

Effects of Progressive Resistance Training on Muscle Mass, Muscle Strength, and Physical Function in Elderly Patients with Sarcopenia

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ABSTRACT

This systematic review and meta-analysis evaluates the effects of progressive resistance training (PRT) on muscle mass, muscle strength, and physical function in elderly patients with sarcopenia. Eleven randomized controlled trials involving 316 participants were included. The results indicate that PRT significantly improves grip strength (SMD = 3.22, 95% CI: 2.62–3.82, $P < 0.00001$), gait speed (SMD = 0.51, 95% CI: 0.27–0.75, $P < 0.00001$), and skeletal muscle index (SMD = 0.39, 95% CI: 0.07–0.72, $P = 0.02$). However, PRT did not show significant effects on chair stand time or the Short Physical Performance Battery (SPPB) score. The findings suggest that PRT is a feasible and effective intervention for improving certain aspects of sarcopenia in the elderly, though its impact on comprehensive physical function requires further investigation.

KEYWORDS

Sarcopenia; Progressive resistance training; Elderly; Muscle strength; Meta-analysis

1. INTRODUCTION

Sarcopenia is defined as a pathological condition characterized by reduced muscle mass, diminished muscle function, and decreased physical performance. Clinically, patients present with symptoms such as slow gait, walking difficulty, frequent falls, and generalized weakness [1, 2]. Sarcopenia represents a significant global public health issue [3]. It is estimated that there are currently about 50 million individuals with sarcopenia worldwide, and this number is projected to reach 500 million by 2050 [4]. Cruz et al. reported that the prevalence of sarcopenia in elderly community residents is as high as 29%, while among elderly patients in care institutions it reaches 33% [1]. Sarcopenia can lead to functional impairment, weakness, fatigue, falls, fractures, hospitalization, various comorbidities (such as osteoporosis and diabetes), mortality, reduced quality of life, and imposes a substantial economic and social burden [5–7]. The escalating prevalence of sarcopenia poses challenges to healthcare, financial, and social welfare systems in various regions, placing considerable caregiving pressure on society and families. A study on public healthcare expenditures in the United States reported that sarcopenia costs approximately \$18.5 billion annually (\$10.8 billion for men, \$7.7 billion for women), accounting for about 1.5% of total direct healthcare costs [8]. This suggests that reducing the prevalence of muscle atrophy by 10% could save approximately \$1.1 billion per year, not even considering the indirect costs of muscle atrophy, such as lost productivity for individuals and caregivers [8]. A European study found that muscle atrophy increases hospital care costs per patient by €884, equivalent to a 58.5% increase in expenditure [9]. Even among hospitalized older adults, those admitted with sarcopenia incur more than five times the hospitalization costs compared to those without sarcopenia [10]. Thus, sarcopenia places a tremendous burden on healthcare resources.

Preventing and treating sarcopenia holds profound significance for improving the quality of life of middle-aged and older adults and alleviating societal burdens [11].

Progressive Resistance Training (PRT) is an exercise regimen that involves gradually increasing resistance loads during training to continuously stimulate muscles for adaptive improvements in strength [12]. It is recognized as an effective and safe intervention strategy for enhancing physical fitness in the elderly [13]. For instance, Chien et al. conducted a 12-week home-based low-intensity progressive resistance training program for older adults with possible sarcopenia. The results showed that the intervention group demonstrated significant improvements in muscle strength, physical function (e.g., performance in the five-time sit-to-stand test), limb muscle mass, and calf circumference, with a high exercise adherence rate of 82% [14]. This indicates that progressive resistance training not only effectively enhances muscle strength and mass and improves physical performance [13], but is also safer and more suitable for frail older adults [15].

Currently, several studies have reported on the use of progressive resistance training in the treatment of sarcopenia in the elderly, but there remains controversy regarding its effects on physical function, muscle mass, and muscle strength. Therefore, this study aims to conduct a systematic review and meta-analysis to synthesize existing research findings and quantitatively evaluate the effects of progressive resistance training on physical function, muscle strength, and muscle mass in elderly patients with sarcopenia. The goal is to provide new evidence-based insights into the efficacy of progressive resistance training in preventing and improving sarcopenia in the elderly.

2. MATERIALS AND METHODS

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

2.1. Search Strategy

Two independent reviewers performed a systematic search using relevant keywords, which were constructed based on the PICOS framework to ensure comprehensive coverage. Optimized search strategies were applied to the following electronic databases to identify articles published up to July 2024: PubMed, Cochrane Library, Scopus, and Web of Science. The search strategies combined Medical Subject Headings (MeSH) terms and free-text keywords, tailored to the specific requirements of each database. The detailed search strategies are presented in Table 1.

Table 1. Search strategies for different databases

Database	Search Strategy
Cochrane	#1 MeSH descriptor: [Aged] explode all trees #2 aged OR elder OR elderly OR aging OR Senescence #3 #1 OR #2 #4 MeSH descriptor: [] explode all trees #5 Progressive resistance training OR PRT #6 sarcopenia OR hypomyositis OR hypomyalgia #7 MeSH descriptor: [Sarcopenia] explode all trees #8 #6 OR #7 #9 #4 OR #5 #10 #3 AND #8 AND #9
Pubmed	((((Resistance Training [MeSH Major Topic]) OR (Resistance Training [Title/Abstract] OR Strength Training [Title/Abstract])) AND ((balance training [MeSH Major Topic]) OR (Equilibrium training [Title/Abstract] OR balance training [Title/Abstract]))) AND (((((aged [MeSH Terms]) OR (aged [Title/Abstract])) OR (aging [Title/Abstract])) OR (elder [Title/Abstract])) OR (elderly [Title/Abstract])) OR (Senescence [Title/Abstract]))) AND (((healthy [MeSH Terms]) OR (healthy [Title/Abstract])) OR (well [Title/Abstract])) OR (fine [Title/Abstract]))
Scopus	(TITLE-ABS-KEY ("aged" OR "aging" OR "elder" OR "elderly" OR "Senescence") AND TITLE-ABS-KEY ("Resistance Training" OR "Strength Training") AND TITLE-ABS-KEY ("balance training" OR "Equilibrium training") AND TITLE-ABS-KEY ("healthy" OR "well" OR "fine"))
Web of science	((TS=(aged OR aging OR elder OR elderly OR Senescence)) AND TS=(balance training OR Equilibrium training)) AND TS=(Resistance Training OR Strength Training) AND TS=(healthy OR well OR fine)

2.2. Inclusion and Exclusion Criteria

2.2.1. Inclusion Criteria

The PICOS framework was followed to determine which studies would be included in this systematic review. Each study had to meet all of the following inclusion criteria:

- (1) Study type: Randomized controlled trial (RCT).
- (2) Participant type: Participants meeting the diagnostic criteria for sarcopenia as defined by the European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group for Sarcopenia (AWGS), and aged 60 years or older.
- (3) Intervention type: Progressive resistance training.
- (4) Outcome measures: At least one of the following outcome measures had to be reported: grip strength, gait speed, chair stand test, skeletal muscle index (SMI), or Short Physical Performance Battery (SPPB) score.
- (5) Language: English.

2.2.2. Exclusion Criteria

- (1) Studies without an experimental design (e.g., longitudinal observational studies, systematic reviews, etc.).

- (2) Studies where the intervention was not purely progressive resistance training or not a single-therapy intervention (e.g., progressive resistance training combined with other exercise interventions, progressive resistance training combined with nutritional supplements, etc.).
- (3) Studies including participants with sarcopenia who were under 60 years of age.
- (4) Studies for which full text was unavailable, or which were commentaries, conference papers, or dissertations.
- (5) Studies with incomplete outcome data.
- (6) Animal studies.

2.3. Study Selection and Data Extraction

During the screening process, two independent reviewers independently screened the literature, extracted data, and cross-checked their work. Potentially relevant articles were initially identified based on their titles and abstracts. After excluding obviously irrelevant studies, the full texts of the remaining articles were retrieved and reviewed in detail to determine final inclusion. The basic information extracted from each included study primarily included: author(s), publication year, sample size, participant sex, participant age, intervention details, intervention duration, intervention intensity, and frequency. Any disagreements between the two reviewers were resolved through discussion and consensus. If necessary, a third reviewer was consulted to make a final decision.

2.4. Quality Assessment

The same two reviewers used the Cochrane Risk of Bias tool (version 5.1.0) to assess the risk of bias in the included two-arm randomized controlled trials. The evaluation covered the following domains: randomization, allocation concealment, blinding, completeness of outcome data, selective reporting, and other potential biases. The risk of bias for each domain was categorized as "low risk," "high risk," or "unclear risk." Studies were classified as Grade A if all domains were rated as "low risk," Grade B if some domains were rated as "low risk," and Grade C if no domains were rated as "low risk."

2.5. Statistical Methods

Meta-analysis was conducted using RevMan 5.3 software. Since all outcome measures included in this study were continuous variables, the weighted mean difference (MD) was used as the effect size when measurement tools and units were consistent across studies. When measurement tools or units were inconsistent, the standardized mean difference (SMD) was used. Both measures were reported with their 95% confidence intervals (95% CI). Heterogeneity was assessed using the Q-test and the I^2 statistic. If $P \geq 0.1$ and $I^2 \leq 50\%$, a fixed-effects model was applied, indicating acceptable homogeneity among studies. If $P < 0.1$ or $I^2 > 50\%$, a random-effects model was used, and potential sources of heterogeneity were further explored. Publication bias was evaluated by generating funnel plots for the outcomes. Results of the meta-analysis were presented using forest plots, with statistical significance set at $P < 0.05$.

3. RESULTS

3.1. Study Characteristics

Figure 1 illustrates the detailed search results at each stage. A total of 637 studies were initially identified. Ultimately, this systematic review included 11 studies involving 316 participants [16–26].

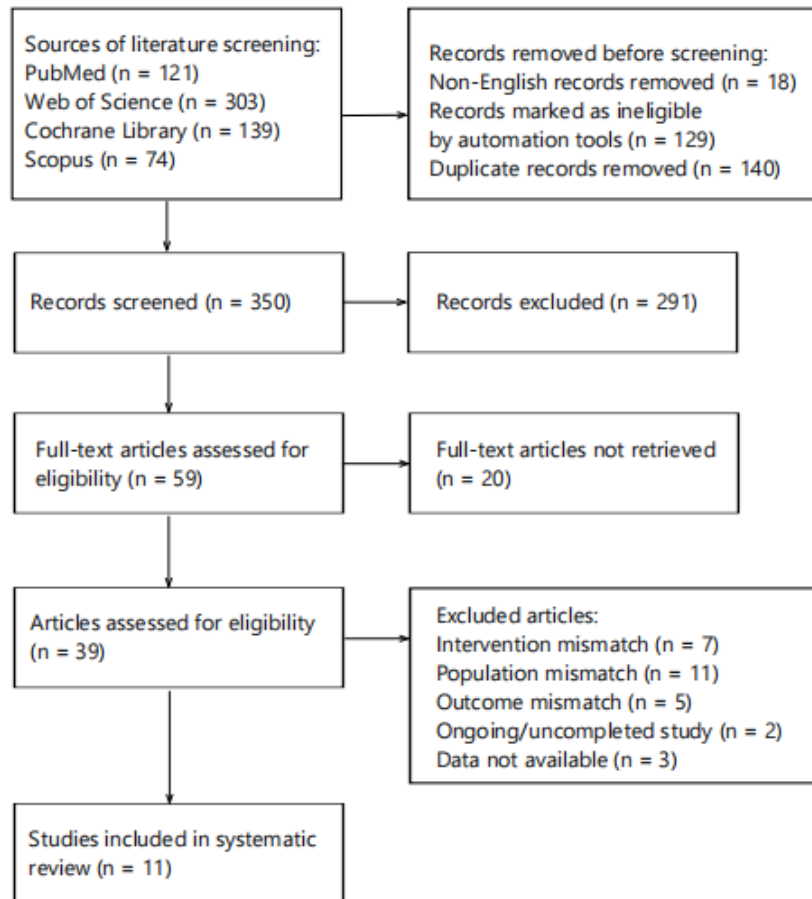


Figure 1. The literature inclusion process

In this systematic review, grip strength, gait speed, chair stand test, skeletal muscle index (SMI), and Short Physical Performance Battery (SPPB) scores were used as the primary outcome measures to evaluate the effects of progressive resistance training (PRT). Specifically, grip strength was assessed in 8 studies [16–19, 21–23, 25], gait speed in 8 studies [17, 18, 20–22, 24–26], chair stand test in 5 studies [16, 18, 19, 22, 26], SMI in 5 studies [17, 18, 21, 22, 25], and SPPB scores in 4 studies [19, 20, 23, 24]. All included studies were randomized controlled trials, and their general characteristics are summarized in Table 2.

Table 2. General characteristics of the included studies

Author	Sample size (E/C)	Gender	Age (years)	Intervention details	Intensity	Frequency	Duration
Vijayakumaran et al. (2023)	8/8	Female	65.5 ± 1.9	Resistance band exercises: squats, hip flexion/extension, seated leg extension, standing chest press, standing diagonal pull, seated row	2–3 sets, 10–15 reps per set	3 times/week	12 weeks
Viana et al. (2022)	18/18	Female	75.11 ± 3.67	Knee flexion/extension	75% 1RM, 40 min	3 times/week	12 weeks
Chien et al. (2022)	20/20	Both	67.6 ± 7.7	Sandbag resistance training: arm curls, shoulder raises, hip abduction/adduction, step-ups, toe raises	0.5–1 kg sandbag, 3 sets, 8–15 reps	3 times/week	12 weeks
Lee et al. (2021)	15/12	Female	70.13 ± 4.41	Shoulder, arm, lower limb, chest, and abdominal exercises	40 min, load increased from 3 to 15.3 lbs	3 times/week	12 weeks
Clark et al. (2021)	24/24	Both	72.3 ± 6.8	Machine-based or bodyweight exercises for major muscle groups	Progressive: 1 set (12–15 reps) → 3 sets (6–10 reps)	3 times/week	12 weeks
Chen et al. (2021)	30/30	Both	74.57 ± 12.83	VR-based resistance training for upper and lower limbs	30 min	2 times/week	12 weeks
Bastone et al. (2020)	17/18	Both	77.55 ± 4.40	Elastic bands, dumbbells, ankle weights for multiple muscle groups	80% 1RM, 3 sets, 8–15 reps	3 times/week	12 weeks
Vezzoli et al. (2019)	20/15	Unclear	73.0 ± 5.5	Seated chest press, horizontal leg press, vertical row, shoulder exercises	60% 1RM, 3 sets, 14–16 reps	3 times/week	12 weeks
Vasconcelos et al. (2016)	14/14	Female	72 ± 4.6	Hip abduction/adduction, knee flexion, squats, knee extension	Weeks 1–4: 50–75% 1RM; Weeks 5–10: 40–60% 1RM	3 times/week	10 weeks
Hassan et al. (2016)	21/21	Both	85.7 ± 7.0	Rehabilitation equipment: elbow/shoulder extension, leg press, knee extension/flexion, etc.	2–3 sets, 10–15 reps, progressive load	2 times/week	24 weeks
Mavros et al. (2015)	14/14	Female	73.3 ± 6.2	Resistance machines: leg press, knee extension, knee flexion, chest press	80% 1RM, 45 min, 1RM tested every 2 weeks	3 times/week	12 weeks

3.2. Methodological Quality Assessment of Included Studies

The risk of bias results obtained using RevMan 5.4 software, as recommended by the Cochrane Handbook 5.1.0, are shown in Figure 2. The results indicate that among the 11 included studies, 3 studies [21, 22, 26] were of high quality, 8 studies [16-20, 23-25] were of moderate quality, and no studies were of low quality. Due to the inherent challenges of blinding in exercise interventions, this may have influenced the methodological quality of the included studies to some extent.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Alessandra de Carvalho Bastone 2020	+	+	+	+	+	+	+
Alessandra Vezzoli 2019	+	?	?	?	+	+	+
Bothaina H Hassan 2016	+	+	-	-	-	-	+
Guan-Bo Chen 2021	+	+	+	+	+	+	+
Joana Ude Viana 2022	+	+	+	+	-	+	+
Karina S S Vasconcelos 2016	+	+	-	+	+	+	+
Leatha A. Clark 2021	+	+	+	+	-	+	+
ReenaK Vijayakumaran 2023	+	-	?	?	+	+	+
Yorgi Mavros 2015	+	+	+	+	+	+	+
Yu-Hao Lee 2021	+	+	-	+	+	+	+
Yu-Hsuan Chien 2022	+	-	?	?	+	+	+

Figure 2. Risk of Bias Assessment of Included Studies

3.3. Effects of Progressive Resistance Training on Grip Strength, Gait Speed, Chair Stand Test, Skeletal Muscle Index, and SPPB Scores

Among the 11 included studies, progressive resistance training (PRT) was found to improve grip strength (SMD = 3.22, 95% CI: 2.62–3.82, $P < 0.00001$), gait speed (SMD = 0.55, 95% CI: 0.31–0.79, $P < 0.00001$), chair stand time (SMD = 4.51, 95% CI: 3.74–5.29, $P < 0.00001$), and skeletal muscle index (SMD = 0.39, 95% CI: 0.07–0.72, $P = 0.02$). However, no significant effect was observed on SPPB scores (SMD = 0.18, 95% CI: -0.08–0.44, $P = 0.18$).

3.3.1. Grip Strength

Among the 11 included studies, 8 studies [16–19, 21–23, 25] analyzed the effect of PRT on grip strength. Two of these studies [18, 23] found that PRT did not improve grip strength in older adults with sarcopenia; in fact, grip strength decreased after 12 weeks of training, although the rate of decline was slower compared to the control group, suggesting a mitigating effect. The other six studies [16–19, 21, 22, 25] concluded that PRT significantly improved grip strength compared to the control group, with a statistically significant difference (SMD = 3.22, 95% CI: 2.62–3.82, $P < 0.00001$). Heterogeneity was low ($I^2 = 22\%$). The forest plot is shown in Figure 3.

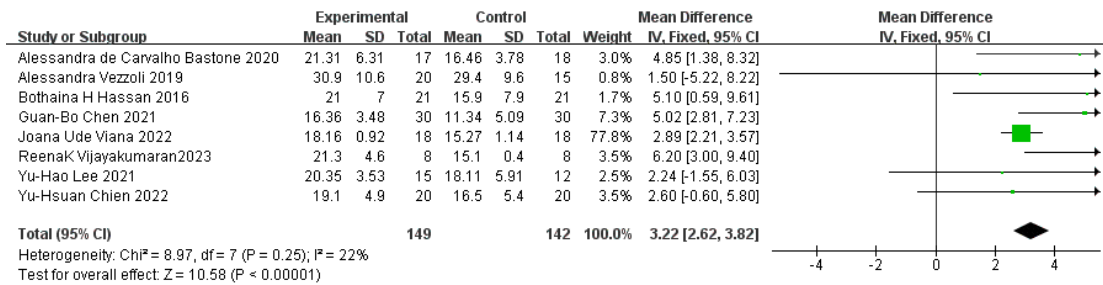


Figure 3. Forest Plot of the Effect of Progressive Resistance Training on Grip Strength in Older Adults with Sarcopenia

3.3.2. Gait Speed

Eight studies analyzed the effect of progressive resistance training (PRT) on patients' gait speed, revealing substantial heterogeneity ($I^2 = 55\%$), as shown in Figure 4. This heterogeneity was primarily attributed to one study [18], in which the intervention group exhibited a decrease in gait speed from 0.82 m/s to 0.71 m/s after 12 weeks of intervention, despite concluding that PRT improved gait speed—a finding inconsistent with its data. After excluding this study, the reanalysis indicated that PRT significantly improved gait speed compared to the control group (SMD = 0.51, 95% CI: 0.27–0.75, $P < 0.00001$), with no heterogeneity ($I^2 = 0\%$), as presented in Figure 5. Thus, study [18] was identified as the source of heterogeneity for the gait speed outcome.

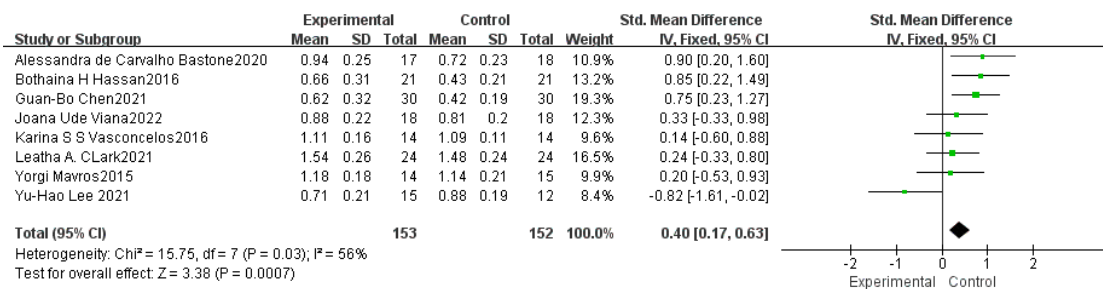


Figure 4. Forest plot of the effect of progressive resistance training on gait speed in older adults with sarcopenia

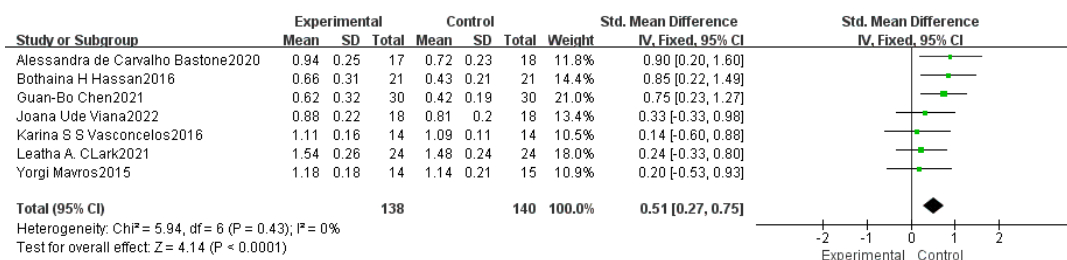


Figure 5. Forest plot of the effect of progressive resistance training on gait speed in older adults with sarcopenia after excluding one study

3.3.3. Chair Stand Test

Five studies [16, 18, 19, 22, 26] analyzed the effect of progressive resistance training (PRT) on the chair stand test. The results showed that PRT reduced chair stand time compared to the control group, with a statistically significant difference (SMD = 1.64, 95% CI: 0.68–2.59, $P = 0.003$). However, substantial heterogeneity was observed ($I^2 = 75\%$), as shown in Figure 6.

Further analysis revealed that in one study [18], the intervention group's chair stand time increased from 15.47 (4.03) s to 17.13 (2.13) s after 12 weeks of intervention, yet the study concluded that PRT improved chair stand performance—a finding inconsistent with its data. After excluding this study,

the pooled analysis of the remaining four studies showed no statistically significant difference between PRT and the control group (SMD = 2.16, 95% CI: 1.16–3.16, P = 0.28), with heterogeneity reduced to $I^2 = 21\%$, as presented in Figure 7. Therefore, it can be concluded that PRT alone may not effectively improve chair stand time.

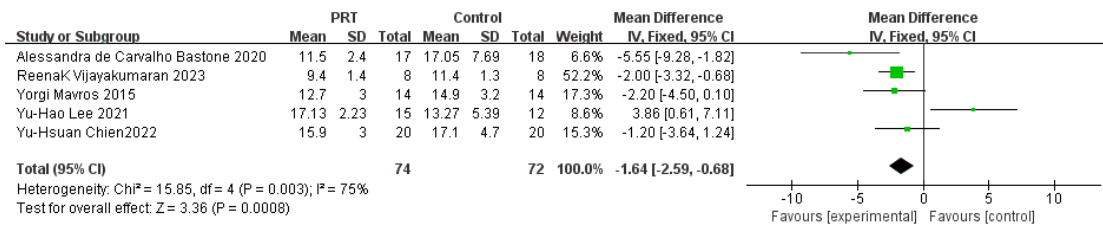


Figure 6. Forest plot of the effect of progressive resistance training on chair stand performance in older adults with sarcopenia

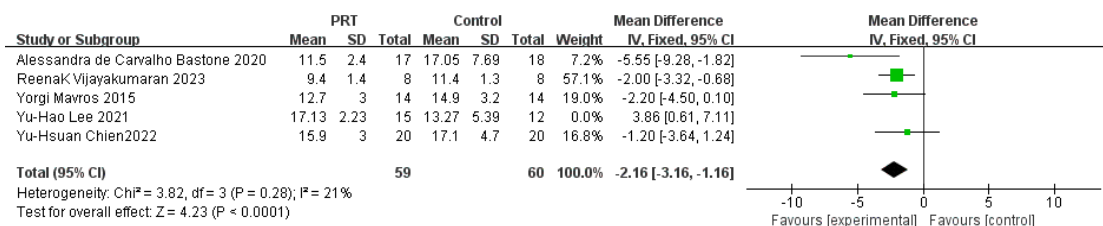


Figure 7. Forest plot of the effect of progressive resistance training on chair stand performance in older adults with sarcopenia after excluding one study

3.3.4. Skeletal Muscle Index

Six studies [17, 18, 21, 22, 25] analyzed the effect of progressive resistance training (PRT) on the skeletal muscle index (SMI) in patients. Among these, one study found that although SMI improved, there was no statistically significant difference compared to the control group. Pooled analysis of the remaining five studies indicated that PRT significantly improved the skeletal muscle index (SMD = 0.39, 95% CI: 0.07–0.72, P = 0.02), with no heterogeneity ($I^2 = 0\%$), as shown in Figure 8.

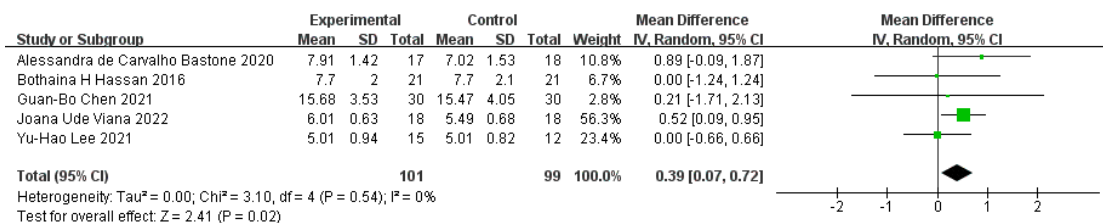


Figure 8. Forest plot of the effect of progressive resistance training on the skeletal muscle index in older adults with sarcopenia

3.3.5. Short Physical Performance Battery (SPPB)**

Four studies [19, 20, 23, 24] analyzed the effect of progressive resistance training (PRT) on the SPPB scores of patients. Among these, two studies [23, 24] reported no significant difference in SPPB scores after training ($p > 0.05$), while the other two studies found significant differences. Pooled effect size analysis revealed that PRT alone did not have a statistically significant effect on SPPB scores (SMD = 0.18, 95% CI: -0.08–0.44, P = 0.08), with substantial heterogeneity ($I^2 = 56\%$), as shown in Figure 9. Thus, progressive resistance training alone does not effectively improve SPPB scores in older adults with sarcopenia.

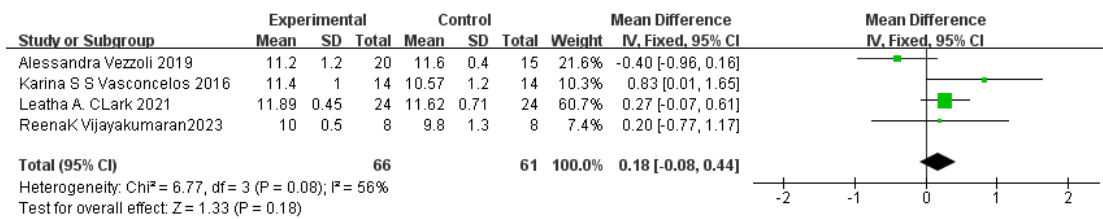


Figure 9. Forest plot of the effect of progressive resistance training on the Short Physical Performance Battery (SPPB) score in older adults with sarcopenia

4. DISCUSSION

This systematic review included 11 randomized controlled trials (RCTs) that examined the effects of progressive resistance training (PRT) on muscle strength, muscle mass, and physical function in older adults with sarcopenia. Our findings indicate that PRT can improve grip strength (SMD = 3.22, 95% CI: 2.62–3.82, $P < 0.00001$), gait speed (SMD = 0.51, 95% CI: 0.27–0.75, $P < 0.00001$), chair stand time (SMD = 4.51, 95% CI: 3.74–5.29, $P < 0.00001$), and skeletal muscle index (SMD = 0.39, 95% CI: 0.07–0.72, $P = 0.02$). These results are consistent with previous studies by Cruz-Jentoft [27] and Lü Meiling [28], among others. However, heterogeneity remains regarding the effect of PRT on grip strength among the included studies. Additionally, the present review found that PRT does not significantly improve SPPB scores in older adults with sarcopenia (SMD = 0.18, 95% CI: –0.08–0.44, $P = 0.18$).

4.1. Heterogeneity in the Effects of Progressive Resistance Training on Grip Strength in Older Adults with Sarcopenia

Current research shows some heterogeneity in the effects of PRT on improving grip strength in elderly patients with sarcopenia. Alessandra et al. observed a significant increase in grip strength ($P < 0.001$) after PRT intervention using elastic bands, dumbbells, and ankle weights targeting upper limb, lower limb, and hip muscle groups [22]. Similarly, Hassan et al. reported a significant between-group difference ($P = 0.002$), with grip strength increasing in the experimental group while decreasing in the control group [25]. Chen et al., using a virtual reality (VR)-assisted PRT program, found an average grip strength improvement of 5.02 kg ($p < 0.001$) [21]. Vijayakumaran et al. also reported significant grip strength improvement ($p = 0.008$) following an elastic band-based PRT intervention in elderly women with sarcopenia [19]. Yu-Hsuan Chien et al. implemented a 12-week sandbag training program, resulting in a grip strength increase of 3.2 kg ($p < 0.001$) [16]. However, some studies present divergent findings. Yu-Hao Lee et al. found no statistically significant difference in grip strength changes between the PRT and control groups, observing only a trend toward a slower rate of grip strength decline in the intervention group [18]. Similarly, Vezzoli et al. detected no significant improvement in grip strength after a 12-week PRT intervention [23].

Furthermore, E Mende (2022) conducted a meta-analysis of randomized controlled trials on machine-assisted progressive resistance training and concluded that its effect on improving grip strength in elderly patients with sarcopenia was minimal (0.08; 95% CI: -0.18, 0.33; $p = 0.57$), which differs markedly from the significant improvement observed in this systematic review (pooled effect size 3.22; 95% CI: 2.62, 3.82; $P < 0.00001$). It should be noted that two studies on machine-assisted progressive resistance training were included in this review but did not report grip strength-related outcomes. Although the current evidence remains contentious, this systematic review provides preliminary supportive evidence for the effectiveness of progressive resistance training in improving grip strength through rigorous methodological analysis. Future research should further clarify the influence of key parameters such as training equipment, load intensity, and intervention duration on effect sizes, and validate their clinical value through large-scale, multicenter randomized controlled trials.

4.2. Progressive Resistance Training Does Not Effectively Improve SPPB Scores in Elderly Patients with Sarcopenia

This study found that progressive resistance training does not effectively improve SPPB scores in elderly patients with sarcopenia (SMD = 0.18, 95% CI: -0.08, 0.44, P = 0.18). This may be because resistance training alone improves muscle mass and strength but has limited effects on other physical functions. Incorporating balance or aerobic training into resistance training may lead to more comprehensive improvements in physical function [29]. Studies by Vezzoli et al. and Joana Ude Viana et al. found that moderate-intensity progressive resistance training effectively increased muscle size and strength in individuals over 65 years old with sarcopenia, regardless of gender. This suggests that moderate-intensity progressive resistance training can effectively induce muscle growth and strength gains in the elderly, although no significant changes were observed in skeletal muscle index or SPPB scores [17, 23]. Vezzoli et al. suggested that using bioelectrical impedance analysis to measure skeletal muscle index and SPPB scores may not be sufficiently sensitive for detecting changes in muscle mass and performance in elderly individuals with type I sarcopenia as defined by EWGSOP [23]. Nevertheless, one year after the intervention, the frailty rate was lower among elderly sarcopenia patients who received progressive resistance training compared to those who did not [17]. Additionally, progressive resistance training using various methods such as sandbags, elastic bands, and machines did not raise safety concerns related to exercise, making it suitable for elderly sarcopenia patients with poor physical fitness [16, 18, 23].

5. CONCLUSION

This study found that progressive resistance training can improve grip strength, gait speed, and skeletal muscle index in elderly patients with sarcopenia. However, its effects on chair stand time and SPPB scores were not significant, which may be related to training methods and content. Additionally, several studies have evaluated the effectiveness of progressive resistance training in community-dwelling older adults, demonstrating its accessibility, low cost, and ability to effectively improve physical function and strength [30, 31]. Due to morphological and functional changes in the musculoskeletal and nervous systems, elderly patients with sarcopenia experience declines in mobility and balance control [32]. Specific therapeutic exercises involving repetitive and reinforced motor training may help counteract age-related negative changes [33]. This study also found that virtual reality (VR) serves as an interactive and engaging approach that combines physical and cognitive demands to optimize physical activity, offering both safety and convenience. Furthermore, sandbags, as a portable tool for progressive resistance training, also demonstrated high safety for elderly sarcopenia patients, with no fall incidents reported across multiple studies. Overall, progressive resistance training programs may represent an optimal strategy for preventing frailty and sarcopenia. Therefore, we recommend that older adults with sarcopenia incorporate progressive, load-bearing resistance training into their daily physical activities to improve muscle mass and reduce frailty associated with sarcopenia. Finally, this study has certain limitations, including heterogeneity in intervention design and a limited number of included studies. Future research should involve more high-quality randomized controlled trials to further evaluate the effects of progressive resistance training on physical function in elderly patients with sarcopenia.

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