Lengthened partial repetitions elicit similar muscular adaptations as a full range of motion repetitions during resistance training in trained individuals (#107078)

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Lengthened partial repetitions elicit similar muscular adaptations as a full range of motion repetitions during resistance training in trained individuals

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Purpose: Resistance training using different ranges of motion may produce varying effects on musclular adaptations. The purpose of this study was to compare the effects of lengthened partial repetitions (LPs) versus full range of motion (ROM) resistance training (RT) on muscular adaptations. **Methods:** In this within-participant study, thirty healthy, resistance-trained participants had their upper extremities randomly assigned to either a lengthened partial or full ROM condition; all other training variables were equivalent between limbs. The RT intervention was an eight-week program targeting upper-body musculature. Training consisted of two training sessions per week, with four exercises per session and four sets per exercise. Muscle hypertrophy of the elbow flexors and elbow extensors was evaluated using B-mode ultrasonography at 45 and 55% of humeral length. Muscle strength-endurance was assessed using a 10-repetition-maximum test on the lat pulldown exercise, both with a partial and full ROM. Data analysis employed a Bayesian framework with inferences made from posterior distributions and the strength of evidence for the existence of a difference through Bayes factors. **Results:** Both muscle thickness and unilateral lat pulldown 10-repetition-maximum improvements were similar between the two conditions. Results were consistent across outcomes with point estimates close to zero, and Bayes factors (0.16 to 0.3) generally providing “moderate” support for the null hypothesis of equal improvement across interventions. **Conclusions:** Trainees seeking to maximize muscle size should likely emphasize the stretched position, either by using a full ROM or LPs during upper-body resistance training. For muscle strength-endurance, our findings suggest that LPs and full ROM elicit similar adaptations.

Lengthened Partial Repetitions Elicit Similar Muscular Adaptations as Full Range of Motion Repetitions During Resistance Training in Trained Individuals.

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ABSTRACT

Purpose: Resistance training using different ranges of motion may produce varying effects on musclular adaptations. The purpose of this study was to compare the effects of lengthened partial repetitions (LPs) versus full range of motion (ROM) resistance training (RT) on muscular adaptations. **Methods:** In this within-participant study, thirty healthy, resistance-trained participants had their upper extremities randomly assigned to either a lengthened partial or full ROM condition; all other training variables were equivalent between limbs. The RT intervention was an eight-week program targeting upper-body musculature. Training consisted of two training sessions per week, with four exercises per session and four sets per exercise. Muscle hypertrophy of the elbow flexors and elbow extensors was evaluated using B-mode ultrasonography at 45 and 55% of humeral length. Muscle strength-endurance was assessed using a 10-repetition-maximum test on the lat pulldown exercise, both with a partial and full ROM. Data analysis employed a Bayesian framework with inferences made from posterior distributions and the strength of evidence for the existence of a difference through Bayes factors. **Results:** Both muscle thickness and unilateral lat pulldown 10-repetition-maximum improvements were similar between the two conditions. Results were consistent across outcomes with point estimates close to zero, and Bayes factors (0.16 to 0.3) generally providing "moderate" support for the null hypothesis of equal improvement across interventions. **Conclusions:** Trainees seeking to maximize muscle size should likely emphasize the stretched position, either by using a full ROM or LPs during upper-body resistance training. For muscle strength-endurance, our findings suggest that LPs and full ROM elicit similar adaptations.

INTRODUCTION

'Portions of this text were previously published as part of a preprint (https://doi.org/10.51224/SRXIV.455)'

Resistance training (RT) is generally considered the most efficacious exercise modality for eliciting muscle hypertrophy in humans (Schoenfeld et al., 2021). Though the contributions of different potential stimuli of skeletal muscle hypertrophy during RT are not fully understood, it is clear that mechanical overload/tension plays a prominent role in initiating the hypertrophic response (Roberts et al., 2023).

The effects of manipulating range of motion (ROM) during RT has been extensively studied, with many investigations focusing on training at longer muscle lengths (Wolf et al., 2023). While generally lacking ecological validity, five studies have compared longer versus shorter muscle length isometric contraction (Akagi et al., 2020; Alegre et al., 2014; Hinks et al., 2021; Kubo et al., 2006; Noorkõiv et al., 2014), and nine studies have compared partial ROM at longer muscle lengths (referred to as lengthened partials and abbreviated as LPs) versus shorter muscle lengths (referred to as shortened partials and abbreviated as SPs) on muscle hypertrophy (Kassiano, Costa, et al., 2022; Larsen, Kristiansen, et al., 2024; Maeo et al., 2020, 2022; Mcmahon et al., 2014; Pedrosa et al., 2021, 2023; Sato et al., 2021; Stasinaki et al., 2018)[1]. Additionally, a recent study compared employing LPs following momentary failure using full ROM versus full ROM alone and found that the former intervention resulted in greater muscle hypertrophy versus full ROM (Larsen, Swinton, et al., 2024)[1]. However, it is worth noting that the LPs group also completed a significantly higher total volume load, which may have influenced the hypertrophic outcomes.

[1] The studies by Larsen et al. (2024) are pre-printed and have yet to undergo peer-review.

More importantly, four studies have compared LPs (LPs) to full range of motion (ROM) resistance training (Goto et al., 2019; Kassiano et al., 2022, Costa, et al., 2022; Pedrosa et al., 2021; Werkhausen et al., 2021). With the exception of Werkhausen et al. (2021), all remaining studies showed that training at longer muscle lengths elicited greater hypertrophy, suggesting that trainees aiming to maximize muscle growth should emphasize training at longer muscle lengths. Notably, the unique findings of Werkhausen et al (2021) may be attributable to their use of a concentric-only protocol and the extremely limited range of motion (a 9° change in knee angle) used by the partials group..

Previous studies investigating manipulations to ROM have important limitations. Research on LPs versus full ROM RT has used single-exercise interventions, which are not representative of typical RT routines that involve multiple exercises, limiting the ecological validity of these findings (Kassiano et al., 2022). Additionally, most studies have focused on lower-body muscles (quadriceps, plantar flexors, hip extensors), with fewer studies on upper-body muscles (elbow flexors and extensors) (Kassiano et al., 2022, Goto et al., 2019). Moreover, these studies typically train muscles through the central 75% of a joint's ROM, not at maximal muscle lengths, leaving it unclear if the benefits of longer muscle length training extend to the extremes of muscle length. Lastly, nearly all studies have been conducted on untrained individuals, limiting generalizability to trained populations.

In an effort to bridge gaps in the current literature, this study aimed to compare the effects of LPs and full ROM RT on upper-body muscle hypertrophy in resistance-trained participants using a multi-exercise routine, with a secondary aim to evaluate their effects on strength-endurance (i.e., 10-RM performance).

MATERIALS & METHODS

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We opted for a within-participant design, assigning each limb to either LPs or full ROM resistance training, to compare their effects on upper-body muscle hypertrophy and strength-endurance over an eight-week, supervised multi-exercise program.

Participants

As with previous studies from our group (Burke et al., 2024), we adopted a Bayesian framework for our analyses with a focus on describing the most plausible values from our experiment versus a dichotomous hypothesis testing of whether an effect existed or not. We adopted a within-participant design and included the use of informative priors to enhance precision. Anticipating a higher attrition rate due to the recruitment methods employed, we aimed to recruit thirty participants at the outset.

We estimated sample size based on expected precision of the average treatment effect using 95% credible intervals and simulated Bayes factor calibration. Informative priors, drawn from relevant meta-analyses (Wolf et al., 2023; Swinton et al., 2022), informed these simulations. Precision assessment across sample sizes of 20, 25, and 30 indicated sufficient reliability with a sample size of twenty to twenty-five participants (Table 1).

Table 1 here

Participants were admitted into the study based on the following criteria: (a) aged between 18-40 years; (b) free from existing cardiorespiratory or musculoskeletal disorders; (c) self-reported to have performed at least one upper-body resistance training session per week on more than 80% of weeks over the past six months; and (d) self-reported as free from the use of anabolic steroids or other illegal agents known to enhance muscle size currently and within the previous year. Participants were also instructed to refrain from consuming creatine products during the study period due to its potential impact on muscle growth when combined with RT (Burke et al., 2023).

Participants were recruited through participation in previous studies and the researchers' personal networks, supplemented by social media posts. After meeting inclusion criteria, a mixed sample of participants was targeted, with emphasis on those with greater training experience. The methods of this study were preregistered prior to data collection and made publicly available on the Open Science Framework (https://osf.io/86v2h).

After being admitted to the study, participants' upper limbs were randomly assigned to one of two experimental conditions: full range of motion (fROM; n = 30) or partial range of motion (pROM; n = 30) using counterbalanced block randomization with two limbs per block via online software (www.randomizer.org). Approval for the study was obtained from the City University ~~university~~ Lehman College Institutional Review Board (#2024-0218). Written informed consent was obtained from all participants prior to beginning the study. All training and data collection were carried out at the same site.

To avoid potential dietary confounding of results, participants were advised to maintain their customary nutritional regimen as previously described (Burke et al., 2024). Dietary adherence was assessed by self-reported five-day food records (including at least one weekend day) using MacroFactor (https://macrofactorapp.com/). Nutritional data were collected twice during the study including one week before the first training session (i.e., baseline) and during the final week of the training protocol. Participants were instructed on how to properly record all food items and their respective portion sizes consumed for the designated period of interest. Each item of food was individually entered into the program, and the program provided relevant information as to total energy consumption, as well as the amount of energy derived from proteins, fats, and carbohydrates for each time-period analyzed.

Resistance Training Procedures

Participants completed two directly-supervised upper-body training sessions per week for eight weeks, with at least one research assistant supervising each participant while performing the protocol outlined ~~below~~in Table 2.~~:~~

Table 2 here

Participants were instructed to perform all sets to momentary muscular failure, defined as the point where they could no longer perform another repetition despite attempting to do so, with research assistants providing verbal encouragement and monitoring adherence to the prescribed ROM. The eccentric phase was performed in approximately two seconds, with a one-second pause at the position where the target muscle was at its longest length. The concentric phase was executed with the intent to move the load explosively. Participants rested for one minute when switching to the opposite limb between sets, alternating limbs set-by-set. The order of limb training was randomized and counterbalanced across sessions. Load adjustments were made as needed to maintain the target repetition range and intensity of effort on a set-to-set basis. To account for ecological validity, we included multiple repetition ranges across exercises.

Participants were instructed not to perform any additional upper-body RT outside of the study protocol but were permitted to perform lower-body RT and other physical activities at their discretion. The research team included experienced researchers with PhDs in exercise-related disciplines as well as graduate-level students in human performance; a majority of the researchers and assistants also held certification in strength and conditioning (via the National Strength and Conditioning Association) and/or from nationally accredited personal training organizations.

Training sessions were carried out between 9 a.m. and 5 p.m., with participants afforded the ability to train at the time of their convenience.

Range of Motion: To achieve an ecologically valid operationalization for fROM and pROM protocols, participants received instruction from the research staff. To ensure the research staff provided standardized instructions to participants, videos were shown to both the research staff and participants, displaying the appropriate ROM and technique for each exercise (see supplementary file at: https://osf.io/a6cpz/).

After randomization of the limbs and prior to the eight-week training program, participants underwent 10-repetition-maximum (10RM) testing with fROM and pROM on both limbs in the unilateral lat pulldown exercise. fROM limb strength was always tested first, followed by pROM limb strength. The order of limb testing was randomized, counterbalanced, and standardized from pre- to post-intervention strength testing. Participants were instructed to perform the 10RM testing following the ROM guidelines of their respective group. The 10-RM testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (NSCA, 2016).

After familiarization with full ROM, participants were instructed to complete a full ROM as comfortably as possible during training in the fROM condition. When the participant was unable to complete another full ROM repetition, the set was terminated. In the pROM condition, participants were instructed to perform half-repetitions (approximately 50% of full ROM), relative to their own individualized full ROM, from the position achieved at the end of the eccentric or lowering phase. The set was terminated when the participant attempted another partial ROM

repetition with 50% of full ROM, but failed to complete the partial ROM repetition. The research staff provided instruction between and during sets as to whether the ROM achieved was adequate in both conditions.

Assessments

Participants underwent pre- and post-intervention testing in separate sessions, refraining from strenuous exercise for at least seventy-two hours prior to testing. The following measurements were taken:

Anthropometry and Muscle Thickness: Height and body mass were measured with a stadiometer and measuring scales (Model 770, InBody Corporation, Seoul, South Korea). Participants fasted for twelve hours before testing, avoided alcohol for twenty-four hours, and voided their bladder immediately before testing.

Muscle thickness (MT) was assessed according to the procedure described by Coleman et al. (2023). The reliability and validity of ultrasound in determining MT has been reported to be very high when compared to the "gold standard" magnetic resonance imaging (Stokes et al., 2021). The same trained ultrasound technician performed all testing using a B-mode ultrasound imaging unit (Model E1, SonoScape, Co., Ltd, Shenzhen, China). The technician applied a water-soluble transmission gel (Aquasonic 100 Ultrasound Transmission gel, Parker Laboratories Inc., Fairfield, NJ, USA) to each measurement site, and a 4–12 MHz linear array ultrasound probe was placed along the tissue interface without depressing the skin.

For the elbow flexors, assessments were conducted on the anterior surface of the upper arm at 45 and 55% of the distance between the antecubital fossa and the acromion process. For the elbow extensors, assessments were obtained on the posterior surface of the upper arm at 45 and 55% between the olecranon tip and the acromion process. When the quality of the image was deemed satisfactory, the technician saved the image to a hard drive and obtained MT dimensions by measuring the distance from the subcutaneous adipose tissue-muscle interface to the muscle-bone interface. Images were obtained at least seventy-two hours post-training to minimize the potential effect of acute muscle swelling. Three images were averaged for each site to derive the final MT value. The test-retest intraclass correlation coefficient (ICC) from our lab for MT measurements is excellent (>0.94), with coefficients of variation (CV) ≤3.3%.

Dynamic Muscle Strength-Endurance

Dynamic upper-body strength-endurance was assessed via 10RM testing in each respective ROM both pre- and post-intervention for the unilateral lat pulldown exercise. Repetition maximum testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (NSCA, 2016). In brief, following ROM instruction participants performed a 5-repetition warm-up set of the exercise at ~50% estimated 10RM, followed by one or two sets of 2-3 repetitions at a load corresponding to ~60-80% estimated 10RM. Participants then performed a set of 10 repetitions at a heavier load. If successful, they attempted a heavier load for 10 repetitions, continuing until they failed to complete 10 repetitions. Weights attempted were multiples of 5 lbs. When necessary, i.e. if the difference between the last successful attempt and a failed attempt was greater than 5 lbs, the weight was reduced and

214 another attempt was granted in order to accurately gauge the 10RM. The heaviest successful
215 attempt was recorded as their 10RM. One minute of rest was provided between warm-up sets,
216 and 3 to 5 minutes of rest were provided between each successive 10RM attempt.

217 **Blinding**

218 To reduce potential bias, the technician obtaining MT measurements was blinded to
219 condition allocation and all statistical analyses were performed by a blinded statistician.

220 **Statistical analysis**

221 All analyses were conducted in R (version 4.4.0) within a Bayesian framework (van de
222 Schoot et al., 2021). Bayesian statistics represents an approach to data analysis and parameter
223 estimation based on Bayes' theorem, offering several advantages over frequentist approaches,
224 including the formal inclusion of information regarding likely differences between intervention
225 conditions based on knowledge from previous studies (e.g., through informative priors (P. Swinton
226 & Murphy, 2022)) and the presentation of inferences based on intuitive probabilities (Magezi,
227 2015).

228 We used a modified version of the workflow suggested by Gelfand & Wang (2002) to
229 estimate the likely precision of our average treatment effect based on the width of the 95%
230 credible intervals across various potential sample sizes. Additionally, we performed simulation-
231 based calibration of Bayes factors to evaluate whether the correct hypothesis would likely be
232 supported given the sample size and study design (Schad et al., 2023). To assess the expected
233 precision, we first simulated prior predictive data for different sample sizes using informative

234 priors. These priors were derived from a meta-analysis on the topic (Wolf et al., 2023) and from
235 meta-analyses examining the distribution of effects in strength and conditioning (P. A. Swinton et
236 al., 2022; P. Swinton & Murphy, 2022). The priors, set on a standardized scale, included
237 distributions for typical improvement ($N(0.44, 0.40^2)$), average treatment effect ($N(0.30, 0.27^2)$),
238 heterogeneous response ($N(0, 0.15^2)$), and measurement error ($N(0, 0.20^2)$). The fitting priors used
239 an average treatment effect prior of $N(0, 0.40^2)$.

240 For the simulation-based calibration of Bayes factors, we assumed equal prior probabilities
241 for the null (H_0) and alternative (H_1) hypotheses. The simulations and model fitting were conducted
242 using a neutral prior of $N(0, 0.40^2)$, with the average treatment effect set to zero in half of the
243 iterations. Calibration was assessed by examining the average posterior model probability (to
244 determine if it matched the expected 50%) and the average percentage of posterior allocated to
245 the true hypothesis. Models were fit across 500 iterations for sample sizes of n=20, 25, and 30
246 (see supplementary file) and judged to provide appropriate precision and assessment of strength
247 of evidence of twenty to twenty-five participants.

248 Inferences were not drawn on within-condition change, as this was not the focus of our
249 research question , although within-condition changes were descriptively presented to help
250 contextualize our findings. The effect of condition (fROM versus pROM) on outcome variables was
251 estimated using linear mixed models with random effect structures included to account for the
252 within-participant design (Bürkner, 2018).

253 All inferences were made from posterior distributions of model parameters describing
254 estimates of the effect of intervention allocation and the strength of evidence for either the null

or alternative hypothesis of a mean group difference through Bayes factors with a standard scale used to qualitatively interpret the numerical value (e.g. “anecdotal”, “moderate”, “strong” support) (Michael & Wagenmakers, 2014) Informative prior distributions were used based on meta-analysis data on the specific research question and general strength and conditioning literature (P. Swinton & Murphy, 2022). All analyses were performed using the R wrapper package Bayesian Regression Models (brms) interfaced with Stan to perform sampling (Bürkner, 2018). A complete Bayesian workflow was adopted, which included prior predictive checks, posterior predictive checks, and simulation-based calibration of Bayes factors (Schad et al., 2023). To improve accuracy, transparency, and replication of the analyses, the WAMBS-checklist (When to Worry and how to Avoid Misuse of Bayesian Statistics) was used and reported (Depaoli & van de Schoot, 2017).

RESULTS

Five participants dropped out over the course of the study, resulting in a final sample of 25 participants (training experience = 4.9 ± 4.1 years) that completed the training intervention and pre-/post-intervention testing (see Table 3 for descriptive characteristics).

Table 3 here

279 The reasons for attrition were as follows: scheduling issues (*n* = 2), commute time issues
280 (*n* = 1), injury unrelated to the study (*n* = 1), and failure to attend the required number of training
281 sessions (*n* = 1). Based on the a priori sample size determination, this sample size of 25 participants
282 was judged to provide appropriate precision and assessment of strength of evidence. All
283 participants included in the data analysis completed at least 14 out of 16 (87.5%) possible training
284 sessions. On average, participants completed 96.5% of training sessions.

285
286 *Muscular Adaptations*
287
288 Initial analyses of within intervention change across outcomes are presented in Figure 1,
289 with results showing both interventions tending to produce small to medium changes based on
290 thresholds specific to strength and conditioning. Estimates of mean group differences are
291 presented in Table 4. Results were consistent across outcomes with point estimates close to zero
292 and Bayes factors (0.16 to 0.39) in general providing "moderate" support for the null hypothesis
293 of equal improvement across interventions (Table 4). Completion of the WAMBS-checklist
294 identified no issues of concern with the analyses, and nutritional intake appeared to remain
295 relatively consistent across the intervention. These findings suggest that both the lengthened
296 partial and full range of motion interventions led to comparable improvements in muscle
297 hypertrophy and strength-endurance. The similarity in outcomes between the two approaches
298 indicates that neither method provided a clear advantage over the other for enhancing muscular
299 adaptations in this trained population. Pre-post hypertrophy measurements can be found in Table
300 5.
301

302

303 **Table 4 here**

304

305 **Figure 1 here**

306

Table 5 here

DISCUSSION

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The current study presents several meaningful findings that provide insight regarding the efficacy of LPs and full ROM RT for stimulating muscular adaptations in resistance-trained individuals. Muscle hypertrophy was similar between conditions, with Bayesian analyses providing anecdotal to moderate support for the null hypothesis (i.e., no difference in effectiveness of either intervention over the other). Similarly, both ROMs appeared to stimulate similar strength-endurance improvements in both partial and full ROM lat pulldown as assessed by 10RM testing. Herein, we discuss the practical implications of these findings, when considered alongside and compared with findings of the current literature examining the effects of LPs on muscular adaptations.

For muscle hypertrophy, analyses showed moderate evidence in support of the null hypothesis across sites, with the exception of the elbow extensor TB55% site, which showed anecdotal evidence in support of the null hypothesis. In all cases, central estimates of group differences were close to zero. There are a number of important considerations when interpreting this study's muscle hypertrophy results. First, this study represents the most ecologically valid comparison of LPs and full ROM RT to date. Since it compared the two approaches in a multi-exercise, multi-modality RT routine in a resistance-trained population, this study's results have the greatest likelihood of generalizing to RT practices for muscle hypertrophy in this population. The results obtained here tentatively suggest that LPs and full ROM provide similar and effective

stimuli for muscle hypertrophy of the elbow flexors and extensors. This should be encouraging for practitioners, as these novel findings allow for considerable flexibility in exercise technique prescriptions. For example, if an experienced trainee is unable to perform a full ROM, or prefers to use pROM, the present evidence suggests pROM RT is similarly effective, provided it is carried out in the lengthened aspect.

Previous studies, however, comparing LPs and full ROM RT have presented different findings. Briefly, of four studies comparing LPs to full ROM RT, three reported greater muscle hypertrophy from LPs, whereas one found similar muscle hypertrophy (Goto et al., 2019; Kassiano et al., 2022, Costa, et al., 2022; Pedrosa et al., 2021; Werkhausen et al., 2021). Moreover, a recent meta-analysis reported a small, potential benefit of LPs over full ROM RT for stimulating muscle hypertrophy (Wolf et al., 2023). While the other studies comparing LPs versus full ROM RT were conducted in less well-trained populations than the present study, no compelling mechanistic or longitudinal training evidence would suggest divergent adaptations in these populations (Wolf et al., 2024)[2]. While acknowledging that more evidence in trained populations is warranted, the totality of available evidence suggests that LPs are at least equally effective compared to a full ROM for stimulating muscle hypertrophy.

Another important consideration when interpreting the results of this study relates to the muscle lengths being utilized. Previous studies have primarily compared relatively short-muscle length training to relatively long-muscle length training (see Figure 2). For example, in a study conducted by Pedrosa et al. (2021), the LP group trained through 100-65 degrees of knee flexion. While greater joint angles are not linearly associated with greater motor tendon unit length

[2] This systematic review is currently under peer-review.

353 (Raiteri et al., 2021), these joint angles suggest that the quadriceps femoris muscle was not being
354 trained through its longest possible muscle lengths. Indeed, most trainees are capable of
355 approximately 140-150 degrees of knee flexion (Kubo et al., 2019; Straub & Powers, 2024). With
356 the exception of a study in the gastrocnemius by Kassiano et al. (2022), wherein the muscle length
357 achieved was likely near maximal, other studies to date compared modestly shorter-muscle length
358 training to modestly longer-muscle length training.

359 **Figure 2 here**

360

361 In contrast, the present study represents a comparison of full ROM RT and lengthened
362 partial RT, both with an emphasis on the lengthened position. In both conditions, research
363 assistants ensured participants were reaching the longest-muscle lengths achievable during the
364 exercise. Additionally, both conditions employed a brief pause in the fully stretched position to
365 accentuate the effect. As a result, the fROM condition in the present study also emphasised the
366 stretched position. In the pROM condition, the average muscle length utilized was even greater;
367 however, both conditions involved training at long-muscle lengths (see Figure 3).

368 **Figure 3 here**

369 Since similar muscle hypertrophy was observed between conditions, we posit that there may be a
370 point of diminishing - or ceasing - returns to longer-muscle length training, such that training at
371 maximal or near-maximal muscle lengths may not be more beneficial than simply training at
372 sufficiently long-muscle lengths. Indeed, the fROM condition observed similar muscle
373 hypertrophy as the LPs condition in the present study, in contrast to previous studies that found
374 a hypertrophic benefit to training at longer - rather than shorter - muscle lengths. Additionally, it

appears that the inclusion of shorter-muscle length training by the full ROM condition did not enhance muscle hypertrophy, suggesting that the inclusion of the lengthened range of motion should be the primary consideration when it comes to range of motion during RT for muscle hypertrophy. This hypothesis is consistent with much of the previous research on the topic, showing a hypertrophic superiority of training at longer versus shorter muscle lengths (Akagi et al., 2020; Alegre et al., 2014; Bloomquist et al., 2013; Burke et al., 2024; Goto et al., 2019, 2019; Hinks et al., 2021; Kassiano, Costa, et al., 2022; Kinoshita et al., 2023; Kubo et al., 2006, 2019; Larsen, Kristiansen, et al., 2024; Larsen, Swinton, et al., 2024; Maeo et al., 2020, 2022; Mcmahon et al., 2014; McMahon et al., 2014; Noorkõiv et al., 2014; Pedrosa et al., 2021, 2023; Sato et al., 2021; Valamatos et al., 2018).

Importantly, the similar magnitude of muscle hypertrophy observed may be a result of the multi-exercise, multi-modality approach employed in the present study. Previous comparisons of LPs and full ROM RT have exclusively used single-exercise interventions (Goto et al., 2019; Kassiano, Costa, et al., 2022; Pedrosa et al., 2021; Werkhausen et al., 2021), which appear to limit the homogeneity of muscle hypertrophy observed across a muscle's different regions (Kassiano, Nunes, et al., 2022). This may explain the divergence between previous studies and the current study's results; in the current study, four different exercises targeting each of the assessed muscle groups (8 exercises in total) were employed within each training week.

In terms of muscle strength-endurance, analysis revealed moderate evidence of no difference between LPs (LPs) and full range of motion (ROM) for increasing both full and partial ROM lat pulldown 10RMs. This contrasts with several studies that have demonstrated ROM-specific strength acquisition, where training within a specific ROM led to greater performance

397 improvements within that same ROM (Bloomquist et al., 2013; Kubo et al., 2019; Martinez-Cava et
398 al., 2022; Massey et al., 2005). Notably, these prior studies defined partial-ROM as shorter muscle
399 lengths (e.g., top-down partials in squat or bench press), while our study's partial-ROM was
400 performed at longer muscle lengths. It is therefore possible, though speculative, that partial-ROM
401 training could provide better transference to full-ROM strength if the partials are completed at
402 longer muscle lengths. Additionally, the results in this study may have been influenced by the
403 cross-education effect, where training one limb with a specific ROM promotes adaptations in the
404 contralateral limb (Bell et al., 2023). Nevertheless, several previous studies have observed strength-
405 endurance improvements across full and partial ROM in resistance-trained populations, regardless
406 of the ROM used during training. While specificity appears to play a small but significant role in
407 maximal performance improvements, our findings suggest that the effect of ROM-specificity may
408 be less influential than anticipated (Crocker, 2000; Hartmann et al., 2012; Rhea et al., 2016). This
409 may also relate to exercise choice, as the lat pulldown is a relatively simple movement where
410 motor learning specificity may be less critical (Rossi et al., 2018).

411 The present study is not without limitations, which should be considered when drawing
412 evidence-based conclusions from its findings. First, it is possible that the study recruited too small
413 a sample to detect appreciable changes, given sample size determination was based on assumed
414 differences obtained from a meta-analysis of previous studies with a different training status to
415 the participants in the present study. Second, the duration of the study was only eight weeks. This
416 duration may not have been a sufficiently long timeframe to produce meaningful hypertrophic
417 differences between conditions that could be detected with the sample size. Duration of the study
418 may be particularly relevant in a well-trained population. It is also possible that some of the

exercises used were novel to many of the participants (i.e. single-arm bayesian curl, dumbbell overhead extension). The novelty of the exercises may have reduced the hypertrophy observed (Gabriel et al., 2006). Whilst the results presented here show that the duration was sufficient to induce small to medium improvements, differential adaptations may require a longer interventional period. Third, the muscle strength-endurance findings should be cautiously interpreted, as the cross-education effect between limbs may have confounded results given the within-participant, contralateral limb comparison design. Similarly, since participants always began testing with fROM strength-endurance testing followed by pROM strength-endurance testing, the true change in pROM strength may have been confounded by the fatigue caused by the preceding fROM 10RM test. This may explain the divergence in results between the present study's results and the literature on the specificity of ROM at-large (Wolf et al., 2023). Fourth, the present study only measured muscle hypertrophy of the elbow flexors and extensors. Although previous studies have examined other muscles including the ankle plantar flexors, knee extensors, and hip extensors, it is unclear whether these results would generalise to all muscle groups. Another limitation is that, due to the ecological validity of the study's training protocol, the ROM was not strictly standardized or precisely measured across subjects and conditions. While this enhances the study's external validity, it reduces its internal validity. Future research in trained individuals should focus on highly standardized ROM protocols to address this issue. Finally, strength-endurance was assessed only in the lat pulldown; we thus cannot necessarily extrapolate these findings to other exercises, particularly those with different strength curves.

CONCLUSION

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The present study showed that LPs and full ROM RT stimulated similar increases in MT of the elbow flexors and extensors over eight weeks of RT in resistance-trained participants. As the first study in resistance-trained participants, as well as the first to employ a multi-modality, multi-exercise RT intervention, these findings have important implications for the experienced trainee seeking to maximize muscle hypertrophy. Based on the results of this study, alongside others, there appears to be a benefit of emphasizing the lengthened position, whether by use of a full ROM with an emphasis on the lengthened position or LPs. The addition of shorter-muscle length ROM in the present study did not appear to enhance muscle hypertrophy compared to exclusively using LPs, calling into question its role in eliciting increases in muscle size. For muscle strength-endurance, both a full ROM and LP RT stimulated similar improvements in both full ROM and partial ROM muscle strength-endurance; however, other studies have suggested that performance adaptations are muscle-specific. Given the totality of current evidence, it appears prudent to train in the specific range of motion of the desired performance adaptation.

458 Contributions
459 MW, PAK, AP, AEM, FA, TH, PAS, and BJS were involved in conceptualizing and designing the
460 study. MW, PAK, AP, AEM, TH, FA, MS, and BL participated in data collection. PAS performed the
461 data analysis. All authors were involved in the interpretation of the results, and drafting the
462 manuscript. All authors approved the final manuscript.
463
464 Conflict of Interest
465 BJS previously served on the scientific advisory board for Tonal Corporation, a manufacturer of
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467
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478
479 Data and Supplementary Material Accessibility
480 Data and anonymized videos of participants performing resistance training sessions in both
481 conditions are available at https://osf.io/a6cpz/.
482
483

REFERENCES

Akagi, R., Hinks, A., & Power, G. A. (2020). Differential changes in muscle architecture and neuromuscular fatigability induced by isometric resistance training at short and long muscle-tendon unit lengths. *Journal of Applied Physiology*, *129*(1), 173–184. https://doi.org/10.1152/japplphysiol.00280.2020

Alegre, L. M., Ferri-Morales, A., Rodriguez-Casares, R., & Aguado, X. (2014). Effects of isometric training on the knee extensor moment–angle relationship and vastus lateralis muscle architecture. *European Journal of Applied Physiology*, *114*(11), 2437–2446. https://doi.org/10.1007/s00421-014-2967-x

Bell, Z. W., Wong, V., Spitz, R. W., Yamada, Y., Song, J. S., Kataoka, R., Chatakondi, R. N., Abe, T., & Loenneke, J. P. (2023). Unilateral high-load resistance training influences strength changes in the contralateral arm undergoing low-load training. *Journal of Science and Medicine in Sport*, *26*(8), 440–445. https://doi.org/10.1016/j.jsams.2023.06.011

Bloomquist, K., Langberg, H., Karlsen, S., Madsgaard, S., Boesen, M., & Raastad, T. (2013). Effect of range of motion in heavy load squatting on muscle and tendon adaptations. *European Journal of Applied Physiology*, *113*(8), 2133–2142. https://doi.org/10.1007/s00421-013-2642-7

Brughelli, M., & Cronin, J. (2007). Altering the Length-Tension Relationship with Eccentric Exercise: Implications for Performance and Injury. *Sports Medicine*, *37*(9), 807–826. https://doi.org/10.2165/00007256-200737090-00004

Burke, R., Piñero, A., Coleman, M., Mohan, A., Sapuppo, M., Augustin, F., Aragon, A. A., Candow, D. G., Forbes, S. C., Swinton, P., & Schoenfeld, B. J. (2023). The Effects of

Creatine Supplementation Combined with Resistance Training on Regional Measures of Muscle Hypertrophy: A Systematic Review with Meta-Analysis. *Nutrients*, *15*(9), 2116. https://doi.org/10.3390/nu15092116

Burke, R., Piñero, A., Mohan, A. E., Hermann, T., Sapuppo, M., Augustin, F., Coleman, M., Korakakis, P. A., Wolf, M., Swinton, P. A., & Schoenfeld, B. J. (2024). Exercise Selection Differentially Influences Lower Body Regional Muscle Development. *Journal of Science in Sport and Exercise*. https://doi.org/10.1007/s42978-024-00299-4

Bürkner, P.-C. (2018). Advanced Bayesian Multilevel Modeling with the R Package brms. *The R Journal*, *10*(1), 395–411.

Crocker, J. E. (2000). *A comparison of full range and limited range of motion strength training*.

Depaoli, S., & van de Schoot, R. (2017). Improving transparency and replication in Bayesian statistics: The WAMBS-Checklist. *Psychological Methods*, *22*(2), 240–261. https://doi.org/10.1037/met0000065

Gabriel, D. A., Kamen, G., & Frost, G. (2006). Neural adaptations to resistive exercise: Mechanisms and recommendations for training practices. *Sports Medicine (Auckland, N.Z.)*, *36*(2), 133–149. https://doi.org/10.2165/00007256-200636020-00004

Gelfand, A. E., & Wang, F. (2002). A simulation-based approach to Bayesian sample size determination for performance under a given model and for separating models. *Statistical Science*, *17*(2), 193–208. https://doi.org/10.1214/ss/1030550861

Goto, M., Maeda, C., Hirayama, T., Terada, S., Nirengi, S., Kurosawa, Y., Nagano, A., & Hamaoka, T. (2019). Partial Range of Motion Exercise Is Effective for Facilitating Muscle

529 Hypertrophy and Function Through Sustained Intramuscular Hypoxia in Young Trained
530 Men. *Journal of Strength and Conditioning Research*, *33*(5), 1286–1294.
531 https://doi.org/10.1519/JSC.0000000000002051
532 Hartmann, H., Wirth, K., Klusemann, M., Dalic, J., Matuschek, C., & Schmidtbleicher, D.
533 (2012). Influence of Squatting Depth on Jumping Performance. *Journal of Strength and*
534 *Conditioning Research*, *26*(12), 3243–3261.
535 https://doi.org/10.1519/JSC.0b013e31824ede62
536 Hinks, A., Davidson, B., Akagi, R., & Power, G. A. (2021). Influence of isometric training at
537 short and long muscle-tendon unit lengths on the history dependence of force.
538 *Scandinavian Journal of Medicine & Science in Sports*, *31*(2), 325–338.
539 https://doi.org/10.1111/sms.13842
540 Kassiano, W., Costa, D., Kunevaliki, G., Soares, D., Zacarias, G., Manske, I., Takaki, Y.,
541 Ruggiero, M., Gomes de Lima Stavinski, N., Francsuel, J., Tricoli, I., Carneiro, M., & Cyrino,
542 E. (2022). Greater gastrocnemius muscle hypertrophy after partial range of motion
543 training carried out at long muscle lengths. *The Journal of Strength and Conditioning*
544 *Research*.
545 Kassiano, W., Nunes, J. P., Costa, B., Ribeiro, A. S., Schoenfeld, B. J., & Cyrino, E. S. (2022).
546 Does Varying Resistance Exercises Promote Superior Muscle Hypertrophy and Strength
547 Gains? A Systematic Review. *Journal of Strength and Conditioning Research*, *36*(6), 1753–
548 1762. https://doi.org/10.1519/JSC.0000000000004258
549 Kinoshita, M., Maeo, S., Kobayashi, Y., Eihara, Y., Ono, M., Sato, M., Sugiyama, T.,
550 Kanehisa, H., & Isaka, T. (2023). Triceps surae muscle hypertrophy is greater after

551 standing versus seated calf-raise training. *Frontiers in Physiology*, *14*, 1272106.
552 https://doi.org/10.3389/fphys.2023.1272106
553 Kubo, K., Ikebukuro, T., & Yata, H. (2019). Effects of squat training with different depths
554 on lower limb muscle volumes. *European Journal of Applied Physiology*, *119*(9), 1933–
555 1942. https://doi.org/10.1007/s00421-019-04181-y
556 Kubo, K., Ohgo, K., Takeishi, R., Yoshinaga, K., Tsunoda, N., Kanehisa, H., & Fukunaga, T.
557 (2006). Effects of isometric training at different knee angles on the muscle-tendon
558 complex in vivo. *Scandinavian Journal of Medicine and Science in Sports*, *16*(3), 159–167.
559 https://doi.org/10.1111/j.1600-0838.2005.00450.x
560 Larsen, S., Kristiansen, B. S., Swinton, P. A., Wolf, M., Fredriksen, A. B., Falch, H. N., Tillaar,
561 R. van den, & Sandberg, N. Ø. (2024). *The effects of hip flexion angle on quadriceps*
562 *femoris muscle hypertrophy in the leg extension exercise*. SportRxiv.
563 https://doi.org/10.51224/SRXIV.407
564 Larsen, S., Swinton, P. A., Sandberg, N. Ø., Kristiansen, B. S., Fredriksen, A. B., Falch, H. N.,
565 Tillaar, R. van den, & Wolf, M. (2024). *Resistance training beyond momentary failure: The*
566 *effects of lengthened supersets on muscle hypertrophy in the gastrocnemius | SportRxiv*.
567 https://sportrxiv.org/index.php/server/preprint/view/414
568 Maeo, S., Meng, H., Yuhang, W., Sakurai, H., Kusagawa, Y., Sugiyama, T., Kanehisa, H., &
569 Isaka, T. (2020). *Greater Hamstrings Muscle Hypertrophy but Similar Damage Protection*
570 *after Training at Long versus Short Muscle Lengths*. *Publish Ah*(September).
571 https://doi.org/10.1249/mss.0000000000002523

572 Maeo, S., Wu, Y., Huang, M., Sakurai, H., & Kusagawa, Y. (2022). Triceps brachii
573 hypertrophy is substantially greater after elbow extension training performed in the
574 overhead versus neutral arm position. *European Journal of Sport Science*, *0*, 1–26.
575 https://doi.org/10.1080/17461391.2022.2100279
576 Magezi, D. A. (2015). Linear mixed-effects models for within-participant psychology
577 experiments: An introductory tutorial and free, graphical user interface (LMMgui).
578 *Frontiers in Psychology*, *6*, 2. https://doi.org/10.3389/fpsyg.2015.00002
579 McMahon, G., Morse, C., Burden, A., Winwood, K., & Onambélé, G. (2014). Valid
580 resistance training protocols on muscle size,subcutaneous fat, and strength. *Journal of*
581 *the International Society of Sports Nutrition*, *28*(1), 245–255.
582 Mcmahon, G., Morse, C. I., Burden, A., Winwood, K., & Onambélé, G. L. (2014). Muscular
583 adaptations and insulin-like growth factor-1 responses to resistance training are stretch-
584 mediated. *Muscle and Nerve*, *49*(1), 108–119. https://doi.org/10.1002/mus.23884
585 Michael, D. L., & Wagenmakers, E.-J. (2014). *Bayesian cognitive modeling: A practical*
586 *course*. Cambridge: Cambridge University Press.
587 Noorkõiv, M., Nosaka, K., & Blazevich, A. J. (2014). Neuromuscular Adaptations
588 Associated with Knee Joint Angle-Specific Force Change. *Medicine & Science in Sports &*
589 *Exercise*, *46*(8), 1525–1537. https://doi.org/10.1249/MSS.0000000000000269
590 NSCA. (2016). *Essentials of strength training and conditioning—NLM Catalog—NCBI*.
591 https://www.ncbi.nlm.nih.gov/nlmcatalog?cmd=PureSearch&term=101647597%5Bnlmid
592 %5D

Pedrosa, G. F., Lima, F. V., Schoenfeld, B. J., Lacerda, L. T., Simões, M. G., Pereira, M. R., Diniz, R. C. R., & Chagas, M. H. (2021). Partial range of motion training elicits favorable improvements in muscular adaptations when carried out at long muscle lengths. *European Journal of Sport Science*, 1–11. https://doi.org/10.1080/17461391.2021.1927199

Pedrosa, G. F., Simões, M. G., Figueiredo, M. O. C., Lacerda, L. T., Schoenfeld, B. J., Lima, F. V., Chagas, M. H., & Diniz, R. C. R. (2023). Training in the Initial Range of Motion Promotes Greater Muscle Adaptations Than at Final in the Arm Curl. *Sports*, *11*(2), 39. https://doi.org/10.3390/sports11020039

Raiteri, B. J., Beller, R., & Hahn, D. (2021). Biceps Femoris Long Head Muscle Fascicles Actively Lengthen During the Nordic Hamstring Exercise. *Frontiers in Sports and Active Living*, *3*, 669813. https://doi.org/10.3389/fspor.2021.669813

Rhea, M. R., Kenn, J. G., Peterson, M. D., Massey, D., Simão, R., Marin, P. J., Favero, M., Cardozo, D., & Krein, D. (2016). Joint-Angle Specific Strength Adaptations Influence Improvements in Power in Highly Trained Athletes. *Human Movement*, *17*(1), 43–49. https://doi.org/10.1515/humo-2016-0006

Roberts, M. D., McCarthy, J. J., Hornberger, T. A., Phillips, S. M., Mackey, A. L., Nader, G. A., Boppart, M. D., Kavazis, A. N., Reidy, P. T., Ogasawara, R., Libardi, C. A., Ugrinowitsch, C., Booth, F. W., & Esser, K. A. (2023). Mechanisms of mechanical overload-induced skeletal muscle hypertrophy: Current understanding and future directions. *Physiological Reviews*, *103*(4), 2679–2757. https://doi.org/10.1152/physrev.00039.2022

Rossi, F. E., Schoenfeld, B. J., Ocetnik, S., Young, J., Vigotsky, A., Contreras, B., Krieger, J. W., Miller, M. G., & Cholewa, J. (2018). Strength, body composition, and functional

615 outcomes in the squat versus leg press exercises. *Journal of Sports Medicine and Physical*
616 *Fitness*, *58*(3), 263–270. https://doi.org/10.23736/S0022-4707.16.06698-6
617 Sato, S., Yoshida, R., Kiyono, R., Yahata, K., Yasaka, K., Nunes, J. P., Nosaka, K., &
618 Nakamura, M. (2021). Elbow Joint Angles in Elbow Flexor Unilateral Resistance Exercise
619 Training Determine Its Effects on Muscle Strength and Thickness of Trained and Non-
620 trained Arms. *Frontiers in Physiology*, *12*(September), 1–9.
621 https://doi.org/10.3389/fphys.2021.734509
622 Schad, D. J., Nicenboim, B., Bürkner, P.-C., Betancourt, M., & Vasishth, S. (2023). Workflow
623 techniques for the robust use of bayes factors. *Psychological Methods*, *28*(6), 1404–1426.
624 https://doi.org/10.1037/met0000472
625 Schoenfeld, B., Fisher, J., Grgic, J., Haun, C., Helms, E., Phillips, S., Steele, J., & Vigotsky, A.
626 (2021). Resistance Training Recommendations to Maximize Muscle Hypertrophy in an
627 Athletic Population: Position Stand of the IUSCA. *International Journal of Strength and*
628 *Conditioning*, *1*(1), Article 1. https://doi.org/10.47206/ijsc.v1i1.81
629 Stasinaki, A. N., Zaras, N., Methenitis, S., Tsitkanou, S., Krase, A., Kavvoura, A., & Terzis, G.
630 (2018). Triceps brachii muscle strength and architectural adaptations with resistance
631 training exercises at short or long fascicle length. *Journal of Functional Morphology and*
632 *Kinesiology*, *3*(2). https://doi.org/10.3390/jfmk3020028
633 Stokes T, Tripp TR, Murphy K, Morton RW, Oikawa SY, Lam Choi H, McGrath J, McGlory C,
634 MacDonald MJ, Phillips SM. Methodological considerations for and validation of the
635 ultrasonographic determination of human skeletal muscle hypertrophy and atrophy.

636 Physiol Rep. 2021 Jan;9(1):e14683. doi: 10.14814/phy2.14683. PMID: 33403796; PMCID:
637 PMC7786033.
638 Straub, R. K., & Powers, C. M. (2024). A Biomechanical Review of the Squat Exercise:
639 Implications for Clinical Practice. *International Journal of Sports Physical Therapy*, *19*(4),
640 490–501. https://doi.org/10.26603/001c.94600
641 Swinton, P. A., Burgess, K., Hall, A., Greig, L., Psyllas, J., Aspe, R., Maughan, P., & Murphy,
642 A. (2022). Interpreting magnitude of change in strength and conditioning: Effect size
643 selection, threshold values and Bayesian updating. *Journal of Sports Sciences*, *40*(18),
644 2047–2054. https://doi.org/10.1080/02640414.2022.2128548
645 Swinton, P., & Murphy, A. (2022). *Comparative effect size distributions in strength and*
646 *conditioning and implications for future research: A meta-analysis*. SportRxiv.
647 https://doi.org/10.51224/SRXIV.202
648 Valamatos, M. J., Tavares, F., Santos, R. M., Veloso, A. P., & Mil-Homens, P. (2018).
649 Influence of full range of motion vs. Equalized partial range of motion training on muscle
650 architecture and mechanical properties. *European Journal of Applied Physiology*, *118*(9),
651 1969–1983. https://doi.org/10.1007/s00421-018-3932-x
652 van de Schoot, R., Depaoli, S., King, R., Kramer, B., Märtens, K., Tadesse, M. G., Vannucci,
653 M., Gelman, A., Veen, D., Willemsen, J., & Yau, C. (2021). Bayesian statistics and
654 modelling. *Nature Reviews Methods Primers*, *1*(1), 1–26. https://doi.org/10.1038/s43586-
655 020-00001-2

656 Warneke, K., Brinkmann, A., Hillebrecht, M., & Schiemann, S. (2022). Influence of Long-
657 Lasting Static Stretching on Maximal Strength, Muscle Thickness and Flexibility. *Frontiers*
658 *in Physiology*, *13*(May), 1–13. https://doi.org/10.3389/fphys.2022.878955
659 Werkhausen, A., Solberg, C. E., Paulsen, G., Bojsen-Møller, J., & Seynnes, O. R. (2021).
660 Adaptations to explosive resistance training with partial range of motion are not inferior
661 to full range of motion. *Scandinavian Journal of Medicine & Science in Sports*, 0–2.
662 https://doi.org/10.1111/sms.13921
663 Wolf, M., Androulakis-Korakakis, P., Fisher, J., Schoenfeld, B., & Steele, J. (2023). Partial Vs
664 Full Range of Motion Resistance Training: A Systematic Review and Meta-Analysis.
665 *International Journal of Strength and Conditioning*, *3*(1), Article 1.
666 https://doi.org/10.47206/ijsc.v3i1.182
667 Wolf, M., Korakakis, P. A., Roberts, M. D., Plotkin, D. L., Franchi, M. V., Contreras, B.,
668 Henselmans, M., & Schoenfeld, B. J. (2024). *Does longer-muscle length resistance training*
669 *cause greater longitudinal growth in humans? A systematic review*. SportRxiv.
670 https://doi.org/10.51224/SRXIV.423
671

Table 1(on next page)

Bayesian sample size determination assessing credible interval precision and simulation-based calibration of Bayes factors.

Abbreviations: CrI = Credible interval.

1 **Table 1**: Bayesian sample size determination assessing credible interval precision and
2 simulation-based calibration of Bayes factors.

Sample size	95% Credible interval length for average treatment effect [95%CrI]	Average posterior model probability [95%CrI]	Average percentage of posterior allocated to H_1 when H_1 true	Average percentage of posterior allocated to H_0 when H_0 true
N=20	0.33 [0.27 to 0.39]	48.2 [38.5 to 58.0]	75%	76%
N=25	0.29 [0.24 to 0.34]	48.9 [40.1 to 56.0]	77%	79%
N=30	0.26 [0.22 to 0.30]	49.1 [41.8 to 55.7]	78%	80%

3 Abbreviations: CrI = Credible interval.

Table 2(on next page)

RT Protocol

Table 2: RT Protocol

Exercise	Sets	Repetition Range
Day 1		
Flat machine chest press	4	5-10
Bench dumbbell row	4	10-15
Dumbbell overhead triceps extensions	4	10-15
Dumbbell supinating curl	4	10-15
Day 2		
Incline machine chest press	4	10-15
Cable single arm pulldown	4	5-10
Cable pushdown	4	5-10
Bayesian curl	4	5-10

Table 3(on next page)

Descriptive characteristics of the participants

Table 3: Descriptive characteristics of the participants

Variable	Men (n = 19)	Women (n = 6)
Height (cm)	173.9±6.5	164.3±7.5
Body mass (kg)	80.1±12.1	63.1±7.7
Age (years)	23.1±4.3	26.2±7.1

Table 4(on next page)

Estimated group differences from Bayesian linear mixed models with informative neutral priors.

Group differences: Positive values favor full range of motion intervention. *p*-values are calculated from the posterior distribution of the mean group difference parameter and express the probability of a positive value. Bayes Factor: Values less than 1 provide support for the null hypothesis. Values greater than 1 provide support for alternative hypothesis.

Table 4: Estimated group differences from Bayesian linear mixed models with informative neutral priors.

Outcome	Estimated Group Difference [95%CrI]	Posterior probability	Bayes Factor
Muscle thickness	*Probability favoring full range of motion*		
Elbow flexor 45% humeral length (mm)	-0.23 [-1.4 to 0.94]	$p = 0.343$	0.19: "Moderate" Evidence support of H_0
Elbow flexor 55% humeral length (mm)	-0.08 [-1.1 to 0.90]	$p = 0.438$	0.16: "Moderate" Evidence support of H_0
Elbow extensor 45% humeral length (mm)	0.40 [-1.1 to 1.9]	$p = 0.701$	0.20: "Moderate" Evidence support of H_0
Elbow extensor 55% humeral length (mm)	0.82 [-0.44 to 2.1]	$p = 0.899$	0.39: "Anecdotal" Evidence support of H_0
Strength-endurance	*Probability favoring full range of motion*		
10RM full (~~lbs~~kg)	-1.2 [-3.7 to 1.3]	$p = 0.177$	0.30: "Moderate" Evidence support of H_0
10RM partial (~~lbs~~kg)	-0.79 [-3.9 to 2.3]	$p = 0.307$	0.23: "Moderate" Evidence support of H_0

Group differences: Positive values favor full range of motion intervention. *p*-values are calculated from the posterior distribution of the mean group difference parameter and express the probability of a positive value. Bayes Factor:

Values less than 1 provide support for the null hypothesis. Values greater than 1 provide support for alternative hypothesis.

Table 5(on next page)

Pre-post hypertrophy & strength-endurance measurements

Table 5: Pre-post hypertrophy & strength-endurance measurements

Hypertrophy	**pROM**		**fROM**	
Measurement (mm)	Pre-Study	Post-Study	Pre-Study	Post-Study
Elbow Flexor 55%	39.6 ± 8.6	41.4 ± 7.8	39.3 ± 7.9	41.1 ± 7.6
Elbow Flexor 45%	36.5 ± 8.9	37.9 ± 8.5	36.5 ± 8.4	37.7 ± 8.5
Elbow Extensor 55%	35.1 ± 9.5	37.0 ± 9.7	34.4 ± 9.6	37.4 ± 9.5
Elbow Extensor 45%	41.5 ± 10.5	44.1 ± 10.3	41.3 ± 10.8	44.4 ± 10.5
Strength-endurance				
Measurement (kg)	Pre-Study	Post-Study	Pre-Study	Post-Study
fROM 10RM	63.4±17.1	66.6±16.9	63.6±12.3	65.6±16.5
pROM 10RM	66.8±20.7	74.6±21.3	65.4±19.2	72.8±21.6

Figure 1

Comparative distribution plot of the estimated standardized mean difference of interventions across outcomes.

Density plots illustrate estimates and uncertainty of standardized mean difference changes across the two interventions. Thresholds describing the magnitude of improvements are obtained from strength and conditioning specific data. N.B. for the elbow flexor 55% measurement, the standardized mean differences for fROM and pROM have nearly-perfect overlap, and are visually indistinguishable.

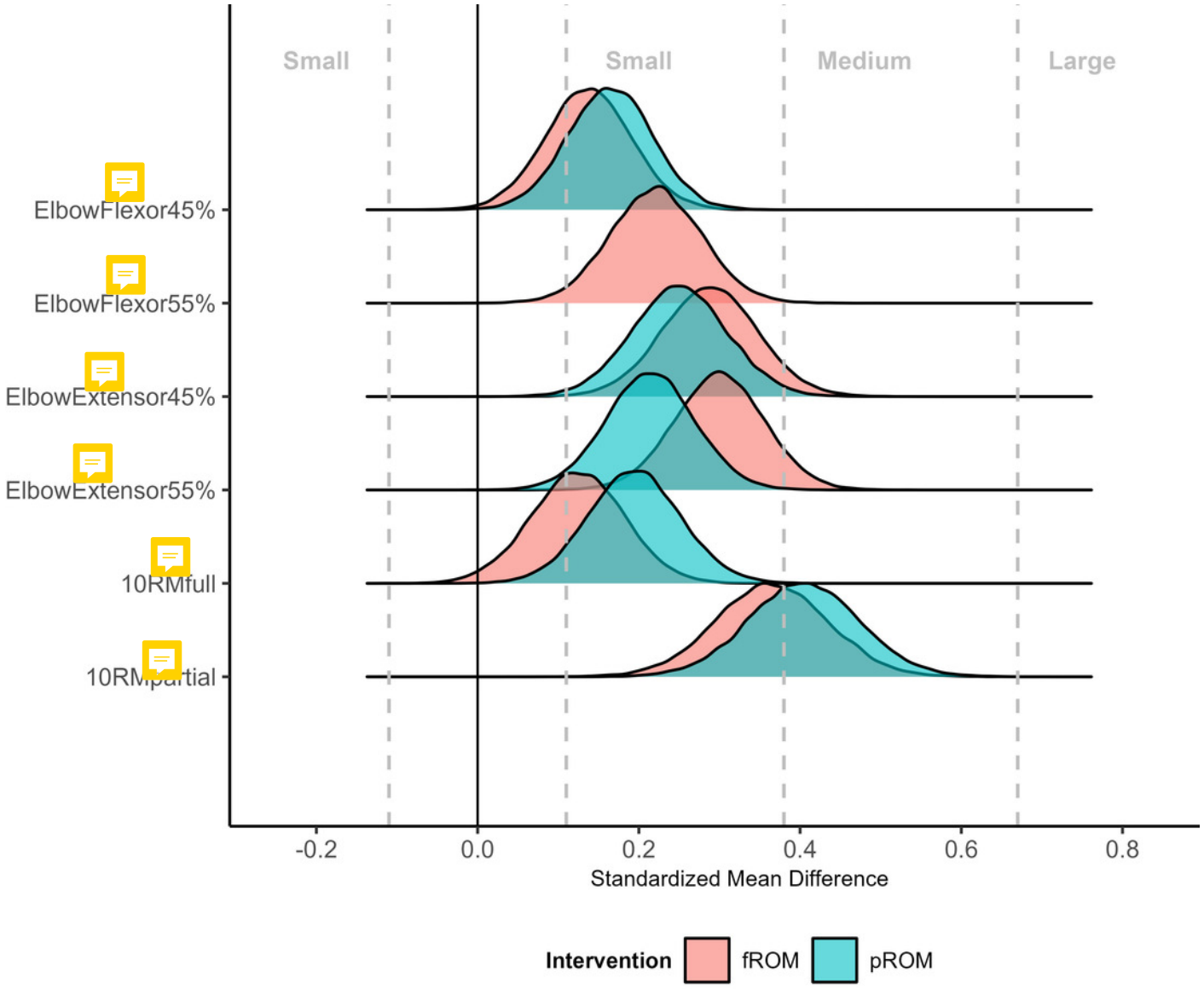
Small
Small
Medium
Large
ElbowFlexor45%
ElbowFlexor55%
ElbowExtensor45%
ElbowExtensor55%
10RMfull
10RMpartial
-0.2
0.0
0.2
0.4
0.6
0.8
Standardized Mean Difference
Intervention
fROM
pROM

Figure 2

Example of the difference in ROM between the fROM and pROM conditions

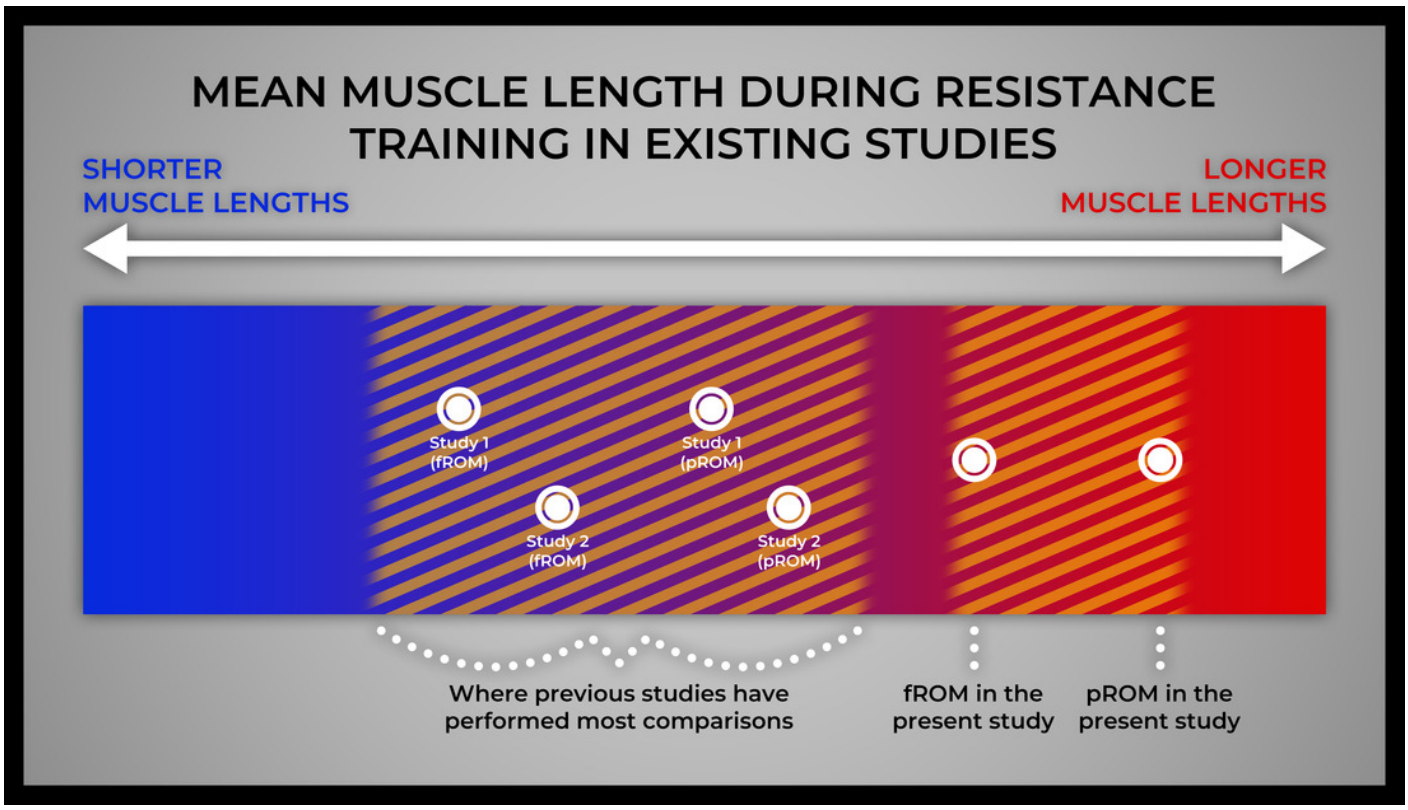

Figure 3

Mean muscle length during resistance training in existing studies