motricidade

ORIGINAL ARTICLE

https://doi.org/10.6063/motricidade.41706

Effects of resistance profile manipulation during elbow flexion on regional muscle thickness of the biceps brachii and brachialis in males

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ABSTRACT

The level of muscle tension generated during a movement can be influenced by the applied resistance profile (RP). Muscle tension produces mechanical stress on muscle fibers, which, depending on its magnitude and duration, is considered one of the primary stimuli for muscle hypertrophy. In resistance training, modifying the resistance profile allows for targeted manipulation of mechanical demand across different joint angles, potentially influencing regional hypertrophy. Despite this theoretical relevance, the effects of resistance profile manipulation on regional muscle thickness remain poorly understood. Therefore, the present study aimed to investigate whether increased muscle tension at specific ranges of motion leads to greater regional hypertrophy. Specifically, the objective was to analyze the effects of two distinct resistance profiles, Ascending (ASCRP) and Descending (DESRP), during elbow flexion exercises on the muscle thickness (MT) of the biceps brachii (BB) and brachialis (B) muscles. Eight untrained male participants (age: 19.5 ± 1.12 years; height: 1.72 ± .02 m; body mass: 66.26 ± 6.48 kg; body mass index: 22.43 ± 2.11 kg/m²) underwent a six-week training intervention, with two sessions per week. Participants performed unilateral elbow flexion exercises using a Scott bench, with the resistance profile applied randomly to each arm. In one arm, the ascending profile (ASCRP) was used, characterized by lower torque in the elongated phase and higher torque in the shortened phase. In the contralateral arm, the descending profile (DESRP) was applied, involving higher torque in the elongated phase and lower torque in the shortened phase. Muscle thickness was assessed by B-mode ultrasonography at three points (50, 60, and 70% of the distance from the acromion to the olecranon), both pre-intervention (PRE) and 72 to 96 hours post-intervention (POST). No significant differences were observed between PRE and POST for ASCRP in any measured region ($p > .05$). However, significant increases in MT were found in DESRP at 50% ($p = .017$, $d = -1.097$) and 60% ($p = .028$, $d = -.980$), with no changes at 70% ($p > .05$). No significant inter-profile differences were observed ($p > .05$). In conclusion, while overall differences between resistance profiles were not statistically significant, DESRP elicited regional hypertrophy in the more proximal areas. These findings suggest that resistance profile manipulation may influence the regional adaptation of elbow flexors, although further research is required to confirm these trends in larger and more diverse populations.

KEYWORDS: resistance training; muscle hypertrophy; resistance profile; biceps brachii; ultrasound imaging.

INTRODUCTION

Strength training (ST) is widely recommended for both athletic and clinical populations due to its well-established benefits for physical performance and overall health (American College of Sports Medicine, 2009). One of the primary objectives of ST is to induce muscle hypertrophy, defined as an increase in muscle cross-sectional area resulting from the growth of sarcomeres and myofibrils, predominantly in parallel (Schoenfeld, 2010).

Over the years, several guidelines have been proposed and continuously updated to optimize training variables for

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Conflict of interests: nothing to declare. Funding: nothing to declare.
Received: 19th May 2025. Acepted: 16th October 2025

muscle hypertrophy, including intensity, volume, proximity to failure, rest intervals, and exercise selection (Grgic et al., 2017, 2022; Schoenfeld et al., 2019, 2021). Among these, exercise selection, particularly from a biomechanical perspective, has gained increasing attention due to its potential influence on regional hypertrophy through manipulation of the associated resistance profile (RP) (Zabaleta-Korta et al., 2021, 2023).

During elbow flexion, the greatest external torque typically occurs between 80° and 90°, requiring substantial activation of the anterior arm muscles, particularly the biceps brachii and brachialis (Murray et al., 1995). However, by manipulating exercise equipment or execution technique, it is possible to alter the RP, thereby shifting the torque curve and potentially eliciting distinct regional and overall muscular adaptations.

Recent research suggests that muscle hypertrophy may be enhanced when higher tension is applied in more lengthened muscle positions during dynamic contractions, compared with shortened positions (Kassiano et al., 2025; Zabaleta-Korta et al., 2023).

Zabaleta-Korta et al. (2023) investigated the effects of RP manipulation by comparing incline bench elbow flexion (ascending resistance profile, ASCRP), where peak tension occurs in the shortened position, with preacher curl (descending resistance profile, DESRP), where peak tension occurs in the lengthened position. Muscle thickness of the elbow flexors was assessed pre- and post-intervention at the proximal, middle, and distal regions (50, 60, and 70% of the distance from the acromion to the olecranon). The nine-week intervention involved recreationally trained women performing four sets of twelve repetitions per session, three times per week, to concentric failure. The authors reported that the DESRP condition significantly increased muscle thickness in the distal region of the biceps brachii, although no significant differences were observed in overall muscle thickness.

In turn, Kassiano et al. (2025) compared preacher curl (DESRP) and incline bench elbow flexion (ASCRP) exercises over an eight-week training period in young, untrained women. Participants completed three sets of eight to twelve maximal repetitions per exercise, twice per week. The results showed that incline bench elbow flexion (ASCRP) induced greater hypertrophy in the proximal region, whereas preacher curl (DESRP) produced larger increases in the distal region.

Conversely, Nunes et al. (2020) compared the preacher curl performed with two different implements, a cable-pulley system and a barbell, to modify the RP, generating an ASCRP with the cable and a DESRP with the barbell. The ten-week intervention involved untrained men and women performing three sets of eight to twelve repetitions, three times per week. Muscle thickness of the elbow flexors was assessed only at the middle region. The authors reported no significant differences in muscle thickness between the two exercise conditions.

Although these studies provide valuable insights, their findings remain inconsistent. Such discrepancies likely stem from methodological heterogeneity, particularly regarding participants' training status (trained vs. untrained), sex, intervention duration (8–10 weeks), exercise selection, and the anatomical sites used to assess muscle thickness (proximal, middle, distal, or single point). Furthermore, few studies have standardized the measurement regions or examined both the biceps brachii and brachialis concurrently, which may lead to incomplete interpretations of localized adaptations. The literature, therefore, lacks a systematic understanding of how different RPs, emphasizing tension in either lengthened or shortened muscle positions, affect regional hypertrophy patterns.

Collectively, existing evidence suggests that distinct RPs may influence the site-specific hypertrophic response of the elbow flexors. However, the inconsistency and limited regional analysis across studies highlight the need for a more comprehensive examination of this relationship.

Therefore, the present study aimed to analyze the effects of different resistance profiles on regional hypertrophy of the biceps brachii and brachialis muscles by measuring muscle thickness across distinct regions. It was hypothesized that greater torque in lengthened muscle positions would result in more pronounced hypertrophy, particularly in the distal regions (60% and 70% of arm length).

METHODS

Participants

The required sample size was calculated using G*Power 3.1 software. Based on an expected effect size of .42, with a statistical power of 95% and a significance level of 5%, a minimum of eleven participants was determined. However, due to circumstances beyond the researchers' control and unrelated to the study procedures, three participants withdrew, resulting in an adjusted final sample of eight participants. This reduction increased the actual effect size to approximately .50.

The final sample comprised eight male participants (age: 19.5 ± 1.20 years; height: 1.72 ± .02 m; body mass: 66.26 ± 6.93 kg; body mass index: 22.43 ± 2.11 kg/m^2), all of whom volunteered to participate in the study and met the following inclusion criteria: i) aged between 18 and 30 years; ii) no resistance training experience for at least six months prior to the study; iii) no positive responses to the Portuguese-adapted version of the PAR-Q; iv) no osteoarticular injuries or conditions compromising elbow flexion execution; and v) no use of medication or dietary supplements that could influence body composition.

All participants were fully informed about the nature and procedures of the study, including any potential risks or discomforts. They were given the opportunity to ask questions and clarify any doubts before enrollment. Following completion of a health screening (anamnesis) and confirmation of eligibility, participants were invited to participate in the study.

After these steps, each participant provided written informed consent. The consent form was prepared in accordance with the principles outlined in the Declaration of Helsinki for research involving human participants. The study protocol was reviewed and approved by the institutional ethics committee under approval number Doc71-CE-UTAD-2023.

Procedures

The objective of this study was to compare regional muscle thickness at different points along the biceps brachii and brachialis following execution of two unilateral elbow flexion exercises: one with an ascending resistance profile (ASCRP) and the other with a descending resistance profile (DESRP).

After providing written informed consent, all participants underwent a one-week familiarization period comprising two sessions to become accustomed to the study exercises. This period was also used to estimate the appropriate load for each participant during the first experimental session.

Following the familiarization phase, anthropometric measurements were taken. One day prior to the start of the intervention protocol, baseline muscle thickness was assessed using B-mode ultrasonography at 50, 60, and 70% of the distance between the acromion and the olecranon, along the anterior aspect of the dominant and non-dominant arms.

The elbow flexion exercises were performed unilaterally on a Scott bench using a pulley system. Each resistance profile (ASCRP or DESRP) was randomly assigned to one upper limb of each participant using an online randomization tool (https://randomizer.org/).

Participants then completed a six-week intervention protocol, training twice per week with a minimum of 48 hours between sessions. At the end of the intervention period, and between 72 and 96 hours following the final training session, post-intervention muscle thickness was measured using the same ultrasonography protocol applied in the pre-intervention assessment.

Intervention protocol

The intervention protocol lasted six weeks, with a training frequency of two sessions per week. Each session began with a single warm-up set for both exercises (one per upper limb), using an external load approximately 40% of that recorded in the previous session. For the first session, this load was based on the individual estimations established during the familiarization period.

Subsequently, participants performed four sets of each exercise to the point of momentary concentric failure. The external load was adjusted to allow a minimum of 8 and a maximum of 12 repetitions per set. The repetition cadence was standardized at 1 second for the concentric phase and 2 seconds for the eccentric phase, controlled using a metronome (Korg MA-2, Tokyo, Japan). A 90-second rest interval was provided between sets (Grgic et al., 2017).

Load progression was regulated based on performance in the previous session. If a participant exceeded 12 repetitions in a given set, the external load was increased by 5% in the subsequent session. Conversely, if the participant failed to complete at least 8 repetitions, the load was reduced by 5%. The two exercises were performed sequentially in each session, with the starting exercise alternating between sessions.

All training sessions were supervised by an experienced examiner who provided standardized verbal encouragement to ensure maximal effort and adherence to the protocol. The structure of this intervention was based on the protocol developed by Zabaleta-Korta et al. (2023). To be included in the statistical analysis, participants were required to attend at least 80% of the training sessions and were not permitted to miss two consecutive sessions.

Description of ASCRP and DESRP Exercises

Two unilateral elbow flexion exercises were performed using a pulley system and a Scott bench, differing only in the applied resistance profile: descending (DESRP) and ascending (ASCRP). Both exercises were executed using a Scott bench (SEC 1SC208, PANNATA, Apiro (MC), Italy) and a pulley machine (Aura Functional Trainer, G3-MSFT300/400, MATRIX, USA).

In the DESRP exercise, participants were seated comfortably with the elbow joint supported on the bench, which was individually adjusted for height and positioning to ensure proper alignment. Foam pads were used when necessary to enhance comfort. The upper arm was positioned parallel to the floor. Participants grasped a handle and performed elbow flexion and extension with the randomized arm, following a cadence of 2 seconds for the eccentric phase and 1 second for the concentric phase, controlled by a metronome (Korg MA-2, Tokyo, Japan). The bench was placed as close as possible to the pulley, which was set at its lowest height. This configuration ensured that the highest torque occurred in the lengthened phase of the movement (see Figure 1).

In the ASCRP exercise, participants were positioned identically and performed the same movement with the same cadence as in DESRP. However, in this case, the bench was positioned approximately 1.5 meters away from the pulley. The pulley was adjusted so that the cable aligned with the direction of the arm during the lengthened phase, reducing torque at this position and progressively increasing resistance as the muscle shortened (see Figure 2).

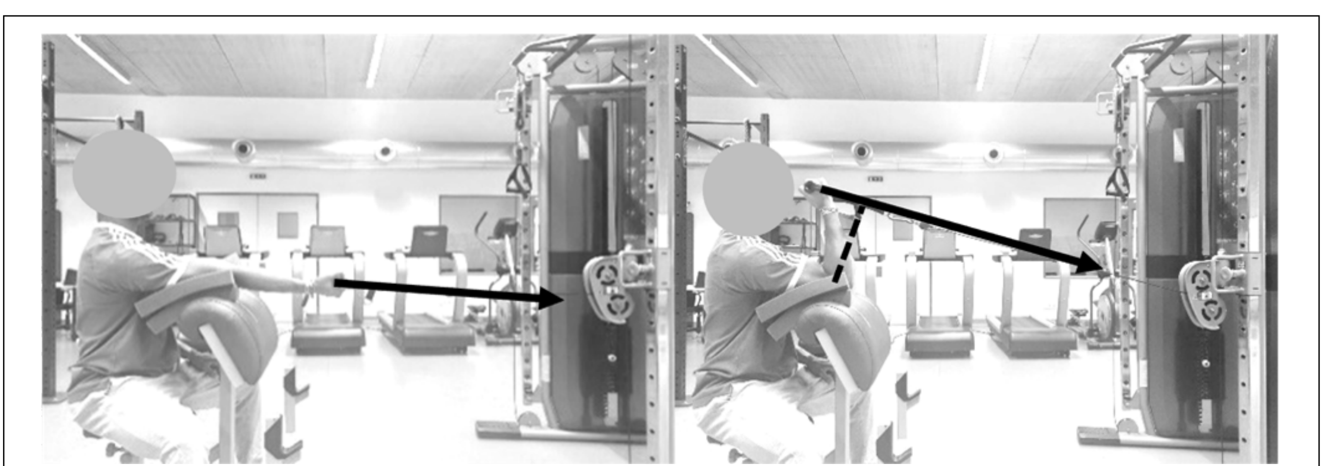
Ultrasonography

Ultrasound images were obtained at baseline (PRE) and post-intervention (POST) using a portable ultrasound device (A6, B&W, Mainland China) equipped with a linear transducer (L745 Sonoscope, Mainland China), operating at a frequency of 7.5 MHz and with an image acquisition width of 50 mm. All ultrasound assessments were conducted under standardized conditions to minimize physiological variability. Measurements were performed at the same time of day for each participant, 72 to 96 hours after the last training session, to avoid the influence of acute exercise-induced muscle swelling. Participants were instructed to maintain their usual dietary and hydration habits throughout the experimental period and to refrain from vigorous physical activity or excessive fluid intake during the 12 hours preceding each evaluation. These procedures were implemented to ensure consistent measurement conditions and to enhance the reliability of muscle thickness assessments.

For each assessment, participants were positioned supine on an examination table, with the upper limb in a relaxed and supinated position to minimize muscle activity and movement. Participants were instructed to maintain this

®Force line; --- Resistance moment Arm.

Figure 1. Elbow Flexion Exercise on Scott Bench with Descending Resistance Profile (DESRP).



®Force line; --- Resistance moment Arm.

Figure 2. Elbow Flexion Exercise on Scott Bench with Ascending Resistance Profile (ASCRP).

position for 10 minutes to allow for fluid redistribution and physiological stabilization prior to image acquisition.

The linear probe was placed perpendicular to the belly of the biceps brachii muscle without applying pressure that could deform the skin. Measurements were taken at 50, 60, and 70% of the distance from the acromion to the olecranon. A water-based coupling gel was applied to the probe without applying pressure to the skin to minimize measurement error.

Image settings were optimized and maintained consistently throughout all assessments. Muscle thickness was defined as the linear distance between the superficial fascia adjacent to the subcutaneous fat layer and the deep interface overlying the bone. Each measurement was taken twice, and the average value was used for analysis. If the difference between the two measurements exceeded .5 mm, a third measurement was taken, and the mean of all three values was used.

All images were acquired by a single trained examiner with prior experience in musculoskeletal ultrasound. A second blinded researcher was responsible for freezing the image and performing muscle thickness measurements of the biceps brachii and brachialis after the primary examiner approved the image quality. Both examiners were blinded to the intervention condition.

Statistical analysis

An exploratory data analysis was initially performed to detect potential data entry errors. Subsequently, descriptive statistics were calculated for all variables, including means, standard deviations, and 95% confidence intervals (95%CI). The assumption of normality was assessed using the Shapiro-Wilk test, homogeneity of variances was verified using Levene's test, and sphericity was tested using Mauchly's test.

Inferential analysis was conducted using a repeated-measures ANOVA with a 2 (intervention: ASCRP vs. DESRP) × 2 (time: PRE vs. POST) × 3 (region: 50, 60, and 70%) design. Effect size estimates were calculated using partial eta squared (ηp^2) for ANOVA results, and Cohen's *d* for paired and independent sample comparisons.

Interpretation thresholds for effect sizes were as follows: for partial eta squared (ηp^2), small, medium, and large effects were defined as values greater than .0099, .0588, and .1379, respectively; for Cohen's *d*, small, medium, and large effects corresponded to values greater than .2, .5, and 08, respectively (Cohen, 2013). The level of statistical significance was set at 5% ($p < .05$).

RESULTS

The ANOVA revealed a significant main effect of time ($F_{(1,14)} = 6.633$; $p = .022$; $\eta p^2 = .321$).

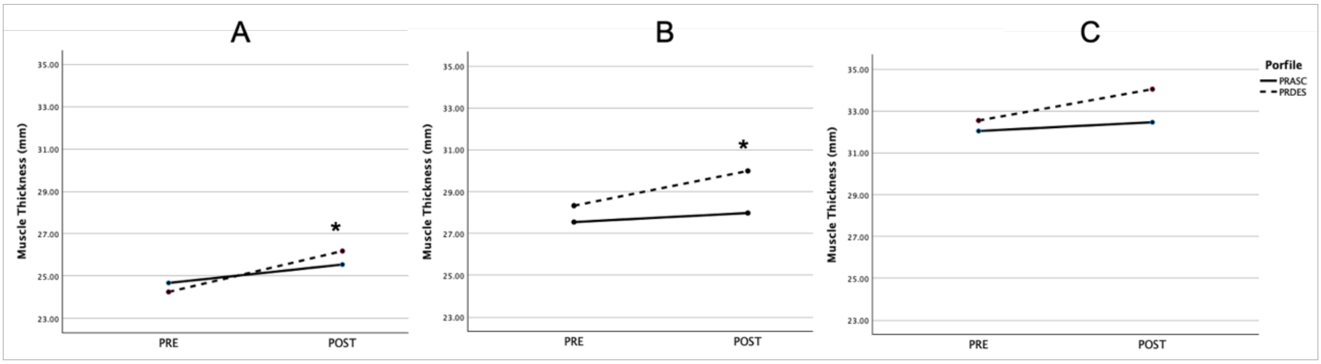
In the DESRP condition, significant differences were observed between PRE and POST in the 50 and 60% regions. Specifically, muscle thickness increased by 7.96 at 50% (95%CI .46–3.41 mm; $p = .017$; $d = 1.097$) and by 5.90 at 60% (95%CI = .24–3.08 mm; $p = .028$; $d = .980$) Table 1 and Figure 3.

No significant differences were observed between the two intervention conditions (ASCRP vs. DESRP) and the three regions (50, 60, and 70%).

Table 1. Mean ± Standard Deviation (SD) of Muscle Thickness in Exercises Performed with Ascending (ASCRP) and Descending (DESRP) Resistance Profiles, Across Different Measured Regions, at Pre- (PRE) and Post-Intervention (POST) Time Points.

Profile	Region	Time	Mean ± SD	95%CI	*p*-value	d Choen
ASCRP	50%	PRE	24.68 ± 2.07	22.35–28.05	.329	.371
		POST	25.54 ± 3.12	20.20–28.80		
	60%	PRE	27.54 ± 1.85	25.50–31.20	.569	.211
		POST	27.98 ± 2.88	23.50–31.40		
	70%	PRE	32.04 ± 1.72	30.25–35.55	.618	.185
		POST	32.46 ± 2.31	29.30–36.60		
DESRP	50%	PRE	24.25 ± 2.57	21.90–28.90	.017*	1.097
		POST	26,18 ± 2,58	22.90–31.00		
	60%	PRE	28.32 ± 1.91	26.15–30.80	.028*	.980
		POST	29.99 ± 2.58	25.40–31.45		
	70%	PRE	32.54 ± 2.04	29.00–35.55	.086	.705
		POST	34.04 ± 2.97	29.40–38.95		

*$p < .05$ between PRE and POST moments.



*p < .05 between PRE and POST in DESRP.

Figure 3. Estimated marginal means of muscle thickness variation between pre- and post-intervention time points, measured at (A) 50%, (B) 60%, and (C) 70% of the distance between the acromion and the olecranon on the anterior aspect of the arm, under ascending (ASCRP) and descending (DESRP) resistance profiles.

DISCUSION

The results of the present study indicate that, although significant differences ($p < .05$) were observed between the pre- and post-intervention moments in muscle thickness for the DESRP condition, specifically at the 50 and 60% regions of the biceps brachii and brachialis, no significant differences ($p > .05$) were found for the ASCRP condition.

Additionally, no statistically significant differences were detected between the two exercise conditions. Therefore, it is not possible to assert that one resistance profile is superior to the other in promoting increases in muscle thickness. However, the significant findings in DESRP in the 50 and 60% regions, accompanied by large effect sizes ($p = .017$, $d = 1.097$; $p = .028$, $d = .980$, respectively), suggest a potential trend indicating that applying greater resistance when the muscle is in a lengthened position (DESRP) may favor increases in muscle thickness following a six-week intervention. Although these findings did not reach between-condition significance, the magnitude of the observed effects (Cohen's d ≈ 1.0) may hold practical relevance for strength and conditioning professionals, particularly when selecting exercises aimed at optimising regional hypertrophy.

The interpretation that greater hypertrophy may occur when higher tension is applied in lengthened muscle positions should be viewed with caution, as no direct measurements of torque or neuromuscular activation were conducted in the present study. From a mechanical standpoint, altering the direction of the cable by changing the pulley's position relative to the ground (see Figures 1 and 2) modifies the external moment arm throughout the range of motion, thereby shifting the point of peak torque toward more lengthened or shortened muscle positions. Thus, while torque was not directly quantified, the design was informed by well-established biomechanical principles.

These results are consistent with those of Nunes et al. (2020) and Zabaleta-Korta et al. (2023), who also did not observe significant differences between exercises with ascending and descending resistance profiles. Nevertheless, the present study identified significant pre- to post-intervention differences at the 50% region under DESRP, a result not previously reported by Nunes et al. (2020) or Zabaleta-Korta et al. (2023) and reported under ASCRP by Kassiano et al. (2025).

One possible explanation for this divergence lies in differences in sample design. In the studies by Kassiano et al. (2025), and Nunes et al. (2020), Zabaleta-Korta et al. (2023), participants were allocated to distinct groups, each performing only one of the evaluated exercises. In contrast, the present study employed a within-subject design, with participants performing both exercises, thus reducing interindividual variability. The literature suggests that endogenous factors such as genetic variability and hormonal responses may influence hypertrophic adaptations to resistance training (Joanisse et al., 2020).

Furthermore, some individuals may exhibit better neuromuscular control, selectively activating different muscles during exercise execution, thereby influencing the level of mechanical tension imposed on each muscle group and, consequently, affecting the hypertrophic response (Avrillon et al., 2021). By allowing each participant to perform both exercises, the present study minimized such variability, which may partially explain the differences observed compared with Kassiano et al. (2025), Nunes et al. (2020), and Zabaleta-Korta et al. (2023).

Kassiano et al. (2025) and Zabaleta-Korta et al. (2023) also reported a significant increase in muscle thickness at the 70% region of the muscle length following the DESRP condition, and Nunes et al. (2020) reported no differences between exercises at 50% region. However, these findings were not replicated in the present study, which instead found significant increases at the 50 and 60% regions, but not at 70% in the DESRP.

This discrepancy may be attributed to important methodological differences, including: (i) weekly training volume and intervention duration. The present study lasted six weeks and applied eight sets per exercise per week, whereas Zabaleta-Korta et al. (2023) employed a 12-week protocol with 12 weekly sets, Kassiano et al. (2025) employed an 8-week protocol with six weekly sets, and Nunes et al. (2020) employed a 10-week protocol with nine weekly sets. Scientific evidence supports a dose–response relationship between training volume and hypertrophy, with higher volumes generally promoting greater muscle growth (Schoenfeld et al., 2017); (ii) differences in exercise mechanics, particularly joint positioning and equipment used. In the present study, and also in the Nunes et al. (2020) study, the shoulder joint was more flexed during execution. In contrast, in Kassiano et al. (2025) and Zabaleta-Korta et al. (2023), it was more extended, possibly enhancing muscle stretch in the distal portion of the biceps brachii and amplifying the hypertrophic stimulus in that region. Moreover, equipment choice may have influenced the resistance profile. The current study used a cable-pulley system, whereas Kassiano et al. (2025) and Zabaleta-Korta et al. (2023) used free weights (dumbbells), and Nunes et al. (2020) utilized both barbell and cable-pulley systems. This distinction could have altered the resistance experienced throughout the range of motion. For example, in dumbbell exercises, especially when the concentric phase is performed as quickly as possible, greater initial acceleration may be required, increasing muscular tension early in the movement, but also potentially resulting in a subsequent reduction in resistance throughout the range. Conversely, the controlled 1-second cadence for the concentric phase in cable exercises (as used in the present study) likely minimised acceleration and allowed for more consistent tension throughout the movement. These methodological differences may explain the significant increases in muscle thickness observed at the 50 and 60% regions in the present study, as opposed to the isolated increase at the 70% region reported by Kassiano et al. (2025) and Zabaleta-Korta et al. (2023) under the DESRP condition, as well as the additional increase at 50% observed under the ASCRP condition in the latter study. In contrast, Nunes et al. (2020) found no significant differences between interventions when muscle thickness was measured only at the 50% region, which was the only assessment site used in their study.

A potential limitation of the present study is the risk of Type II statistical error, as the initially planned sample size of 20 participants was not fully achieved. This limitation should be taken into account when interpreting the findings, and future studies are encouraged to recruit larger samples to increase statistical power. Moreover, extending the intervention duration in future research may enable a more accurate evaluation of long-term hypertrophic adaptations. Although efforts were made to standardize testing conditions (time of day, hydration, and rest period), the absence of direct measurements of dietary intake, hydration status, and torque quantification represents an additional limitation that should be addressed in subsequent investigations.

CONCLUSIONS

In conclusion, it appears that the muscle thickness of the anterior arm muscles is not significantly influenced by the resistance profile (ASCRP and DESRP). However, there seems to be a trend toward increased muscle thickness in the DESRP condition.

These findings should be interpreted in light of the specific characteristics of the participants in the present study and the relatively short duration of the intervention.

Future studies should investigate these effects in other muscle groups, in populations with resistance training experience, and across longer intervention periods.

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