How Slow Should You Go? A Systematic Review With Meta-Analysis of the Effect of Resistance Training Repetition Tempo on Muscle Hypertrophy

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Abstract

Enes, A, Piñero, A, Hermann, T, Zamanzadeh, A, Hennessy, T, Montenegro, D, Parnell, C, Jia, A, Weitzman, T, Wolf, M, Korakakis, PA, Swinton, PA, and Schoenfeld, BJ. How slow should you go? A systematic review with meta-analysis of the effect of resistance training repetition tempo on muscle hypertrophy. *J Strength Cond Res* 39(12): 1331–1339, 2025—We systematically searched the literature for interventions that compared different resistance training tempos for eccentric (ECC) or concentric (CON) actions. We estimated pre-/poststudy changes and between-condition differences in lean/muscle mass for healthy adults, restricting inclusion to studies that controlled all other training variables. Hierarchical meta-analyses were conducted within a Bayesian framework, with change estimates made within groups, and the primary emphasis placed on pairwise differences between dichotomously coded slower (repetition time: 1.7–4.5 seconds, averaging ~3.5 seconds) and faster (repetition time: 0.3–2 seconds, averaging ~1 second) interventions. When combining data across all 14 included studies (4 CON and 9 ECC manipulated interventions, 1 for both in a cross-over design), meta-analyses of within-group changes showed similar pooled effects for faster (0.43 [95% CrI: 0.29–0.58]) and slower tempos (0.34 [95% credible interval (CrI): 0.22–0.47)]. Meta-analyses of pairwise differences across the same studies showed central estimates that trivially favored faster over slower tempos (pooled mean = 0.09 [95% CrI: −0.04 to 0.22]), with a low probability that the between-condition effect size was at least small ($p = 0.450$), medium ($p = 0.001$), or large ($p < 0.001$). Subgroup analyses of pairwise differences stratified by muscle action type (ECC or CON), body region (upper or lower body), and training to failure (yes or no) generally produced trivial to small effects, although the certainty of estimates varied across analyses. In conclusion, resistance training tempo appears to have minimal overall effect on muscle hypertrophy, with potential differences emerging under specific conditions.

Key Words: eccentric action, concentric action, velocity, repetition cadence, muscle growth

Introduction

Evidence suggests that manipulation of resistance training (RT) program variables can enhance muscle hypertrophy (13). Repetition tempo, operationally defined as the time of concentric, isometric, and/or eccentric muscle actions during dynamic RT (18), has been proposed as a variable that may influence hypertrophic adaptations (30). Resistance training tempo is frequently expressed as a 4-digit number with each digit representing the duration of each individual action in a repetition (30). For example, a repetition tempo of 4-0-2-0 would describe a duration of 4 seconds on the eccentric action, no isometric pause at the initial transition phase, 2 seconds on the concentric action, and no isometric pause at the final transition phase. To date, research has focused on manipulating the concentric and eccentric actions of dynamic repetitions; the effect of altering the isometric phase remains poorly studied. Altering the duration of each muscle action can elicit specific metabolic and mechanical responses (30), suggesting the possibility that manipulation of this variable may help optimize the adaptive response to RT. In addition, manipulating the repetition tempo may be a useful strategy for individuals who are unable to train with moderate-to-high loads or fast movements, such as those in rehabilitation or with joint-related issues. This approach can serve to increase the time under tension while reducing joint-related stress, thus providing a sufficient stimulus for hypertrophy (30).

Mechanical tension is well-established as a primary mechanism for inducing skeletal muscle hypertrophy (27). Accordingly, some researchers have speculated that slower concentric tempos may enhance RT-induced muscle hypertrophy by reducing momentum during performance (29) and thereby, ostensibly, increasing mechanical tension on the working muscle. Moreover, it has been hypothesized that slower eccentric tempos may provide a greater hypertrophic stimulus by providing more resistance to gravity during lengthening actions, which would conceivably maintain greater mechanical tension throughout a set (1). Other researchers have proposed that the higher total time-under-tension of the

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target musculature associated with slower tempos may confer a hypertrophic advantage (24). Although these hypotheses seemingly have a logical rationale, randomized controlled trials on the topic have produced somewhat conflicting findings (30).

Several reviews and meta-analyses have attempted to elucidate the effects of repetition tempo on muscle growth. A 2015 meta-analysis by Schoenfeld et al. (21) reported similar increases in hypertrophic measures with repetition durations ranging from 0.5 to 8 seconds. In 2018, Hackett et al. (9) conducted a systematic review that included 7 studies investigating repetition tempo. For the quadriceps, 3 studies showed greater quadriceps hypertrophy for "moderate-slow" (≥2 seconds) vs. "fast" (≤1 second) tempos, whereas 2 other studies indicated conflicting evidence on within-group hypertrophy with one showing increases in muscle size only for moderate-slow training another showing hypertrophic benefits only for fast tempos. The 2 studies that assessed biceps brachii hypertrophy showed greater increases for fast vs. moderate-slow training. It should be noted that both aforementioned reviews included studies that investigated total repetition duration (i.e., the sum of tempos for concentric, isometric, and eccentric actions per repetition); thus, inferences cannot necessarily be extrapolated to how the tempos of the individual muscle actions may influence muscle development. More recently, a narrative review by Wilk et al. (30) concluded that a combination of slower eccentric tempos and faster concentric tempos would help to optimize hypertrophy; however, these conclusions were not based on a systematic analysis of the literature nor were attempts made to quantify the magnitude of effects. Therefore, the purpose of this systematic review with meta-analysis is to evaluate the independent effects of manipulating eccentric and concentric repetition tempo during RT on measures of muscle hypertrophy.

Methods

Experimental Approach to the Problem

We conducted this review in accordance with the guidelines of the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA). The study was preregistered on the Open Science Framework (https://osf.io/fzhnx).

Search Strategy

To identify relevant studies for the topic, we conducted a comprehensive search of the PubMed/MEDLINE, Scopus, and Web of Science databases using the following Boolean search syntax: (duration OR tempo OR cadence OR velocity OR speed) AND ("resistance training" OR "resistance exercise" OR "weight lifting" OR "weightlifting" OR "strength exercise" OR "strength training" OR "strengthening" OR "resistive exercise" OR "resistive training") AND ("muscle hypertrophy" OR "muscular hypertrophy" OR "muscle mass" OR "muscle fiber" OR "muscle size" OR "muscle fibre" OR "muscle thickness" OR "cross-sectional area"). As previously described (19), we also screened the reference lists of articles retrieved and applicable review papers and drew on the authors' personal knowledge of the topic, to uncover any additional studies that might meet inclusion criteria (8). Moreover, we performed secondary "forward" and "backward" searches for citations of included studies in Google Scholar.

As previously described (5), the search process was conducted separately by 4 researchers (M.W., A.E., C.P., T.W.). Initially, we screened all titles and abstracts to uncover studies that might meet inclusion/exclusion criteria using online software (https://www.rayyan.ai/). Full texts of potentially relevant studies were then reviewed to determine eligibility. Disputes that could not be resolved by the search team were settled by a third researcher (B.J.S.). The search was finalized in March 2025.

Inclusion Criteria

We included studies that satisfied the following criteria: (a) had a randomized design (either within- or between-group design) and directly compared different resistance training tempos on the eccentric or concentric actions for estimates of region- or site-specific pre-/poststudy changes in lean/muscle mass using a validated measure (dual-energy X-ray absorptiometry [DXA], bioelectrical impedance analysis, magnetic resonance imaging [MRI], computerized tomography [CT], ultrasound, muscle biopsy, or limb circumference measurement) in healthy adults (≥18 years of age) of any RT experience while controlling all other training variables (in the case of volume, this represented either sets per muscle per session or volume load per session [i.e., sets × reps × load]); (b) involved at least 2 RT sessions per week for a duration of at least 4 weeks; (c) published in a peer-reviewed English language journal or on a preprint server. We excluded studies that (a) included participants with comorbidities that might impair the hypertrophic response to RT (musculoskeletal disease/injury/cardiovascular impairments); (b) employed unequal dietary supplement provision (i.e., one group received a given supplement and the other received an alternative supplement/placebo); (c) manipulated the tempos for the both concentric and eccentric actions between groups (e.g., 2-0-4 vs. 4-0-2, etc.).

Data Extraction

As previously described (5), 4 researchers (A.P., P.A.K., T.H., A.J.) independently performed the data extraction and extracted the following data from each included study: author name(s), title and year of publication, sample size, participant characteristics (i.e., sex, training status, age), description of the training intervention (duration, volume, frequency, modality), nutrition control (yes/no), tempo (seconds), manipulated muscle action (i.e., eccentric, concentric), method for hypertrophy assessment (i.e., DXA, MRI, CT, ultrasound, biopsy, circumference), and mean pre- and poststudy values for lean/muscle mass with corresponding standard deviations. When outcome data were not reported in the text, we attempted to contact the corresponding author(s) to obtain the data as previously described (19). If data were unavailable, we extracted values from graphs (when available) via online software (https://automeris.io/WebPlotDigitizer/). To account for the possibility of coder drift, a third researcher (A.Z.) re-coded 30% of the studies, which were randomly selected for assessment (Cooper et al., 2009). Per case agreement was determined by dividing the number of variables coded the same by the total number of variables. Acceptance required a mean agreement of 0.90. Any discrepancies in the extracted data were resolved through discussion and mutual consensus of the coders.

Methodological Quality

The methodological quality of the included studies was assessed using the "Standards Method for Assessment of Resistance

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Training in Longitudinal Designs" (SMART-LD) scale (19). The SMART-LD includes 20 items that address a combination of study bias and reporting quality: general (items 1–2), participants (items 3–7), training program (items 8–11), outcomes (items 12–16), and statistical analyses (17–20). Each item was scored as 1 (sufficiently reported) or 0 (insufficient). Total scores were used to classify studies as "good quality" (16–20 points); "fair quality" (12–15 points); or "poor quality" (≤11). Six reviewers (A.E., A.P., M.W., P.A.K., T.H., and D.M.) independently rated each study. Disagreements were resolved by majority consensus.

Statistical Analyses

All meta-analyses were conducted within a Bayesian framework to allow for more intuitive interpretation compared with traditional frequentist approaches, using subjective probabilities (14). This approach avoids dichotomous interpretations (e.g., significance vs. nonsignificance) and focuses on estimating the most probable values of the average effect, while addressing practical questions such as which tempo is likely to elicit the greatest hypertrophy. Primary analyses focused on pairwise comparisons of "slower" and "faster" tempos. For CON actions, slower tempos ranged from ~2 to ~4.5 seconds, with faster tempos ranging from ~0.5 to ~1 seconds. For ECC actions, slower tempos ranged from ~1.66 to ~4.5 seconds, with faster tempos ranging from ~0.25 to ~2 seconds. Subgroup analyses assessed the effects of manipulating ECC and CON tempos separately. In addition, for ECC actions where there were sufficient data, subgroup analyses were performed for hypertrophy of lower- and upper-body muscles, and for training performed either to failure or not. Because of the use of different measurement technologies, comparative effect sizes were calculated in the form of standardized mean differences. To account for the small sample sizes generally used in S&C, a bias correction was applied (16). Hierarchical models were included for analyses where studies provided multiple data points because of more than 2 comparisons and/or multiple hypertrophy measures. Inferences were made based on the posterior distribution of the pooled effect size, associated 95% credible intervals, and the probability that the pooled effect was at least as small, medium, or large S&C specific thresholds (26).

Results

A total of 3,479 records were initially identified via search engines and an additional 7 were uncovered through forward/backward searches. Of these, 14 studies ultimately met inclusion criteria. Supplementary figure S1, Supplemental Digital Content 1, http://links.lww.com/JSCR/A708 displays a PRISMA flowchart of the search process.

Descriptive Data

Fourteen studies were included (Table 1 for summary), totaling a pooled sample size of 278 participants. Three studies included nontraining control groups (6,10,26). Only 2 studies included resistance-trained participants, all of whom were male (1,18); only 73 of the 278 participants were female. Notably, 8 females from one study (10) were not included in the female-count, as the authors did not report how many female participants completed the intervention. Thirteen studies were conducted with young adults (23.3 ± 3.2 years), with only one study (17) conducted with older males (66.4 ± 0.2 years).

Eight studies employed a parallel-group design (1,11,12,17,24,25,26,28), 4 employed a within-subject design (3,10,18,23), one study employed a mixed within-subject parallel-group design (15), and one study employed a within-subject cross-over design (6). Most interventions lasted 6–12 weeks (average ~8.5 weeks) with a session frequency of 2–4 times per week. One study involved 8 weeks of eccentric-only training, followed by a 5-week washout and then 8 weeks of concentric-only training, totaling 21 weeks (6).

All studies employed direct measurements for hypertrophic assessments. Nine studies used ultrasound imaging to measure muscle thickness (3,6,12,17,18,25,28), cross-sectional area (CSA) (1,11) and fascicle length (25). One study reported both CSA and muscle thickness, but it was unclear which was measured because of inconsistent reporting (1). Four studies assessed hypertrophic adaptations using MRI, measuring muscle volume (26), CSA (10,24), or both (15). One study used peripheral quantitative computed tomography and biopsies to measure the CSA of the elbow flexors and the muscle fibers, respectively (23). Eight studies measured hypertrophic adaptations of the quadriceps femoris only (3,11,15,18,24,25,26,28) and 5 studies measured only the elbow flexors (1,6,10,12,23), whereas one study (17) measured muscle thickness of both upper and lower limbs (biceps brachii and rectus femoris, respectively).

Eleven studies employed isotonic training (1,3,10–12,17,18,24,25,26,28) and 3 studies employed isokinetic training modalities (6,15,23). Among isotonic studies, 8 involved performance of both CON and ECC actions, with 2 involving ECC actions only (25,26) and 2 involving CON actions only (26,28). In isokinetic studies, 2 studies manipulated ECC tempo only (15,23) and one study manipulated ECC tempo for 8 weeks, followed by manipulating CON tempo with the opposite limb after a washout (6). Five isotonic studies performed machine-based training (3,17,18,25,26), 5 used free-weight training (1,10–12,24), and one used dynamometry (28). All isokinetic studies used dynamometry (6,15,23). Ten studies used single-joint exercises (1,3,6,10,12,15,18,23,26,28), 3 studies used multi-joint exercises (11,24,25), and one study used a combination of both single- and multi-joint exercises (17). Eight studies used bilateral training (1,11,12,17,24,25,26,28), and 6 studies used unilateral training (3,6,10,15,18,23).

Repetition tempo for ECC actions ranged from 0.25 to 4.5 seconds, averaging ~1 second for tempos considered faster, vs. ~3.5 seconds for slower. The repetition tempo for CON actions ranged from 0.5 to 4.5 seconds, averaging ~0.73 seconds for tempos considered faster, vs. ~3.2 seconds for slower. No study included intentional pauses during transition phases. Set volume per muscle group averaged 4.4 sets per session (range: 1–9). Six studies required that participants trained to failure (1,3,11,12,24,26), 7 studies did not involve training to failure (6,10,15,17,23,25,28), and one study used a mix of failure, beyond-failure, and subfailure training to equate repetitions between limbs (18). Eight studies did not equate volume load between conditions (1,3,11,12,17,23,25,26), whereas 6 studies did equate the volume load (4,6,10,15,24,28). Only one study (25) did not equate set volume between conditions. Repetition ranges varied from 3 to 20 per set, with 2 studies not reporting range (3,11). Time under tension ranged from 4.3 to ~152.5 seconds per set. Only 4 studies reported sources of funding (15,23,24,26).

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Table 1
Summary of studies.*

Study	Sample	Design	RT program	Hypertrophy measurement	Results
Azevedo et al. (3)	10 young untrained adults ($M = 8$; $F = 2$)	Within-subject; each leg randomly allocated to 2 or 4 s ECC (1 s CON) for 8 wk	Isotonic seated knee extension for 5 sets to failure @70%1RM 2×/wk	MT of RF, VL, VM via US	No differences for VL and RF; VM favored fast ECC
Farthing and Chilibeck (6)	36 young untrained adults ($M = 13$; $F = 23$)	Parallel with nontraining control; random allocation to 30°·s^{-1} (~3.33 s) or 180°·s^{-1} (~0.56 s) ECC-only for 8 wk	Isokinetic dynamometer elbow flexors for 2–6 sets of 8 reps 3×/wk	MT of proximal, middle, and distal EF via US	No pre-post differences for control; no pre-post differences for proximal MT; pre-post differences for middle and distal MT for both training groups (fast and slow ECC)
Hisaeda et al. (10)	19 young untrained adults	Within-subject with nontraining control; random allocation to 2 or ~0.5 s CON (2 s ECC) for 8 wk	Isotonic EF for 6 sets of 10 reps @50%1RM 4×/wk	CSA of EF via MRI	CSA favored fast CON
Kojic et al.(12)	20 young untrained adults ($M = 11$; $F = 9$)	Parallel; random allocation to 4 or 1 s ECC (1 s CON) for 7 wk	Isotonic EF for 3–4 sets to failure 2×/wk	MT of EF via US	No differences between groups
Kojic et al.(11)	18 young untrained adults ($M = 10$; $F = 8$)	Parallel; random allocation to 4 or 1 s ECC (1 s CON) for 7 wk	Isotonic barbell back squat for 3–4 sets to failure @60–70% 1RM 2×/wk	CSA of RF, VL, VM, VI via US	No differences for RF, VM, VI; VL favored slow ECC
Marzilger et al. (15)	28 young untrained males	Within-subject, parallel with nontraining control; random allocation to 45°·s^{-1} (~1.66 s), 120°·s^{-1} (~0.63 s), 210°·s^{-1} (~0.36 s), or 300°·s^{-1} (~0.25 s) ECC-only for 11 wk	Isokinetic dynamometer knee extensors for 5 sets of 3, 8, 14, or 20 reps 3×/wk	CSA and MV of VL via MRI	No differences between conditions
Nogueira et al. (17)	20 older untrained males	Parallel; random allocation to 2–3 s or ~1 s CON (2–3 s ECC) for 10 wk	Isotonic leg press, knee ext., knee flex., chest press, seated row, elbow ext., and elbow flex for 6 sets of 8–10 reps 2×/wk	MT of BB and RF via US	BB and RF favored fast CON
Pearson et al. (18)	13 young trained males	Within-subject; each leg randomly allocated to 1 or 3 s ECC (1 s CON) for 8 wk	Isotonic seated knee ext. for 3–4 sets of 8–10 reps 2×/wk	MT of proximal and distal RF/VI via US	No differences for proximal; distal favored by fast ECC
Pereira et al. (1)	12 young trained males	Parallel; random allocation to 4 or 1 s ECC (1 s CON) for 12 wk	Isotonic EF of 3 sets to failure 2×/wk	CSA or MT† of BB via US	No differences between groups, but effect size favored slow ECC
Shepstone et al. (23)	12 young untrained males	Within-subject; each arm randomly allocated to 0.35 rad·s^{-1} (~4.5 s) or 3.66 rad·s^{-1} (~0.43 s) ECC-only for 8 wk	Isokinetic dynamometer EF for 1–4 sets of 10 reps 3×/wk	CSA of EF via pQCT and of muscle fibers via biopsy	CSA favored by fast ECC
Shibata et al. (24)	22 young untrained males	Parallel; random allocation to 4 or 2 s ECC (2 s CON) for 6 wk	Isotonic parallel back squat for 3 sets to failure @70%1RM 2×/wk	CSA of proximal, middle and distal QF via MRI	No differences between groups
Stasinaki et al. (25)	18 young untrained adults ($M = 10$; $F = 8$)	Parallel; random allocation to 4 or <1 s ECC-only for 6 wk	Isotonic ECC-only Smith machine squat for 5 sets of 6 reps @90%1RM or 9 sets of 9 reps @70%1RM 2×/wk	MT and fascicle length of VL via US	MT favored slow ECC; fascicle length favored fast ECC
Ünlü et al. (26)	41 young untrained males	Parallel with nontraining control; random allocation to 30°·s^{-1} (~4.5 s) or 180°·s^{-1} (~0.75 s) ECC-only, 30 or 180°·s^{-1} CON-only, or 180°·s^{-1} ECC (180°·s^{-1} CON) for 12 wk	Isotonic seated knee ext. for 3 sets to failure 3×/wk	MV of QF via MRI	No differences between groups
Wang et al. (28)	33 young untrained females	Parallel; random allocation to fast (0.5 ± 0.1 s) or slow (2.9 ± 0.3 s) CON-only training for 8 wk	Isotonic dynamometer knee extensors for 4 sets of 10 reps @60%1RM 3×/wk	MT of QF via US	No differences between groups

*M = males; F = females; ECC = eccentric; CON = concentric; MT = muscle thickness; RF = rectus femoris; VL = vastus lateralis; VM = vastus medialis; US = ultrasound; 1RM = one-repetition maximum; EF = elbow flexors; CSA = cross-sectional area; MRI = magnetic resonance imaging; VI = vastus intermedius; MV = muscle volume; BB = biceps brachii; pQCT = peripheral quantitative computed tomography; QF = quadriceps femoris.
†Unclear reporting by authors.

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Meta-Analysis of Within-Group Changes

Meta-analyses of within-group changes using hierarchical models including all measurements from the 14 included studies are presented in Figure 1. When combining data from CON and ECC studies, the pooled standardized mean change of faster (0.43 [95% CrI: 0.29–0.58]) and slower tempos (0.34 [95% CrI: 0.22–0.47)] indicated within-group hypertrophic adaptations of a medium effect magnitude, suggesting that interventions included in this review were generally effective for eliciting muscle hypertrophy.

Meta-Analysis of Between-Group Differences

Meta-analyses of pairwise between-group standardized mean differences are presented in Figure 2. When combining data from CON and ECC studies, results were inconclusive. Central estimates trivially favored faster tempos (pooled mean = 0.09 [95% CrI: −0.04 to 0.22]), with a low probability of at least a small (p = 0.450), medium (p = 0.001), or large (p < 0.001) effect.

We performed exploratory analyses to investigate differences across specific tempo categories. There was insufficient data to analyze tempos on a continuous basis. Categorization into Fast (≤1 second) vs. Moderate (2–3 seconds) and Fast vs. Slow (≥4 seconds) showed no appreciable differences. Supplementary Figure S2, Supplemental Digital Content 2, http://links.lww.com/JSCR/A709 presents these results.

Subgroup Analyses

Subgroup analyses of pairwise group differences were stratified by ECC and CON action type, and for ECC actions further stratified by body region (upper vs. lower) and training to failure (yes vs. no), where sufficient data were available (Figures 3–5, respectively). Meta-analysis of studies comparing faster and slower tempos during ECC actions showed similar effects regardless of condition (pooled mean = 0.06 [95% CrI: −0.11 to 0.22]), with low probabilities of at least a small (p = 0.325), medium (p = 0.001), or large (p < 0.001) pooled effect in favor of faster tempos. Central effect size estimates were further from zero and favored faster tempos in the subgroup analysis of CON actions (pooled mean = 0.14 [95% CrI: −0.29 to 0.60]), but with greater uncertainty. Correspondingly, the probabilities of at least a small (p = 0.597), medium (p = 0.126), or large (p = 0.016) effect in favor of faster tempos were marginally higher.

Subgroup analysis by body region restricted to tempo comparisons of ECC actions indicated negligible effects for both upper- (pooled mean = 0.14 [95% CrI: −0.46 to 0.58]) and lower-body (pooled mean = 0.03 [95% CrI: −0.16 to 0.21]) regions, with relatively low probabilities of at least a small (p = 0.526), medium (p = 0.136), or large (p < 0.001) effect in favor of faster tempos (see supplemental figure S3, Supplemental Digital Content 3, http://links.lww.com/JSCR/A710). In contrast, subgroup analysis by training to failure, also restricted to ECC actions, suggested a modest advantage for faster tempos when training short of failure (pooled mean = 0.21 [95% CrI: 0.00–0.44]), with a high probability of at least a small effect (p = 0.868), but low probabilities of at least medium (p = 0.084) or large (p = 0.001) effects. For studies in which participants trained to failure, central estimates instead favored slower tempos (Pooled mean = −0.11 [95% CrI: −0.38 to 0.12]), although with greater uncertainty and low probabilities of at least a small (p = 0.533), medium (p = 0.035), or large (p = 0.004) effect.

Analyses of Small Study Effects

A funnel plot (Figure 6) depicting effect sizes relative to within-study standard errors did not indicate concerns regarding publication bias or small-study effects.

Methodological Qualitative Assessment

Using the SMART-LD tool, the included studies had a mean methodological quality score of 13.4 out of 20 (range: 9–18). Three

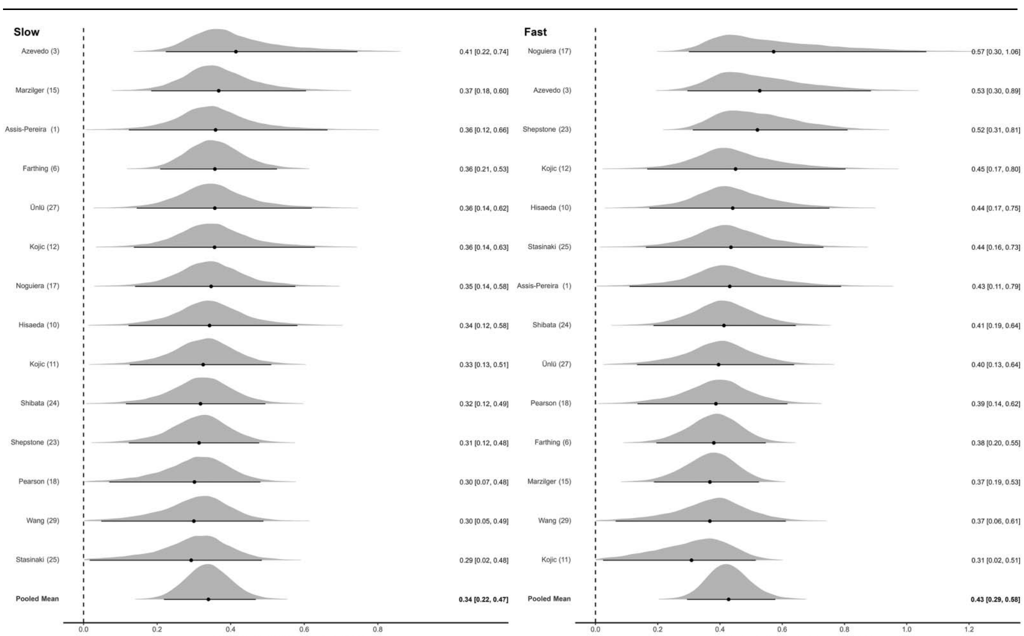

Figure 1. Forest plots from meta-analyses of noncontrolled effect sizes for slower (left) and faster (right) tempo interventions. Distributions show the pooled (bottom) and study within-group effect size posterior distributions, which are regularized ("shrunken") via partial pooling in the hierarchical model, which borrows strength across studies.

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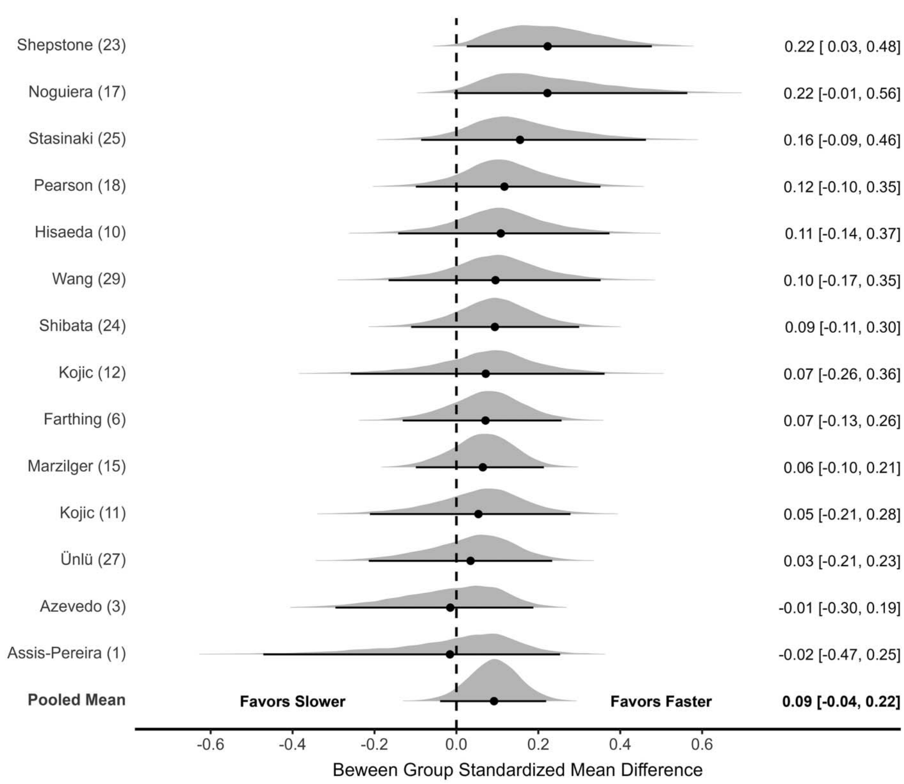

Figure 2. Forest plot from meta-analysis comparing slower and faster tempos across both eccentric and concentric studies. Distributions show the pooled (bottom) and study within-group effect size posterior distributions, which are regularized ("shrunken") via partial pooling in the hierarchical model, which borrows strength across studies.

studies were judged to be of good quality (23,26,28), 10 studies were judged to be of fair quality (3,6,10–12,15,17,18,24,25), and one study was judged to be of poor quality (1). The individual ratings for each study are presented in supplementary figure S4, Supplemental Digital Content 4, http://links.lww.com/JSCR/A711.

Discussion

To our knowledge, this is the first systematic review and meta-analysis to isolate and quantify the independent effects of manipulating eccentric and concentric repetition tempos on muscle hypertrophy using a Bayesian framework. Unlike prior reviews

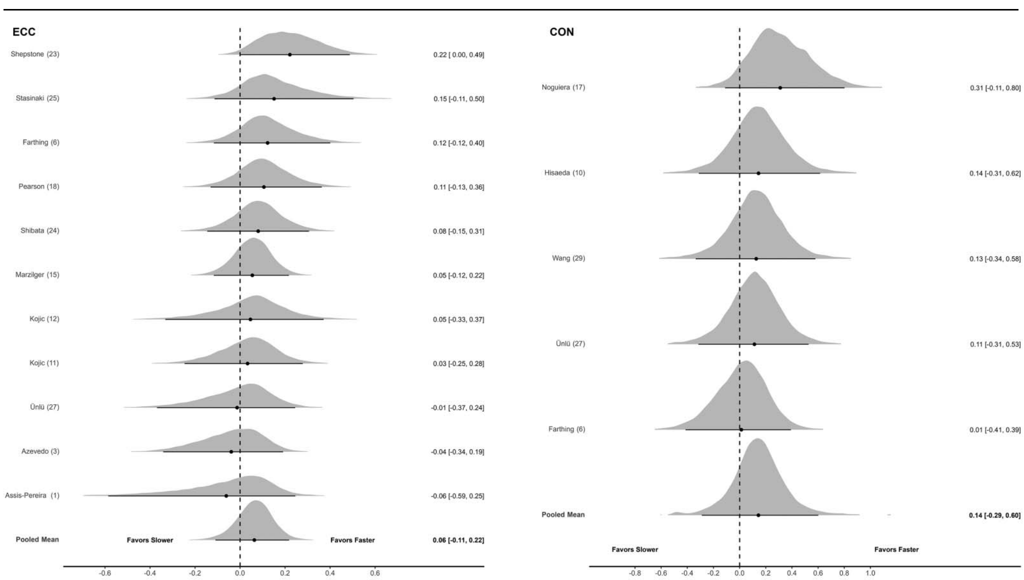

Figure 3. Forest plots from meta-analyses comparing slower and faster tempos across eccentric studies (left) and concentric studies (right). Distributions show the pooled (bottom) and study within-group effect size posterior distributions, which are regularized ("shrunken") via partial pooling in the hierarchical model, which borrows strength across studies.

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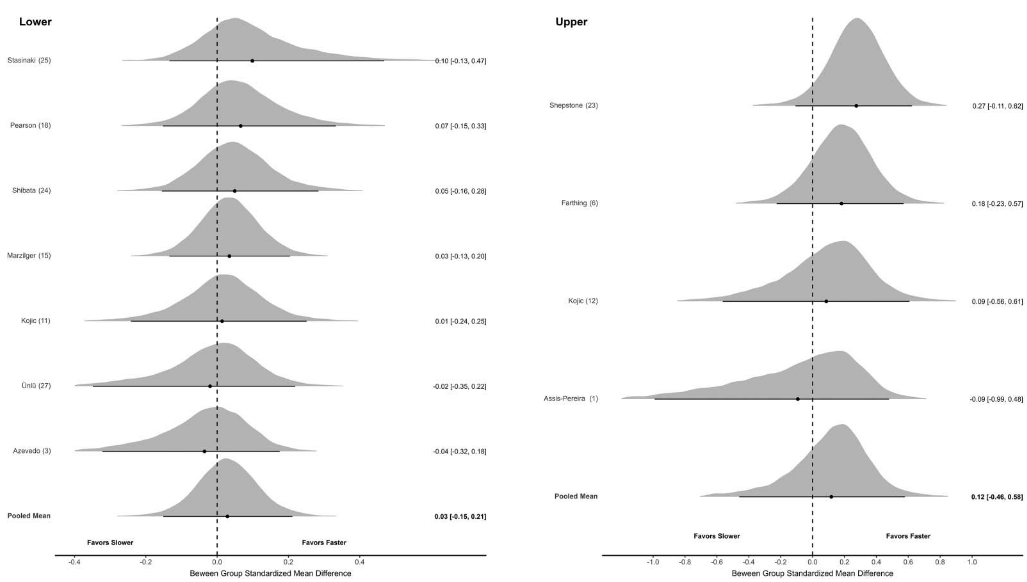

Figure 4. Forest plots from meta-analyses comparing slower and faster tempos across eccentric studies assessing lower-body (left) and upper-body (right) regions. Distributions show the pooled (bottom) and study within-group effect size posterior distributions, which are regularized ("shrunken") via partial pooling in the hierarchical model, which borrows strength across studies.

that assessed total repetition duration, our approach provides more targeted and probabilistic insights into how manipulating the tempo of individual muscle actions during RT affects muscle hypertrophy. Our analyses showed that the included studies were effective at stimulating muscle hypertrophy based on comparisons of within-group changes with S&C specific thresholds, and that manipulation of tempos generally did not provide a consistent advantage, although some differences may emerge under specific conditions such as training to failure.

When directly comparing faster vs. slower repetition tempos, our estimates indicate a likely trivial standardized mean difference (pooled mean = 0.09 [95% CrI: −0.04 to 0.22]). These findings are consistent with a meta-analysis by Schoenfeld et al. (21) who reported a wide range of RT repetition durations (∼0.5–∼8 seconds) produced similar hypertrophic responses. However, Schoenfeld et al. (21) did not quantify the magnitude of effect on the individual muscle actions (i.e., CON or ECC), limiting comparison to results of the present study. Moreover, inclusion criteria of Schoenfeld et al. (21) required training to concentric failure, which differs from the present meta-analysis where some studies did not involve participants training to failure when manipulating either CON (17,28) or ECC (10,15,23,25). Given evidence suggesting that training to failure is not essential for maximizing hypertrophic adaptations (20), it would seem that manipulating the repetition tempo for eccentric and concentric phases, regardless of proximity to failure, can elicit similar magnitudes of hypertrophy.

Subgroup analyses of data by type of action indicated trivial differences between conditions for both CON (pooled mean = 0.14 [95% CrI: −0.29 to 0.60]) and ECC tempos (pooled mean =

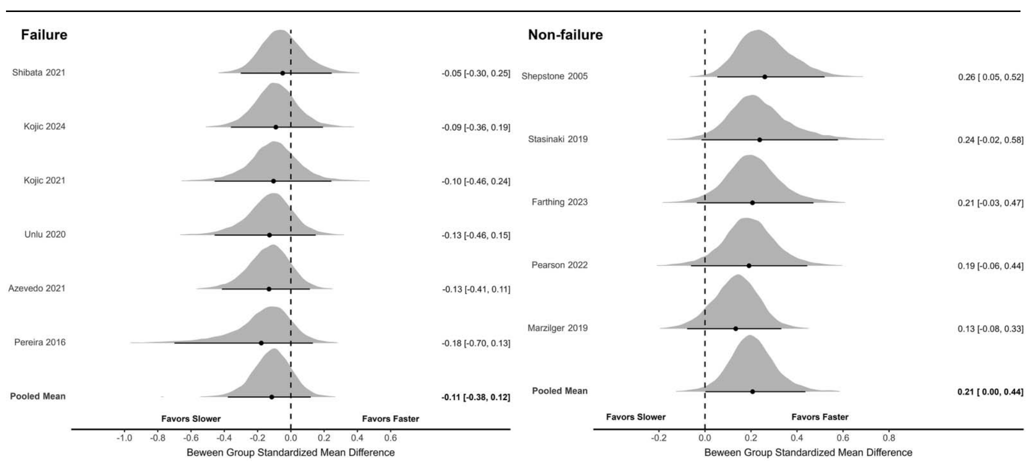

Figure 5. Forest plots from meta-analyses comparing slower and faster tempos across eccentric studies with failure (left) and non-failure (right) repetitions.

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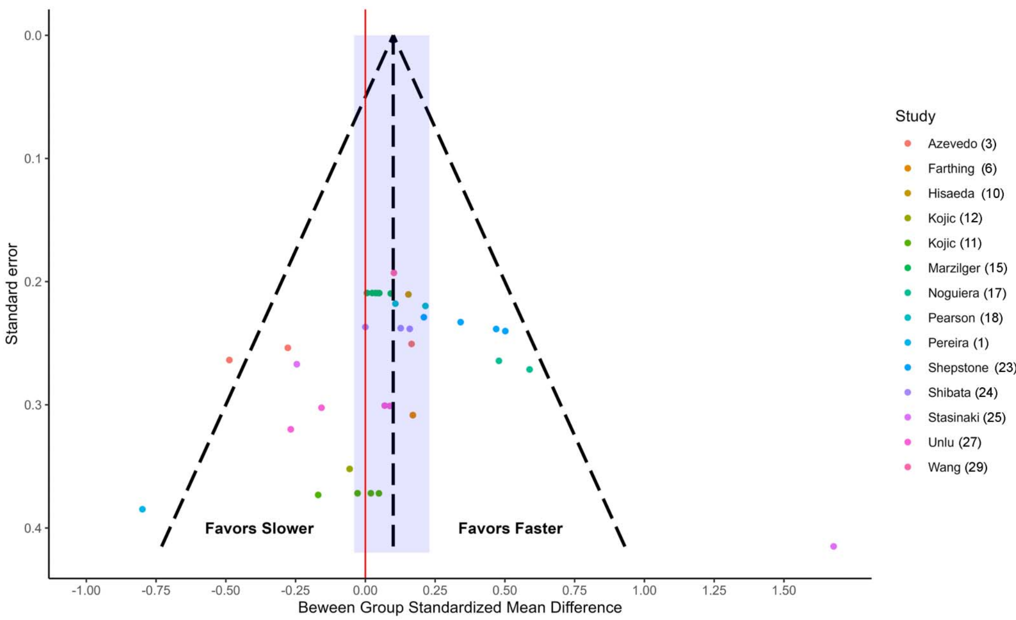

Figure 6. Funnel plot of between group standardized mean differences.

0.06 [95% CrI: −0.11 to 0.22]). These findings contrast with the conclusions of Wilk et al. (30) who suggested that moderate-to-slow ECC tempos might be more beneficial than fast tempos for muscle development. However, the conclusions of Wilk et al. (30) were drawn from a narrative review and did not quantify effect sizes. Our results challenge previous speculation that a slower CON tempo would enhance muscular adaptations by reducing the use of momentum during RT (29). This finding aligns with more recent evidence indicating that the use of external momentum in untrained individuals does not impair hypertrophy of the elbow flexors and extensors (2), suggesting that momentum may not inhibit hypertrophy.

Subgroup analysis based on body region revealed that variations in tempo showed no meaningful differences in hypertrophic response between the upper and lower body, although the limited CON data on the topic restricted this analysis to ECC actions. Contrary to our findings, Hackett et al. (9) suggested that moderate-to-slow and fast velocities might be more beneficial for lower body (i.e., quadriceps femoris) and upper body (i.e., biceps brachii), respectively; however, the authors also acknowledge that the studies supporting these suggestions manipulated the tempos for both muscle actions, limiting the ability to draw conclusions about specific phases. Alternatively, Gray et al. (7) compared different CON velocities with a standardized 2-second ECC phase in older individuals and reported no differences in lean tissue mass after a 48-week study period. It should be noted that muscle development was assessed by DXA in a whole-body manner, limiting inferences for regional changes as required in the present study. Collectively, the current data suggest that both fast and slow ECC tempos can elicit similar hypertrophic outcomes across upper- and lower-body regions.

Subgroup analysis on the interaction between repetition tempo and training to failure was also restricted to ECC actions because of limited data for CON actions. Results suggest a modest hypertrophic benefit for employing somewhat faster eccentric tempos under nonfailure conditions, with a high probability of at least a small effect. Alternatively, slower tempos were marginally superior when training to failure with low probabilities of at least a small effect, thus warranting skepticism in drawing inferences as to the finding's practical relevance. A mechanistic rationale for these discrepancies remains elusive. More research is needed to directly investigate the relationship between tempo and proximity to failure and quantify specific tempo ranges that may help to optimize muscle hypertrophy.

Our study has several limitations that should be acknowledged. As with all meta-analyses, our inferences are limited by the design and quality of included studies. A key limitation is the variability in how repetition tempo was prescribed and monitored. For example, studies that instructed participants to perform a phase "as fast as possible" may have allowed inconsistent execution. Better standardization and reporting of tempo instructions is warranted in future research. Moreover, although there is some evidence to suggest that very slow RT tempos may be suboptimal for hypertrophy when accounting for total repetition duration (>10 seconds) (22), there is a paucity of research investigating the topic specific to isolated CON and ECC tempos. Future research should examine whether an upper threshold for tempo exists beyond which hypertrophy becomes compromised. Another limitation is the substantial heterogeneity in the included studies regarding exercise selection, training modalities, and participant characteristics. To address this, we employed hierarchical Bayesian models, which allow for partial pooling and better estimation of effects under varying conditions. Although this approach mitigates some of the noise, we recommend caution in generalizing these results without context-specific considerations. In addition, concentric velocity necessarily slows as one approaches muscle failure. Thus, it is unclear whether this confounds the effects of initial tempo in studies with a close proximity to failure. Finally, whether manipulating CON or ECC tempos can lead to different muscle architecture adaptations (e.g., ECC tempos eliciting distinct longitudinal growth) remains unclear.

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Practical Applications

Our results suggest that coaches and practitioners can use a relatively wide range of CON and ECC repetition tempos (~0.25 to ~4.5 seconds) to promote muscle hypertrophy. For example, individuals who cannot perform high-load or high-velocity movements—such as during rehabilitation or in cases of joint discomfort—can select ECC and/or CON repetition tempos based on comfort, safety, and personal preference, without compromising hypertrophic adaptations. Although no differences were detected between ECC tempos, logic dictates that load should be sufficiently controlled during this action so that the target musculature generates tension. Given the well-established mechanistic role of mechanical stress in mediating hypertrophy (27), simply allowing the load to drop under gravitational pull would conceivably compromise muscle development. Future research should endeavor to examine this hypothesis. Moreover, given the generally similar effects regarding muscle hypertrophy irrespective of tempo, coaches and practitioners can use ECC and CON repetition tempos as a tool for variety or managing training stress across different phases of a RT program, while prioritizing other RT variables when seeking to maximize muscle hypertrophy such as volume and proximity-to-failure.

References

1. Assis-Pereira PE, Motoyama YL, Esteves GJ, et al. Resistance training with slow speed of movement is better for hypertrophy and muscle strength gains than fast speed of movement. *Int J Appl Exerc Physiol* 5: 37–43, 2016.
2. Augustin F, Piñero A, Enes A, et al. Do cheaters prosper? Effect of externally supplied momentum during resistance training on measures of upper body muscle hypertrophy. *Int J Exerc Sci* 18: 329–342, 2025.
3. Azevedo PHSM, Oliveira MGD, Schoenfeld BJ. Effect of different eccentric tempos on hypertrophy and strength of the lower limbs. *Biol Sport* 39: 443–449, 2022.
4. Barakat C, Barroso R, Alvarez M, et al. The effects of varying glenohumeral joint angle on acute volume load, muscle activation, swelling, and echo-intensity on the biceps brachii in resistance-trained individuals. *Sports (Basel)* 7: 204, 2019.
5. Burke R, Piñero A, Coleman M, et al. The effects of creatine supplementation combined with resistance training on regional measures of muscle hypertrophy: A systematic review with meta-analysis. *Nutrients* 15: 2116, 2023.
6. Farthing JP, Chilibeck PD. The effects of eccentric and concentric training at different velocities on muscle hypertrophy. *Eur J Appl Physiol* 89: 578–586, 2003.
7. Gray M, Powers M, Boyd L, Garver K. Longitudinal comparison of low- and high-velocity resistance training in relation to body composition and functional fitness of older adults. *Aging Clin Exp Res* 30: 1465–1473, 2018.
8. Greenhalgh T, Peacock R. Effectiveness and efficiency of search methods in systematic reviews of complex evidence: Audit of primary sources. *BMJ* 331: 1064–1065, 2005.
9. Hackett DA, Davies TB, Orr R, Kuang K, Halaki M. Effect of movement velocity during resistance training on muscle-specific hypertrophy: A systematic review. *Eur J Sport Sci* 18: 473–482, 2018.
10. Hisaeda H, Nakamura Y, Kuno S, Fukunaga T, Muraoka I. Effect of high-speed resistance training on muscle cross-sectional area and speed of movement. *Jpn J Phys Fit Sports Med* 45: 345–355, 1996.
11. Kojic F, Mandic D, Duric S. The effects of eccentric phase tempo in squats on hypertrophy, strength, and contractile properties of the quadriceps femoris muscle. *Front Physiol* 15: 1531926, 2024.
12. Kojić F, Ranisavljev I, Ćosić D, et al. Effects of resistance training on hypertrophy, strength and tensiomyography parameters of elbow flexors: Role of eccentric phase duration. *Biol Sport* 38: 587–594, 2021.
13. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: Progression and exercise prescription. *Med Sci Sports Exerc* 36: 674–688, 2004.
14. Kruschke JK, Liddell TM. The Bayesian new statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychon Bull Rev* 25: 178–206, 2018.
15. Marzilger R, Bohm S, Mersmann F, Arampatzis A. Effects of lengthening velocity during eccentric training on vastus lateralis muscle hypertrophy. *Front Physiol* 10: 957, 2019.
16. Morris B. Estimating effect sizes from pretest-posttest-control group designs. *Organ Res Methods* 11: 364–386, 2008.
17. Nogueira W, Gentil P, Mello SN, et al. Effects of power training on muscle thickness of older men. *Int J Sports Med* 30: 200–204, 2009.
18. Pearson J, Wadhi T, Barakat C, et al. Does varying repetition tempo in a single-joint lower body exercise augment muscle size and strength in resistance-trained men? *J Strength Cond Res* 36: 2162–2168, 2022.
19. Pinero A, Burke R, Augustin F, et al. Throwing cold water on muscle growth? A meta-analysis of the effects of cooling strategies on hypertrophy when combined with resistance training. *Eur J Sport Sci* 24: 177–189, 2024.
20. Refalo MC, Helms ER, Trexler ET, Hamilton DL, Fyfe JJ. Influence of resistance training proximity-to-failure on skeletal muscle hypertrophy: A systematic review with meta-analysis. *Sports Med* 53: 649–665, 2023.
21. Schoenfeld BJ, Ogborn DI, Krieger JW. Effect of repetition duration during resistance training on muscle hypertrophy: A systematic review and meta-analysis. *Sports Med* 45: 577–585, 2015.
22. Schuenke MD, Herman JR, Gliders RM, et al. Early-phase muscular adaptations in response to slow-speed versus traditional resistance-training regimens. *Eur J Appl Physiol* 112: 3585–3595, 2012.
23. Shepstone TN, Tang JE, Dallaire S, et al. Short-term high- vs. low-velocity isokinetic lengthening training results in greater hypertrophy of the elbow flexors in young men. *J Appl Physiol* 98: 1768–1776, 2005.
24. Shibata K, Takizawa K, Nosaka K, Mizuno M. Effects of prolonging eccentric phase duration in parallel back-squat training to momentary failure on muscle cross-sectional area, squat one repetition maximum, and performance tests in university soccer players. *J Strength Cond Res* 35: 668–674, 2021.
25. Stasinaki A, Zaras N, Methenitis S, Bogdanis G, Terzis G. Rate of force development and muscle architecture after fast and slow velocity eccentric training. *Sports (Basel)* 7: 41, 2019.
26. Ünlü G, Çevikol C, Melekoğlu T. Comparison of the effects of eccentric, concentric, and eccentric-concentric isotonic resistance training at two velocities on strength and muscle hypertrophy. *J Strength Cond Res* 34: 337–344, 2020.
27. Wackerhage H, Schoenfeld BJ, Hamilton DL, Lehti M, Hulmi JJ. Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise. *J Appl Physiol* 126: 30–43, 2019.
28. Wang Z, Taniguchi M, Saeki J, Ichihashi N. Effects of high-velocity versus low-velocity resistance training on muscle echo intensity in healthy young women: A randomized controlled trial. *Sports Health* 17: 637–645, 2024.
29. Westcott WL, Winett RA, Anderson ES, et al. Effects of regular and slow speed resistance training on muscle strength. *J Sports Med Phys Fitness* 41: 154–158, 2001.
30. Wilk M, Zajac A, Tufano JJ. The influence of movement tempo during resistance training on muscular strength and hypertrophy responses: A review. *Sports Med* 51: 1629–1650, 2021.

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