Sports Med
DOI 10.1007/s40279-017-0676-4

SYSTEMATIC REVIEW

Effect of Movement Velocity During Resistance Training on Dynamic Muscular Strength: A Systematic Review and Meta-Analysis

Timothy B. Davies[1] · Kenny Kuang[1] · Rhonda Orr[1] · Mark Halaki[1] · Daniel Hackett[1]

Abstract

Background Movement velocity is an acute resistance-training variable that can be manipulated to potentially optimize dynamic muscular strength development. However, it is unclear whether performing faster or slower repetitions actually influences dynamic muscular strength gains.

Objective We conducted a systematic review and meta-analysis to examine the effect of movement velocity during resistance training on dynamic muscular strength.

Methods Five electronic databases were searched using terms related to movement velocity and resistance training. Studies were deemed eligible for inclusion if they met the following criteria: randomized and non-randomized comparative studies; published in English; included healthy adults; used isotonic resistance-exercise interventions directly comparing fast or explosive training to slower movement velocity training; matched in prescribed intensity and volume; duration ≥4 weeks; and measured dynamic muscular strength changes.

Results A total of 15 studies were identified that investigated movement velocity in accordance with the criteria outlined. Fast and moderate-slow resistance training were found to produce similar increases in dynamic muscular strength when all studies were included. However, when intensity was accounted for, there was a trend for a small effect favoring fast compared with moderate-slow training when moderate intensities, defined as 60–79% one repetition maximum, were used (effect size 0.31; $p = 0.06$). Strength gains between conditions were not influenced by training status and age.

Conclusions Overall, the results suggest that fast and moderate-slow resistance training improve dynamic muscular strength similarly in individuals within a wide range of training statuses and ages. Resistance training performed at fast movement velocities using moderate intensities showed a trend for superior muscular strength gains as compared to moderate-slow resistance training. Both training practices should be considered for novice to advanced, young and older resistance trainers targeting dynamic muscular strength.

Key Points

This is the first systematic review and meta-analysis to investigate the effect of movement velocity during resistance training on muscular strength.

Analyses showed that fast and moderate-slow resistance training produce similar gains in muscular strength.

Fast compared with moderate-slow resistance training performed at moderate intensities (60–79% one repetition maximum) showed a trend for superior gains in dynamic muscular strength with training status and age not influencing the results.

1 Introduction

Muscular strength is an important component of fitness and has been shown to improve health, functional ability, and quality of life of apparently healthy [1, 2] and chronic

Electronic supplementary material The online version of this article (doi:10.1007/s40279-017-0676-4) contains supplementary material, which is available to authorized users.

✉ Daniel Hackett
daniel.hackett@sydney.edu.au

[1] University of Sydney, Sydney, NSW, Australia

Published online: 20 January 2017

disease populations [3, 4] in addition to improving the performance of athletes [5]. For individuals desiring increased dynamic muscular strength [i.e., 1 repetition maximum (1 RM)], the American College of Sports Medicine (ACSM) provides resistance-training recommendations for novice (no resistance-training experience) to advanced (>12 months resistance-training experience) trainers [5]. These recommendations consist of information related to acute training variables such as exercise selection, sets per exercise, repetitions per set, rest between sets, training volume, intensity, and movement velocity. Specifically, movement velocities ranging from slow to moderate are recommended for individuals with <12 months resistance-training experience, whilst for advanced trainers, a wide range of velocities are advocated, with encouragement to maximize concentric velocity [5]. However, the evidence cited to support movement velocity recommendations has been derived from either acute studies [6, 7] or studies that did not adequately control for critical training variables such as volume (sets × repetitions × load) and relative intensity [8, 9]. Hence, it is unclear whether manipulation of movement velocity during resistance exercises actually influences dynamic muscular strength gains.

Movement velocities used during resistance training are commonly described as the time taken to perform the concentric (muscle shortening) and eccentric (muscle lengthening) muscle actions. Various movements with fast velocity have been studied and include ballistic strength/power training (such as throwing weighted objects) [10] and plyometric training [11]. However, for the purposes of the current review, resistance training performed with fast movement velocity is defined as ≤1:1 (i.e., ≤1 s concentric: ≤1 s eccentric) or with maximal concentric velocity (e.g., explosive); moderate velocity is define as 1–2:1–2, whilst slower movement velocity is >2:2 [5]. It should be noted that even though a trainer may attempt to deliberately manipulate movement velocity, this may not be possible depending on the load used [9]. For example, it is difficult to perform sets of repetitions at fast movement velocities using ≥85% 1 RM [9] or when performing sets to concentric failure [12]. Consequently, many studies that have investigated the effect of resistance-exercise movement velocity on muscle performance have assigned heavier loads for the slower-training group and lighter loads for the faster-training group (commonly referred to as power training) [12–17]. The majority of these studies demonstrated no differences in dynamic muscular strength between slower and faster movement velocities, although the results are most likely confounded due to inadequate control of training intensities and/or volume.

The purpose of this review was to use systematic review and meta-analytical approaches to examine the effect of fast- compared with moderate-slow movement velocity resistance training on dynamic muscular strength. Where possible, subgroup analyses were conducted to determine whether training intensity, training status, and age (i.e., elderly vs. adult) influenced these effects. Information gathered from this meta-analysis will be useful to strength and conditioning coaches (and athletes) when devising resistance-training programs to maximize dynamic muscular strength development.

2 Methods

2.1 Search Strategy and Study Selection

A search from the earliest record up to and including August 2016 was carried out using the following electronic databases: MEDLINE, PubMed, Scopus (first 2000 articles in order of relevance), SPORTDiscus and Web of Science. The search strategy employed combined the terms 'tempo' OR 'speed' OR 'slow' OR 'fast' OR 'velocity' OR 'power' OR 'cadence' OR 'explosive' AND 'weightlifting' OR 'weight lifting' OR 'weight-training' OR 'weight training' OR 'resistance-training' OR 'resistance training' OR 'resistance exercise' OR 'strength-training' OR 'strength training.' The titles and abstracts of the retrieved articles were individually evaluated by two reviewers (T.D. and K.K.) to assess the eligibility of studies to be included in the review and meta-analysis. Any disagreements were solved by consensus by a third reviewer (D.H.). The reviewers were not blinded to the studies' authors, institutions, or journals of publication. Studies with abstracts that did not provide sufficient information according to the inclusion criteria were retrieved for full-text evaluation. The corresponding authors of articles that were potentially eligible were contacted for any missing data or clarification of data presented. This systematic review and meta-analysis was conducted in accordance with the recommendations outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [18].

2.2 Eligibility Criteria

Articles were eligible for inclusion if they met the following criteria: (1) randomized and non-randomized comparative study; (2) scientific article published in English; (3) adult participants (≥18 years of age); (4) participants recruited had no known medical condition or injury; (5) isotonic resistance-training intervention; (6) intervention group (fast) in which the concentric and/or eccentric phase of each repetition was performed in ≤1 s or described as lifting with maximal concentric velocity (e.g., 'explosive'); (7) comparison group (moderate-slow) that performed repetitions (i.e., concentric plus eccentric phase) at a slower movement velocity or not intending to lift with maximal concentric velocity; (8) matched in prescribed intensity (% 1 RM or RM) and volume (repetitions × sets); (9) interventions ≥4 weeks duration; and (10) measured dynamic muscular strength changes.

2.3 Data Extraction

Two reviewers (T.D. and D.H.) separately and independently evaluated full-text articles and conducted data extraction, using a standardized, predefined form. Relevant data regarding participant characteristics (age, training experience, and body weight), study characteristics [training frequency, exercises prescribed, sets, repetitions, rest between sets, intensity, tempo of exercise(s), intervention length, and compliance], and dynamic muscular strength testing were collected. Shortly after extractions were performed, the reviewers crosschecked the data to confirm their accuracy. Any discrepancies were discussed until a consensus was reached, with any disagreements being resolved by consultation with a third reviewer (M.H.).

2.4 Quality Analysis

Methodological quality of studies meeting the inclusion criteria was assessed using a modified Downs and Black quality assessment tool [19] (Electronic Supplementary Material Appendix S1). Briefly, scores ranged from 0 to 29 points, with higher scores reflecting higher-quality research. Scores above 20 were considered good, scores of 11–20 were considered moderate, and scores below 11 were considered poor methodological quality [20]. Studies were independently rated by two reviewers (T.D. and D.H.) and checked for internal (intra-rater) consistency across items before the scores were combined into a spreadsheet for discussion. If disagreements between ratings occurred, they were resolved by discussion or consensus was reached through the assistance of a third reviewer (M.H.).

2.5 Statistical Analysis

Data are presented as mean ± standard deviation (SD) or confidence interval (CI). All analyses were conducted using Comprehensive Meta-Analysis version 2 software (Biostat Inc., Englewood, NJ, USA). The level of significance was set at $p < 0.05$, and trends were declared at $p = 0.05$ to ≤0.10. Effect size (ES) values were calculated as standardized differences in the means. An ES of 0.2 was considered a small effect, 0.5 a moderate effect, and 0.8 a large effect [21]. Within-group change in dynamic muscular strength was determined by calculation of the difference between pre- and post-intervention. The mean relative percentage change (post- minus pre-training dynamic muscular strength, divided by pre-training dynamic muscular strength, multiplied by 100) was calculated for the fast and moderate-slow groups. When studies had multiple outcomes (e.g., tested dynamic muscular strength on multiple movements), ESs were averaged across outcomes. Additionally, the variance of ESs was calculated as $V = 0.25\ (V_1 + V_2 + 2r\sqrt{V_1}\sqrt{V_2})$, where '$V_1$' and '$V_2$' are the variance of outcome 1 and 2 respectively and 'r' is the correlation coefficient (set at 0.5) between the two outcomes [22].

Between-study variability was examined for heterogeneity, using the I^2 statistic for quantifying inconsistency [23]. The heterogeneity thresholds were set at $I^2 = 25\%$ (low), $I^2 = 50\%$ (moderate), and $I^2 = 75\%$ (high) [23]. To be conservative, a random-effects model of meta-analysis was applied to the pooled data. A funnel plot and rank correlations between effect estimates and their standard errors (SEs), using Kendall's τ statistic [24], were used to examine publication bias when a significant result ($p < 0.05$) was found. The primary analysis compared the effect of fast versus moderate-slow repetitions on outcomes of dynamic muscular strength. Sub-group analyses were performed on dynamic muscular strength outcomes in relation to training intensity, training status, and age (i.e., elderly vs. adult).

3 Results

3.1 Description of Studies

The database search yielded 33,423 potential studies with the addition of three studies identified from reference lists and external sources (Fig. 1). Fifteen studies [25–39] met the eligibility criteria and were included in the systematic review and meta-analysis. There were a total of 509 participants (292 males and 217 females) aged 19–73 years. Of the 15 studies that were included in the analysis, four studies included elderly participants [26, 27, 37, 38], with the remaining studies using younger adult participants [25, 28–36, 39] (Table 1).

Training status varied, with 108 participants having previous resistance-training experience [25, 28, 30, 31, 34] and 401 participants having no prior resistance-training experience [26, 27, 29, 32, 33, 35–39] (Table 1). The training specifics of each study are presented in Table 2. All included studies had participants in both the fast and moderate-slow interventions complete the same resistance-training program. This included 1–6 sets of 2–13 repetitions at loads of either 30–95% 1 or 6–12 RM. Six studies stated that both interventions performed resistance exercise to concentric failure [25, 31–33, 35, 39].

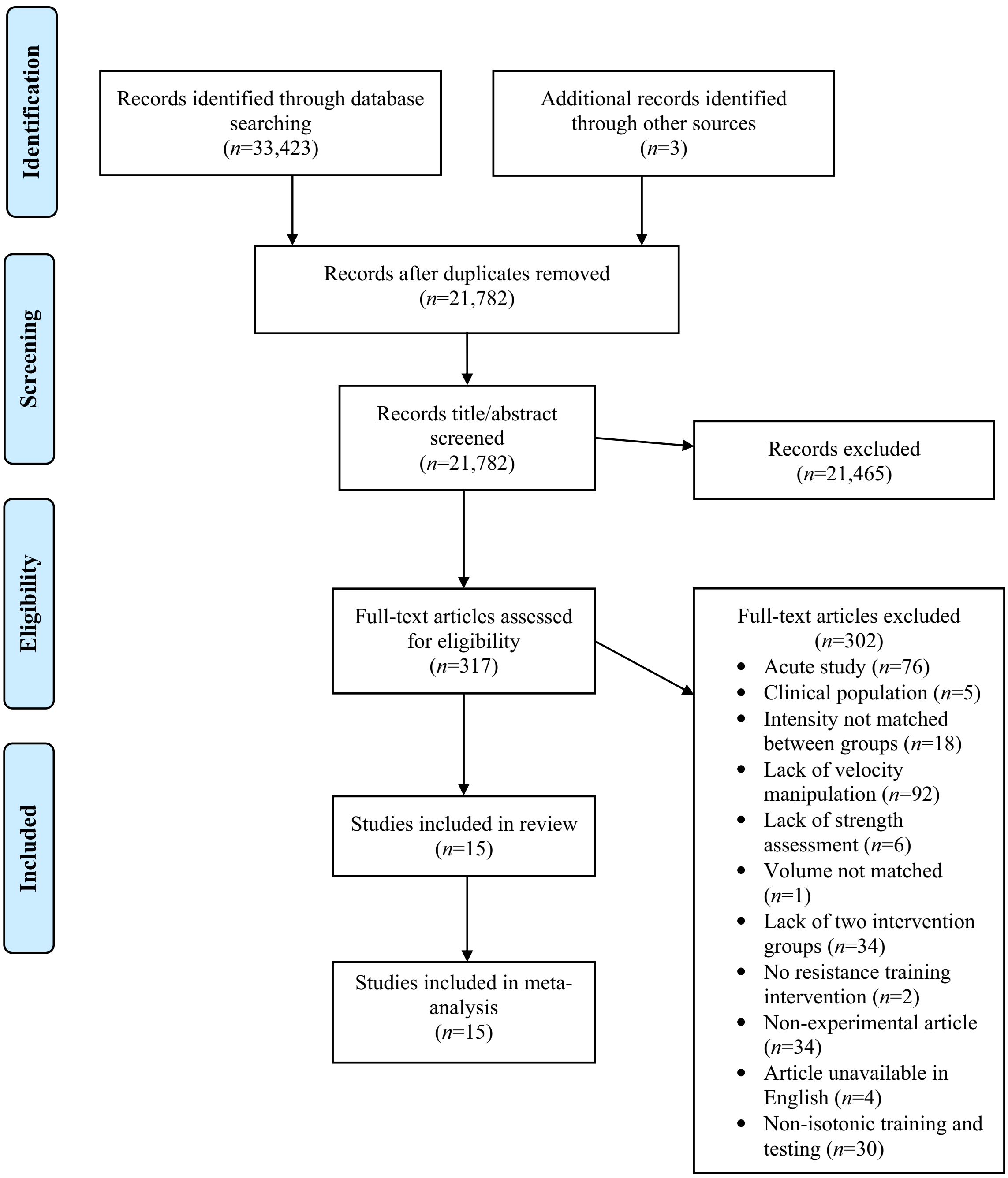


Fig. 1 Flow chart of the study retrieval process

Participants in the fast condition performed the concentric phase of repetitions explosively in eight studies [26–31, 34, 39], while the remaining studies provided a 1-s tempo [25, 32, 33, 35–38]. The eccentric phase was performed with a 1- to 3-s tempo [25–27, 29, 31–33, 35–38] or with verbal instruction to be moderate-slow and controlled [28, 30, 34, 39]. Participants in the moderate-slow condition performed the concentric phase of each repetition with a tempo of 1.7–3 s [25–27, 29, 31–33, 35–38] or with deliberate intent to reduce velocity [28, 30, 34, 39]. The eccentric phase was performed with a tempo of 1.7–3 s [25–27, 29, 31–33, 35–38] or with verbal instruction to be moderate-slow and controlled [28, 30, 34, 39].

All studies tested dynamic muscular strength using the 1 RM [25–39]. Two studies tested 1 RM on both upper and lower body movements [26, 35], seven studies tested 1 RM on lower body movements only [27, 32, 34, 36–39], and six studies tested 1 RM on upper body movements

Table 1 Participant characteristics of included studies

Study	Group	Number of participants	Sex: M (%)	Age (years)[a]	Height (cm)[a]	Weight (kg)[a]	Training status
Assis-Pereira et al. [25]	Fast	6	100	28.3 ± 8.2	172.3 ± 5.3	72.3 ± 9.3	Trained
	Slow	6	100	30.3 ± 5.6	172.6 ± 4.8	73.8 ± 5.1	Trained
Bottaro et al. [26]	Fast	11	100	66.6 ± 5.8	171.7 ± 5.9	62.0 ± 8.0	Untrained
	Slow	9	100	66.3 ± 4.8	169.6 ± 6.4	61.4 ± 8.7	Untrained
Fielding et al. [27]	Fast	15	100	73.2 ± 4.6	157.6 ± 5.8	74.7 ± 13.2	Untrained
	Slow	15	100	72.1 ± 5.0	157.2 ± 5.4	71.2 ± 21.7	Untrained
Gonzalez-Badillo et al. [28]	Fast	9	100	21.9 ± 2.9	177.0 ± 8.0	70.9 ± 8.0	Trained
	Slow	11	100	21.9 ± 2.9	177.0 ± 8.0	70.9 ± 8.0	Trained
Hisaeda et al. [29]	Fast	14	59	22.0 ± 2.0	167.2 ± 7.4	62.5 ± 8.7	Untrained
	Slow	14	59	22.0 ± 2.0	167.2 ± 7.4	62.5 ± 8.7	Untrained
Jones et al. [30]	Fast	15	100	20.1 ± 0.9	180 ± 1.0	103.50 ± 19.3	Trained
	Slow	15	100	19.9 ± 0.8	180 ± 1.0	92.1 ± 15.1	Trained
Liow and Hopkins [31]	Fast	13	69.2	23.0 ± 6.0	NR	NR	Trained
	Slow	12	75	23.0 ± 5	NR	NR	Trained
Morrissey et al. [32]	Fast	10	0	24.0 ± 3.0	161.0 ± 6.0	58.0 ± 8.0	Untrained
	Slow	11	0	24.0 ± 4.0	162.0 ± 5.0	57.0 ± 7.0	Untrained
Munn et al. 1 set [33]	Fast	23	81.7	20.6 ± 6.1	168.1 ± 9.1	64.2 ± 11.6	Untrained
	Slow	23	81.7	20.6 ± 6.1	168.1 ± 9.1	64.2 ± 11.6	Untrained
Munn et al. 3 sets [33]	Fast	23	81.7	20.6 ± 6.1	168.1 ± 9.1	64.2 ± 11.6	Untrained
	Slow	23	81.7	20.6 ± 6.1	168.1 ± 9.1	64.2 ± 11.6	Untrained
Pareja-Blanco et al. [34]	Fast	10	100	23.3 ± 3.2	177.0 ± 7.0	73.6 ± 9.2	Trained
	Slow	11	100	23.3 ± 3.2	177.0 ± 7.0	73.6 ± 9.2	Trained
Pereira and Gomes [35]	Fast	6	16.7	27.8 ± 6.6	161.8 ± 5.7	55.3 ± 8.8	Untrained
	Slow	8	37.5	26.1 ± 6.6	168.6 ± 8.7	65.5 ± 12.4	Untrained
Usui et al. [36]	Fast	7	100	22.5 ± 0.5	169.4 ± 4.7	68.7 ± 5.2	Untrained
	Slow	9	100	22.2 ± 2.1	175.0 ± 7.2	71.6 ± 5.8	Untrained
Watanabe et al. [37]	Fast	9	77.8	69 ± 4.7	158.4 ± 10.2	60.8 ± 13.2	Untrained
	Slow	9	77.8	69.9 ± 5.1	159.8 ± 10.9	58.3 ± 13.0	Untrained
Watanabe et al. [38]	Fast	17	48.5	66.8 ± 3.8	158.3 ± 6.6	59.8 ± 6.6	Untrained
	Slow	18	50	66.8 ± 5.2	158.6 ± 8.5	61.0 ± 9.1	Untrained
Young and Bilby [39]	Fast	8	100	19.0–23.0	NR	NR	Untrained
	Slow	10	100	19.0–23.0	NR	NR	Untrained

M males, *NR* not reported, *SD* standard deviation

[a] Data are reported as mean ± SD or as a range

only [25, 28–31, 33]. Further, 1-RM testing was performed with both isolated and compound movements in one study [27], nine studies tested 1 RM with compound movements only [26, 28, 30–32, 34–36, 39], and five studies tested 1 RM with isolated movements only [25, 29, 33, 37, 38]. The squat was used for dynamic muscular strength testing in five studies [32, 34–36, 39], bench press in four studies [28, 30, 31, 35], leg extension [27, 37, 38] and bicep curl [25, 29, 33] in three studies, and leg press [26, 27] in two studies, while the chest press [26], dumbbell pull [31], and hamstring curl [37] were each used in one study.

3.2 Methodological Quality

The mean ± SD quality rating score was 20.8 ± 2.2 out of a possible score of 29 (Table 3). All studies scored 0 (not reported or unable to determine) for attempting to blind participants or researchers to the intervention they received or to their randomization assignment. One study stated its participants were recruited over the same period of time [30]. All studies reported the aims or purpose, outcome measures, characteristics of participants, details of the interventions, main findings, and point estimates of random variability. The trained and untrained participants were

Table 2 Training characteristics of included studies

Study	Group	Exercise prescription	Duration (weeks)	Frequency (days/week)	Strength test	Velocity manipulation
Assis-Pereira et al. [25]	Fast	SC: 3 × 8 RM, 2 min rest between sets	12	2	1 RM SC	1 s ECC, 1 s CON
	Slow					4 s ECC, 1 s CON
Bottaro et al. [26]	Fast	LP, KE, KF, CP, SR, EE, EF: 3 × 8–10 repetitions at 40–60% 1 RM, 1 min 30 s rest between sets	10	2	1 RM LP and CP	2–3 s ECC, explosive CON
	Slow					2–3 s ECC and CON
Fielding et al. [27]	Fast	LP and KE: 3 × 8 at 70% 1 RM, rest between sets NR	16	3	1 RM LP and KE	2 s ECC, 1 s at full extension, explosive CON
	Slow					2 s ECC, 1 s at full extension, 2 s CON
Gonzalez-Badillo et al. [28]	Fast	SMBP: 3–4 × 2–8 repetitions at 60–80% 1 RM, 3 min rest between sets	6	3	1 RM SMBP	Controlled ECC, maximal intended CON velocity
	Slow					Controlled ECC, intentionally half-maximal CON velocity
Hisaeda et al. [29]	Fast	UBC: 6 sets of 10 repetitions at 50%, 30 s rest between sets	8	4	1 RM UBC (both arms)	2 s ECC, explosive CON
	Slow					2 s ECC, 2 s CON
Jones et al. [30]	Fast	BP, IBP, CGBP, BTNP, AC, PS, CL, HC, RDL: 3–4 sets of 2–10 repetitions at 65–95% 1 RM on heavy days and 50–75% on light days	14	2	1 RM BP	Deliberate speed ECC, maximal acceleration CON
	Slow					Deliberate speed ECC, normal acceleration CON
Liow and Hopkins [31]	Fast	BP and DP: 3 sets to failure at 80% 1 RM, 3 min rest between sets	6	2	1 RM BP and DP	~1.7 s ECC, explosive CON (≤0.86 s)
	Slow					~1.7 s ECC, slow and even rate CON (~1.7 s)
Morrissey et al. [32]	Fast	BS: 3 × 8 RM, rest between sets NR	7	3	1 RM BS	1 s ECC and CON
	Slow					2 s ECC and CON
Munn et al. 1 set [33]	Fast	UBC: 1 set to failure at 6–8 RM, 2 min rest between sets	7	3	1 RM UBC	1 s ECC and CON
	Slow					3 s ECC and CON
Munn et al. 3 sets [33]	Fast	UBC: 3 sets to failure at 6–8 RM, 2 min rest between sets	7	3	1 RM UBC	1 s ECC and CON
	Slow					3 s ECC and CON
Pareja-Blanco et al. [34]	Fast	PS: 3–4 × 2–8 repetitions at 60–80% 1 RM, 3 min rest between sets	6	3	1 RM PS	Controlled ECC, maximal intended CON velocity
	Slow					Controlled ECC, intentionally half-maximal CON velocity
Pereira and Gomes [35]	Fast	SMBS and SMBP: 1 set at 8–10 RM, rest between sets NR	12	3	1 RM SMBS and SMBP	1.75 rad/s (~1.8 s) for movement completion
	Slow					0.44 rad/s (~7.3 s) for movement completion

Table 2 continued

Study	Group	Exercise prescription	Duration (weeks)	Frequency (days/week)	Strength test	Velocity manipulation
Usui et al. [36]	Fast	PS: 3 sets of 10 repetitions at 50% 1 RM, 1 min rest between sets	3	8	1 RM PS	1 s ECC, 1 s CON, 1 s pause
	Slow					3 s ECC, 3 s CON
Watanabe et al. [37]	Fast	KF, KE: 3 × 8 repetitions at 50% 1 RM, 1 min rest between sets	12	2	1 RM KF and KE	1 s ECC and CON
	Slow					3 s ECC, 1 s at full extension, 3 s CON
Watanabe et al. [38]	Fast	KE: 3 × 13 repetitions at 30% 1 RM, 1 min rest between sets	12	2	1 RM KE	1 s ECC and CON
	Slow					3 s ECC, 1 s at full extension, 3 s CON
Young and Bilby [39]	Fast	HS: 4 × 8–12 RM, 3 min rest between sets	7.5	3	1 RM HS	Controlled ECC, explosive CON
	Slow					Controlled ECC, slow and controlled CON

AC arm curl, *BP* bench press, *BS* back squat, *BTNP* behind-the-neck press, *CGBP* close-grip bench press, *CL* clean, *CON* concentric, *CP* chest press, *DP* dumbbell pull, *ECC* eccentric, *EE* elbow extension, *EF* elbow flexion, *HC* hamstring curl, *HS* half squat, *IBP* incline bench press, *KE* knee extension, *KF* knee flexion, *LP* leg press, *NR* not reported, *PS* parallel squat, *rad* radians, *RDL* Romanian deadlift, *RM* repetition maximum, *SC* Scott curl; *SMBP* Smith machine bench press, *SMBS* Smith machine back squat, *SR* seated row, *UBC* unilateral bicep curl

randomly selected and were considered to be representative of these populations. There was no evidence of data dredging, and all measures of dynamic muscular strength were valid and reliable. Compliance rate was reported in seven studies and was ≥87.5% [27, 28, 33–35, 37, 38]. Supervision of training sessions was reported in seven studies [27, 28, 30–32, 34, 39], while it was unknown as to whether the remaining studies provided supervision [25, 26, 29, 33, 35–38].

3.3 Dynamic Muscular Strength

3.3.1 Combined Studies

Fast training was found to increase dynamic muscular strength by 21.8%, while moderate-slow training increased dynamic muscular strength by 20.8% (Table 4). The difference in dynamic muscular strength between interventions was small (ES 0.07, 95% CI −0.13 to 0.27), with no significant difference between groups ($p = 0.48$; Fig. 2). There was no heterogeneity of the effect between fast and moderate-slow training on dynamic muscular strength ($I^2 = 0\%$). Kendall's τ statistic ($\tau = 0.00$; $p = 0.95$) and funnel plots revealed no publication bias in any study (Fig. 3).

3.3.2 Intensity

A trend for a small effect favoring fast compared with moderate-slow training was found when studies were restricted to interventions using moderate intensities (60–79% 1 RM) (ES 0.31, 95% CI −0.01 to 0.63; $p = 0.06$) [25, 27, 28, 30, 34, 35, 39]. There were no significant effects between fast and moderate-slow training when studies were restricted to low (<60% 1 RM, ES −0.06, 95% CI −0.45 to 0.32; $p = 0.76$) [26, 29, 36–38] or high intensities (≥80% 1 RM, ES −0.08, 95% CI −0.41 to 0.25; $p = 0.63$) [31–33]. There was no heterogeneity of the effect between fast and moderate-slow training on dynamic muscular strength when intensity was accounted for ($I^2 = 0\%$). Kendall's τ statistic and funnel plots revealed no publication bias in studies that used low intensities ($\tau = 0.00$; $p = 0.98$), moderate intensities ($\tau = 0.00$; $p = 0.82$), or high intensities ($\tau = 0.00$; $p = 0.91$).

3.3.3 Training Status

There were no significant effects found between fast versus moderate-slow training on dynamic muscular strength for studies that had trained (ES 0.25, 95% CI −0.13 to 0.62; $p = 0.19$) [25, 28, 30, 31, 34] and untrained (ES 0.00, 95% CI −0.23 to 0.24; $p = 0.98$) participants [26, 27, 29, 32, 33, 35–39]. There was no heterogeneity of the effect between fast and moderate-slow training on dynamic muscular strength when training status was accounted for ($I^2 = 0\%$). Kendall's τ statistic and funnel plots revealed no publication bias in studies that used trained ($\tau = 0.00$; $p = 0.86$) or untrained participants ($\tau = 0.00$; $p = 0.91$).

3.3.4 Age

No significant effects were found between fast and moderate-slow training when studies were restricted to elderly (ES 0.20, 95% CI −0.17 to 0.57; $p = 0.30$) [26, 27, 37, 38]

Table 3 Results of the modified Downs and Black methodological quality assessment [19]

Study	Year	Reporting[a]										External validity[b]			Internal validity																Score
															Bias[c]							Confounding[d]									
	Items	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total /29
Assis-Pereira et al. [25]	2016	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	1	0	0	0[e]	18
Bottaro et al. [26]	2007	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	1	1	0	0[e]	20
Fielding et al. [27]	2002	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	1	1	1	1	1	25
Gonzalez-Badillo et al. [28]	2010	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	0	1	1	1	21
Hisaeda et al. [29]	1996	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	1	1	0	0[e]	19
Jones et al. [30]	1999	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	0[e]	1	1	1	1	0[e]	0[e]	1	1	0	1	22
Liow and Hopkins [31]	2003	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	0[e]	1	0	1	19
Morrissey et al. [32]	1998	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	1	1	0	1	19
Munn et al. [33]	2005	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	1	1	1	0[e]	24
Pareja-Blanco et al. [34]	2014	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	1	1	1	1	23
Pereira and Gomes [35]	2007	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	0	1	1	0[e]	21
Usui et al. [36]	2016	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	1	1	0	0[e]	20
Watanabe et al. [37]	2014	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	1	1	1	0[e]	22
Watanabe et al. [38]	2013	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0[e]	1	0[e]	0[e]	1	1	1	0[e]	22
Young and Bilby [39]	1993	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	0[e]	1	1	0[e]	1	0[e]	0[e]	0[e]	1	0	1	17

1 = criteria met, 0 = criteria not met

[a] Reporting category includes items such as, study aims, reported outcomes, patient characteristics, confounders, adverse events, and loss to follow-up

[b] External validity includes questions regarding the study population

[c] Internal validity: bias includes items such as blinding, follow-up, and compliance

[d] Internal validity: confounding includes items such as study selection, randomization, and study power

[e] Item was unable to be determined, scored 0

Table 4 The effects of fast vs. moderate-slow resistance training programs on muscular strength

Study	Fast				Moderate-slow				Std diff in mean: effect size (SE)	95% CI	p-Value
	n	Pre-training [kg][a]	Post-training [kg][a]	Change [%][b]	*n*	Pre-training [kg][a]	Post-training [kg][a]	Change [%][b]			
Assis-Pereira et al. (2016) [25]	6	49.0 ± 6.4	58.3 ± 14.9	19.0	6	46.3 ± 6.8	61.3 ± 8	32.4	−0.48 (0.59)	−1.62 to 0.67	0.42
Bottaro et al. CP (2007)[c] [26]	11	45.1 ± 6.5	57.8 ± 8.7	28.2	9	50.2 ± 8.1	62.7 ± 8.5	24.9	0.02 (0.45)	−0.88 to 0.88	0.96
Bottaro et al. LP (2007)[c] [26]	11	174.3 ± 33.7	221.6 ± 42.0	27.1	9	176.7 ± 26.1	223.9 ± 37.7	26.7	0.00 (0.45)	−0.86 to 0.90	1.00
Fielding et al. KE (2002)[c, d, e] [27]	15	5.8 ± 0.4	8.3 ± 0.4	44.1	15	5.5 ± 0.5	7.8 ± 0.7	41.8	0.42 (0.37)	0.10 to 1.59	0.25
Fielding et al. LP (2002)[c, d, e] [27]	15	177.7 ± 9.9	244.4 ± 9.6	37.5	15	168.3 ± 15.6	223.5 ± 16.7	32.8	0.84 (0.38)	−0.30 to 1.14	0.03
Hisaeda et al. (1996) [28]	7	11.3 ± 3.4	14.0 ± 3.8	23.9	7	10.9 ± 3.7	13.6 ± 3.6	24.8	0.00 (0.53)	−1.05 to 1.05	1.00
Gonzalez-Badillo et al. (2014) [29]	9	75.8 ± 17.9	88.2 ± 15.1	16.4	11	73.9 ± 9.7	80.8 ± 11.2	9.3	0.42 (0.45)	−0.47 to 1.31	0.35
Jones et al. (1999) [30]	15	114.7 ± 17.2	125.5 ± 15.5	9.4	15	130.0 ± 18.2	135.0 ± 19.0	3.8	0.33 (0.37)	−0.39 to 1.06	0.36
Liow et al. BP (2003)[c] [31]	13	58.0 ± 17.0	66.0 ± 19.0	13.8	12	54.0 ± 15.0	60.0 ± 16.0	11.1	0.11 (0.40)	−0.61 to 0.96	0.78
Liow et al. DP (2003)[c] [31]	13	57.0 ± 18.0	64.0 ± 16.0	12.3	12	60.0 ± 20.0	64.0 ± 19.0	6.7	0.17 (0.40)	−0.67 to 0.90	0.67
Morrissey et al. (1998) [32]	10	67.0 ± 20.0	82.0 ± 16.0	22.4	11	57.0 ± 8.0	74.0 ± 10.0	29.8	−0.15 (0.44)	−1.01 to 0.71	0.73
Munn et al. (2005) 1 set [33]	23	5.8 ± 4.0	8.0 ± 5.1	37.9	23	5.4 ± 2.0	6.9 ± 1.9	27.8	−0.18 (0.30)	−0.69 to 0.47	0.54
Munn et al. (2005) 3 sets [33]	23	5.6 ± 2.3	8.2 ± 3.3	46.4	23	5.7 ± 2.8	8.0 ± 2.2	40.4	−0.11 (0.30)	−0.76 to 0.40	0.72
Pareja-Blanco et al. (2014) [34]	10	89.2 ± 15.9	105.2 ± 18.0	17.9	11	94.8 ± 17.0	104.0 ± 17.0	9.7	0.39 (0.44)	−0.48 to 1.25	0.38
Pereira et al. (2007) BP[c] [35]	6	40.1 ± 17.4	46.4 ± 19.3	15.7	8	53.2 ± 25.2	60.6 ± 25.8	13.9	0.05 (0.54)	−0.94 to 1.18	0.93
Pereira et al. (2007) SQ[c] [35]	6	98.4 ± 26.0	118.1 ± 26.5	20.0	8	100.9 ± 37.6	124.6 ± 35.8	23.5	0.12 (0.54)	−1.01 to 1.11	0.82
Usui et al. (2016)[d] [36]	7	104.3 ± 18.5	106.5 ± 14.1	2.1	9	118.5 ± 27.2	129.3 ± 30.4	9.1	−0.35 (0.51)	−1.34 to 0.65	0.49
Watanabe et al. (2014) [37]	9	56.7 ± 10.9	67.2 ± 13.8	18.5	9	59.6 ± 14.2	70.7 ± 14.8	18.6	0.04 (0.47)	−0.88 to 0.97	0.93
Watanabe et al. (2013) KE[c] [38]	17	47.7 ± 13.5	51.3 ± 14.2	7.5	18	47.9 ± 11.2	51.7 ± 12.2	7.9	−0.02 (0.34)	−0.73 to 0.59	0.96
Watanabe et al. (2013) KF[c] [38]	17	43.7 ± 11.3	51.2 ± 12.3	17.2	18	42.9 ± 9.6	51.2 ± 10.9	19.3	−0.07 (0.34)	−0.68 to 0.65	0.84
Young et al. (1993) [39]	8	174.5 ± 24.2	209.3 ± 24.9	19.9	10	166.3 ± 22.3	202.9 ± 23.4	22.0	−0.07 (0.47)	−1.00 to 0.86	0.88
Mean effect, total	–	–	–	21.8	–	–	–	20.8	0.07 (0.10) [f]	−0.13 to 0.27 [f]	0.48 [f]

% percentage, *BP* bench press, *CI* confidence interval, *CP* chest press, *DP* dumbbell pull, *KE* knee extension, *KF* knee flexion, *kg* kilograms, *LP* leg press, *n* number, *SD* standard deviation, *SE* standard error of the mean, *Std Diff* standard difference, *SQ* squat

[a] Pre- and post-training values are presented as mean ± SD

[b] Calculated as post-training value minus pre-training value, divided by pre-training value, multiplied by 100

[c] Effect sizes were combined for analysis

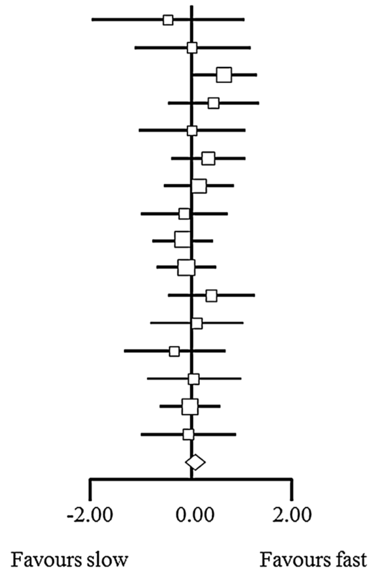
[d] Data extracted from graph

[e] Strength values converted from Newtons

[f] Values based on combined analysis

Study name	Statistics for each study: Effect size (std diff in means)	Statistics for each study: 95% CI	Relative weight (%)
Assis-Pereira et al. (2016) [25]	-0.48	-1.99 to 1.03	1.72
Bottaro et al. (2007) [26]	0.01	-1.13 to 1.15	2.98
Fielding et al. (2002) [27]	0.63	-0.02 to 1.28	9.22
Gonzalez-Badillo et al. (2014) [28]	0.42	-0.48 to 1.32	4.83
Hisaeda et al. (1996) [29]	0.00	-1.06 to 1.06	3.50
Jones et al. (1999) [30]	0.33	-0.40 to 1.06	7.25
Liow et al. (2003) [31]	0.14	-0.54 to 0.82	8.46
Morrissey et al. (1998) [32]	-0.15	-1.00 to 0.70	5.34
Munn et al. (2005) 1 set [33]	-0.18	-0.77 to 0.41	11.27
Munn et al. (2005) 3 sets [33]	-0.11	-0.70 to 0.48	11.27
Pareja-Blanco et al. (2014) [34]	0.39	-0.46 to 1.24	5.34
Pereira et al. (2007) [35]	0.09	-0.83 to 1.01	4.61
Usui et al. (2016) [36]	-0.35	-1.35 to 0.65	3.90
Watanabe et al. (2014) [37]	0.04	-0.88 to 0.96	4.61
Watanabe et al. (2013) [38]	-0.04	-0.63 to 0.55	11.27
Young et al. (1993) [39]	-0.07	-1.01 to 0.87	4.41
Pooled effect	**0.07**	**-0.13 to 0.27**	

Std diff in means and 95% CI



Combined statistics
Heterogeneity: $Tau^2 = 0$; $Chi^2 = 7.25$; df = 15 (p = 0.95)
Test for overall effect: Z = 0.71 (p = 0.48)

Fig. 2 Forest plot of the results of the meta-analysis. The *open squares* and *error bars* signify the standardized difference (*std diff*) values in the means (effect size) and 95% confidence interval (*CI*) values, respectively. The *open diamond* represents the pooled effect sizes. *df* degrees of freedom

and young to middle-aged participants (ES = 0.02, 95% CI −0.21 to 0.25; p = 0.86) [25, 28–36, 39]. There was no heterogeneity of the effect between fast and moderate-slow training on dynamic muscular strength when age was accounted for (I^2 = 0%). Kendall's τ statistic and funnel plots revealed no publication bias in studies that used elderly participants (τ = 0.00; p = 0.47) or young to middle-aged participants (τ = 0.00; p = 0.97).

4 Discussion

To the authors' knowledge, this is the first systematic review and meta-analysis to investigate whether movement velocity during resistance training affects dynamic muscular strength development. The data show that similar increases in dynamic muscular strength are achieved with fast compared with moderate-slow training. However, a trend for a small effect favoring fast training on dynamic muscular strength was found when moderate loads (60–79% 1 RM) were used. Dynamic muscular strength gain between conditions was not influenced by training status and age. Studies were methodologically sound with no publication bias and were shown to have examined the same effect.

4.1 Combined Studies

The findings from our meta-analysis of combined studies showed no differences in dynamic muscular strength gains between fast training and moderate-slow resistance training. The speed at which a resistance exercise should be performed to maximize dynamic muscular strength has been the subject of debate for decades. Traditionally, performing resistance exercise with fast movement velocities is associated with power training [6], while for individuals targeting dynamic muscular strength and hypertrophy, purposefully slower movement velocities are encouraged [40]. Arguments for performing repetitions with slower movement velocities include reducing momentum, prolonging muscle tension, and accentuation of other factors implicated in muscular development. Slow-training was largely popularized by Nautilus founder Arthur Jones [41], who argued that slow and controlled cadences (repetitions

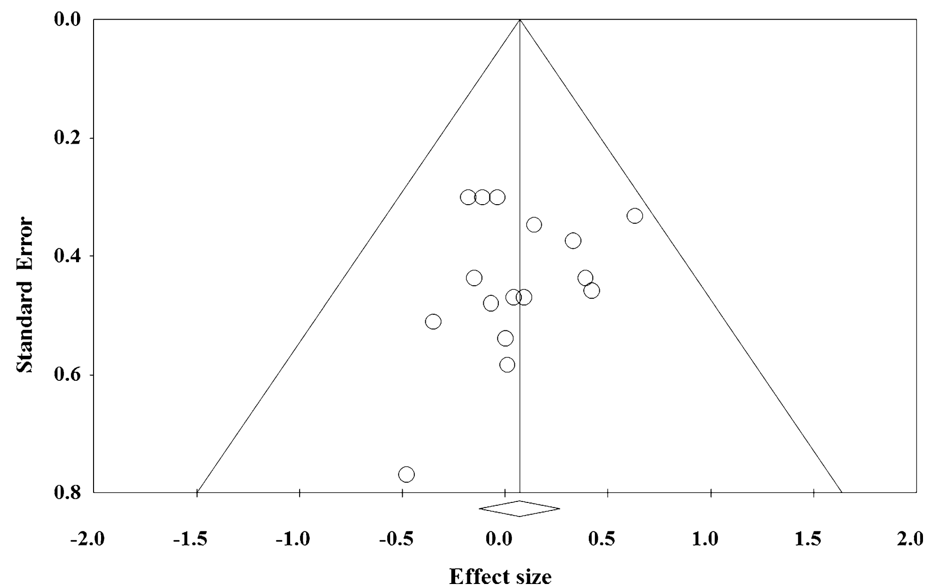


Fig. 3 Funnel plot of publication bias: standard error by effect size

performed at ~4:2 s) are superior to fast training speeds. However, faster training has the potential to offer individuals greater overall improvement of muscle function capabilities, as faster compared with slower movement velocity is shown to enhance muscle power [27, 30, 39] and rate of force development [39, 42].

Improvements in dynamic muscular strength following resistance training are related to morphological [43] and neurological [44] adaptations. The principal morphological adaptation is an increase in muscle fiber cross-sectional area due to increased size and number of myofibrils [45]. In comparison, the main neurological adaptation is an increase in muscle activation as a result of greater motor unit recruitment and/or firing frequency [45]. Despite similar increases in dynamic muscular strength found for fast versus moderate-slow velocity conditions, it is possible that dynamic muscular strength development from these training practices resulted through different mechanisms. While faster training is thought to provide a better stimulus for neural adaptations that would lead to greater strength, slower training has been shown to increase metabolic stress and muscle tension, which are thought to be important factors implicated in the promotion of muscular hypertrophy [46, 47]. Only four studies included in this review reporting changes in site-specific muscular hypertrophy used appropriate imaging modalities [25, 37–39]. The mean change in muscle hypertrophy across these studies favored moderate-slow compared to fast training (6.2 vs. 2.8%, respectively), which provides some support for the conclusion that improvements in dynamic muscular strength for each condition may have resulted through different mechanisms.

Even though fast and moderate-slow movements were defined as ≤1:1 versus >1:1 s, it is important to note that large variations in the velocities may have occurred throughout the range of motion (ROM). At the beginning of the concentric phase of an isotonic exercise, the movement velocity is likely to be lower because of increased inertia compared with higher movement velocities at the end of the ROM due to decreased inertia. This would be opposite for elastic-band training with higher movement velocities during the initial phase of a concentric contraction due to the slack of the band and increased band tension reducing velocity at the end of the ROM [48].

4.2 Intensity

The results of this review showed that fast compared with moderate-slow training performed at a moderate intensity (60–79% 1 RM) demonstrated a trend for greater increases in dynamic muscular strength (by 1.2%). Therefore, it appears that the ability to perform repetitions at high movement velocities may influence dynamic muscular strength adaptations, providing a sufficient load is used. The force–velocity relationship shows that as the velocity of movement increases, muscular force production decreases, due to fewer muscle cross-bridges formed to develop force [49]. This physiological phenomena led to the creation of the Super Slow® exercise protocol (repetitions performed at 10:4 s) [50]. It is proposed that lifting loads quickly results in lower muscular force and thus diminishes the training effect [49]. However, it has been shown that attempting to drastically reduce movement velocity subsequently reduces muscle force production [51, 52], which is an important factor that influences dynamic muscular strength development.

To date, two studies have examined the effects of Super Slow® training compared with training using faster movement velocities on dynamic muscular strength, with mixed results found [8, 40]. It should be noted that when performing resistance exercises with slow movement velocities, the relative loads used are generally low (≤50% 1 RM). However, heavier loads (80–100% 1 RM) are required to provide the necessary mechanical stimuli to optimize gains in dynamic muscular strength [5, 53]. This may explain the similar dynamic muscular strength gains found for fast compared with moderate-slow training performed at low intensities (<60% 1 RM). Higher (~80% 1 RM) compared with lower (≤50% 1 RM) intensities for power training have been shown to result in superior strength gains [6, 17, 54]. However, the ability to perform fast movement velocities is impaired as the relative intensity increases; therefore, it becomes increasingly difficult to make a clear distinction between fast and slower movement velocities. The studies included in our review that used high intensities (≥80% 1 RM) for fast compared with moderate-slow training all performed sets to concentric failure. As these participants approached failure, it is likely that movement velocity would unintentionally decline [12], and movement velocities for the final repetitions of a set would become similar in both fast and slow conditions [13, 48]. Therefore, it was not surprising that dynamic muscular strength gains did not differ between fast and moderate-slow training performed at high intensities (≥80% 1 RM).

It should be noted that five of the seven studies that performed resistance training at a moderate intensity also performed each repetition of each set as fast as possible (i.e., high movement intention). Behm and Sale [42] showed that high-velocity and low-velocity movements (in this case, isometric contractions) produced a similar increase in high-velocity muscular strength when the intention to move against the external resistance was as fast as possible. Therefore, this implies that the intention to move as fast as possible may be the principal stimulus that leads to muscular strength development following resistance training. Further research is required to confirm whether resistance training performed with high movement intention leads to greater increases in dynamic muscular strength.

4.3 Training Status and Age

During the first weeks of resistance training, neurological adaptations are thought to be responsible for the rapid increases in dynamic muscular strength, while long-term improvements are likely attributed to muscular hypertrophy [45]. It is conceivable that faster movement velocities (due to the neurological adaptations) would lead to greater increases in initial dynamic muscular strength gains in the untrained. However, despite the results of our review showing a small effect favoring fast training for untrained participants, it failed to reach statistical significance (p = 0.19). The finding of no significant effect for fast versus moderate-slow training on dynamic muscular strength in trained participants supports the ACSM recommendation that experienced trainers should use a wide range of movement velocities [5]. As resistance-training experience increases, the rate of dynamic muscular strength improvement decreases, which is a training principle referred to as the 'law of diminishing returns' [55]. Therefore, acute training variables such as movement velocity should be altered over time (i.e., periodization) to enable training gains to be optimized and reduce the risk of a training program losing its efficacy.

Our results showed that participant age did not influence the dynamic muscular strength gains between fast and moderate-slow training. Even though loss of dynamic muscular strength occurs with aging, the capacity to improve strength is not impaired, as is evident from our findings. While there are studies that have shown similar increases in muscle strength for older (>55 years) compared with younger (<40 years) individuals following resistance training [56–58], other studies have found strength gains to be higher in older [59] and younger [60, 61] adults. However, it does appear that dynamic muscular strength improvements for older adults are due more to neural adaptations compared with younger adults [62]. It was therefore interesting that faster compared with moderate-slow training did not lead to greater gains in dynamic muscular strength for older adults.

4.4 Methodological Quality

The mean quality of studies was rated as good based on the Downs and Black quality assessment scores [19]. Across the 15 studies that were included in the review process, 17 out of 29 items were fully met. The criteria for four items were met by the majority of studies (i.e., eight or more studies), whilst the criteria for six items were met by a minority of studies. Criteria for a further three items were not met by any study. Two of the three criteria not met by any study were concerned with blinding (1) participants and (2) assessors of main outcomes to the training programs. Although the methodological quality of the studies included in this review would have been improved if blinding had occurred, blinding of participants to particular exercise interventions is not possible. The last item not met by any study was concerned with the concealment of the randomization assignment to interventions. Studies that do not meet this item increase the risk of participants being selected into a more or less appropriate group, known as selection bias. Despite there being insufficient information provided from some studies to accurately rate all items, there is a good possibility that the methodological quality of studies was underestimated. This suggests that there would be a lower risk that internal validity (bias and confounding) influenced the overall results.

4.5 Strengths and Limitations

Our review was strengthened by the use of a systematic search, precise eligibility criteria, and meticulous data extraction and quality assessment procedures. A meta-analytical approach was used to overcome the concern that studies may have had small sample sizes that provide insufficient power to detect significant differences between the two training conditions. Sub-group analyses were used to allow other aspects of training, such as intensity, age, and training experience, to be examined as potential confounders.

There are several limitations that should be taken into account when interpreting the findings of this review. Firstly, acute programming variables such as intensity (i.e., loading) and movement velocity varied between each study. Even though we attempted to address this issue through sub-group analyses, it is possible that these influenced the results. Secondly, the training status of participants varied considerably, with a wide spectrum being included in the analysis. Some studies included participants who were elderly with little training experience, whilst other studies included participants who were highly trained and used resistance training as part of their practices for a particular sport. Therefore, it is difficult to generalize findings to athletes, the elderly, or recreationally trained individuals specifically. Thirdly, over half the studies had interventions lasting between 6 and 8 weeks, which is considered the minimum amount of time required to detect a significant change in dynamic muscular strength following resistance training [63]. It is therefore possible that results may have differed for faster versus moderate-slow training if the majority of studies used interventions of a longer duration (e.g., $\geq$12 weeks). Fourthly, five of the 15 included studies measured strength with multiple movements, which is problematic when analyzing the extracted data statistically. If both movements are included in the analysis, the meta-analysis software will assign more weight to the studies with multiple movements and therefore create an improper estimate of the summary effect [22]. We counteracted this issue by combining the summary effects and calculating an individual variance of the affected studies (described in Sect. 2.5). Lastly, the difference between fast ($\leq$1:1 s) and moderate-slow (>1:1 s) movement velocities may not have been large enough to detect meaningful differences in dynamic muscular strength.

4.6 Future Directions and Practical Applications

While the total number of studies included in this review was relatively similar to other systematic reviews investigating dynamic muscular strength [64–66], there was a lack of studies representing particular population groups (such as elderly, recreationally trained, and athletic populations). Specifically, only a small number of studies included highly trained participants who commonly use advanced resistance-training methodologies in an attempt to optimize dynamic muscular strength [5]. Therefore, future studies should be directed towards investigating the short- and long-term effects of fast compared with moderate-slow movement velocity resistance training on dynamic muscular strength in resistance-trained populations. This review only measured velocity and strength in a dynamic manner; therefore, the results of the current study only apply to dynamic strength testing, and future studies will need to confirm if these results are similar when muscular strength is measured isometrically and isokinetically.

It appears that performing resistance exercises with fast and moderate-slow movement velocities at various intensities is equally efficacious for individuals targeting dynamic muscular strength. However, for novice lifters, it is important that faster movements are not performed at the expense of utilizing safe and appropriate lifting to ensure injury risk is reduced as well as providing a sufficient training stimulus [67]. For the elderly, performing resistance training with fast or explosive movements would not only lead to increases in dynamic muscular strength, but also the development of muscular power. An improvement in muscular power is particularly important for the elderly to improve balance [68], prevent falls [54], and increase functionality (e.g., positively affecting activities of daily living). Finally, advanced resistance trainers and athletes seeking to optimize dynamic muscular strength adaptation as part of their overall training should consider manipulating movement velocities throughout a periodized training plan. This may help advanced resistance trainers and athletes break through dynamic muscular strength plateaus. Training with faster movement velocities (i.e., explosive strength or muscular power) may benefit sports performance [30, 31, 69], while training with a wide-range of velocities may be effective in the development of muscular hypertrophy, which is commonly targeted in off-season resistance-training programs [44, 68].

5 Conclusion

The results of this systematic review and meta-analysis show that similar increases in dynamic muscular strength can occur when using either a fast or moderate-slow movement velocity when all intensities are combined, irrespective of age and training status. However, if moderate intensities are used, there is a trend for increased strength gains when using faster movement velocities. This information is important to resistance trainers of all ages and training statuses.

Compliance with Ethical Standards

Funding No sources of funding were used in the preparation of this manuscript.

Conflict of interest Timothy B. Davies, Kenny Kuang, Rhonda Orr, Mark Halaki, and Daniel Hackett declare they have no conflict of interest that is relevant to the content of this review.

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