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Review

Does High-Velocity Resistance Exercise Elicit Greater Physical Function Benefits Than Traditional Resistance Exercise in Older Adults? A Systematic Review and Network Meta-Analysis of 79 Trials

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Abstract

Background: A systematic review and network meta-analysis was undertaken to examine the effectiveness of different modes of resistance exercise velocity in fast walking speed, timed-up and go, 5-times sit-to-stand, 30-second sit-to-stand, and 6-minute walking tests in older adults.
Methods: CINAHL, Embase, LILACS, PubMed, Scielo, SPORTDiscus, and Web of Science databases were searched up to February 2022. Eligible randomized trials examined the effects of supervised high-velocity or traditional resistance exercise in older adults (ie, ≥60 years). The primary outcome for this review was physical function measured by fast walking speed, timed-up and go, 5-times sit-to-stand, 30-second sit-to-stand, and 6-minute walking tests, while maximal muscle power and muscle strength were secondary. A random-effects network meta-analysis was undertaken to examine the effects of different resistance exercise interventions.
Results: Eighty articles describing 79 trials (n = 3 575) were included. High-velocity resistance exercise was the most effective for improving fast walking speed (standardized mean difference [SMD] −0.44, 95% confidence interval [CI]: 0.00 to 0.87), timed-up and go (SMD −0.76, 95% CI: −1.05 to −0.47), and 5-times sit-to-stand (SMD −0.74, 95% CI: −1.20 to −0.27), while traditional resistance exercise was the most effective for 30-second sit-to-stand (SMD 1.01, 95% CI: 0.68 to 1.34) and 6-minute walking (SMD 0.68, 95% CI: 0.34 to 1.03).
Conclusion: Our study provides evidence that resistance exercise velocity effects are specific in older adults, as evidenced by physical function test dependence. We suggest that prescriptions based on the velocity of contraction should be individualized to address the specific functional needs of participants.

Keywords: Muscle power, Physical function, Strength training

Aging, even in the absence of chronic disease, is associated with several biological changes in the neural and musculoskeletal systems (1,2). While reductions of ~1.0% per year are observed in muscle mass (3–5), declines in muscle strength and muscle power (ie, the product of force production by the speed of movement) are greater and faster (6,7), affecting the ability to undertake activities of daily living in older adults (8,9). In addition, older adults presenting with lower levels of muscle strength and power are at increased risk of physical disability (10), falling (11,12), and frailty (13), which ultimately lead to dependent living and higher risk of hospitalizations and all-cause mortality (14,15). Therefore, strategies to preserve muscle strength and power, and physical function are critical in older adults, as established by the World Health Organization's concept of healthy aging (16).

Resistance exercise is a well-established intervention to improve physical function in older adults (17–20). As previously demonstrated, various resistance exercise modes can improve muscle strength and power (19–21), which partially accounts for gains in physical function (22). Recently, exercise guidelines have advocated high-velocity resistance exercise (defined as resistance exercise attempted to move the load as fast as possible during the concentric phase) as the most effective resistance exercise mode for improving physical function in older adults (23,24). This potential superiority of high-velocity compared to traditional resistance exercise (defined as resistance exercise prescribed at a set cadence of ≥2 seconds during the concentric phase or not attempting to move the load as fast as possible) relies on superior neural rather than muscle fiber adaptations (25) and the greater relevance of muscle power production to the performance of daily living activities (8,9,26–28). However, conflicting results in physical function are derived from previous randomized trials (29–31) and pairwise meta-analyses (32–34). For example, previous pairwise meta-analyses from Steib et al. (32). and Tschopp et al. (33), involving a small number of studies, indicate an advantage in favor of high-velocity compared to traditional resistance exercise when several physical function tests are combined (32,33). In contrast, despite similar results, de Rosa Orssatto et al. (34). and Balachandran et al. (35) suggest that the evidence is inconclusive to support such superiority. This may be related to several factors, such as (a) studies involving participants with varying health status (eg, healthy, frail, and mobility-limited participants), (b) studies undertaking resistance exercise combined with aerobic or balance exercise interventions, and (c) analyses combining several physical function tests which would result in a composite measure. These issues likely affect comparisons between these 2 resistance exercise modes precluding individualization in older adults. Therefore, although previous exercise guidelines recommend high-velocity resistance exercise for greater improvements in physical function (23,24), a more comprehensive assessment of the literature is necessary to better target specific exercise prescriptions to older adults based on individual clinical needs.

The utilization of only direct comparisons between high-velocity and traditional resistance exercises may also represent a limitation in previous meta-analyses (32–34). For instance, the inclusion of studies comparing high-velocity or traditional resistance exercise versus control condition would improve precision and comprehensiveness in assessing the effects of different velocities of resistance exercise on physical function in older adults. Network meta-analysis, comparing multiple interventions simultaneously by combining direct and indirect evidence within a network of randomized trials, is considered very effective in providing comparative effectiveness and supporting clinical decision-making (36). As a result, for this systematic review and network meta-analysis we aimed to determine which resistance exercise velocity mode, high-velocity or traditional, is most effective for improving walking speed, lower-limb mobility, power, strength and endurance, cardiorespiratory fitness, and walking endurance by using a range of tests such as fast walking speed, timed-up and go, 5-times sit-to-stand, 30-second sit-to-stand, and 6-minute walking tests in older adults. These tests are commonly used in exercise trials to assess physical function in this age group and are strongly associated with a variety of clinical endpoints such as mortality, cardiovascular disease and death, and physical disability (37–41). In addition, we also examined the moderating effects of physical health status on these outcomes.

Methods

Study Eligibility Criteria

To be included, published randomized trials compared traditional resistance exercise versus high-velocity resistance exercise versus control, traditional resistance exercise versus high-velocity resistance exercise, traditional resistance exercise versus control, or high-velocity resistance exercise versus control in untrained older adults (ie, ≥60 years). High-velocity resistance exercise was defined as resistance exercise that attempted to move the load as fast as possible during the concentric phase, while traditional resistance exercise was defined as resistance exercise prescribed at a set cadence (eg, ≥2 seconds) or not attempting to move the load as fast as possible. These programs were required to be delivered under supervision involving physically healthy or impaired older participants (eg, self-reported physical disability, mobility-limited, sarcopenia (42), and frailty). The exclusion criteria were: (a) studies including older adults exclusively with acute or chronic cardiovascular or metabolic conditions (eg, osteoarthritis, type II diabetes, cancer, chronic hemodialysis, heart failure, hospitalized, osteoporosis, and fibromyalgia); (b) studies involving within-participant design; (c) interventions involving any other type of exercise component (eg, aerobic exercise and balance exercise); (d) interventions combining hybrid traditional and high-velocity resistance exercise simultaneously; (e) interventions involving nutrition components (eg, protein supplementation and caloric restriction); (f) studies with interventions lasting less than 4 weeks; (g) not reporting specific outcomes included in this review; and (h) studies written in a language other than English, Portuguese, or Spanish.

Data Searches and Sources

A systematic search was conducted by a researcher (P.L.) using CINAHL, Embase, LILACS, PubMed, Scielo, SPORTDiscus, and Web of Science databases from inception to February 2022. The search strategy is presented in the Supplementary Appendix 1. All procedures undertaken in the present study were reported in accordance with the Cochrane Back Review Group (CRBG) (43), the Implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science (PERSiST) (44), and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Network Meta-analyses (PRISMA-NMA) statement (45) with registration at the international prospective register of systematic reviewers (PROSPERO identifier: CRD42022297254).

Study Selection Process and Data Extraction

In the search strategy, titles and abstracts were first independently evaluated following the eligibility criteria. Eligibility was assessed independently in duplicate (P.L. and D.J.P.T.), with differences resolved by consensus. When abstracts did not provide sufficient information, they were selected for full-text evaluation. Full-text articles meeting criteria were retrieved and read independently by both reviewers and assessed for inclusion in the study. In addition, a manual search of references in selected studies was performed to detect studies potentially eligible for inclusion.

One reviewer (P.L.) extracted data using a standardized form, while a second reviewer (D.J.P.T.) checked the information. Relevant information extracted from studies included publication information (ie, authors and year of publication), demographic and clinical characteristics such as age, body mass index (BMI), and health status (eg, self-reported physical disability, mobility-limited, sarcopenia, and frailty), experimental design and sample size, prescription characteristics such as delivery, modality, frequency, volume, intensity, and concentric and eccentric time of contraction when available.

End Points

The primary outcome for this review was objectively assessed physical function measured by: (a) fast walking speed (a measure of gait speed), (b) timed-up and go test (ie, time in seconds to rise from the chair, walk a distance, turn, walk back to the chair, and sit down; a measure of lower-limb function and mobility), (c) 5-times sit-to-stand test (ie, time in seconds to rise as fast as possible from the chair 5 times; a measure of lower-limb power and strength), (d) 30-second sit-to-stand test (ie, number of times that a participant can rise to a full stand from a seated position within 30 seconds; a measure of lower-limb strength and endurance), and (e) 6-minute walking test (ie, distance covered in meters when participants were instructed to walk as far as they could during 6 minutes; a measure of cardiorespiratory fitness and walking endurance). Secondary outcomes included maximal muscle power measured by a multijoint lower-limb exercise or task test (eg, leg press exercise, stair climbing, countermovement jump, and sit-to-stand test) and expressed as W or W.kg^{-1}, and maximal muscle strength measured by the leg press 1-repetition maximum test (1-RM). Information was extracted from baseline versus immediate postintervention assessment. For the outcomes assessed, when articles did not include dispersion values of change such as standard deviation (*SD*), standard errors, or 95% confidence intervals (95% CI), the *SD* of the change was calculated assuming a correlation of $r = 0.5$ between the baseline and postintervention assessment measures by the square root of (46) $\left(\left(SD^2_{\text{Baseline}} + SD^2_{\text{Post -intervention}}\right) - \left(2 \times r \times SD_{\text{Baseline}} \times SD_{\text{Post -intervention}}\right)\right)$.

Study Risk of Bias Assessment and Certainty of Evidence (GRADE)

The risk of bias was evaluated according to the Cochrane risk-of-bias tool 2.0 (RoB 2) (47), with each assessment focused on the outcome level. The study quality assessment for all included studies was performed independently by 2 reviewers (P.L. and D.J.P.T.), with disagreements resolved by consensus. The certainty of the evidence for the network of interventions was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach for network meta-analysis (48). The several domains considered for downgrading the certainty of evidence were study limitations (ie, based on the risk of bias assessment), indirectness (ie, based on transitivity assumption), inconsistency (ie, based on inconsistency assumption), imprecision (ie, uncertainty around the pairwise estimate with confidence intervals crossing the null value or including values favoring different treatments), and publication bias (ie, based on comparison-adjusted funnel plot and the Egger's test) (48).

Data Synthesis and Analysis

Continuous outcome data in both pairwise and network meta-analyses (NMA) were summarized as standardized mean differences (SMD) and their 95% confidence intervals (95% CI). Pairwise comparisons between high-velocity resistance exercise, traditional resistance exercise, and control conditions were conducted in R (R Development Core Team, Vienna, Austria) using the package "meta" (49). The frequentist graph theoretical was performed following the current PRISMA guideline for NMA (50,51), and it was conducted using the R package "netmeta" (52). A random-effects model was undertaken as studies differ both clinically and methodologically (ie, between-study variability). The between-study variability (ie, heterogeneity) of the intervention effects within each intervention comparison was assessed by I^2, and the magnitude of the between-study variance (τ^2) and estimated using the generalized DerSimonian and Laird estimator and the Q-profile approach. For each NMA, we assessed a priori the transitivity and consistency assumptions. Statistical assessment of the transitivity assumption implies that the distribution of potential treatment effect modifiers is balanced across the available direct comparisons (53). We used the percentage of male participants, average age, BMI, health status, and overall risk of bias as potential intervention effect modifiers, with values reported for each study. We evaluated each network for inconsistency using the random-effects design-by-treatment interaction model (54) and locally by splitting the direct and indirect evidence (55).

Intervention effects were ranked according to *p* scores, measuring the extent of certainty that an intervention is better than the other (56). Comparisons were made when more than 1 study was included for each comparator and were considered statistically significant when the 95% CI did not include the value of zero effect. According to Cohen (57), SMD values of 0.0 to ≤0.5 indicate small; 0.51 to 0.79, medium; and ≥0.8, large effects. Extreme-study effects (ie, outliers) were explored with the forward search algorithm (58) using the R package "NMAoutlier" (59). When obvious outliers were detected, these were excluded in a sensitivity analysis to assess the robustness of the results. NMA with subsets and sensitivity analyses were conducted for the primary outcome with consideration for potential intervention effect modifiers, health status, and overall risk of bias. When the number of studies was more than 10, a comparison-adjusted funnel plot was drawn to assess publication bias and small-study effects.

Results

Following the deletion of duplicates and records marked as ineligible, a total of 2 375 potential records were identified. Of these, 1 333 records were excluded based on titles and abstracts due to their irrelevance to the research question, and 14 reports were not available for full-text assessment, resulting in 1 028 records deemed eligible for full-text review. A total of 955 reports were excluded due to reasons described in Supplementary Figure 1. After including 7 additional studies (30,60–65) via reference lists, a total of 80 articles (29–31,60–136) describing 79 randomized trials were included in the present systematic review and network meta-analysis (fast walking speed, $n = 12$; timed-up and go, $n = 40$; 5-times sit-to-stand test, $n = 18$; 30-second sit-to-stand test, $n = 24$; 6-minute walking test, $n = 15$; leg press muscle power [expressed in W], $n = 10$; leg press muscle power [expressed in W.kg^{-1}], $n = 4$; stair climbing muscle power, $n = 3$; sit-to-stand muscle power, $n = 3$; countermovement jump muscle power, $n = 3$; and leg press muscle strength, $n = 24$).

Study, Participant, and Intervention Characteristics

A total of 3 575 participants (women, $n = 2$ 491; men, $n = 836$; not reported, $n = 248$) with a median age of 70.2 years (interquartile range [IQR] = 67.3 to 72.6 yrs) and BMI of 27.6 kg.m^{-2} (IQR = 25.6 to 28.6 kg.m^{-2}) were included. Most studies included physically healthy participants (55 out of 79 studies, 69.2%), followed by participants with a self-reported disability or mobility limitations (8 out of 79 studies, 10.1%), sarcopenia (6 out of 79 studies, 7.6%), and frailty (5 out of 79 studies, 6.3%). Five studies included both physically healthy and participants with some physical disability (6.3%).

From the 80 articles included, a total of 101 interventions were analyzed. While 31 interventions examined high-velocity resistance exercise (30.7%), 70 examined traditional resistance exercise (69.3%). Regarding exercise prescription characteristics, the median intervention duration of studies evaluating high-velocity resistance exercise was 12 weeks (IQR: 12–14 weeks), with a median of 36 sessions (IQR: 24–36 sessions). Information about high-velocity resistance exercise volume was reported for 29 out of the 31 interventions (93.5%) with a median of 42 sets per week (IQR: 32–61 sets per week), while peak intensity was reported for 25 out of the 31 interventions (80.6%) with a median of 70% of 1-RM (IQR: 50%–75% of 1-RM). For studies examining traditional resistance exercise, the median duration was 12 weeks (IQR: 12–16 weeks) and 36 sessions (IQR: 24–38 sessions). Information about volume was reported for 60 out of the 70 interventions (85.7%) with a median of 50 sets per week (IQR: 36–72 sets per week), while intensity was reported for 50 out of the 70 interventions with a median of 75% of 1-RM (IQR: 70%–80% of 1-RM). Sixty-seven out of the 79 studies included were randomized controlled trials. Studies were designed to compare resistance exercise programs versus nonactive controls (53 out of 67 studies, 79.1%), stretching control (5 out of 67 studies, 7.5%), health education control (5 out of 67 studies, 7.5%), walking control (2 out of 67 studies, 3.0%), and nutrition placebo control (2 out of 67 studies, 3.0%). The characteristics of the individual studies are presented in Supplementary Table 1.

Risk of Bias Assessment

A total of 57 studies examined the effects of resistance exercise velocity modes on physical function, while 20 and 24 studies examined muscle power and muscle strength, respectively. For the primary outcome of this review, 70.2% of the studies presented a *high risk of bias* (40 out of 57 studies), and 26.3% of the studies presented *some concerns* in physical function assessment (15 out of 57 studies). For the secondary outcomes, 70.0% of the studies presented a *high risk of bias* (14 out of 20 studies) in muscle power assessment, while 79.2% of the studies presented a *high risk of bias* (19 out of 24 studies) in muscle strength assessment. The individual risk of bias assessment is presented in Supplementary Tables 2–4.

Analysis of the Outcomes

Physical function outcomes

All pairwise comparison results estimated in the meta-analysis model are reported in Supplementary Tables 5–9. The network geometry of studies examining physical function outcomes is presented in Figure 1. High-velocity resistance exercise was the most effective for improving fast walking speed (p score = 92.8%) and reducing the time to perform the timed-up and go (p score = 89.5%) and the 5-times sit-to-stand test (p score = 82.1%) compared to controls (Table 1). Traditional resistance exercise was the most effective intervention for improving 30-second sit-to-stand (p score = 85.1%) and 6-minute walking test (p score = 79.1%; Table 1). Statistically significant differences were not observed between traditional and high-velocity resistance exercise for physical function outcomes (p = .239–.837).

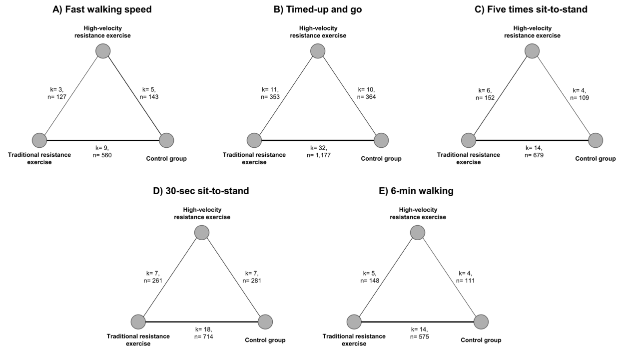

Figure 1. Network geometry of studies examining (**A**) fast walking speed, (**B**) timed-up and go, (**C**) 5-times sit-to-stand, (**D**) 30-second sit-to-stand, and (**E**) 6-minute walking. k, number of comparisons; n, sample size.

Subgroup analyses for physical health status are presented in Figures 2 and 3. High-velocity resistance exercise resulted in significant improvements in fast walking speed (SMD = 1.28, 95% CI: 0.74 to 1.82), timed-up and go (SMD = −0.88, 95% CI: −1.21 to −0.54), 30-second sit-to-stand (SMD = 0.93, 95% CI: 0.43 to 1.43), and 6-minute walking test (SMD = 0.74, 95% CI: 0.11 to 1.38) for those physically healthy but not 5-times sit-to-stand where significant effects were only observed in physically impaired participants (SMD = −1.26, 95% CI: −2.20 to −0.32). In traditional resistance exercise, significant effects were observed regardless of physical health status on timed-up and go (SMD = −0.74 to −0.62), 5-times sit-to-stand (SMD = −1.09 to −0.52), and 30-second sit-to-stand (SMD = 0.77 to 1.10). For fast walking speed and 6-minute walking test, traditional resistance exercise resulted in significant effects for mixed physically healthy and physically impaired participants (SMD = 0.47, 95% CI: 0.10 to 0.84) and physically healthy participants (SMD = 0.76, 95% CI: 0.36 to 1.16), respectively.

The heterogeneity I^2 ranged from 61.1% to 69.9% in NMA for the outcomes of physical function. The global test for inconsistency (ie, design-by-treatment interaction random-effects model) indicated inconsistency for fast walking speed (Q = 18.2, p < .001). The locally side-split analyses for fast walking speed indicated a source of inconsistency between direct and indirect evidence for high-velocity resistance exercise versus control (p = .049; Supplementary Table 10). Visual assessment of comparison-adjusted funnel plots suggested no evidence of small-study effects (Egger test, p = .137–.743), except 5-times sit-to-stand outcome (Egger test, p = .025; Supplementary Figure 2). There was no evidence of publication bias after omitting the outlier (Coelho-Junior & Uchida (64)) from 5-times sit-to-stand (p = .114). Outliers were detected with the forward search algorithm for fast walking speed (Ortega & Cuartas, 2020 (127)), 5-times sit-to-stand (Coelho-Junior & Uchida, 2021 (64)), 30-second sit-to-stand, and 6-minute walking test (Filho et al., 2022 (65); Supplementary Figure 3). After omitting outliers, sensitivity analyses results were not different from the primary analyses for 5-times sit-to-stand and 6-minute walking test. Sensitivity analysis for fast walking speed provided traditional resistance exercise (SMD = 0.27, 95% CI: 0.01 to 0.52, p = .042; p score = 76.6%) as the best intervention modality, while heterogeneity reduced from 63.8% in the primary analysis to 40.2% (Supplementary Table 11). For 30-second sit-to-stand, we found high-velocity resistance exercise (SMD = 1.08, 95% CI: 0.66 to 1.49, p < .001; p score = 85.8%) as the best intervention modality

Table 1. Network Meta-Analysis Results for Physical Function Outcomes

Comparisons	*k*	SMD	95% CI	*p*-Value	I^2	*p*-Score	Certainty
Fast walking speed							
HVRE vs Control groups	5	0.44	0.00 to 0.87	.048	63.8%	*HVRE: 92.8%*	⊕⊖⊖⊖
TRE vs Control groups	9	0.16	−0.16 to 0.48	.329		*TRE: 47.8%*	Very low*,†,‡
HVRE vs TRE	3	0.28	−0.19 to 0.74	.239			
Timed-up and go							
HVRE vs Control groups	10	−0.76	−1.05 to −0.47	<.001	61.1%	*HVRE: 89.5%*	⊕⊕⊖⊖
TRE vs Control groups	32	−0.64	−0.83 to −0.45	<.001		*TRE: 60.6%*	Low*,‡
HVRE vs TRE	11	−0.11	−0.41 to 0.17	.422			
Five-times sit-to-stand							
HVRE vs Control groups	4	−0.74	−1.20 to −0.27	.002	63.1%	*HVRE: 82.1%*	⊕⊖⊖⊖
TRE vs Control groups	14	−0.66	−0.96 to −0.34	<.001		*TRE: 67.9%*	Very low*,‡,§
HVRE vs TRE	6	−0.08	−0.52 to 0.36	.716			
30-Second sit-to-stand							
HVRE vs Control groups	7	0.89	0.43 to 1.34	<.001	76.3%	*TRE: 85.1%*	⊕⊕⊖⊖
TRE vs Control groups	18	1.01	0.68 to 1.34	<.001		*HVRE: 64.9%*	Low*,‡
HVRE vs TRE	7	−0.12	−0.58 to 0.33	.597			
6-Minute walking							
HVRE vs Control groups	4	0.63	0.07 to 1.18	.027	69.9%	*TRE: 79.1%*	⊕⊕⊖⊖
TRE vs Control groups	14	0.68	0.34 to 1.03	<.001		*HVRE: 70.3%*	Low*,‡
HVRE vs TRE	5	−0.06	−0.59 to 0.48	.837			

Notes: 95% CI = 95% confidence interval; HVRE = high-velocity resistance exercise; *k* = number of comparisons; TRE = traditional resistance exercise; SMD = standardized mean difference.

*Certainty of evidence downgraded due to study limitations, with studies most studies presenting with high risk in the risk of bias assessment.

†Certainty of evidence downgraded due to inconsistency, with a source of inconsistency between direct and indirect evidence identified.

‡Certainty of evidence downgraded due to imprecision, with confidence intervals from interventions crossing null values or including values favoring both interventions tested.

§Certainty of evidence downgraded due to publication bias, with visual assessment of comparison-adjusted funnel plots suggesting evidence of small-study effects.

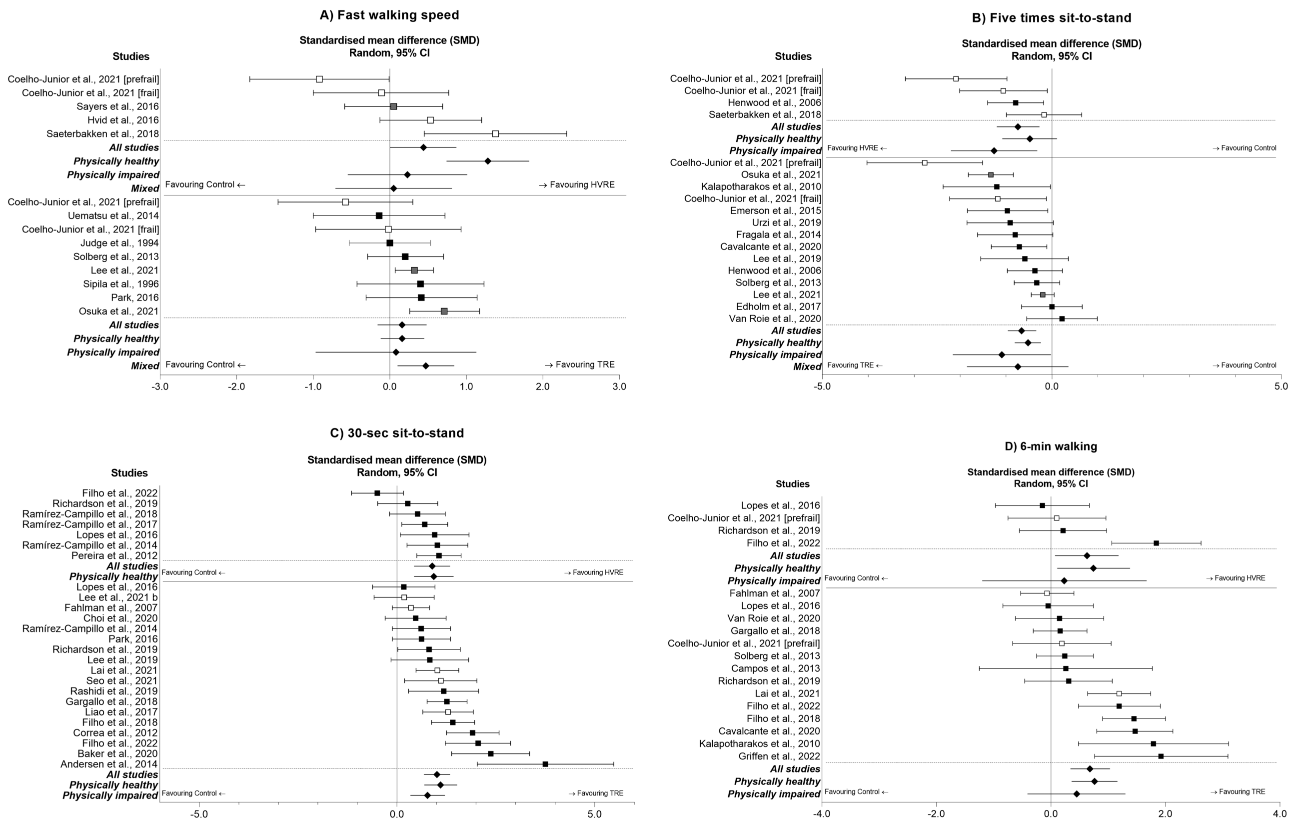

Figure 2. Network meta-analysis on (**A**) fast walking speed, (**B**) 5-times sit-to-stand, (**C**) 30-second sit-to-stand, and (**D**) 6-minute walking test based on health status. White squares indicate studies involving physically impaired participants; gray squares indicate studies involving mixed participants; black squares indicate studies involving physically healthy participants. CI = confidence interval; HVRE = high-velocity resistance exercise; TRE = traditional resistance exercise.

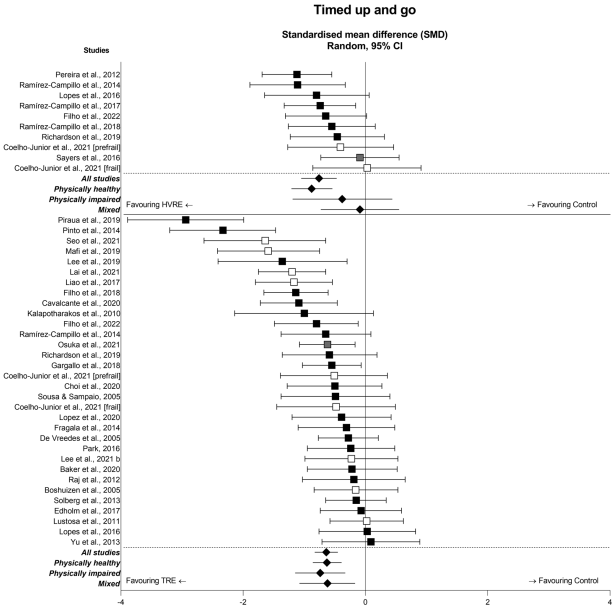

Figure 3. Network meta-analysis on timed-up and go based on health status. White squares indicate studies involving physically impaired participants; gray squares indicate studies involving mixed participants; black squares indicate studies involving physically healthy participants. CI = confidence interval; HVRE = high-velocity resistance exercise; TRE = traditional resistance exercisel.

with a small reduction of heterogeneity (Supplementary Table 11). Regarding the certainty of the evidence, the ranking of interventions for improving physical function outcome was graded *low* for timed-up and go, 30-second sit-to-stand, and 6-minute walking tests, while a *very low* grade was observed for fast walking speed and 5-times sit-to-stand (Table 1).

Muscle power and muscle strength outcomes

Pairwise meta-analysis models for muscle power outcomes and muscle strength are presented in Supplementary Tables 12–17. The network geometry of studies examining muscle power and muscle strength outcomes is presented in Supplementary Figure 4. High-velocity resistance exercise was the most effective for improving leg press muscle power (expressed in W) compared to traditional resistance exercise and control condition (p score = 99.9%; Table 2). For leg press muscle strength, traditional resistance exercise was the most effective intervention compared to the control (p score = 86.6%; Table 2). There was a statistical difference between traditional and high-velocity resistance exercises for leg press muscle power (p = .003) but not for leg press muscle strength (p = .538). NMA were not undertaken for leg press muscle power (expressed in $W.kg^{-1}$), stair climbing, sit-to-stand, and countermovement jump muscle power, given the small number of studies for each comparator (≤1).

Subset analyses for physical health status are presented in Supplementary Figures 5 and 6. Both traditional and high-velocity resistance exercise resulted in significant improvements in leg press muscle power (expressed in W) for those physically healthy (SMD = 0.61 to 0.99) and mixed physically healthy and physically impaired participants (SMD = 0.78 to 1.03), but not for those physically impaired. Improvements in leg press muscle strength were only observed in physically healthy participants following high-velocity resistance exercise (SMD = 1.12, 95% CI: 0.75 to 1.50), while traditional resistance exercise provided significant results for leg press muscle strength regardless of physical health status (SMD = 0.95 to 1.22).

The heterogeneity I^2 was 49.6% and 58.6% for leg press muscle power and muscle strength, respectively. The global test for inconsistency was not significant for leg press muscle power (Q = 4.59, p = .205) and muscle strength (Q = 1.72, p = .633), and differences between direct and indirect evidence were not observed in locally side-split analyses (Supplementary Table 18). Visual assessment of comparison-adjusted funnel plots suggested no evidence of small-study effects for leg press muscle power (Egger test, p = .970) but did for muscle strength (Egger test, p < .001; Supplementary Figure 7). Outliers were detected with the forward search algorithm for leg press muscle power (Fielding et al. (29)) and muscle strength (Filho et al. (65); Supplementary Figure 8). After omitting outliers, sensitivity analyses results were not different from the primary analyses (Supplementary Table 19). Heterogeneity was reduced from 49.6% in the primary analysis to 0% in leg press muscle power, while a small reduction was observed in leg press muscle strength (Supplementary Table 19). Based on the GRADE approach, the certainty of evidence was considered *moderate* for leg press muscle power and *very low* for leg press muscle strength (Table 2).

Table 2. Network Meta-Analysis Results for Muscle Strength and Muscle Power Outcomes

Comparisons	k	SMD	95% CI	p-Value	I^2	p-Score	Certainty
Leg press muscle power							
HVRE vs Control groups	4	0.90	0.49 to 1.30	<.001	49.6%	*HVRE: 99.9%*	⊕⊕⊕⊖
TRE vs Control groups	5	0.35	−0.04 to 0.73	.080		*TRE: 48.1%*	Moderate*
HVRE vs TRE	7	0.55	0.19 to 0.92	.003			
Leg press 1-RM							
HVRE vs Control groups	8	1.10	0.75 to 1.46	<.001	58.6%	*TRE: 86.6%*	⊕⊖⊖⊖
TRE vs Control groups	23	1.21	0.95 to 1.46	<.001		*HVRE: 63.4%*	Very low*,†,‡
HVRE vs TRE	11	−0.10	−0.44 to 0.23	.538			

Notes: 1-RM = 1-repetition maximum; 95% CI = 95% confidence interval; HVRE = high-velocity resistance exercise; k = number of comparisons; SMD = standardized mean difference; TRE = traditional resistance exercise; W = Watts.

*Certainty of evidence downgraded due to imprecision, with confidence intervals from interventions crossing null values or including values favoring both interventions tested.

†Certainty of evidence downgraded due to study limitations, with studies most studies presenting with high risk in the risk of bias assessment.

‡Certainty of evidence downgraded due to publication bias, with visual assessment of comparison-adjusted funnel plots suggesting evidence of small-study effects.

Discussion

In the present systematic review with network meta-analysis, we investigated the effects of high-velocity and traditional resistance exercise on physical function, muscle power, and strength outcomes in physically healthy and impaired older adults. Although both resistance exercise velocities effectively improved performance-based physical function outcomes in these participants, we found that the neuromuscular changes derived are velocity specific, as evidenced by physical function test dependence. While high-velocity resistance exercise provided better results for fast walking speed, 5-times sit-to-stand, timed-up and go, and muscle power outcomes, traditional resistance exercise resulted in greater effects on 30-second sit-to-stand, 6-minute walking, and muscle strength. These findings indicate that resistance exercise prescription based on the velocity of contraction should be individualized in older adults to optimize improvements in the specific physical function outcomes desired.

It is well recognized that resistance exercise is an efficient intervention to improve physical function in older adults (17–20,23,24). However, there is a lack of information on the most effective resistance exercise mode. In the current study, we found that resistance exercise velocity effects are specific and depend on the characteristics the test is quantifying. Attempting to achieve a high execution velocity resulted in greater improvements in physical function tests with a time component, while endurance tasks, where participants had to work longer, derived superior benefits from traditional low-to-moderate-velocity movement. This difference may be related to the specific neuromuscular adaptations promoted by fast or slow controlled contractions within resistance exercise (137). Therefore, we suggest that resistance exercise velocity should be individualized to specifically address deficits in older adults' neuromuscular performance per the concept of *one-size-does-not-fit-all*.

Older adults with a higher risk of disabilities, such as those suffering from frailty or mobility limitations, are vulnerable to stressors and adverse outcomes (13). Given reductions in a physical reserve capacity, interventions targeting basic tasks of daily living such as walking, change of direction, balance, and standing up from a chair are critical in these individuals. Therefore, older adults who are physically impaired could especially benefit from targeted high-velocity resistance exercise. This may provide a greater safety margin before the threshold for disabilities is reached and assist in reducing the risk of falls and hospitalizations (28,138,139). Subsequently, goals such as improving muscular endurance could be prioritized by introducing traditional resistance exercises or even different exercise components such as aerobic and balance exercises within a multimodal exercise program (23,24).

In regards to physically healthy older adults, this group can be targeted based on initial assessment, preventing physical disability and maintaining healthy aging (16). For example, participants who perform poorly on 30-second sit-to-stand or 6-minute walking tests can be targeted with traditional resistance exercise, the most effective intervention for these outcomes. Alternatively, hybrid programs comprising both velocity modes can be used to develop different components of physical function simultaneously (140), although further investigations are required to elucidate the response to this model, including within an overall periodized program. Therefore, individualizing the resistance exercise program using high-velocity or traditional resistance exercises can target participants at different stages, such as reversing physical disability or preserving physical function before the threshold for disabilities.

The strengths of the present study are: (a) the inclusion of 79 resistance exercise randomized trials with 3 575 older adults; (b) studies examining resistance exercise modes without the interference of other exercise components such as aerobic or balance interventions; (c) a network meta-analysis involving simultaneous comparison among high-velocity and traditional resistance exercise and control conditions; (d) investigation of the most effective resistance exercise velocity mode for different physical function tests; and (e) subgroup analyses providing specific information for physically healthy or impaired older adults. However, there are also limitations worthy of comment. First, the majority of studies had a high risk of bias. Several concerns regarding the *randomization process*, *measurement of outcomes*, and *selection of reported results* were identified. These affected the precision, magnitude, and certainty of the evidence. Second, we observed a high heterogeneity across analyses on physical function. This may be a result of different settings or characteristics of studies included, in addition to the lack of or poor reporting of resistance exercise characteristics such as volume and intensity in the studies included. Third, participants in the high-velocity resistance exercise group likely had their performance affected by accumulated fatigue throughout sessions, sets and repetitions, reducing their ability to recruit all motor units at optimal discharge rates and maintain appropriate velocity (141). As a result, this may have reduced our ability to observe even greater differences between resistance exercise velocities. Fourth, we did not include other commonly used physical function tests, such as the usual walking speed or the 400-m walk. Given the availability of studies assessing performance measures or sensitivity to change following resistance exercise, this systematic review and meta-analysis were planned to focus on those with a higher number of studies available (eg, 6-minute walking test vs 400-m walk test) and higher sensitivity to change following resistance exercise programs (eg, fast walking speed and timed-up and go vs usual walking speed) in older adults (37,142). Finally, only a few studies were conducted on patients who were physically impaired, and these may have limited our findings for this group.

In conclusion, our study provides evidence that resistance exercise effects on physical function are velocity specific, as evidenced by physical function test dependence in older adults. While high-velocity resistance exercise promoted greater improvements in physical function tests with a time component, traditional resistance exercise was the most effective intervention for improving performance where participants had to work longer. These results are of clinical importance as they indicate that resistance exercise prescription based on the velocity of contraction should be individualized and specific to target the relative deficits of participants' and their needs within the resistance exercise program. Moreover, older adults will often present with a range of deficits in physical function and consequently, both high-velocity and traditional resistance exercise may be required to enhance multiple domains of physical function.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None declared.

Author Contributions

P.L. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; Conception and design: P.L., A.R., and R.R.; Acquisition, analysis, or interpretation of data: P.L., A.R., M.P., R.U.N., D.R.T., D.A.G., D.J.P.T., S.R.F., and R.R.; Drafting of the manuscript: P.L., A.R., M.P., R.U.N., D.R.T., D.A.G., D.J.P.T., S.R.F., and R.R.; Critical revision of the manuscript for important intellectual content: P.L., A.R., M.P., R.U.N., D.R.T., D.A.G., D.J.P.T., S.R.F., and R.R.; Statistical analysis: P.L. and M.P.

Data Availability

Data used in the present study such as data extraction templates, forms, and analysis will be made available upon request to the corresponding author.

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