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Effects of final partial range of motion vs. full range of motion resistance training on muscle adaptations in physically active young men: a within-subject study

Efectos del entrenamiento de fuerza con amplitud de movimiento parcial final frente a amplitud de movimiento total sobre las adaptaciones musculares en hombres jóvenes físicamente activos: un estudio intrasujeto

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Abstract. Purpose: The present study aimed to compare final partial range of motion (final pROM) vs. full range of motion (fROM) in muscle hypertrophy and strength in physically active young men. Methods: Ten physically active young men (age=22.90±2.47 years; body mass=83.85±11.67 kg; height=176.30±6.22 cm) participated in a randomized, within-subject experimental design in which resistance training was performed using the upper- and lower-limbs with final pROM or fROM three times per week for six weeks. For all subjects, an arm or thigh was randomly selected and assigned for the final pROM condition, and the contralateral limb for the fROM condition. The subjects performed three sets of 12 repetitions at 60% of one-repetition maximum (1-RM), with two-minute rest interval between the sets and between limbs. The muscle hypertrophy of the elbow flexors and the knee extensors and the 1-RM test in the specific range of motion (ROM) that has been trained was measured before and after the intervention. An analysis of covariance was used to compare the different conditions on muscle hypertrophy and strength. Results: The results showed that there was no statistically significant difference between the conditions for elbow flexors muscle hypertrophy (p=0.920; Cohen's d=0.046) and knee extensors muscle hypertrophy (p=0.291; Cohen's d=0.152). Similarly, there was no statistically significant difference between the conditions for 1-RM of the arm (p=0.161; Cohen's d=0.898) and 1-RM of the thigh (p=0.276; Cohen's d=0.533). Conclusions: Therefore, these findings suggest that there was no statistically significant difference between the different ROM, however, the moderate-large effect size (leg=0.533 and arm=0.898) in favor of final pROM in the strength, may indicate a potential direction for future research in physically active young men.
Keywords: Range of Motion, Articular; Hypertrophy; Humans; Muscle Strength; Strength Training

Resumen. Objetivo: El presente estudio tuvo como objetivo comparar la amplitud de movimiento parcial final (ADMp final) frente a la amplitud de movimiento completa (ADMc) en la hipertrofia muscular y fuerza en hombres jóvenes físicamente activos. Métodos: Diez hombres jóvenes físicamente activos (edad=22,90±2,47 años; masa corporal=83,85±11,67 kg; altura=176,30±6,22 cm) participaron en un diseño experimental aleatorizado, intra-sujeto, en el que se realizó entrenamiento de fuerza utilizando los miembros superiores e inferiores con ADMp final o ADMc tres veces por semana durante seis semanas. Para todos los sujetos, se seleccionó aleatoriamente un brazo o muslo y se asignó para la condición ADMp final, y la extremidad contralateral para la condición ADMc. Los sujetos realizaron tres series de 12 repeticiones al 60% del máximo de una repetición, con un intervalo de descanso dos minutos entre las series y entre las extremidades. Se midió la hipertrofia muscular de los flexores del codo y los extensores de la rodilla y la prueba de máximo de una repetición en amplitud de movimiento específica entrenada antes y después de la intervención. Se utilizó un análisis de covarianza para comparar las diferentes condiciones sobre la hipertrofia muscular y fuerza. Resultados: Los resultados mostraron que no hubo diferencias estadísticamente significativas entre las condiciones para la hipertrofia muscular de los flexores del codo (p=0,920; d de Cohen=0,046) y la hipertrofia muscular de los extensores de la rodilla (p=0,291; d de Cohen=0,152). Del mismo modo, no hubo diferencias estadísticamente significativas entre las condiciones para máximo de una repetición del brazo (p=0,161; d de Cohen=0,898) y máximo de una repetición del muslo (p=0,276; d de Cohen=0,533). Conclusiones: Por lo tanto, estos hallazgos sugieren que no hubo diferencias estadísticamente significativas entre las diferentes amplitudes de movimiento, sin embargo, el tamaño del efecto moderado-grande (pierna=0,533 y brazo=0,898) a favor de la ADMp final en fuerza, puede indicar una dirección potencial para futuras investigaciones en hombres jóvenes físicamente activos.
Palabras claves: Rango del Movimiento Articular; Hipertrofia; Humanos; Fuerza Muscular; musculación

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Introduction

Resistance training (RT) promotes diverse musculoskeletal adaptations that have beneficial effects on health in general (Dewangga et al., 2024; dos Santos et al., 2023; Marcos-Pardo et al., 2024). The effects of manipulating different RT methods, techniques, and variables on muscle hypertrophy and strength have been a constant focus of research (Krzysztofik et al., 2019; Schoenfeld et al., 2021; Vilaça-Alves et al., 2024). Range of motion (ROM) is the variable that has received some attention in the literature and remains a controversial topic (Kassiano, Costa, Nunes, et al., 2023a; Newmire & Willoughby, 2018, 2020; Ottinger et al., 2023; Pallarés et al., 2021; Schoenfeld & Grgic, 2020; Wolf et al., 2023). ROM can be defined as the total possible movement around a joint and is most often measured in centimeters of displacement (Newmire & Willoughby, 2018). ROM manipulation can influence various directions of neuromuscular adaptations and has become an object of study with research potential in the field of sports science (Pallarés et al., 2021; Wolf et al., 2023). However, this variable remains ignored in recent positions (Schoenfeld et al., 2021).

Partial ROM (pROM) is a movement with shorter displacement relative to full ROM (fROM) spectrum (Newmire & Willoughby, 2018), ROM manipulation is a specialized RT technique used by bodybuilders and weightlifters focus on obtaining some benefit in regional or local muscle hypertrophy (Newmire & Willoughby, 2020), or in strength gain (Massey et al., 2004). Some acute aspects, such as greater area under the oxygen hemoglobin dissociation curve and blood lactate concentration, as well as greater muscle activation, may justify the use of pROM (Goto et al., 2019). Likewise, Pallarés et al. (2021) demonstrated in a systematic review that RT with fROM is more effective than RT with pROM in maximizing muscle hypertrophy of the lower-limbs, as well as in strength and functional performance. Similarly, fROM seems to promote greater improvements in upper-limb strength (Pinto et al., 2012) and greater improvements in muscle hypertrophy (Bloomquist et al., 2013). Perhaps the chronic adaptations produced by RT with fROM may be because muscle damage is greater than in RT with pROM, regardless of the load used (Baroni et al., 2017).

Conversely, Kassiano et al. (2022) pointed out in a recently published letter some inconsistencies in the study by Pallarés et al. (2021), especially regarding the importance of the length-tension relation in muscle adaptations. Likewise, a recent systematic review demonstrated that performing RT exercises in a longer muscle length leads to greater muscle hypertrophy when compared to shorter muscle lengths (Kassiano, Costa, Nunes, et al., 2023a). Such a finding is supported by several studies that compared initial pROM (that is, longer muscle length) to final pROM (shorter muscle length) and fROM and found superior results for initial pROM in muscle hypertrophy and strength of lower-limbs (Kassiano, Costa, Kunevaliki, et al., 2023a; Pedrosa et al., 2022) and upper-limbs (Goto et al., 2019; Pedrosa et al., 2023).

Other studies have compared RT with final pROM vs. fROM (Bloomquist et al., 2013; Pinto et al., 2012). Pinto et al. (2012) demonstrated that fROM led to significantly greater gains in strength when compared to final pROM. However, the study presents an important limitation, as the strength measuring test only considered fROM. Pedrosa et al. (2022) compared changes in strength and distal muscle hypertrophy between different ROMs in the seated leg extension exercise and it was demonstrated that the exercise performed with fROM induced greater gains in the distal quadriceps muscle hypertrophy than the exercise performed with final pROM, but disregarded the final angles of the knee extension (~30°), an aspect that reduces the time under tension which can impact muscle adaptations (Newmire & Willoughby, 2018). Although this scenario of RT with initial pROM may have a large potential to impact on chronic adaptive changes (Kassiano, Costa, Nunes, et al., 2023b), the current literature still lacks deeper research regarding RT with final pROM compared to fROM. Therefore, the present study aimed to compare the effect of final pROM vs. fROM in muscle hypertrophy and strength in active young men performing scott bench curls and seated leg extension exercises for a period of 6 weeks of training. Based on the literature, we hypothesized that RT with fROM would lead to greater hypertrophic adaptations, while strength would be similar in these different conditions.

Materials and Methods

Experimental Approach to the Problem

To investigate this study's hypothesis, within-subjects design was used. The upper- and lower-limbs of the 10 subjects were submitted to two different conditions: a) RT with fROM; and b) RT with final pROM. Scott bench curls and seated leg extensions (Righetto, Campinas, São Paulo) were the exercises selected to train the elbow flexors and knee extensors, respectively. This RT intervention was conducted three times per week for six weeks with at least 48 hours between sessions. The criteria for the subjects to remain in the study included attendance in at least 90% of the scheduled sessions and not missing two consecutive sessions. The dependent variables were measured at the beginning and the end of the intervention. The tests to assess muscle hypertrophy and strength were conducted 2-3 days before and after the first and the last RT sessions.

Subjects

Ten physically active young men participated in the present study (Table 1). The inclusion criteria were: (a) trained for at least three months in RT; (b) age between 18-40 years. The exclusion criteria were: (a) history of smoking in the last three months; (b) presence of any cardiometabolic or cardiovascular disease; (c) systemic hypertension (≥140/90 mmHg) with or without the use of hypertension medication; (d) self-reported use of anabolic steroids, drugs, or substances with a potential impact on physical performance; (e) presence of any musculoskeletal injury. The study protocol followed the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Federal University of Juiz de Fora (4.180.706).

Table 1.
Participants' Demographic and Anthropometric Characteristics.

Characteristics	Participants (n=10)
Age (years)	22.90 (2.47)
Body mass (kg)	83.85 (11.67)
Height (cm)	176.30 (6.22)
Body mass index (kg/m^2)	26.96 (3.40)
Body fat percentage (%)	15.12 (6.27)
Systolic blood pressure (mm Hg)	124.57 (3.46)
Diastolic blood pressure (mm Hg)	81.29 (5.05)

Data are presented as means (standard deviations).

Sample Size Justification

A sample size calculation was performed a priori using the program G*Power (version 3.1.9.7) based on the F-test in Analysis of Variance (ANOVA): repeated measures, within-subjects to determine the minimum number of subjects needed for the present study. In order to determine the effect size, two studies were selected (Pedrosa et al., 2022; Pinto et al., 2012). We extracted the Δ% of strength of the final pROM and fROM groups in both studies. After extracting the Δ% strength from the selected studies, we found an effect size for upper-limbs *Cohen's d*=1.213 (Pinto et al., 2012) and for lower-limbs the effect size was *Cohen's d*=0.575 (Pedrosa et al., 2022). Therefore, considering the following parameters: α err prob=0.05; power (1-β err prob)=0.80; two conditions, two points of time for the measures (pre- and post-training); corr among rep measures=0.5; and nonsphericity correction ϵ=1; the sample sizes were 6 (Pinto et al., 2012) and 10 subjects (Pedrosa et al., 2022), respectively. A sample comprising 15 subjects was selected to prevent a type II error from occurring. However, there were two dropouts due to exclusion criteria and three due to missing two consecutive training sessions.

Intervention

The subjects performed scott bench curls and seated leg extension exercises three times per week for six weeks. For all subjects, an arm or thigh was randomly selected and assigned for the final pROM condition, and the contralateral limb for the fROM condition. In order to standardize the execution of the exercises, the scott bench curls were done in a sitting position with the shoulders flexed at a 45° angle and forearms supinated. The elbow flexion was approximately 0-135° in the fROM condition and approximately 50-135° in the final pROM condition (Figure 1a). In the seated leg extension, subjects were in a sitting position with 110° degrees of hip flexion (torso and thigh), and the medial malleolus of the tibia was positioned 2 cm below the cushion of the machine. In order to minimize compensatory movements, the subjects were restricted with a 4-point seat belt harness across the torso. The fROM was determined as a knee flexion of 90-0°, and final pROM as a flexion of 45-0° (Figure 1b). To ensure that the ROM was respected during the scott bench curls and seated leg extension exercises, a resistance band and a metal structure were used to serve as references for the correct ROM, as previously standardized for the same exercises (Pedrosa et al., 2022; Pedrosa et al., 2023). A metal goniometer (Staline®, USA) was used to accurately define joint angles. Each RT session started with a general warm-up composed of five minutes in a cycle ergometer at a self-selected intensity, followed by a general mobilization of elbow and knee joints. Then, a specific warm-up was conducted in which the subjects did two sets of 20 repetitions of each exercise. The load was at 30% 1-RM, and the rest interval was one minute between sets, two minutes between limbs. After specific warm-up, the subjects performed three sets of 12 repetitions at 60% 1-RM, with two-minute rest interval between the sets and between limbs. The rest interval between the warm-up exercises and the main sets was five minutes. During the execution of the movements, the subjects' rate was controlled with the use of a digital metronome (DM90, Seiko®, Tokyo, Japan), being 2 s for the eccentric phase and 1 s for the concentric phase. However, if the rate was lost at any moment during execution, subjects were asked to maintain the highest velocity possible with the aim of completing the proposed repetitions. The scott bench curls were performed first, followed by seated leg extensions. This order was chosen to avoid the greater metabolic stress associated with leg extension, as it involves a greater amount of muscle mass when compared to scott bench curls (Ribeiro et al., 2017), similar to the already studied comparison between back squats and bench presses (Sánchez-Medina & González-Badillo, 2011). Furthermore, as a form of load progression, in the first training session of the week, in the last set of each exercise, each subject was asked to perform two more repetitions than the 12 previously established. If the subject managed to perform them with good execution technique, the load for the next RT session was adjusted. All training sessions were closely supervised by an experienced trainer to ensure safety and compliance with the procedures, and also because previous research demonstrated greater adaptation gains in supervised RT sessions (Coleman et al., 2023).

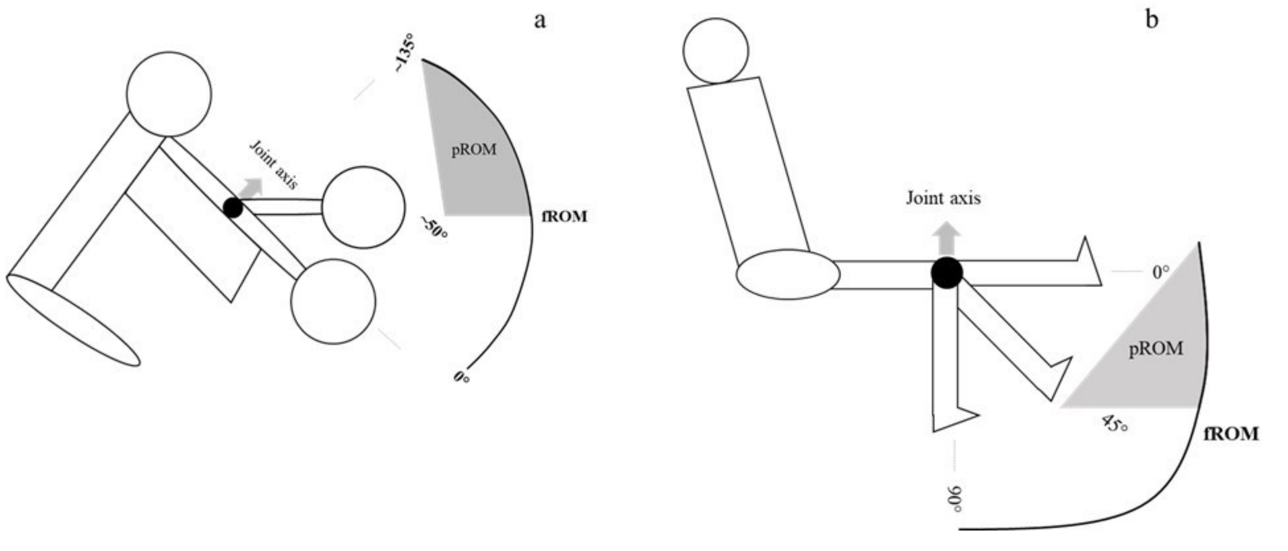

Figure 1. Range of motion performed by the different conditions in the resistance training sessions.

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Anthropometric Measurement and Body Composition

The height and body mass of the subjects were measured with a stadiometer (Sanny®, São Paulo, Brazil) and a mechanical scale (Filizola®, São Paulo, Brazil), respectively. The subjects were wearing only shorts during body mass measurement and were instructed to take a deep breath before measuring height. The body fat percentage was estimated with ultrasound equipment (BodyMetrix™ BX2000; IntelaMetrix, Inc., Livermore, CA, USA) with a wave frequency of 2.5 MHz, previously validated for cadavers and men (Miclos-Balica et al., 2021; Wagner et al., 2019). The present study used the density formula proposed by Jackson and Pollock (1978) for three parts of the body (chest, abdomen, thigh), and to estimate body fat percentage the following formula was used: $\frac{4.95}{\text{body density}} - 4.5 \text{x}\ 100$ (Siri, 1993). During measurement, the ultrasound probe was applied perpendicular to the skinfold and obliquely (chest) or parallel (abdomen and thigh) to the longitudinal axis. A water-soluble gel (Mercur S.A., Body Care, Santa Cruz do Sul, RS, Brazil) was applied to the ultrasound transducer to improve acoustic coupling and eliminate the need for excessive contact pressure on the skin. All measures were taken on the right side of the subjects' bodies and by a single ultrasound technician to avoid variability between different professionals.

Muscle Hypertrophy Assessment

The muscle hypertrophy of the elbow flexors and the knee extensors were measured at rest. For the upper-limbs, the subjects were lying down with forearms supinated and arms completely relaxed. To measure the lower-limbs, the subjects were in a sitting position with a knee flexion of approximately 10°. This knee angle was selected to avoid over stretching the posterior thighs (Reeves et al., 2009), thus helping reduce the fascicle curvature and improving the measure's reliability (Blazevich et al., 2006). The subjects were instructed not to perform any physical activity during the 72 hours before the laboratory visit. Before the measures were taken, the subjects lay down for 15 minutes to restore the normal flow of body fluids. During this period, the anterior regions of the arm and the thigh were marked in order to identify the points for acquiring the image. The ultrasound images were acquired with a 13 cm × 5 cm portable ultrasound device with a wave frequency of 2.5 MHz (BodyMetrix™ BX2000; IntelaMetrix, Inc., Livermore, CA, USA). The portable ultrasound device was previously validated for muscle hypertrophy using the imaging technique for the following points of the body: abdomen, biceps brachii, pectoralis, thigh, trapezius, and triceps brachii (Ribeiro et al., 2022). The images were acquired pre- and post-training (24 hours before and 72 hours after the end of the study) for the limbs that were trained with fROM and final pROM. Futhermore, the following anatomic repair areas were used: elbow flexors - 60% of the distance between the acromion process of the scapula and the lateral epicondyle of the humerus (Sato et al., 2021); and knee extensors - 50% of the distance between the greater trochanter and the lateral femoral condyle (Bloomquist et al., 2013). The ultrasound probe was applied perpendicular to the skinfold for measurement. A water-soluble gel (Mercur S.A., Body Care, Santa Cruz do Sul, RS, Brazil) was applied to the ultrasound transducer to improve acoustic coupling and eliminate the need for excessive contact pressure on the skin. With the static image, a mouse cursor was used to measure the distance from the muscle-adipose tissue interface to the muscle-bone interface. Three measures were taken, and the mean value was defined based on those measures. Reliability measurements were not carried out in the present study; however, we did not find a statistically significant difference between the different muscle hypertrophy measures ($p>0.05$) associated with a low coefficient of variation (<20%). All the images were acquired by a single trained professional who was blinded to the different conditions. The procedures were repeated in the post-training.

Strength Assessment

The one-repetition maximum (1-RM) test was performed to assess the strength of the subjects in scott bench curls and seated leg extension exercises. The test repeated the ROM applied to each limb; that is, if the limb was trained in the fROM or final pROM condition, the corresponding test was performed. To eliminate the learning effect and to improve reproducibility and reliability scores, the subjects participated in a familiarization session 48-72 hours prior to the 1-RM test (baseline), as was done in previous studies that compared different ranges of movement (Pedrosa et al., 2022; Pinto et al., 2012). Familiarization with the 1-RM test was determined within a maximum of three attempts, with 4-minute rest periods between attempts. There was a rest of 10 minutes between different limbs and 20 minutes between exercises.

After a period of 48-72 hours after the 1-RM test, a re-test was performed. Therefore, 1-RM tests and re-tests were completed on two different days. The 1-RM load was determined as the highest load achieved in either of the two test days, as long as it did not exceed a 5% difference. No exercise was authorized in the period between the test sessions so as not to interfere with the results. The 1-RM test was determined within five attempts, with a 4-minute rest between attempts of the same exercise, 10 minutes between different limbs, and 20 minutes between different exercises. A test was considered valid if the subject completed the ROM previously defined in each exercise. Reliability measurements were not carried out in the present study; however, we did not find a statistically significant difference between the 1-RM test and retest ($p > 0.05$) associated with a low coefficient of variation (<20%). The 1-RM test was conducted pre- and post-training by a single trained professional who followed the procedures according to the National Strength and Conditioning Association (NSCA, 2016).

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Statistical Analysis

All data were expressed as mean and standard deviation. The Gaussian distribution of the data was verified through the Shapiro-Wilk test. The one-way Analysis of Variance (ANOVA) or Student's t test and the coefficient of variation were used to compare and analyze the variation between the different measurements of the ultrasound images and between the 1-RM test and re-test, respectively. Given interlimb baseline differences in muscle hypertrophy and 1-RM outcomes between subjects, data for these outcomes were modeled using an Analysis of Covariance (ANCOVA) on the change scores (Wu & Lai, 2015), with post-study values as the dependent variable, condition (fROM vs final pROM) as fixed factors, and the baseline values as a covariate, followed by a Tukey post-hoc test to compare muscle hypertrophy and 1-RM results. Eta squared (η^2) was the measure of effect size for the main significant effects (Wu & Lai, 2015), with the following interpretation: small<0.06; moderate=0.06-0.14; large≥0.14. Between-condition point estimates, confidence intervals, and effect sizes (Cohen's d) were reported for all primary outcomes with the following interpretation: trivial (<0.2), small (0.20–0.49), moderate (0.50–0.79), and large (>0.80) based on the classifications set out by Cohen (1988). Statistical significance was set a priori at 5%. Analyses were performed using JASP version 0.17.1 (JASP Team, 2023). Figures were created with GraphPad® (Prism 8.0, San Diego, CA, USA).

Results

Muscle Hypertrophy

ANCOVA showed that pre-training values of elbow flexors muscle hypertrophy were significantly related to a possible statistically significant difference between the conditions [F(1, 17)=16.090; p<0.001; η^2=0.486]. However, there was no statistically significant difference between the conditions for elbow flexors muscle hypertrophy [F(1, 17)=0.010; p=0.920; η^2=0.000317; Cohen's d=0.046]. Conversely, ANCOVA showed no significant relation between the pre-training values for knee extensors muscle hypertrophy and a possible statistically significant difference between the conditions [F(1, 17)=1.187; p=0.291; η^2=0.065]. There was no statistically significant difference between the conditions for knee extensors muscle hypertrophy [F(1, 17)=1.187; p=0.291; η^2=0.065; Cohen's d=0.152] (Figure 2).

Strength

ANCOVA showed that the pre-training values of 1-RM of scott bench curls were not significantly related to a possible statistically significant difference between the conditions [F(1, 17)=3.014; p=0.101; η^2=0.136]. There was no statistically significant difference between the conditions for 1-RM of preacher curl [F(1, 17)=2.153; p=0.161; η^2=0.097; Cohen's d=0.898]. Conversely, ANCOVA showed that pre-training values of 1RM of leg extension were significantly related to a possible statistically significant difference between the conditions [F(1, 17)=38,847; p<0.001; η^2=0.680]. There was no statistically significant difference between the conditions for 1RM of leg extension [F(1, 17)=1.269; p=0.276; η^2=0.022; Cohen's d=0.533] (figure 3).

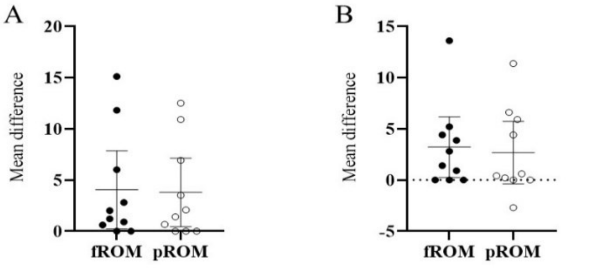

Figure 2. Muscle hypertrophy. A - Muscle hypertrophy on the knee extensors; B - Muscle hypertrophy on the elbow flexors.

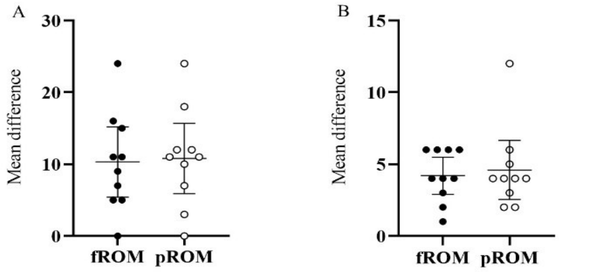

Figure 3. 1-RM test. A – 1-RM test performed on the knee extensors; B – 1-RM test performed on the elbow flexors.

Table 2 shows the mean values accompanied by the dispersion measure. Additionally, we performed the effect size of the difference from pre- to post-intervention and the relative difference.

Table 2.
Differences from pre- to post-intervention in the dependent variables.

Characteristics	fROM	Final pROM
Biceps brachii muscle hypertrophy pre (mm)	32.57 (4.84)	33.48 (6.52)
Biceps brachii muscle hypertrophy post (mm)	35.79 (4.75)	36.16 (4.85)
Effect size (d)	0.707	0.491
Δ%	10%	8%
Quadriceps femoris muscle hypertrophy pre (mm)	36.89 (3.95)	37.90 (4.99)
Quadriceps femoris muscle hypertrophy post (mm)	40.93 (3.24)	41.69 (4.00)
Effect size (d)	1.179	0.884
Δ%	11%	10%
1-RM of preacher curl pre (kg)	16.80 (2.35)	20.10 (1.20)
1-RM of preacher curl post (kg)	21.00 (2.00)	24.70 (2.75)
Effect size (d)	2.030	2.286
Δ%	25%	23%
1RM of leg extension pre (kg)	67.60 (13.77)	75.70 (10.80)
1RM of leg extension post (kg)	77.90 (10.87)	86.50 (9.35)
Effect size (d)	0.875	1.127
Δ%	15%	14%

Discussion

This study aimed to compare the effect of RT with different ROMs on the muscle hypertrophy and strength in physically active young men. Regarding the muscle hypertrophy, there was no statistically significant difference when compared to the conditions. Conversely, despite there was no statistically significant difference when compared to the conditions, we can observe a moderate-large effect size in favor of final pROM on the strength. These results partially support our initial hypothesis, since there was no difference in strength gains; however, we did not expect similar results for muscle hypertrophy.

Muscle Hypertrophy

Comparative studies between fROM vs. pROM on the muscle hypertrophy of the elbow flexors during scott bench curls are limited and have involved only untrained individuals. Pinto et al. (2012) compared fROM (0-130°) to pROM (50-100°) on scott bench curls in untrained young men for 10 weeks of RT. The results of the study showed that both RT conditions (i.e., fROM and pROM) significantly improved the muscle hypertrophy of the elbow flexors compared to the control group. Although the hypertrophic responses were not different between fROM vs. pROM, the magnitude of the size of the effect of fROM (ES=1.09) was almost twice as high as that of pROM (ES=0.57). Therefore, the authors suggested that training with fROM could have a higher impact on muscle hypertrophy than training with pROM. These results are not in accordance with our study, since no statistically significant difference was shown between fROM compared to final pROM for muscle hypertrophy elbow flexors, as well as our study had a trivial effect size (ES=0.046) when compared to the study of Pinto et al. (2012). This may be due to the subjects' level training, since the subjects in our study had some experience in RT.

Recently, Pedrosa et al. (2023) measured the muscle hypertrophy of the elbow flexors after eight weeks of RT using an initial ROM (0-68°) and a final ROM (68-135º) in scott bench curls on untrained women. As result, the arm that trained in the initial pROM condition significantly increased the distal muscle hypertrophy of the elbow flexors. However, when methodologically examining the present study, we noted that the final pROM condition trained at the final angles of the scott bench curls exercise, so less torque production is expected. For this reason, we expected that RT with fROM would induce greater gains in elbow flexors muscle hypertrophy; however, our results were contrary to our initial hypothesis. It is worth noting that the subjects of the study mentioned above were untrained women and the analysis of elbow flexors muscle hypertrophy was carried at 50% and 70% of the length of the humerus (Pedrosa et al., 2023), aspects that differ from our study.

Few studies have compared different ROMs on the muscle hypertrophy of the knee extensors in seated leg extensions. One of them used concentric isokinetic training (Valamatos et al., 2018) and the other, dynamic training (Pedrosa et al., 2022). Valamatos et al. (2018) did not find a significant difference in the hypertrophy of the vastus lateralis after 15 weeks of isokinetic training with fROM (100-0°) and pROM (60-0°). In contrast, Pedrosa et al. (2022) found that fROM (100-30°) significantly increased the hypertrophy of the vastus lateralis when compared to final pROM (i.e., 65–30º) after 12 weeks of RT of seated leg extensions on untrained women. These differences can be partially explained mainly by the differences between the ROM [i.e., fROM (90-0°) and final pROM (45-0°)] adopted in our study when compared to the study by Pedrosa et al. (2022). Furthermore, the same study also compared four different ROMs: fROM (100-30°), initial pROM (100-65°), final pROM (65-30°) and variable ROM. The results did not show a statistical difference in the muscle hypertrophy (40% proximal-distal direction) of the vastus lateralis and rectus femoris among fROM, initial pROM, and variable ROM. Despite this, these three ROMs were statistically superior to the final pROM in other portions of the vastus lateralis and rectus femoris. In this respect, recent evidence seems to suggest additional and/or superior hypertrophy when training with longer muscle lengths compared to shorter muscle lengths (Kassiano, Costa, Kunevaliki, et al., 2023b; Maeo et al., 2021; Maeo et al., 2023; Pedrosa et al., 2022; Pedrosa et al., 2023).

The results in the recent literature are promising regarding the distal hypertrophic response when using initial pROM (Pedrosa et al., 2022; Pedrosa et al., 2023) at longer muscle lengths (Kassiano, Costa, Nunes, et al., 2023b). However, it remains unclear whether using different ROMs in RT with shorter and longer muscle lengths would interfere with a more proximal hypertrophic response of the muscle. These questions are beyond the scope of the present study, in which we assessed only the 50% of the length of the femur, our results are different from the literature, given that previous studies have shown advantages in training with fROM when compared to final pROM for the goal of muscle hypertrophy of the elbow flexors in scott bench curl exercises (Pallarés et al., 2021; Wolf et al., 2023). Still, both fROM and final pROM can be equally used in seated leg extensions for the hypertrophy of the vastus lateralis. Hence, considering that we found no statistically significant differences between fROM and final pROM, the exercise prescription will depend on the preferences and/or limitations of the participants who perform RT.

Strength

One study (Pinto et al., 2012) compared the gains in dynamic strength in 1-RM between fROM and pROM after 10 weeks of RT on the scott bench. Similarly, to our study, the results of Pinto et al. (2012) showed significant improvements in 1-RM in both groups between pre- and post-intervention. Conversely, fROM showed a higher significant increase in 1-RM when compared to pROM (Pinto et al., 2012), while in the present study, the final pROM showed a moderate-large effect size when compared to fROM. These differences between results can be partially attributed to the level of training of the study subjects. While Pinto et al. (2012) used untrained young men in its sample, in the present study physically active men were used. Although this was not reported, some of the subjects of our study were or had been involved in RT on a non-regular basis. Because of this, several studies relating to RT have resorted to washout periods to minimize the effects of prior training on the subjects of the study (Brigatto et al., 2020; Fonseca et al., 2020), which was not done in the present study. Even though the findings (NSCA, 2016; Ratamess et al., 2009) have not made specific recommendations about the ROM, fROM is conventionally prescribed to generate muscle adaptations and performance results (Newmire & Willoughby, 2018) and is therefore the most used by RT enthusiasts and practitioners. Because of this, the subjects of our study may have normally used fROM in their RT sessions, and using pROM for six weeks of RT may have provided a new stimulus to the muscle (Jung et al., 2023), which could have enhanced strength for pROM when compared to fROM. In addition to this, we conducted in our study a within-subjects design that, despite offering a certain advantage in reducing variability among subjects (MacInnis et al., 2017), may have also allowed for a cross-education effect. In this case, the evidence suggests that cross-education is potentially influenced by neural factors, which would result in different strength parameters (Beyer et al., 2016). Because of this, we cannot discard the hypothesis that strength gains in one limb may have influenced the strength gains in a contralateral limb (Munn et al., 2004). Likewise, these same justifications can be extended to the results observed in the seated leg extension exercise in the present study. In contrast, Pedrosa et al. (2022) found that 1-RM was significantly higher in fROM when compared to final pROM in the 1-RM test performed with fROM. The present study showed different results, where 1-RM for final pROM was significantly higher when compared to fROM, even though the ROMs used in the two studies were different. Therefore, according to our study, using a final pROM can benefit strength in subjects with limitations preventing RT with fROM.

The present study also has some considerable limitations. The first is that the trained conditions should perform the 1-RM test at both ROM (fROM and pROM). In this way, we could better interpret and discuss the results for strength. The second is that we have not assessed regional hypertrophy in our study. Therefore, it is possible that RT with final pROM could improve hypertrophy in the most proximal region of the muscle during the analyzed exercises. The third is that we conducted in our study a within-subjects design which can result in a cross-education effect. Furthermore, the study did not include a dietary control, an aspect that could also have an impact on the results.

Conclusions

In summary, we conclude that both fROM and final pROM produced similar gains in muscle hypertrophy of the elbow flexors and knee extensors, the results showed that both ROM can be equally used in scott bench curls and seated leg extensions. Regarding the strength, results showed that final pROM was better than fROM for strength. However, we advise future research to assess trained individuals after a washout period in order to check whether the adaptive responses regarding final pROM remain superior to fROM for strength. Additionally, new research should include experimental designs that avoid the possibility of cross-education between contralateral limbs during RT and studies that compare fROM to initial pROM, in order to analyze the effect of muscle length, especially of the elbow flexors on muscle adaptations.

Abbreviations

ROM: range of motion; RT: resistance training; final pROM: final partial range of motion; fROM: full range of motion; 1-RM: one-repetition maximum; ANOVA: analysis of variance; η^2; Eta squared; ANCOVA: analysis of covariance.

Ethics and consent to participate

The study protocol followed the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Federal University of Juiz de Fora (4.180.706).

Consent for publication

Not applicable.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

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Authors' contributions

PP: designed the study, supervised data collection, wrote part of the manuscript and administered the project. JGV: designed the study, carried out the data analysis, wrote part of the manuscript and administered the project. YC: designed the study, wrote part of the manuscript and supervised data collection. MN: trained the staff who collected the data, supervised the data collection, and reviewed the study. JN: designed the study, administered the project and reviewed the study. JMV: designed the study, administered the project and reviewed the study.

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