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Research

High-velocity power training has similar effects to traditional resistance training for functional performance in older adults: a systematic review

Robert T Morrison [a], Sue Taylor [a], John Buckley [b], Craig Twist [c], Chris Kite [a,d,e,f]

[a] Chester Medical School, Faculty of Health, Medicine and Society, University of Chester, University Centre Shrewsbury, Shrewsbury, UK; [b] The School of Allied Health Professions, Keele University, Staffordshire, UK; [c] School of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK; [d] School of Public Health Studies, Faculty of Education, Health and Wellbeing, University of Wolverhampton, UK; [e] Warwickshire Institute for the Study of Diabetes, Endocrinology and Metabolism (WISDEM), University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK; [f] Centre for Sport, Exercise & Life Sciences, Coventry University, Coventry, UK

KEY WORDS

Meta-analysis
Resistance training
Aging
Physical functional performance
Physical therapy

ABSTRACT

Questions: What is the effect of high-velocity power training (HVPT) compared with traditional resistance training (TRT) on functional performance in older adults? What is the quality of intervention reporting for the relevant literature? **Design**: Systematic review and meta-analysis of randomised controlled trials. **Participants**: Older adults (aged > 60 years), regardless of health status, baseline functional capacity or residential status. **Interventions**: High-velocity power training with the intent to perform the concentric phase as quickly as possible compared with traditional moderate-velocity resistance training performed with a concentric phase of ≥ 2 seconds. **Outcome measures**: Short Physical Performance Battery (SPPB), Timed Up and Go test (TUG), five times sit-to-stand test (5-STS), 30-second sit-to-stand test (30-STS), gait speed tests, static or dynamic balance tests, stair climb tests and walking tests for distance. The quality of intervention reporting was assessed with the Consensus on Exercise Reporting Template (CERT) score. **Results**: Nineteen trials with 1,055 participants were included in the meta-analysis. Compared with TRT, HVPT had a weak-to-moderate effect on change from baseline scores for the SPPB (SMD 0.27, 95% CI 0.02 to 0.53; low-quality evidence) and TUG (SMD 0.35, 95% CI 0.06 to 0.63; low-quality evidence). The effect of HVPT relative to TRT for other outcomes remained very uncertain. The average CERT score across all trials was 53%, with two trials rated high quality and four rated moderate quality. **Conclusion**: HVPT had similar effects to TRT for functional performance in older adults, but there is considerable uncertainty in most estimates. HVPT had better effects on the SPPB and TUG, but it is unclear whether the benefit is large enough to be clinically worthwhile. **[Morrison RT, Taylor S, Buckley J, Twist C, Kite C (2023) High-velocity power training has similar effects to traditional resistance training for functional performance in older adults: a systematic review. *Journal of Physiotherapy* 69:148–159]**

Introduction

The World Health Organization describes healthy ageing as 'the process of developing and maintaining the functional ability that enables wellbeing in old age'.[1] Age-related functional decline is characterised by a loss of independence in completing activities of daily living,[2] which has a detrimental impact on quality of life,[3] mortality[4] and the incidence of injurious falls.[5] Because functional decline falls under the physical domain of frailty syndrome,[6] functional trajectories influence frailty risk, making people more vulnerable to negative health outcomes.[7] Whilst acute functional decline can be caused by a medical event, progressive functional decline is often latent and can begin as early as the fifth decade of life.[8–10]

Muscular strength, defined as the ability to apply force to an external resistance or object,[11] is a predictor of functional decline,[12–14] deteriorating by ~15% every decade beyond 50 years of age[15] and by 3.4% annually in people aged > 75 years.[16] The force-velocity relationship illustrates how angular velocity and torque determine movement at each anatomical joint.[17,18] Functional trajectories are influenced by a loss in either force or velocity as people age,[19,20] with movement velocity considered more essential in determining functional performance.[21,22] Consequently, muscle power (the product of force and velocity) is a critical component of functional performance in older individuals[23,24] that declines faster than strength over time,[25,26] with reductions of up to 6% per year in people aged > 70 years.[27] Addressing deficits in strength or power through resistance training may help to mitigate age-related functional decline.[28,29]

Resistance training refers to exercise where muscular contractions are resisted by external loads.[30] High-velocity power training (HVPT) is typically performed with lighter loads (0 to 60% of one-repetition maximum (1RM)) at faster concentric speeds (≤ 1 second); it aims to enhance the rate of force development and peak muscular power.[31,32] To improve maximum strength, traditional moderate-velocity resistance training (TRT) typically employs loads < 60% of

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1RM with a concentric movement duration of 2 to 3 seconds.[33] While multiple studies support the utility of both TRT and HVPT for improving functional performance in older adults,[29,34–40] the relative effect of each training modality on functional performance is likely to be task specific.[41] This is because health-related domains such as cardiorespiratory fitness, muscular strength, muscular endurance, flexibility and body composition,[42] as well as skill-related domains such as power, agility, balance, speed, coordination and reaction time, all influence functional performance to varying degrees.[43] Although both TRT and HVPT can enhance muscular strength, HVPT is regarded as more helpful for activities of daily living, such as rising from a chair or balance recovery for fall prevention,[44,45] which are important components of older individuals' quality of life, independence and health.

To date, several systematic reviews have made direct comparisons of the effectiveness of these modalities on older adults' functional performance[24,37,46–49] but did not fully address the quality of the intervention reporting, which limits the translation and application into practice. Two previous reviews were narrative syntheses that did not quantitatively synthesise study data.[24,37] Three additional systematic reviews included a small number of studies in their analyses (six studies,[47] three studies[46] and four studies[49]); the data were possibly incomplete and the small sample sizes reduced confidence in the findings. A more recent systematic review included 14 trials, but the selection criteria excluded studies where external loading was $<$ 60% of 1RM.[48] Although heavier loads are superior to improve maximum strength,[50] lower resistance training loads ($<$ 60% of 1RM) still provide substantial increases in muscular strength and physical function in older adults,[36,51] meaning that relevant studies may have been omitted. Further, the authors of that review acknowledged that the exclusion of balance outcomes was a limitation of their review. Although balance is not a functional task, it is important to include as it limits movement confidence[52] and is part of the widely used Short Physical Performance Battery (SPPB).

This systematic review aimed to rate the quality of reporting of the exercise interventions in the included studies using a specific tool. In addition, the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) method was used to rate the quality and strength of the evidence.

Therefore, the research questions for this systematic review and meta-analysis were:

1. What is the effect of HVPT compared with TRT on functional performance in older adults?
2. What is the quality of intervention reporting for the relevant literature?

Method

This systematic review was prospectively registered on PROSPERO, conducted in accordance with the Cochrane guidelines for systematic reviews of interventions,[53] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[54] The PRISMA-2020 reporting checklist and PRISMA-S reporting checklist for searches were utilised (see Tables 1 and 2 on the eAddenda).

Identification and selection of studies

Eligible studies had to be randomised trials (including parallel, cluster and crossover designs) and reported in English. No limits were placed on the geographical location or date of publication. Endnote X9 software[a] was used to manage the study records retrieved.

Electronic searches

A comprehensive search was performed of the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed (MEDLINE), Web of Science, CINAHL and SportDiscus (via EBSCOhost) on 5 February 2021. All databases were searched using a customised algorithm (see Appendix 1 on the eAddenda). Additionally, a search for theses was performed using ProQuest Dissertations and Theses Global[b]. Grey literature was identified using Google Scholar[c]. To increase search sensitivity, citation tracking for prior and derivative papers was performed using Connected Papers[d]. Finally, retraction or errata from the included studies was searched for using PubMed. Search results were imported into the Rayyan tool[55] for deduplication and study selection.

Each paper retrieved by the searches was evaluated by two reviewers. Trials were included if they met the predetermined eligibility criteria summarised according to the Population, Intervention, Comparator, Outcome, and Study (PICOS) model[54] (Box 1). The initial screening of title and abstract classified papers as eligible, ineligible or potentially eligible. Where a reviewer could not exclude a paper from the title and abstract or information was missing, two reviewers inspected the full-text version of the paper and discussed relevant points. Any disagreements were resolved through arbitration by a third member of the review team. The selection process was recorded using the PRISMA flow diagram (Figure 1), with the included studies summarised in Table 3; further details are available in Appendix 2 on the eAddenda.

Assessment of characteristics of studies

Risk of bias

The risk of bias for each included study was evaluated using version 2 of the Cochrane risk of bias tool.[56] Bias was assessed based on five domains: randomisation process (selection bias), deviations from intended interventions (performance bias), missing outcome data (attrition bias), measurement of the outcome (detection bias) and selection of the reported result (reporting bias).

Each potential source of bias was graded as high, low or unclear, along with a justification for each decision in a 'Risk of Bias' table. Summary judgements were categorised as low risk, some concerns or high risk, according to the Cochrane guidelines.[56] Blinding of participants is unfeasible in exercise interventions and all studies scored 'high' on this component; however, this was excluded when considering overall performance bias risk.

Two reviewers assessed each trial independently with discordances arbitrated by a third team member. Cohen's κ was used to determine inter-rater agreement. Where study details were inadequate, study authors were contacted for clarification.

Reporting quality

Intervention reporting quality was assessed using the Consensus on Exercise Reporting Template (CERT).[57] The CERT was developed to establish a consensus on reporting exercise interventions that would not only improve transparency of the research, but also allow exercise interventions to be replicated and implemented into clinical care.[58] It provides guidance on 16 items across seven domains that are required to make exercise interventions replicable. Specific domains include materials, provider, delivery, location, dosage, tailoring and compliance. Individual trials were scored on this 16-item checklist with a maximum score of 19. The CERT has previously been implemented by grading studies based on percentage of total score.[59] Studies satisfying $>$ 75% of criteria were considered to have a high level of reporting, 60 to 74% as moderate and $<$ 60% as low.

Study design

All trials that met the inclusion criteria (Box 1) and reported quantitative data in their analysis were included. Whilst trials must have compared interventions of HVPT with TRT, data were also included where the same additional interventions were completed concurrently in both groups.

Box 1. Inclusion criteria.

Design
- Randomised controlled trial

Participants
- Adults aged > 60 years

Intervention
- High-velocity power training
- Concentric phase performed as quickly as possible

Comparator
- Traditional moderate-velocity resistance training
- Concentric cadence ≥ 2 seconds

Outcome measures
- Objective measures of functional performance

Participants

This review included adults aged > 60 years regardless of health status, baseline functional capacity or residential status (eg, community dwelling or institutionalised).

Interventions

Trials were included where they had an intervention group allocated HVPT and a comparison group allocated TRT. Where other groups existed, only data pertaining to the HVPT and TRT groups were considered. For the purposes of this review, HVPT must have been used with the intent to perform the concentric portion of an exercise as quickly as possible, whereas TRT was any training protocol without the explicit intent to maximise concentric velocity.

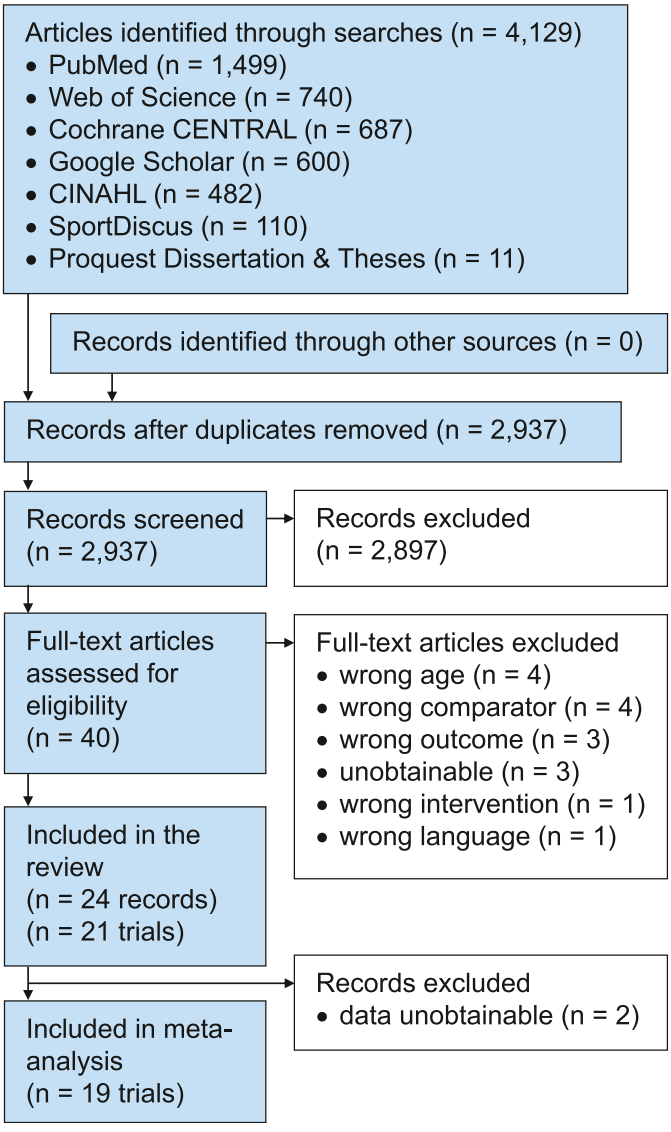

Figure 1. Flow of studies through the review.

Outcome measures

Trials had to report an objective measure of functional performance. Primary outcome measures were the Short Physical Performance Battery (SPPB), Timed Up and Go test (TUG), five times sit-to-stand test (5-STS), 30-second sit-to-stand test (30-STS), gait speed tests, stair climb tests, walking tests for distance, and static and dynamic balance tests.

Data analysis

Appendix 2 on the eAddenda details the specific items for data extraction. A standardised form was devised in Microsoft Excel[e] to extract baseline and post-intervention measures. One reviewer extracted data and a second reviewer independently cross-checked the accuracy of data extraction for all papers. Subsequently, one reviewer entered study data into the Cochrane Collaboration's Review Manager 5.4 software.[f]

Where multiple publications existed for the same trial, these were linked together. The initial paper was used as the primary reference; however, data were extracted from all publications to obtain the maximum information possible. Where change-from-baseline data were not reported, the Cochrane Revman calculator[f] was used to calculate change scores. In cases where the standard deviation (SD) of the change score was not reported, a standard equation[53] was used to calculate them in Microsoft Excel. Where possible, the effects of interventions on all continuous outcome data were presented as a mean difference (MD) and 95% confidence interval (95% CI). Where studies used different scales to measure the same outcome, data were presented as a standardised mean difference (SMD) and 95% CI. A sensitivity analysis was performed in these cases to remove studies with different scales and present the remaining studies as MD. Imperial units were converted to metric units where applicable.

Only data taken directly before and after the intervention were used. For example, de-training phases at follow-up were excluded as the focus of this review was on intervention effectiveness rather than residual effects. In the case of trials reporting multiple time points, the longest period of intervention was used. In the event of missing data, two attempts were made to contact study authors to obtain missing data, with a response waiting time of 6 weeks from the first contact attempt. Where data could not be obtained,[60,61] a sensitivity analysis was intended to be performed to assess the impact of these studies, but only if it were thought that this would introduce significant bias.

Statistical heterogeneity was assessed by both visual inspection of forest plots and formal statistical tests. For visual inspection, heterogeneity was ascertained by the overlap of CIs for each study, with little or no overlap indicating substantial heterogeneity. Formal assessment used the chi-square test to determine whether differences in results were due to chance alone. Heterogeneity was then quantified by the I^2 statistic, which shows the percentage of variation across the studies resulting from heterogeneity and not chance.[53] In accordance with Cochrane guidelines, I^2 values of 0 to 40% were interpreted as low, 30 to 60% as moderate, 50 to 90% as substantial and 75 to 100% as considerable heterogeneity.[53] In cases of moderate, substantial or considerable heterogeneity, study effects were inspected, and an attempt was made to explain heterogeneity via removal of outlier studies and subgroup analysis. To explore publication and small study biases, a funnel plot and Egger's test for asymmetry was used where at least 10 different-sized studies were pooled.[62]

Where studies were judged to be sufficiently similar, a meta-analysis was conducted by grouping continuous outcome data, with results presented as forest plots. A random-effects model was chosen as it was deemed more generalisable to the wider population.[63] Change from baseline scores were the primary focus to account for between-group variability. Post-intervention group differences were included to assess whether the intervention produced a

Table 3
Characteristics of included studies.

Trial	Participants	Intervention			Outcome measures
		Regimen	HVPT	TRT	
Balachandran 2010 [75]	n = 21/17 Age: 71 y (SD 11) BMI: > 30 kg/m^2 % Female: 100 Healthy	Modality: Pneumatic machines Period: 15 wk Session: 40 to 60 min Frequency: 2/wk	3 x 10 to 12 reps 50 to 80% 1RM AFAP	3 x 10 to 12 reps 70% 1RM 2 s	• SPPB (composite)
Bean 2004 [76]	n = 21/20 Age: 78 y (SD 10) BMI: < 30 kg/m^2 % Female: 100 Healthy	Modality: Bodyweight/vests Period: 12 wk Session: 30 min Frequency: 3/wk	3 x 10 reps RPE < 16 AFAP	3 x 10 reps NR 2 s	• SPPB (5-STS, static balance, gait speed)
Bean 2009 [77]	n = 138/138 Age: 75 y (SD 10) BMI: < 30 kg/m^2 % Female: 69 Mobility limitation	Modality: Bodyweight/vests Period: 16 wk Session: 45 to 60 min Frequency: 3/wk	2 x 10 to 12 reps RPE 11 to 16 AFAP	2 x 10 reps RPE 11 to 16 2 s	• SPPB (composite)
Bottaro 2007 [78]	n = 24/20 Age: 66 y (SD 8) BMI: < 25 kg/m^2 % Female: 0 Healthy	Modality: Machines Period: 10 wk Session: NR Frequency: 2/wk	3 x 8 to 10 reps 40 to 60% 1RM AFAP	3 x 8 to 10 reps 40 to 60% 1RM 2 to 3 s	• TUG (8 ft) • 30-STS
Correa 2012 [79]	n = 58/58 Age: 67 y (SD 5) BMI: NR [a] % Female: 100 Healthy	Modality: Machines/bodyweight Period: 12 wk [b] Session: NR Frequency: 2/wk	3 to 4 x 8 to 12 reps 8RM to 12RM AFAP	3 to 4 x 8 to 12 reps 8RM to 12RM 2 s	• 30-STS
Drey 2011 [69,70]	n = 69/69 Age: 77 y (SD 10) BMI: < 30 kg/m^2 % Female: 70 Pre-frail	Modality: Bodyspider machine Period: 12 wk [c] Session: 25 min Frequency: 2/wk	2 x 6 to 15 reps RPE 10 to 16 AFAP	2 x 6 to 15 reps RPE 10 to 16 2 to 3 s	• SPPB (5-STS, static balance, gait speed)
Englund 2017 [71]	n = 26/26 Age: 65 y (SD 6) BMI: < 30 kg/m^2 % Female: 62 Healthy	Modality: Multi-joint dynamometer Period: 6 wk Session: NR Frequency: 3/wk	3 x 8 reps NR 240 deg/s	3 x 8 reps NR 75 deg/s	• SPPB (composite) • TUG
Gray 2018 [73]	n = 99/53 Age: 81 y (SD 10) BMI: < 30 kg/m^2 % Female: 72 Healthy	Modality: Machines/free-weights Period: 48 wk [d] Session: 60 min Frequency: 2/wk	3 x 10 reps 50% 1RM AFAP	3 x 10 reps 80% 1RM 2 s	• TUG (8ft) • 30-STS
Henwood 2006 [66–68]	n = 67/53 Age: 70 y (SD 9) BMI: < 30 kg/m^2 % Female: 56 Healthy	Modality: Machines Period: 24 wk Session: 60 min Frequency: 2/wk	3 x 8 reps 40 to 75% 1RM AFAP	3 x 8 reps 75% 1RM 3 s	• 5-STS • Static balance • 6 m walk (3 variation) • 400 m walk • Stair climb
Kelly 2016 [80]	n = 38/38 Age: 72 y (SD 10) BMI: > 30 kg/m^2 % Female: 63 Total knee arthroplasty	Modality: Machines/bodyweight Period: 7 wk Session: NR Frequency: 2/wk	3 x 10 reps 50 to 80% 1RM AFAP [e]	3 x 10 reps 50 to 80% 1RM 2 s	• TU • 6-minute walk • Stair climb
Lopes 2016 [72]	n = 55/37 Age: 67 y (SD 11) BMI: < 30 kg/m^2 % Female: 100 Healthy	Modality: Machines Period: 12 wk Session: 60 min Frequency: 3/wk	3 to 4 x 6 to 8 reps 40% 1RM AFAP	3 x 6 to 8 reps 60% 1RM 2 to 3 s	• 6-minute walk • 30-STS • TUG • Postural control
Marsh 2009 [81]	n = 45/36 Age: 75 y (SD 10) BMI: > 30 kg/m^2 % Female: 70 Healthy	Modality: Machines Period: 12 wk Session: 60 min Frequency: 2/wk	3 x 8 to 10 reps 40 to 70% 1RM AFAP	3 x 8 to 10 reps 40 to 70% 1RM 2 to 3 s	• SPPB (composite)
Mierzwicki 2020 [60]	n = 18/14 Age: 86 y (SD 10) BMI: NR % Female: 71 (Pre-)frail	Modality: Pneumatic machines Period: 10 wk Session: 30 to 40 min Frequency: 2/wk	2 x 15 to 20 reps 50% 1RM AFAP	2 to 3 x 5 reps 87 to 93% 1RM Slow and controlled	• TUG • 5-STS • 30-STS • 10 m fast walk
Miszko 2003 [82]	n = 65/39 Age: 73 y (SD 6) BMI: < 30 kg/m^2 % Female: 56 Healthy	Modality: Machines Period: 16 wk [f] Session: NR Frequency: 3/wk	3 x 6 to 8 reps 40% 1RM AFAP	3 x 6 to 8 reps 80% 1RM ~4 s	• CS-PFP balance and endurance tests

Table 3 (*Continued*)

Trial	Participants	Intervention			Outcome measures
		Regimen	HVPT	TRT	
Monteiro 2019 [83]	N = 80/80 Age: 75 y (SD 11) BMI: < 30 kg/m^2 % Female: 100 Healthy	Modality: Machines Period: 16 wk Session: NR Frequency: 3/wk	3 to 4 x 3 to 6 reps 40 to 60% 1RM < 1 s	2 to 3 x 8 to 12 reps 60 to 80% 1RM Slow to moderate	• TUG (8 ft)
Pamukoff 2014 [84]	n = 20/15 Age: 71 y (SD 5) BMI: > 30 kg/m^2 % Female: 45 Healthy	Modality: Machines Period: 6 wk Session: 60 min Frequency: 3/wk	2 x 8 to 10 reps 1 x AMRAP 50% 1RM AFAP	2 x 8 to 10 reps 1 x AMRAP 50% 1RM 2 to 3 s	• Forward and lateral lean step recovery (dynamic balance)
Ramírez-Campillo 2014 [85]	n = 60/45 Age: 67 y (SD 9) BMI: > 30 kg/m^2 % Female: 100 Healthy	Modality: Machines/free-weights Period: 12 wk Session: 70 min Frequency: 3/wk	3 x 8 reps 45 to 75% 1RM AFAP	3 x 8 reps 75% 1RM 3 s	• TUG (8 ft) • 30-STS • 10 m fast walk
Richardson 2019 [74]	n = 54/50 Age: 67 y (SD 12) BMI: < 30 kg/m^2 % Female: 50 Healthy	Modality: Machines Period: 10 wk Session: NR Frequency: 1 and 2 /wk	3 x 14 reps 40% 1RM AFAP	3 x 7 reps 80% 1RM 2 s	• TUG (8 ft) • 30-STS • 6-min walk
Sayers 2003 [61]	n = 30/25 Age: 73 y (SD 2) BMI: < 30 kg/m^2 % Female: 100 Healthy	Modality: Pneumatic machines Period: 16 wk Session: NR Frequency: 3/wk	3 x 8 reps 70% 1RM AFAP	3 x 8 reps 70% 1RM 2 s	• Gait speed usual • gait speed fast • 10-STS • Stair climb • Dynamic balance
Tiggemann 2016 [86]	n = 30/25 Age: 65 y (SD 7) BMI: < 30 kg/m^2 % Female: 100 Healthy	Modality: Machines Period: 12 wk Session: NR Frequency: 2/wk	2 to 3 x 8 to 15 reps RPE 13 to 18 AFAP	2 to 3 x 8 to 15 reps RPE 13 to 18 2 s	• TUG (3 m) • 5-STS • 6-min walk • Stair climb
Yoon 2017 [87]	n = 58/30 Age: 76 y (SD 6) BMI: < 25 kg/m^2 % Female: 100 Mild cognitive impairment	Modality: Elastic bands Period: 12 wk Session: NR Frequency: 2/wk	2 to 3 x 12 to 15 reps RPE 12 to 13 AFAP	2 to 3 x 8 to 10 reps RPE 15 to 16 > 2 s	• SPPB (composite) • TUG (8 ft)

AFAP = as fast as possible, AMRAP = as many repetitions as possible, BMI = body mass index, CS-PFP = continuous scale physical functional performance, HVPT = high-velocity power training, NR = not reported, RCT = randomised control trial, RM = repetition maximum, RPE = rating of perceived exertion, SPPB = short physical performance battery, TRT = traditional resistance training, TUG = Timed Up and Go, 5-STS = five times sit-to-stand, 10-STS = 10 times sit-to-stand, 30-STS = 30-s sit-to-stand.

[a] Assumed > 30 from body composition.
[b] First 6 weeks TRT.
[c] 8-week vitamin D supplementation.
[d] First 24 weeks TRT.
[e] Open chain exercises ≤ 1 s.
[f] First 8 weeks TRT.

between-group effect where baseline group differences existed that may bias the estimate of the treatment effect.[64] For the primary comparison, data were pooled from all relevant trials stratified by functional test outcome. The results section includes meta-analyses that revealed statistically significant effects, with all remaining analyses found in Appendix 3 on the eAddenda.

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach was used to assess overall certainty of evidence.[65] The GRADE included the assessment of study limitations, consistency of effect, indirectness, imprecision and publication bias. All outcomes began as high certainty and were downgraded based on the GRADE criteria. Decisions were justified with notes and comments. The degree of certainty was classified as high, moderate, low or very low (Table 4).

Subgroup analysis

Post hoc subgroup analysis was performed for baseline body mass index (BMI), training frequency (< three versus ≥ three/week), age (< 70 versus ≥ 70 years) and intervention duration (< 12 versus ≥ 12 weeks). See differences between protocol and review in Appendix 4 on the eAddenda.

Sensitivity analysis

To determine the stability of the results in this systematic review, sensitivity analysis was performed by excluding studies judged as overall high risk of bias or rated low quality by the CERT checklist.

Results

Flow of studies through the review

The search yielded 4,129 records, with 2,937 remaining after removal of duplicates. After title and abstract screening, 40 records remained, reducing to 24 after full-text analysis (Figure 1, Appendices 2 and 5 on the eAddenda). Included studies were based on 21 trials.[60,61,66–87] Henwood et al[66–68] and Drey et al[69,70] presented multiple papers from the same cohort.

The authors of five trials were contacted to obtain missing outcome data.[60,61,71–73] Unfortunately, after two attempts, there was no response from two authors.[60,61] Neither trial reported favourable effects of HVPT over TRT on any outcome: TUG test,[60] dynamic balance, stair-climb and gait speed.[61]

The third paper from the Henwood et al trial[66] included a subset of participants who were re-trained after a wash-out period. As this paper was omitted from the main meta-analyses, a sensitivity analysis was conducted for each relevant outcome. This same trial[66] was the only one to report the backwards walking and 400 m walk tests. Whilst the effect for the backwards walking test was very uncertain, there was a favourable effect for HVPT in the 400 m walk test (MD

Table 4
Summary of findings table for primary outcomes: high-velocity power training versus traditional lower velocity training.

Outcomes (Change from baseline)	Difference (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
Short Physical Performance Battery (SPPB)	SMD 0.27 (0.02 to 0.53)	245 (6 RCTs)	⊕⊕⊖⊖ low [a,b]	High-velocity power training may improve SPPB performance slightly compared with lower velocity training but with some uncertainty
Timed Up and Go test (TUG)	SMD 0.35 (0.06 to 0.63)	305 (10 RCTs)	⊕⊕⊖⊖ low [b,c]	High-velocity power training may improve TUG performance slightly compared with lower velocity training but with some uncertainty
Five times sit-to-stand (5-STS)	SMD 0.00 (−0.70 to 0.69)	127 (4 RCTs)	⊕⊕⊖⊖ low [b,d]	High-velocity power training may have little to no effect on 5-STS performance compared with lower velocity training
30-second sit-to-stand test (30-STS)	MD 0.96 (−0.49 to 2.41)	179 (6 RCTs)	⊕⊕⊖⊖ low [b,e]	High-velocity power training may have little to no effect on 30-STS performance compared with lower velocity training
Static balance	SMD 0.36 (−0.33 to 1.04)	126 (4 RCTs)	⊕⊕⊖⊖ low [b,f]	High-velocity power training may have little to no effect on static balance compared with lower velocity training
Dynamic balance	MD −0.23 (−0.85 to 0.38)	41 (2 RCTs)	⊕⊖⊖⊖ very low [b,g]	High-velocity power training may have little to no effect on dynamic balance compared with lower velocity training
Usual gait speed	SMD −0.35 (−1.04 to 0.34)	102 (3 RCTs)	⊕⊕⊖⊖ low [b,h]	High-velocity power training may have little to no effect on usual gait speed compared with lower velocity training
Fast gait speed	SMD 0.08 (−0.64 to 0.79)	68 (2 RCTs)	⊕⊖⊖⊖ very low [b,i]	High-velocity power training may have little to no effect on fast gait speed compared with lower velocity training
Long walking tests	SMD 0.17 (−0.15 to 0.49)	153 (5 RCTs)	⊕⊕⊖⊖ low [b,j]	High-velocity power training may have little to no effect on long walking test performance compared with lower velocity training
Stair climb tests	SMD 0.20 (−0.27 to 0.67)	101 (3 RCTs)	⊕⊕⊖⊖ low [b,k]	High-velocity power training may have little to no effect on stair climb performance compared with lower velocity training

High certainty: We are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty: We are moderately confident in the effect estimate. The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: Our confidence in the effect estimate is limited. The true effect may be substantially different from the estimate of the effect. Very low certainty: We have very little confidence in the effect estimate. The true effect is likely to be substantially different from the estimate of effect.
RCT = randomised controlled trial.
[a] Downgraded once: five trials unclear/high risk of selection bias, four trials unclear/high risk of performance bias, three trials unclear/high risk of detection bias, and all trials unclear risk of reporting bias.
[b] Downgraded once: imprecision.
[c] Downgraded once: all trials unclear/high risk of selection bias, six trials unclear/high risk of performance bias, seven trials unclear/high risk of detection bias, and all trials unclear risk of reporting bias.
[d] Downgraded once: three trials unclear/high risk of selection bias, three studies unclear/high risk of performance bias, two trials unclear/high risk of detection bias, and all trials unclear risk of reporting bias.
[e] Downgraded once: all trials unclear/high risk of selection bias, detection bias, and reporting bias; five trials unclear/high risk of performance bias.
[f] Downgraded once: three trials high risk of selection bias, three trials unclear/high risk of performance bias, one trial high risk of attrition bias, three trials unclear/high risk of detection bias, all unclear risk of reporting bias.
[g] Downgraded twice: unclear or high risk of bias across all domains.
[h] Downgraded once: two trials high risk of selection bias, two trials unclear risk of performance bias, two trials unclear/high risk of detection bias, and all trials unclear risk of reporting bias.
[i] Downgraded twice: both included trials unclear/high risk of selection bias, performance bias, detection bias, and reporting bias.
[j] Downgraded once: all trials unclear/high risk of selection bias and reporting bias; four trials unclear/high risk of performance bias; five trials high risk of detection bias.
[k] Downgraded once: all trials unclear/high risk of selection and reporting bias; and two trials unclear risk of performance bias.

11.36 seconds), although it was unclear whether the effect was large enough to be clinically worthwhile (95% CI 0.26 to 22.46).

One study[74] trained groups at different frequencies; these data were treated separately for meta-analysis. The SPPB data from another study[71] were excluded from meta-analysis as post-intervention scores were maximum (12 points) for both HVPT and TRT groups, meaning that the magnitude of improvement beyond this score could not be ascertained. Also, the static balance outcome reported by one study[72] was omitted due to having multiple discrete measures on different scales.

Characteristics of the included studies

The characteristics of studies included in this systematic review are summarised in Table 3 with full details in Appendix 2 on the eAddenda. This review included 21 trials with 1,055 participants. All the included studies were randomised controlled trials (RCTs). There was a total of 57 groups; nine trials had two groups (one HVPT and one TRT),[60,61,71,75–78,80,84,86] eight trials had three groups (two intervention and one control),[69,72,73,79,81,82,85,87] two trials had four groups (three intervention and one control),[66,83] and one trial had five groups (four intervention and one control).[74] The sample sizes ranged from 18[60] to 138 participants[77] randomised. Most trials (k = 19, 90%) were conducted in a university setting (gymnasium/therapy centre). An outpatient physical therapy centre was used in one trial[80] and one trial was conducted in a community gymnasium.[82]

Risk of bias

Details of the risk of bias assessment for all included trials are found in Appendix 2 on the eAddenda. Review authors' judgements are shown in Figures 2 and 3. Inter-rater agreement for this assessment was calculated as high (Cohen's κ = 0.788, 95% CI 0.515 to 1.000). Overall, 16 (76%) of the trials were judged as having a high

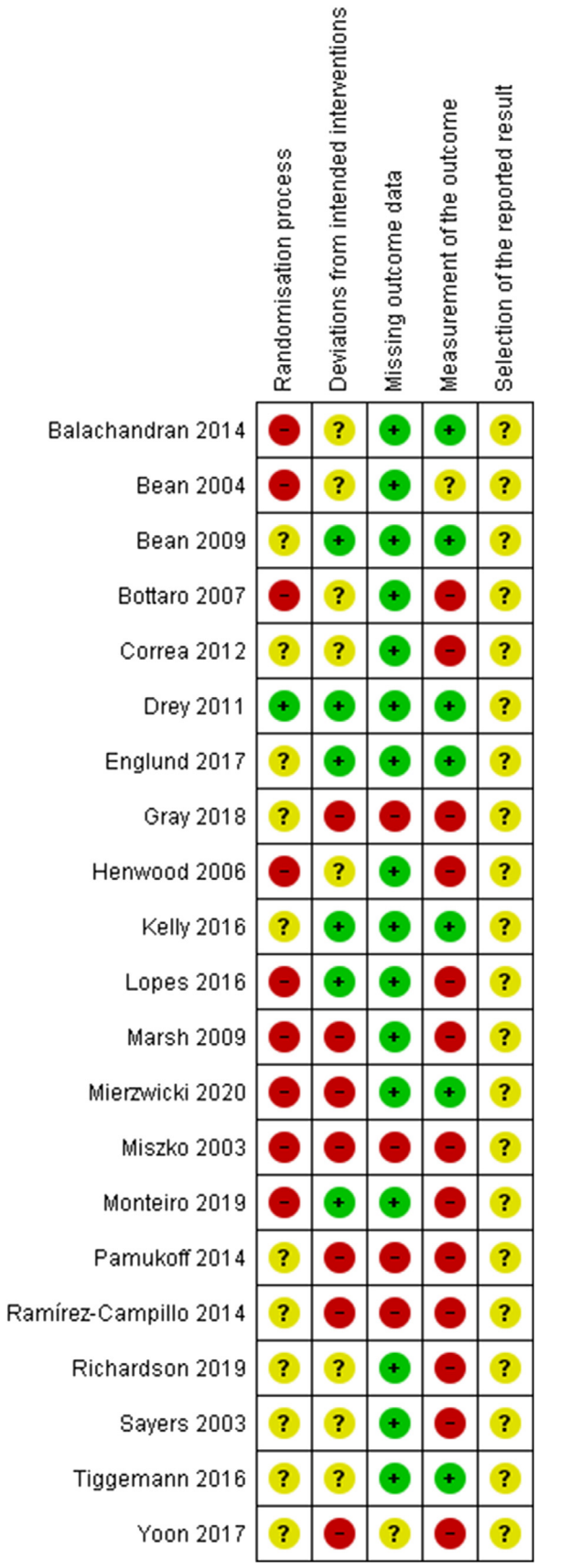

Figure 2. Authors' judgement of methodological quality using the Cochrane Risk of Bias 2 tool.

overall risk of bias and five (24%) were deemed as having some concerns. No trial was judged as having a low overall risk of bias.

One trial was judged as low risk for selection bias,[69] 11 trials (52%) as unclear risk[61,71,73,74,77,79,80,84–87] and nine trials (43%) were deemed

Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

to be high risk.[60,66,72,75,76,78,81–83] In terms of performance bias, six trials (29%) were judged as low risk,[69,71,72,77,80,83] eight trials (38%) as unclear risk[61,66,74–76,78,79,86] and seven trials (33%) as high risk.[60,73,81,82,84,85,87] Most trials (k = 16, 76%) were judged to be at low risk of attrition bias,[60,61,66,69,71,72,74–81,83,86] one trial as unclear risk[87] and four as high risk.[73,82,84,85] For detection bias, most trials (k = 13, 62%) were judged as high risk[61,66,72–74,78,79,81–85,87] and seven trials (33%) as low risk.[60,69,71,75,77,80,86] All trials were judged to have an unclear risk of reporting bias.

Quality of reporting

The average CERT score across all trials was 53% (Figure 4; Appendices 6 and 7 on the eAddenda). Two trials (10%) were rated 'high' quality,[77,81] whilst four trials (19%) were rated 'moderate'.[61,76,80,84] Common downgrade criteria included: not reporting qualifications/experience of those delivering the intervention, details for supervision, adherence, replication and study adherence/fidelity. Conversely, almost all trials (k = 18, 86%) provided detail on exercise progression and one trial did not provide an adequate description of the intervention.[71]

Participants

Of the 1,055 participants who were randomised, 224 were lost to follow-up, resulting in follow-up data being available for 831 participants. Across studies that reported participant sex (k = 20), 70% of the sample were female. All participants were female in nine trials[61,72,75,76,79,83,85–87] and all male in one trial.[78]

The mean participant age ranged from 65[71] to 86 years.[60] Most trials (k = 17, 81%) had participants that were assumed healthy. Three trials incorporated participants who were classified as pre-frail or frail[60,69,77] and one trial included participants who were post-total knee arthroplasty.[80]

Interventions

The intervention period ranged from 6[71,84] to 48 weeks,[73] with a mean period of 14 weeks. However, only part of the intervention period compared HVPT with TRT in three trials.[73,79,82] Training frequency was twice per week in 12 trials,[60,66,69,73,75,78–81,86,87] and three times/week in nine trials.[61,71,72,76,77,82–85] One trial had groups training both once and twice/week[74] and these were treated separately for meta-analysis. Where reported (k = 11), session duration ranged from 25[69] to 70 minutes,[85] with the most common session duration being 60 minutes (k = 6).[66,72,73,81,84] Session duration was not reported in 10 trials.[61,71,74,78–80,82,83,86,87]

Most studies defined HVPT as 'a concentric velocity as fast as possible' (k = 18, 86%) and three trials defined HVPT as a 24 deg/second concentric velocity,[71] < 1 second,[83] and ≤ 1 second,[80] respectively. TRT was performed in nine trials at a concentric velocity of 2 seconds,[61,73–77,79,80,86] 2 to 3 seconds in five trials,[69,72,78,81,84] 3 seconds in two trials,[66,85] 4 seconds in one trial,[82] > 2 seconds in one trial,[87] and 75 deg/second in one trial.[71] TRT was defined in two trials

Figure 4. Summary graph of results for the reporting quality evaluation: % of trials rated by each Consensus on Exercise Reporting (CERT) domain.

as 'slow and controlled' and 'slow to moderate' concentric velocities, respectively.[60,83]

Interventions used weight-stack resistance machines in nine trials,[66,72,74,78,81–84,86] pneumatic resistance machines in three trials,[60,61,75] elastic resistance bands in two trials,[69,87] bodyweight with weighted vests in two trials,[76,77] a multi-joint dynamometer in one trial,[71] and combined interventions in four trials (Table 3).[73,79,80,85] To determine training intensity, trials used a wide range of % 1RM or RPE scale values (Table 3). Intensity was not reported in one trial.[71]

Outcomes

Reported outcomes (Table 3) included the TUG test (k = 11),[60,71–74,78,80,83,85–87] SPPB composite test score (k = 7),[69,71,75–77,81,87] 5-STS (k = 5),[60,66,69,76,86] 30-STS (k = 6),[60,72–74,78,79,85] various balance tests (k = 7),[61,66,69,72,76,82,84] endurance-oriented walking tests (k = 6),[66,72,74,80,82,86] gait speed tests (k = 6),[60,61,66,69,76,85] and stair climb tests (k = 4).[61,66,80,86]

Effects of interventions

Ten outcomes were assessed when HVPT was compared with TRT for functional performance in older adults (Tables 4 and 5). The estimates of effect were very uncertain for the 5-STS, static balance, dynamic balance, usual gait speed, fast gait speed, long walking, and stair climb outcomes for change from baseline, or comparison of post-intervention values (Table 5, and Figures 5 to 11 in Appendix 3 on the eAddenda). Findings for the 30-STS showed comparable change scores although post-intervention values revealed an effect in favour of HVPT (Figure 12 in Appendix 3 on the eAddenda). A sensitivity analysis to include additional data from Henwood et al[66] for the 5-STS, static balance, usual gait speed, fast gait and stair climb outcomes did not influence results (Figures 13 to 17 in Appendix 3 on the eAddenda). The removal of Drey et al,[69] who used a different 5-STS scale, did not influence results when pooled as a MD (MD 0.36 seconds, 95% CI −1.27 to 1.98; three trials, 83 participants, I^2 = 85%; Figure 18 in Appendix 3 on the eAddenda). Subgroup analyses revealed a favourable effect for HVPT in the TUG, 30-STS and static balance outcomes for higher training frequencies (Appendix 8 on the eAddenda).

Table 5
Effect estimates and heterogeneity for change from baseline and post-intervention values.

Outcome (test)	Trials	Change scores from baseline					Post-intervention values				
		N	SMD	95% CI		I^2 (%)	N	SMD	95% CI		I^2 (%)
				Lower	Upper				Lower	Upper	
SPPB	69,75–77,81,87	245	0.27	0.02	0.53	0	245	0.23	−0.02	0.48	0
TUG	71–74,78,80,83,85–87	305	0.35	0.06	0.63	33	305	0.27	0.04	0.50	3
5-STS	66,69,76,86	127	0.00	−0.70	0.69	72	127	0.26	−0.25	0.78	50
30-STS	72–74,78,79,85	179	0.96[a]	−0.49	2.41	73	179	0.86[a]	0.08	1.64	0
Static balance	66,69,76,82	126	0.36	−0.33	1.04	70	126	0.30	−0.15	0.76	36
Dynamic balance	72,84	15	−0.48	−1.51	0.56	0	15	−0.33	−1.36	0.69	0
Usual gait	66,69,76	102	−0.35	−1.04	0.34	64	102	−0.09	−0.80	0.61	66
Fast gait	66,85	68	0.08	−0.64	0.79	55	68	0.03	−0.63	0.69	47
Long walking tests	72,74,80,82,86	153	0.17	−0.15	0.49	0	153	0.32	−0.00	0.64	0
Stair climb	66,80,86	101	0.20	−0.27	0.67	29	101	−0.24	−0.64	0.15	0

SPPB = short physical performance battery, TUG = Timed Up and Go test, 5-STS = five times sit-to-stand, 30-STS = 30-second sit-to-stand.
[a] mean difference.

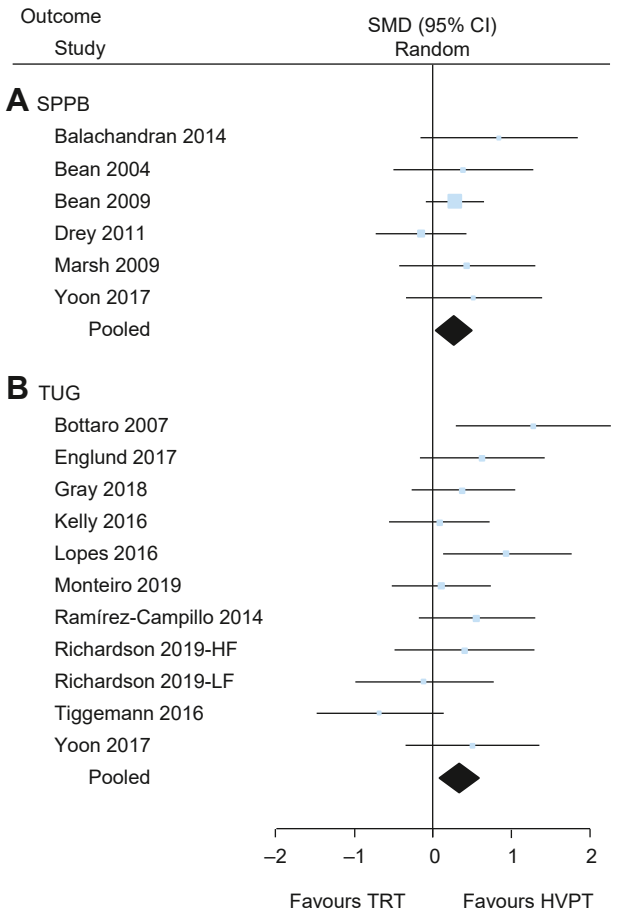

Figure 19. Forest plot showing the effect of high-velocity power training (HVPT) relative to traditional resistance training (TRT) as change scores for (A) the short physical performance battery (SPPB) and (B) Timed Up and Go test (TUG).

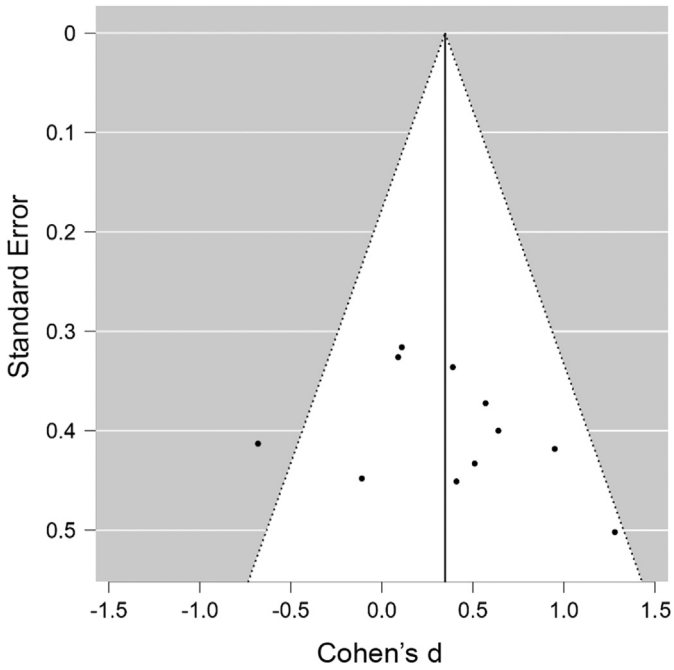

Figure 27. Funnel plot for the Timed Up and Go test outcome.

There were weak to moderate effects for change from baseline scores favouring HVPT for the SPPB and TUG outcomes. Figure 19 depicts simplified forest plots for these meta-analyses. Detailed forest plots are found in Figure 20 in Appendix 3 on the eAddenda.

For the SPPB, results were based on pooled SMD as one study utilised a modified scale.[75] Meta-analysis revealed a weak to moderate effect in favour of HVPT on change from baseline SPPB score (SMD 0.27, 95% CI 0.02 to 0.53; six trials, 245 participants, I^2 = 0%; low-certainty evidence; Table 5; Figure 19A; Figure 20 in Appendix 3 on the eAddenda). In sensitivity analyses, this effect was not retained following removal of trials rated as having a high overall risk of bias or removal of trials rated 'low' (< 60%) on the CERT checklist (Figures 21 and 22 in Appendix 3 on the eAddenda). A sensitivity analysis was performed because Balachandran et al[75] used a circuit training protocol for HVPT but not TRT. The removal of this trial, with the results pooled as a MD, revealed an uncertain effect (MD 0.33, 95% CI 0.00 to 0.67; five trials, 228 participants, I^2 = 0%; Figure 23 in Appendix 3 on the eAddenda).

Two variants of the TUG test were reported, so results were based on pooled SMD. There was a weak to moderate effect in favour of HVPT for TUG change from baseline scores (SMD 0.35, 95% CI 0.06 to 0.63; 10 trials, 305 participants, I^2 = 33%; low-certainty evidence; Table 5; Figure 19B, Figure 24 in Appendix 3 on the eAddenda). This was supported by a weak to moderate effect for HVPT in comparison of post-intervention values (SMD 0.27, 95% CI 0.04 to 0.50, I^2 = 3%; low-certainty evidence; Figure 24 in Appendix 3 on the eAddenda). Sensitivity analyses revealed no effect for TUG change scores or post-intervention values when trials rated as having a high overall risk of bias or trials rated 'low' on the CERT checklist were removed (Figures 25 and 26 in Appendix 3 on the eAddenda). The largest outlier was removed to explore heterogeneity in the TUG change score analysis. This resulted in the I^2 statistic being reduced to 0% with the effect maintained (SMD 0.42, 95% CI 0.18 to 0.66). There was no indication of publication and small studies bias. Visual inspection of a funnel plot did not find marked asymmetry and Egger's test did not show asymmetry (Figure 27).

Discussion

This systematic review and meta-analysis provides evidence that HVPT may be as effective as TRT for functional performance in older adults, but there is still considerable uncertainty. Twenty-one RCTs were included and 19 (1,007 participants) were meta-analysed. However, most trials lacked pre-registration and were judged to have a high overall risk of bias with poor intervention reporting quality, resulting in the quality of evidence being classified as low to very low. Although meta-analyses for two global tests of functional performance, the SPPB and TUG tests, showed weak to moderate effects in favour of HVPT, these estimates were imprecise with some uncertainty.

All of the reported outcomes rely on the integration of several health and skill-related domains,[88] thus the results may have been influenced by changes in rate of force development, maximal strength or a combination of both.[88–90] Accordingly, individual components of global tests of functional performance should be reported where effects of muscle power and strength are being investigated, particularly where tests incorporate disparate movements.[91] However, as functional performance is a multidimensional concept, it is not possible to identify the relative contribution of power or strength to each individual test component.[92,93] The majority of included trials reported positive changes from baseline for both interventions, suggesting that each intervention may provide a distinct benefit. This implies that, in terms of strength or power, functional performance cannot be limited to an either/or strategy and that a combined approach may produce the best results. Notably, this is consistent with the American College of Sport Medicine position stand for resistance training progression in older adults,[33] which recommends the concurrent performance of both HVPT (one to three sets, 30 to 60% 1RM, 12 to 15 repetitions) and TRT (one to three sets, 60 to 80% 1RM, 8 to 12 repetitions). However, current global physical activity guidelines do not recommend a specific dose of power training, although they recognise the role of multicomponent physical activity involving aerobic, balance and resistance training activities.[94–96]

Training specificity, which is often overlooked in trials comparing HVPT and TRT, was an important factor that limited interpretation of the findings of this systematic review. While training adaptation occurs at the specific speeds performed,[97] this remains a contentious issue.[98] Some authors suggest that the intent to move faster, even at slower actual velocities (eg, TRT), may provide comparable changes in rate of force development.[97,99] Yet, focusing on training that mirrors the demands of a certain task improves functional performance to a greater extent.[100–102] The specific physiological adaptations that occur during functional movement training can be attributed to the Specific Adaptation to Imposed Demands principle[103] and are affected by Fitts law.[104] As a result, muscle power is compromised until task mastery has occurred.[105] This concept has been demonstrated by improvements in rate of force development over a single practice session.[106] Only three trials in this review incorporated some outcome practice during the intervention period;[76,80,85] one of these used specific sit-to-stand training with weighted vests, reporting a large effect size in favour of HVPT.[76] Moreover, strength can be developed in a generalised manner and transfers the capacity to generate force across tasks, whereas skill transfer (ie, power) is limited.[107] Given the lack of training specificity across all outcomes, it is plausible that the transfer of strength developed from either HVPT or TRT explains their comparable effect. Adaptations to HVPT may have been attenuated by a lack of task-specific practice to maximise rate of force development.[108] Hypothetically, higher velocity training may have a role for specific 'functional training';[109] purpose-driven exercise that mirrors activities of daily living.[110] This type of application is important for older adults' quality of life, mobility and independence;[111] however, data on this topic remain scarce.[112]

Strength curves based on the muscles' force-angle (torque) relationship govern the mechanical loading of exercise movements,[113] classified as: ascending, descending and bell-shaped.[114] Training protocols used in the trials included pneumatic machines, weight-stack machines, elastic resistance, body weight and free weights. Elastic resistance and free weights have different strength curves than resistance machines and are likely to provide a unique training stimulus,[115,116] with pneumatic machines being shown to improve movement velocities when compared with free weights.[117] Consequently, it remains unclear whether a particular method of training had a greater influence on the results.

There were some limitations to this systematic review and meta-analysis. Study selection criteria meant that other interventions with a power component such as plyometric training or jump training were omitted. Despite a comprehensive search, it is possible that some relevant literature was missed. Only studies published in English were included, meaning that some publications in other languages may have been missed. Version 2 of the Cochrane risk of bias tool has poor to modest inter-rater reliability, meaning that the risk of bias findings should be interpreted with caution. There were some differences between the study protocol and the review related to the definition of HVPT, and pre-defined subgroup and sensitivity analyses. These changes did not influence the overall results (see Appendix 4 on the eAddenda).

Several factors may influence the overall completeness of the evidence. Limited follow-up in primary studies means that this systematic review included only baseline and immediately post-intervention data and did not seek to evaluate the retained effects of either training modality. Factors outside of functional performance outcomes, such as quality of life, were not considered. There is also a paucity of pragmatic studies that examine real-world outcomes outside of a university or therapy clinic. Most studies used supervised group training sessions that may have influenced the participants' effort as per the Hawthorne effect.[118] The generalisability of the findings were limited by most participants being female, reportedly healthy and without functional impairment at baseline. Although a precise threshold has not been identified,[119,120] participants were possibly above the threshold required to see meaningful differences from resistance training, as seen in the relatively small change scores. A lack of functional impairment at baseline across outcomes precluded further subgroup analysis in this regard. For example, the mean baseline values in all studies reporting the SPPB outcome were > 7, which is considered a threshold for functional impairment.[121] Individuals with greater functional impairment can still increase muscle strength and power and may benefit the most from resistance training.[122] It is unknown whether TRT and HVPT may have comparable effects in this population.

To reduce the risk of bias in future trials, pre-registration, disclosure of the randomisation process and blinding of assessors should be performed. Moreover, the lack of participants with low physical functioning highlights the need to include a wider range of baseline functional capacity in trials. Given the diverse interventions, there is a need to conduct more studies using similar protocols for machines, elastic bands or task-specific training, combined with more specific training for outcomes. This would ensure a consistency of training stimulus and enable a better comparison between HVPT and TRT. Finally, the value of either modality may not be fully revealed from a focus on specific functional outcomes; therefore, a broader range of outcomes should be considered for future research. Future trials should compare the effects of HVPT and TRT on quality of life, exercise-related perceived exertion and exercise adherence in older adults.

In conclusion, this review discovered that there is low to very low quality evidence that the efficacy of HVPT may be equivalent to TRT protocols for functional performance in older adults, but the true effect remains uncertain due to the high degree of imprecision. There is currently insufficient evidence to recommend HVPT over TRT in practice. Across the included studies, there was a lack of training specificity and diverse protocols, which may have diluted the true effect of either modality. Future research is required to determine whether specific and/or combined protocols may be more favourable with either of these individual approaches for enhancing functional performance in older individuals.

What is already known on this topic: Functional performance is a vital component of quality of life, independence and health in older adults. Both higher and lower velocity resistance training are viable options to improve functional performance.
What this study adds: Resistance training at both higher and lower velocities are similarly effective in improving older adults' functional performance, although the estimated difference in effect was uncertain. High-velocity power training had better effects than traditional resistance training on the Short Physical Performance Battery and Timed Up and Go test, but it is unclear whether these benefits are large enough to be clinically worthwhile.

Footnotes: [a] Endnote. Version Endnote X9. Philadelphia, PA: Clarivate Analytics; 2013.
[b] ProQuest Dissertations and Theses Global, www.proquest.com.
[c] Google Scholar, https://scholar.google.com/.
[d] Connected Papers, www.connectedpapers.com.
[e] Microsoft Excel, https://office.microsoft.com/excel: Microsoft; 2018.
[f] Revman. London: The Cochrane Collaboration; 2020.
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