenia diagnosis. However, it varies in importance and role in clinical diagnosis [6]. Our findings confirm that exercise can improve walking speed among the target population, which is in line with existing research [34]. Another cross-sectional analysis showed that exercise intervention improved patients' walking speed in the 3-meter step test [35]. However, there is a significant heterogeneity in the studies included, which is predominantly due to the walking speed testing parameters of different studies, such as starting position, walking distance and endpoint configuration, which can skew the results of the study.

The TUG test, which includes standing, walking, turning, and sitting, provides overall assessment of gait, transfer ability, flexibility, and dynamic balance [36]. The TUG test consists of several movement components, therefore it can be influenced by various factors, such as cognitive impairment and balance problems, which makes the test a complex yet essential indicator of overall physical function [37]. Improvements in TUG test performance therefore reflects a broader enhancement in physical capacity. Consistent with earlier findings [26], our findings indicate that exercise training can improve TUG times.

Nevertheless, this study has several limitations that may limit the applicability of its findings. To begin with, most RCTs included were of low methodologic quality, and several exhibited risks of operational and detection bias due to inadequate blinding, which may have compromised the validity of the results. Second, most studies were female-predominant, which may have limited their generalizability. Finally, the small number of eligible studies warrants caution when interpreting the pooled outcomes.

Conclusion

Exercise interventions effectively improve muscle mass, strength, and physical function in elderly people with sarcopenia. Both resistance training and its combination with aerobic exercise has proven to be effective clinical interventions in this population. Exercise routines should be customized based on an individual's health conditions and needs. These findings support incorporating structured exercise into routine management of sarcopenia, while more high-quality trials are needed to refine recommendations and guide clinical practice.

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Disclosure of conflict of interest

None.

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