INTERNATIONAL JOURNAL OF
-EXERCISE SCIENCE-

Original Research

Does Performing Partial Repetitions Beyond Momentary Failure Enhance Muscle Hypertrophy in Volume-Load-Equated Calf-Raise Resistance Training?

Amirali Goli*[1], Parsa Attarieh*[2], João Pedro Nunes†[3], Saman Nehegadar*[2], Saeed Khani*[2], Mohmad Fashi‡[1], Sajjad Ahmadizad‡[1]

[1]Department of Biological Sciences in Sport, Faculty of Sport Sciences and Health, Shahid Beheshti University. Tehran, Iran; [2]Department of Exercise Physiology, Faculty of Sport Sciences and Health, University of Tehran, Tehran, Iran; [3]School of Medical and Health Sciences, Edith Cowan University. Joondalup, Australia

Abstract

International Journal of Exercise Science 19(4): 1-10, 2026. *https://doi.org/10.70252/IJES2026403*
The aim of this study was to determine whether extending traditional calf-raise resistance training sets with partial-range-of-motion (ROM) repetitions in the more dorsiflexed ROM enhances muscular hypertrophy. Sixteen untrained men (25.0±1.7y) completed 10 weeks of unilateral standing calf-raise training (2×/wk) in a within-subject design: one leg performed traditional 10-14RM sets to full-ROM momentary failure (MF; 4-6 sets/session) and the other leg performed half as many sets to full-ROM failure followed by partial-ROM repetitions to a second failure in the more dorsiflexed ROM (PBF; 2-3 sets/session). Total volume-load was equated between conditions; repetitions were counted the same way regardless of the ROM. Muscle hypertrophy was assessed as changes in muscle thicknesses of the gastrocnemius medialis and lateralis via B-mode ultrasound imaging. After training, both MF and PBF elicited equivalent (equivalence test P-values <0.05) changes in muscle thickness (averaged muscle thicknesses; MF:8%, PBF:8%). Per-set analyses, however, revealed greater efficiency (P<0.05) with PBF (0.16%) in comparison to MF (0.08%). In conclusion, adding "longer-length" partial-ROM repetitions to failure beyond full-ROM failure (PBF) permits a greater accumulation of volume-load per set and elicit greater changes in muscle size on a per-set basis analysis. Under volume-load-equated conditions, PBF and training to full-ROM failure (MF) seem to evoke similar changes in gastrocnemius thickness after 10 weeks of unilateral standing calf-raise training in untrained young men.

Keywords: Strength training, muscle growth, lengthened partials, regional hypertrophy, time-efficient

Introduction

Manipulating load, volume, rest intervals, range of motion (ROM), and proximity to momentary failure (MF) is suggested to be fundamental in resistance training for optimizing the mechanical stimuli that drive muscle hypertrophy.[1–3] Specifically, the proximity to MF (defined as the inability to complete another concentric repetition in proper form, despite attempting to do so with maximal effort)[4] has been shown to influence hypertrophic outcomes, with sets performed closer to failure eliciting greater gains.[2] Of note, however, trainees largely underestimate their true proximity to MF,[5] prompting interest in techniques that extend effort beyond the initial point of failure to investigate whether additional adaptations can be obtained.

*Corresponding Author: João Pedro Nunes; Email: joaonunes.jpn@hotmail.com

"Beyond-failure" techniques, including drop-set, rest-pause, cheated reps, and partial-ROM repetitions at "longer muscle lengths" (i.e., continuing the set by performing only the initial portion of the ROM) [a], allow the continuation of a set past the initial failure point, suggested to potentially enhance the hypertrophic stimulus per set.[6–10] A few studies investigating such techniques have reported augmented hypertrophy compared to traditional training protocols.[11–15] Among them, partial-ROM training at long muscle lengths has gained recent attention,[16–19] having shown greater increases in muscle size than both short-length partial-ROM[20–22] and full-ROM[20,21] training. It is possible that executing partial-ROM repetitions after reaching full-ROM MF either simply guarantees the set is completed to (or close to) true momentary failure, or it prolongs the mechanical work done with high levels of muscle activation – both being of importance to the hypertrophic stimulus.[2,6,9] However, despite the promising rationale, empirical support remains limited.

Recently, Larsen et al.[23] compared four sets of full-ROM MF followed by long-muscle-length partial-ROM repetitions to a second MF in partial-ROM versus four sets of traditional full-ROM MF in a 10-week unilateral standing calf-raise protocol in untrained young men. The beyond-MF condition evoked greater increases in medial gastrocnemius muscle thickness (10%) than the traditional first-MF condition (7%), supporting the potential utility of the method. Of note, however, the beyond-MF condition was completed with ~80% more total volume-load (TVL; sets × repetitions × load) due to the greater number of repetitions performed beyond first failure. As such, it remained unclear whether the observed benefits were due to an intrinsic superiority of the method itself or simply a function of greater accumulated volume within the sets.

In this context, the present study compared the effects of unilateral standing calf-raise training performed to full-ROM momentary failure (MF; 4-6 sets/session) versus full-ROM failure followed by partial-ROM repetitions to partial-ROM failure (PBF; 2-3 sets/session) on changes in gastrocnemius medialis (GM) and lateralis (GL) thickness in untrained young men. A within-subject design was employed, and TVL was experimentally equated between conditions. Outcomes were analyzed under TVL-equated conditions as well as normalized for the number of sets. This approach permits MF and PBF to be re-compared on a set-matched basis and, for the first time, compared under TVL-matched conditions. It was hypothesized that MF and PBF would elicit equivalent hypertrophy under TVL-equated conditions, whereas PBF would be superior on a per-set basis [20–23].

Methods

Participants

Recruitment was carried out through social media and home delivery of flyers in the university area. Interested subjects completed detailed health history and physical activity questionnaires, and were subsequently admitted if they met the following inclusion criteria: men, 18-35 years old, free from cardiac, orthopedic, or musculoskeletal disorders that could impede exercise practice, not consume drug or supplement ergogenic aids, and not be involved in the practice of resistance training over the six months before the start of the study. The exclusion criterion was defined as having a training attendance of <80%. Of the 18 volunteers, 16 met the criteria, were evaluated at baseline, and completed the training sessions (age = 25.0 ± 1.7 years; body mass = 75.2 ± 4.4 kg; stature = 176.0 ± 3.2 cm; BMI = 24.3 ± 1.1 kg/m^2). This sample size is considered satisfactory (n ≥ 15 per group) to achieve a power of 0.8 and an α of 0.05 for improving muscle size with a moderate effect size of 0.55[24] in a two-group, two-time point design. Subjects were instructed to avoid changes in their habitual recreational physical activities and dietary intake during the study period. Written informed consent was obtained from all subjects after a detailed description of study procedures was provided.

A within-subject design was employed to investigate the effects of two distinct calf training protocols on muscle hypertrophy. This design was selected to eliminate inter-individual variability in training responses. For the training, subjects' legs were randomly allocated to one of the two conditions, balanced for self-reported leg dominance (the leg to kick a ball): MF and PBF. Subjects were randomly assigned a number in an Excel list to determine whether their dominant leg would follow MF or PBF training, while the non-dominant leg would undergo the other condition. The study was conducted as follows: one week was used for one training familiarization session, one week was used for baseline assessments, 10 weeks for the progressive training program, and one week for post-training testing (>72 hours after the final session). Muscle hypertrophy was defined as changes in MT measured by B-mode ultrasound imaging. All training sessions were supervised by at least two researchers with international personal trainer certifications to standardize the technique. The study was approved by the University Ethics Committee (IR.SBU.REC.1403.021) and carried out fully in accordance with the ethical standards of the International Journal of Exercise Science.[25]

Protocol

Unilateral standing calf raises were performed on a plate-loaded standing calf-raise machine. Sets were performed with loads to reach full-ROM failure in 10-14 repetitions. Subjects were instructed to perform each repetition using a 1-second concentric phase and a 2-second eccentric phase, with no pause at the transition between muscle actions, and no bouncing/countermovement between repetitions. The ROM was determined for each participant based on their maximum dorsiflexion and plantarflexion capacity during the exercise, visually confirmed constantly by at least two researchers. Full ROM was defined from the subject's maximal dorsiflexion to their peak plantarflexion, whereas Partial ROM was defined from the subject's maximal dorsiflexion to their neutral ankle position (90° foot-shin). Full-ROM failure was defined as the inability to reach peak plantarflexion, whereas Partial-ROM failure was defined as the inability to reach a neutral ankle position, despite verbal encouragement. When a participant was unable to reach the required ROM for two consecutive repetitions despite attempting to do so with maximal effort and correct technique, the set was terminated.

Two pilot sessions were conducted before the study commenced with six individuals to establish the expected number of partial-ROM repetitions that could be performed beyond full-ROM failure until partial-ROM failure. For the pilot sessions, subjects completed with each leg 2 sets to full-ROM failure with no restriction to repetitions (repetitions were then annotated), followed by partial-ROM repetitions until they could no longer complete the limited-range movement (repetitions were then annotated). Both full-ROM and partial-ROM repetitions were counted as 1 repetition. Only sets where subjects reached first failure within the 10-14RM full-ROM range were considered; across individuals, the number of partial-ROM repetitions ranged from 6 to 12 (expected total repetitions per set in PBF condition: ~16-26). These observations were used to structure the training program in a way that matched TVL between conditions, considering MF would be performed starting with 4 sets. Accordingly, PBF was then chosen to be done with half of the sets of MF.

The training program was conducted twice weekly on non-consecutive days (≥48 hours apart) in the afternoon for 10 weeks. Subjects completed MF and PBF in the same session. The starting leg was alternated between sessions to control for order effects. MF was performed in sets of 10-14RM to full-ROM failure, while PBF was performed in sets of 10-14RM to full-ROM failure followed by partial-ROM repetitions to partial-ROM failure. MF was performed in 4 sets per session during weeks 1-6, progressing to 6 sets in weeks 7-10, while PBF was performed in 2 sets in weeks 1-6 and 3 sets in weeks 7-10. The load was established initially based on the familiarization sessions and subsequently adjusted on a session-based incrementally by 5-10% to the nearest 0.5kg when participants exceeded 14RM to full-ROM failure in the first set of the session. Rest intervals were standardized to 2 minutes between sets and 5 minutes between legs. The number of repetitions and the load used were recorded to compute TVL.

Measures of MT were obtained using a B-mode ultrasound machine with an L741 8-12MHz linear probe (SonoScape E1 EXP, China) by the same experimenter, blinded to condition allocation. Subjects were instructed to show up to the laboratory in the morning hours fasting for at least 8 h, and not perform vigorous exercise for the previous 48 h. Ultrasound measurements started after subjects were lying down in prone position on a medical plinth for 10 min. Images were acquired at 25% of the distance between the lateral femur condyle and the lateral malleolus of the tibia. For image acquisition, water-soluble transmission gel was applied over the skin on the region of interest, and measurements were done with caution not to depress the muscle tissue, with the probe placed perpendicular to the tissue interface. The images were analyzed using ImageJ software (NIH, USA), and MT was defined as the distance between its superficial and deep aponeuroses. Inter-day test-retest reliability scores were satisfactory (ICC [3,1] = 0.98; relative typical error = 1.1%).

Statistical Analysis

Normality was checked by Shapiro-Wilk's test. Analyses were performed based on effect size (ES), calculated individually as the difference between post- and pre-training scores divided by group-pooled pre-training standard deviations, with Hedges' g correction factor for small samples.[26] An ES of 0.00–0.19 was considered as trivial, 0.20–0.49 as small, 0.50–0.79 as moderate, and ≥ 0.80 as large.[26] Mean ESs were computed for each group, and between-group differences (ES_{diff}) were calculated as PBF-ES minus MF-ES. To account for differences in training volume, ESs were: 1) adjusted for total volume load (TVL) via linear regression (with intercept and slope used to calculate TVL-adjusted ESs); and (2) normalized by dividing by the total number of training sets performed to calculate per-set ESs. Equivalence between groups was tested using two one-sided tests (TOST) with ESs as variables. For ES and TVL-adjusted-ES analyses, the standardized equivalence bounds were set at trivial (±0.20). For per-set ES analyses, the equivalence bounds were scaled accordingly (±0.00208; 0.20 divided by 96 sets from the MF group). Within-group ESs were tested against zero using one-sample t-tests with Bonferroni correction to analyze the effect compared to baseline. Between-group differences in TVL were tested using an independent t-test. Statistical significance was accepted at $P < 0.05$. The data were expressed as mean, standard deviation, and confidence intervals (CIs), and analyses were done using Jamovi v.2.3 (The Jamovi Project).

Results

Subjects completed all the training sessions. No injuries occurred during the intervention. The TVL was not significantly different between conditions (MF: 13.1 ± 4.5 ton; PBF: 11.8 ± 4.1 ton; P = 0.392). Initial analyses based on marginal means adjusted for pre-training scores, and pre-training scores plus TVL, showed significant changes in GM MT and GL MT for both MF (8%) and PBF (8%), with significantly equivalent results between them. Analyses per set revealed non-equivalent results, with greater effects observed for PBF in comparison to MF for both GM (0.15% vs. 0.08%) and GL (0.16% vs. 0.09%). Table 1 presents the results, and Figure 1 displays the individual relative changes.

Table 1. Pre- and post-training raw data and effect sizes (ESs), along with between-group differences for muscle thickness (MT) of the gastrocnemius medialis (GM) and gastrocnemius lateralis (GL) following momentary failure (MF; n = 16) and partials beyond failure (PBF; n = 16) training conditions.

	MF	PBF	ES_{diff}	TOST P-values		Interpretation
GM MT						
Pre (mm)	20.3 ± 2.9	19.9 ± 3.2				
Post (mm)	21.7 ± 2.9	21.3 ± 3.1				
ES	0.45 (0.25, 0.65)	0.45 (0.27, 0.62)	-0.01 (-0.19, 0.18)	0.034	0.042	MF = PBF
ES (TVL adj.)#	0.36 (0.16, 0.56)	0.35 (0.18, 0.52)	-0.01 (-0.19, 0.18)	0.034	0.042	MF = PBF
ES (per set)†	0.005 (0.003, 0.007)	0.009 (0.006, 0.013)	0.005 (0.002, 0.008)	<0.001	0.918	MF < PBF
GL MT						
Pre (mm)	20.4 ± 2.7	21.0 ± 3.1				
Post (mm)	22.0 ± 2.8	22.6 ± 3.2				
ES	0.56 (0.43, 0.69)	0.55 (0.34, 0.75)	-0.01 (-0.17, 0.15)	0.016	0.030	MF = PBF
ES (TVL adj.)#	0.71 (0.57, 0.84)	0.69 (0.49, 0.90)	-0.01 (-0.17, 0.15)	0.016	0.030	MF = PBF
ES (per set)†	0.006 (0.004, 0.007)	0.011 (0.007, 0.016)	0.006 (0.002, 0.009)	<0.001	0.953	MF < PBF

Notes. # = adjusted for pre-training values + total volume-load (TVL). † = pre-to-post training differences divided by total number of sets. Data are mean ± SD, ESs for each condition are Hedges' g (95%CI lower, upper bounds), and ES_{diff} is the difference between conditions in Hedges' g and (90%CI lower, upper bounds) for two one-sided tests of equivalence.

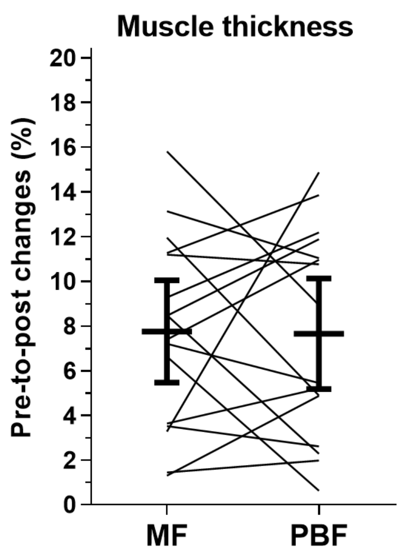

Figure 1. Percentage changes in gastrocnemius medialis and lateralis (average) thicknesses following momentary failure (MF) and partials beyond failure (PBF) training conditions. Data are mean and 95%CIs, with each line representing individual data points.

Discussion

The present study compared the effects of calf-raise traditional full-ROM training to momentary failure (MF) versus calf-raise training performed with partial repetitions beyond full-ROM momentary failure (PBF) on gastrocnemius muscle hypertrophy. While both training protocols produced similar changes in muscle thickness (MT) under a volume-load-equated perspective, PBF demonstrated superior effects on a per-set basis.

The comparable hypertrophic responses between MF and PBF under volume-matched conditions align with evidence from two recent reviews, indicating that most training variables have nil to trivial influence on hypertrophy when total volume-load is equated across training programs.[8,27] On the other hand, the per-set analyses indicate that each set of PBF elicited a superior hypertrophic stimulus. However, this does not necessarily imply that performing twice the number of sets would double the hypertrophic response for PBF. Instead, Larsen et al.[23] observed a 10% increase in GM MT after four sets of PBF, versus 7% for four sets of MF, despite PBF completing 80% more volume-load. The lack of doubled gains may be due to increased muscle damage in early training sessions associated with training at longer muscle lengths, which may hamper recovery rates,[28–30] or simply because the dose-response relationship between set volume and muscle hypertrophy is non-linear, consistent with the diminishing returns principle.[2]

In addition, the 8% hypertrophic gain observed for PBF was achieved with approximately 64% more repetitions per set, but half as many sets, resulting in ~20% fewer repetitions overall compared to MF. Extrapolating this outcome, had PBF performed the same number of total repetitions as MF, the estimated PBF hypertrophic response might have reached ~10%, aligning with what was observed by Larsen et al.,[23] and consistent with the hypothesis that lengthened partial-ROM repetitions may provide a slightly more effective stimulus for hypertrophy.[23] Supporting this notion, Kassiano et al.[21] reported that lengthened partial-ROM calf raises led to MT increases of 15% versus 7% for full-ROM (equal number of sets and repetitions). Together, these findings suggest that including longer-length partial-ROM repetitions to calf training may produce superior calf hypertrophic adaptations than the traditional full-ROM training on a per-set basis, although PBF and MF are similarly effective when volume-load is equated.

The minor superiority of PBF on per-set and per-repetition perspectives may be explained mechanistically. During contractions, as the ankle dorsiflexes, the gastrocnemii operate at a lower moment arm while producing a higher active force.[31] Consequently, for a given external load, repetitions performed in the longer-length ROM may impose approximately 30% greater mean active force on the gastrocnemii compared to full-ROM repetitions.[31] Furthermore, contractions at longer muscle lengths are associated with increased mechanical tension (considered the main driver of muscle hypertrophy),[32–35] primarily from the titin,[36,37] which seems to activate distinct titin-mediated hypertrophic mechanisms.[35,38] Thus, despite likely involving smaller fascicle excursions, partial-ROM repetitions likely induce greater muscle fiber mechanical tension. Although the plantar flexors do not reach very long lengths on the descending limb of the force–length relationship to engage passive tension components,[19,31] when the muscle is active, titin attaches to actin, reducing titin's free-length region and shifting the passive force–length curve to the left.[36] This shift likely allows muscles operating near the plateau region to still place high tension on titin and benefit from training in ankle partial-ROM dorsiflexed positions, as previously shown.[21] Whether greater titin activation is the main source of increased muscle growth during this type of training remains to be investigated. Moreover, considering that titin stimulation with high tension and long length training[39] is believed to play a key role in promoting longitudinal hypertrophy through the addition of sarcomeres in series,[35,38] it remains to be determined how longitudinal muscle growth contributes to overall muscle size increases following this type of training. Given the complexity of methods like microendoscopy and laser diffraction imaging used to measure sarcomere length and estimate changes in serial sarcomere number, future studies may at least estimate it through changes in resting fascicle length in multiple slack muscle positions, along with measures of tendon stiffness, as done before.[40]

Certain methodological limitations should be acknowledged. First, no objective tools such as electrical goniometers and velocity tracking devices were used for movement analysis during training, although subjects were instructed and supervised to train on the specified ROM and encouraged to undergo all sets to failure in both conditions. Second, the lack of a PBF group with doubled set volume (or an MF group with halved sets) precludes definitive conclusions about whether the equation of repetitions or sets would have evoked the discussed results in the current training experiment.[8] The inclusion of a non-training control group or a control period could also have improved the interpretability of the findings about the natural variability in MT over time.[41] Third, hypertrophy was assessed at a single site for the GM and GL. Assessing multiple regions along the muscle length, including the soleus, and using cross-sectional area or muscle volume measures would have provided a more comprehensive characterization of the adaptations.[42] Fourth, it is important to note that the present study was conducted in untrained young men, and the findings are therefore specific to this population. Training is known to modify muscle-tendon passive properties, often leading to shorter fascicle operating lengths during contraction,[43,44] which may influence the advantage of longer-length training schemes. Thus, it remains to be determined whether similar effects would occur in trained individuals. In addition, although longer-length training has been shown to be effective in females,[20,21] future studies may further extend the evidence regarding PBF training in this population.

The applicability of the PBF method is limited to exercises where the partial-ROM contractions do not impose a risk to the practitioner, like calf raises,[21,23] leg extensions,[20] and biceps curls.[22] Its use in multi-joint exercises is mostly restricted to machine-based exercises, like horizontal leg-press and chest press, but not squat and bench press, when not assisted by spotters. The validity of PBF still remains to be explored to multi-joint, full-body exercise routines to offer a valid strategy to practitioners with reduced time for training.[10]

In conclusion, when total volume-load is equated, a 10-week calf-raise training yields comparable increases in gastrocnemius size in untrained young men, whether it is performed with 2-3 sets of partial repetitions to failure beyond traditional full-ROM failure (PBF) or 4-6 sets of full-ROM momentary failure (MF).

References

1.Schoenfeld BJ. The mechanisms of muscle hypertrophy and their application to resistance training. *J Strength Cond Res.* 2010;24(10):2857-2872. https://doi.org/10.1519/JSC.0b013e3181e840f3

2.Robinson ZP, Pelland JC, Remmert JF, et al. Exploring the dose-response relationship between estimated resistance training proximity to failure, strength gain, and muscle hypertrophy: A series of meta-regressions. *Sports Med*. 2024; 54(9):2209-2231. https://doi.org/10.1007/s40279-024-02069-2

3.Schoenfeld BJ, Fisher J, Grgic J, et al. Resistance training recommendations to maximize muscle hypertrophy in an athletic population: Position Stand of the IUSCA. *Int J Strength Cond*. 2021;1:1.

4.Steele J, Fisher J, Giessing J, Gentil P. Clarity in reporting terminology and definitions of set endpoints in resistance training. *Muscle and Nerve.* 2017;56(3):368-374. https://doi.org/10.1002/mus.25557

5.Steele J, Malleron T, Har-Nir I, et al. Are trainees lifting heavy enough? Self-selected loads in resistance exercise: A scoping review and exploratory meta-analysis. *Sports Med.* 2022;52(12):2909-2923. https://doi.org/10.1007/s40279-022-01717-9

6.Ozaki H, Abe T, Loenneke JP, Katamoto S. Stepwise load reduction training: A new training concept for skeletal muscle and energy systems. *Sports Med.* 2020;50(12):2075-2081. https://doi.org/10.1007/s40279-020-01341-5

7.Krzysztofik M, Wilk M, Wojdała G, Gołas A. Maximizing muscle hypertrophy: A systematic review of advanced resistance training techniques and methods. *Int J Environ Res Public Health*. 2019;16(24):E4897. https://doi.org/10.3390/ijerph16244897

8.Kassiano W, Costa B, Nunes JP, Aguiar AF, De Salles BF, Ribeiro AS. Are we exploring the potential role of specialized training techniques in muscle hypertrophy? Int J Sports Med. 2021;42(6):494-496. https://doi.org/10.1055/a-1342-7708

9.Duchateau J, Stragier S, Baudry S, Carpentier A. Strength training: In search of optimal strategies to maximize neuromuscular performance. *Exerc Sport Sci Rev.* 2021;49(1):2-14. https://doi.org/10.1249/JES.0000000000000234

10.Iversen VM, Norum M, Schoenfeld BJ, Fimland MS. No time to lift? Designing time-efficient training programs for strength and hypertrophy: A narrative review. *Sports Med.* 2021;51(10):2079-2095. https://doi.org/10.1007/s40279-021-01490-1

11.Prestes J, Tibana RA, de Araujo Sousa E, et al. Strength and muscular adaptations after 6 weeks of rest-pause vs. traditional multiple-sets resistance training in trained subjects. *J Strength Cond Res*. 2019;33(Suppl 1):S113-S121. https://doi.org/10.1519/JSC.0000000000001923

12.Karimnagar M, Arazi H, Mehrabani J. Twelve weeks rest-pause and traditional resistance training: Effects on myokines and performance adaptations among recreationally trained men. *Stresses.* 2023;3(1):302-315. https://doi.org/10.3390/stresses3010022

13.Stragier S, Baudry S, Carpentier A, Duchateau J. Efficacy of a new strength training design: The 3/7 method. *Eur J Appl Physiol.* 2019;119(5):1093-1104. https://doi.org/10.1007/s00421-019-04099-5

14.Fink J, Schoenfeld, Kikuchi N, Nakazato K. Effects of drop set resistance training on acute stress indicators and long-term muscle hypertrophy and strength. *J Sports Med Phys Fitness.* 2018;58(5):597-605. https://doi.org/10.23736/S0022-4707.17.06838-4

15.Varović D, Žganjer K, Vuk S, Schoenfeld BJ. Drop-set training elicits differential increases in non-uniform hypertrophy of the quadriceps in leg extension exercise. *Sports.* 2021;9(9):119. https://doi.org/10.3390/sports9090119

16.Kassiano W, Costa B, Nunes JP, Ribeiro AS, Schoenfeld BJ, Cyrino ES. Which ROMs lead to Rome? A systematic review of the effects of range of motion on muscle hypertrophy. *J Strength Cond Res.* 2023;37(5):1135-1144. https://doi.org/10.1519/JSC.0000000000004415

17.Newmire DE, Willoughby DS. Partial range of motion resistance training: A feasible bodybuilding training regiment for local or regional muscle hypertrophy ? *Strength Cond J.* Published online 2020:ahead of print. https://doi.org/10.1519/SSC.0000000000000550

18.Wolf M, Androulakis-Korakakis P, Fisher JP, Schoenfeld BJ, Steele J. Partial vs full range of motion resistance training: A systematic review and meta-analysis. *Int J Strength Cond.* 2023;3(1):ijsc.v3i1.182.

19.Ottinger CR, Sharp MH, Stefan MW, Gheith RH, Espriella F, Wilson JM. Muscle hypertrophy response to range of motion in strength training: A novel approach to understanding the findings. *Strength Cond J.* 2023;45(2):162-176. https://doi.org/10.1519/SSC.0000000000000737

20.Pedrosa GF, Lima F V, Schoenfeld BJ, et al. Partial range of motion training elicits favorable improvements in muscular adaptations when carried out at long muscle lengths. *Eur J Sport Sci.* 2022;22(8):1250-1260. https://doi.org/10.1080/17461391.2021.1927199

21.Kassiano W, Costa B, Kunevaliki G, et al. Greater gastrocnemius muscle hypertrophy after partial range of motion training carried out at long muscle lengths. *J Strength Cond Res.* 2022;37(9):1746-1753. https://doi.org/10.1519/JSC.0000000000004460

22.Sato S, Yoshida R, Kiyono R, et al. Elbow joint angles in elbow flexor unilateral resistance exercise training determine its effects on muscle strength and thickness of trained and non-trained arms. *Front Physiol.* 2021;12:734509. https://doi.org/10.3389/fphys.2021.734509

23.Larsen S, Swinton PA, Sandberg NO, et al. Resistance training beyond momentary failure: The effects of past-failure partials on muscle hypertrophy in the gastrocnemius. *Front Psychol.* 2025;16:1494323. https://doi.org/10.3389/fpsyg.2025.1494323

24.Schoenfeld BJ, Ogborn D, Krieger JW. Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. *J Sports Sci.* 2017;35(11):1073-1082. https://doi.org/10.1080/02640414.2016.1210197

25.Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci.* 2019;12(1):1-8. https://doi.org/10.70252/EYCD6235

26.Borenstein M, Hedges L V, Higgins JPT, Rothstein HR. Introduction to Meta-Analysis. Wiley; 2009.

27.Nunes JP, Kassiano W, Costa B, Mayhew JL, Ribeiro AS, Cyrino ES. Equating resistance-training volume between programs focused on muscle hypertrophy. *Sports Med.* 2021;51(6):1171-1178. https://doi.org/10.1007/s40279-021-01449-2

28.McMahon G, Onambele-Pearson G. Joint-angle specific neuromuscular time-course of recovery following isometric resistance exercise at shorter and longer muscle lengths. *J Appl Physiol.* 2024;136(4):889-900. https://doi.org/10.1152/japplphysiol.00820.2023

29.Nosaka K, Sakamoto K. Effect of elbow joint angle on the magnitude of muscle damage to the elbow flexors. *Med Sci Sports Exerc.* 2001;33(1):22-29. https://doi.org/10.1097/00005768-200101000-00005

30.Maeo S, Meng H, Yuhang W, et al. Greater hamstrings muscle hypertrophy but similar damage protection after training at long versus short muscle lengths. *Med Sci Sports Exerc*. 2021;53(4):825-837. https://doi.org/10.1249/MSS.0000000000002523

31.Maganaris CN. Force-length characteristics of the in vivo human gastrocnemius muscle. *Clin Anat.* 2003;16(3):215-223. https://doi.org/10.1002/ca.10064

32.Jorgenson KW, Phillips SM, Hornberger TA. Identifying the structural adaptations that drive the mechanical load-induced growth of skeletal muscle: A scoping review. *Cells.* 2020;9(7):1658. https://doi.org/10.3390/cells9071658

33.Roberts MD, McCarthy JJ, Hornberger TA, et al. Mechanisms of mechanical overload-induced skeletal muscle hypertrophy: Current understanding and future directions. *Physiol Rev.* 2023;103(4):2679-2757. https://doi.org/10.1152/physrev.00039.2022

34.Wackerhage H, Schoenfeld BJ, Hamilton DL, Lehti M, Hulmi JJ. Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise. *J Appl Physiol.* 2019;126(1):30-43. https://doi.org/10.1152/japplphysiol.00685.2018

35.Ibata N, Terentjev EM. Why exercise builds muscles: Titin mechanosensing controls skeletal muscle growth under load. *Biophys J.* 2021;120(17):3649-3663. https://doi.org/10.1016/j.bpj.2021.07.023

36.Herzog W. Why are muscles strong, and why do they require little energy in eccentric action? *J Sport Heal Sci.* 2018;7(3):255-264. https://doi.org/10.1016/j.jshs.2018.05.005

37.Herzog W, Duvall M, Leonard TR. Molecular mechanisms of muscle force regulation: A role for titin? *Exerc Sport Sci Rev.* 2012;40(1):50-57. https://doi.org/10.1097/JES.0b013e31823cd75b

38.Krüger M, Kötter S. Titin, a central mediator for hypertrophic signaling, exercise-induced mechanosignaling and skeletal muscle remodeling. *Front Physiol.* 2016;7:76. https://doi.org/10.3389/fphys.2016.00076

39.Blazevich AJ, Herzog W, Nunes JP. Triggering sarcomerogenesis: Examining key stimuli and the role attributed to eccentric training - Historical, systematic, and meta-analytic review. *J Sport Heal Sci.* Published online 2025:ahead of print. https://doi.org/10.1016/j.jshs.2025.101073

40.Bizet B, Nordez A, Tallio T, et al. Eight weeks of eccentric training at long-muscle length increases fascicle length independently of adaptations in passive mechanical properties. *J Appl Physiol.* 2025;138(4):939-949. https://doi.org/10.1152/japplphysiol.00859.2024

41.Hammert WB, Dankel SJ, Kataoka R, et al. Methodological considerations when studying resistance-trained populations: Ideas for using control groups. *J Strength Cond Res.* 2024;38(12):2164-2171. https://doi.org/10.1519/JSC.0000000000004978

42.Nunes JP, Blazevich AJ, Schoenfeld BJ, et al. Determining changes in muscle size and architecture following exercise training: One site does not fit all. *J Strength Cond Res.* 2024;38(4):787-790. https://doi.org/10.14814/phy2.13374

43.Kubo K, Ishigaki T, Ikebukuro T. Effects of plyometric and isometric training on muscle and tendon stiffness in vivo. *Physiol Rep.* 2017;5(15):e13374.

44.Lambrianides Y, Epro G, Arampatzis A, Karamanidis K. Evidence of different sensitivity of muscle and tendon to mechano-metabolic stimuli. *Scand J Med Sci Sport.* 2024;34(5):e14638. https://doi.org/10.1111/sms.14638