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Forearm Position Influences Triceps Brachii Activation During Triceps Push-Down Exercise

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ABSTRACT

Introduction: This study investigated the influence of forearm position (supinated or pronated) on the EMG activity of the triceps brachii lateralis head (TLA), triceps brachii longus head (TLO), flexor carpi radialis (FR), and extensor carpi radialis (ER) muscles during the triceps push-down exercise. Also, we analyzed the effect of different grips (handle vs standard padded pulley strap) to verify EMG activity of these muscles. **Methods:** Twenty-two adults participated in this study. They performed the single-arm triceps push-down exercise in four conditions: pronated forearm with handle (PRON-H), supinated forearm with handle (SUP-H), pronated forearm with standard padded pulley strap (PRON-S), and supinated forearm with standard padded pulley strap (SUP-S). Surface electrodes were placed over the TLA, TLO, FR, and ER on the dominant side. **Results:** The TLO showed higher EMG activity for SUP-H compared to all other conditions ($p<0.001$). Also, the FR EMG activity was higher with PRON-H condition ($p<0.001$), while the ER EMG activity was higher with SUP-H condition ($p<0.001$). Regarding the number of repetitions, participants performed fewer repetitions in the SUP-H condition compared to the PRON-H ($p<0.001$). **Conclusion:** Our study suggests that the position of the forearm during the triceps push-down exercise has a significant impact on the recruitment of specific muscles and overall exercise performance.

Keywords: EMG, muscle recruitment, strength training.

INTRODUCTION

Strength training is a widely used modality that has been associated with improvements in strength, muscle hypertrophy, general conditioning, and health-related outcomes (Moesgaard et al., 2022; Westcott, 2012). It is widely used by athletes, patients, trainers, and clinical therapists (Moesgaard et al., 2022), and there is a constant interest in finding specific exercises and variations to optimize muscle activation, strength, and hypertrophy. Strength training enthusiasts are constantly seeking to optimize their strength and hypertrophy by incorporating variations exercises. As an example, the triceps push-down exercise, which is commonly used to target the triceps brachii muscle (Hussain et al., 2020; Steele et al., 2017).

In practical gym settings, strength training enthusiasts suggest that performing the triceps push-down exercise with the forearm in a supinated position results in greater recruitment of the triceps brachii musculature compared to the pronated position. Previous studies have shown that the position of the forearm can influence muscle recruitment during curl (Marcolin et al., 2018) and pulldown exercises (Signorile et al., 2002). Specifically, the biceps brachii torque (Kohn et al., 2018; Timm et al., 1993) and electromyographic (EMG) activity (Gordon et al., 2004) are greater in the supinated than in the pronated position. However, to the best of our knowledge, there are no reports in the literature examining the influence of forearm position on the triceps brachii, wrist flexors, and extensors muscles recruitment during the triceps push-down exercise.

Since the carpus muscles can influence the elbow joint (Chaytor et al., 2020; Davidson et al., 1995; Hsu et al., 2008; Otoshi et al., 2014), it is plausible that they may also affect the muscle recruitment during the triceps push-down exercise. Therefore, we aimed to investigate the influence of forearm position (supinated or pronated) on the EMG activity of the triceps brachii lateralis head (TLA), triceps brachii longus head (TLO), flexor carpi radialis (FR), and extensor carpi radialis (ER) muscles during the triceps push-down exercise. Also, we aimed to analyze the effect of different grips (handle vs standard padded pulley strap) to check EMG activity of these muscles. We hypothesized that the supinated forearm position would result in higher EMG activity in the triceps brachii muscle due to a potential decrease in recruitment of the wrist flexors in this position.

METHODS

Study design

This is a single arm within person randomized study comparing EMG activity of elbow extensors and wrist flexors and extensors muscles in young adult participants. This study was approved by the local Research Ethics Board, which follows the Helsinki Declaration.

Participants

Individuals were eligible if they met the following criteria: male and female aged between 18-35 years; with or without strength training experience. Exclusion criteria were any muscle or joint injury in the upper limbs in the last six months; movement limitations of the upper limbs or any other health problem that could affect the performance of the proposed exercises. All participants received clarifications about the experimental protocols and signed an informed written consent form before data collection.

Data collection

The data collection occurred in two sessions, with an interval of 48 to 72 hours between them. No session exceeded two hours. We collected data only on the dominant limb for all tests in both sessions.

On the first session, initially, the participants observed a demonstration of the expected movement of the triceps push-down exercise, for all conditions: pronated forearm with handle (PRON-H), supinated forearm with handle (SUP-H), pronated forearm with standard padded pulley strap (PRON-S) and supinated forearm with standard padded pulley strap (SUP-S). Then, they performed a familiarization exercise, which was also regarded as a warm-up to prevent any potential impact of fatigue on the EMG activity. This involved performing a series of 20 submaximal repetitions for each condition, with a two-minute break between sets. We instructed the participants to keep their arms alongside the trunk, elbows flexed at 90° pointed downwards, spine in anatomical position, knees slightly flexed, and shoulders stabilized, to perform elbow extension with range of motion 90 to 0°, measured by a manual goniometer. We targeted two marks with an adhesive tape on the equipment cable to ensure that all repetitions reached the desired range of motion. A marking was also made on the floor so that participants could keep their distance from the dual adjustable pulley cable station machine (Flex Fitness Equipment, Cedral, São Paulo, Brazil). After the familiarization, participants rested for two minutes and their one repetition maximum (1RM) was estimated using the Brzycki (1993) equation for unilateral elbow extension on the dual adjustable pulley machine with a supinated forearm with handle. We followed the protocol proposed by LeSuer et al. (1997) using a range of 6 to 10 repetitions to ensure the reliability of load estimation. In instances where participants exceeded the recommended number of repetitions, a two-minute rest interval was implemented prior to their subsequent attempt with a higher load. The cadence was controlled with a metronome app (Metronome Beats, Stonekick, London, UK), maintaining 2 seconds for concentric and 2 seconds for eccentric phases.

On the second session, participants began the experiment by completing a warm-up, which included performing one set of 15 repetitions for each forearm position (supinated and pronated) of the triceps push-down exercise using a handle. The warm-up was conducted at a 60% 1RM, with a cadence of 2:2 seconds. Then, to record the EMG activity of the TLA, TLO, FR and ER we used four wireless sensors with two channels of 16-bit resolution (Trigno Wireless; Delsys®, Natick, Massachusetts, USA) at a sampling frequency of 2000 Hz. Only one researcher placed the sensors over the muscles on all participants, following previous recommendations for sensor placement (Hermens et al., 2000; Perotto and Delagi, 2005). After being attached to the skin, we performed a verification test to ensure good signal acquisition and electrode functioning. Then, participants performed the maximal voluntary isometric contraction (MVIC) tests, with elbow positioned at 90° of elbow flexion. The participants performed three 5-second maximal contractions (De Luca, 1984), with a 3-minute interval between contractions. The MVIC of the TLA, TLO, FR were measured at the triceps push-down exercise with PRON-H position. The MVIC for ER were measured at the triceps push-down exercise with SUP-H position. After, finishing the MVIC tests, the participants rested for three minutes and performed the maximum number of repetitions of dynamic contractions of unilateral triceps push-down exercise in four conditions: PRON-H, SUP-H, PRON-S, and SUP-S. The sequence of conditions was counterbalanced and randomized according to the forearm position. For handling conditions, the participant gripped the handle to perform the exercises. For exercises using a standard padded pulley strap, it was attached directly to the participant's wrist, leaving the hand free, aiming to minimize the use of wrist flexors and extensors muscles during the exercise. The distance between the participant and the pulley machine remained equal across all conditions (Figure 1).The stipulated load was the same in all conditions, being calculated at 80% 1RM of the supinated forearm with handle. The dynamic contractions had a controlled cadence of 2 seconds of concentric and 2 seconds of eccentric phases, controlled by a metronome app (Metronome Beats, Stonekick, London, UK). There was a 3-minute interval between conditions. When the participants changed the movement pattern and/or left the previously stipulated cadence, the set was interrupted.

EMG analysis

We processed EMG data using the EMGworks Analysis Software (Delsys Inc., Boston, Massachusetts, USA). We filtered the signal using a 4th order Butterworth digital bandpass filter (10-500 Hz). For analyses, we excluded the first and last repetitions for each elbow extension condition. Then, we calculated the average root mean square (RMS) of these repetitions. Afterward, we normalized the RMS value of each muscle by dividing the mean activity from the triceps extension set by the mean processed signals collected during the MVIC. We normalized the triceps brachii and wrist flexors with the pronated forearm with handle condition and the wrist extensors with the supinated forearm with handle condition. In the three series of MVIC, we collected data for five seconds, but for analysis, we considered only the mean of three intermediate seconds.

Statistical analyses

Shapiro Wilk and Mauchly's tests verified normality and sphericity, respectively. When necessary, the

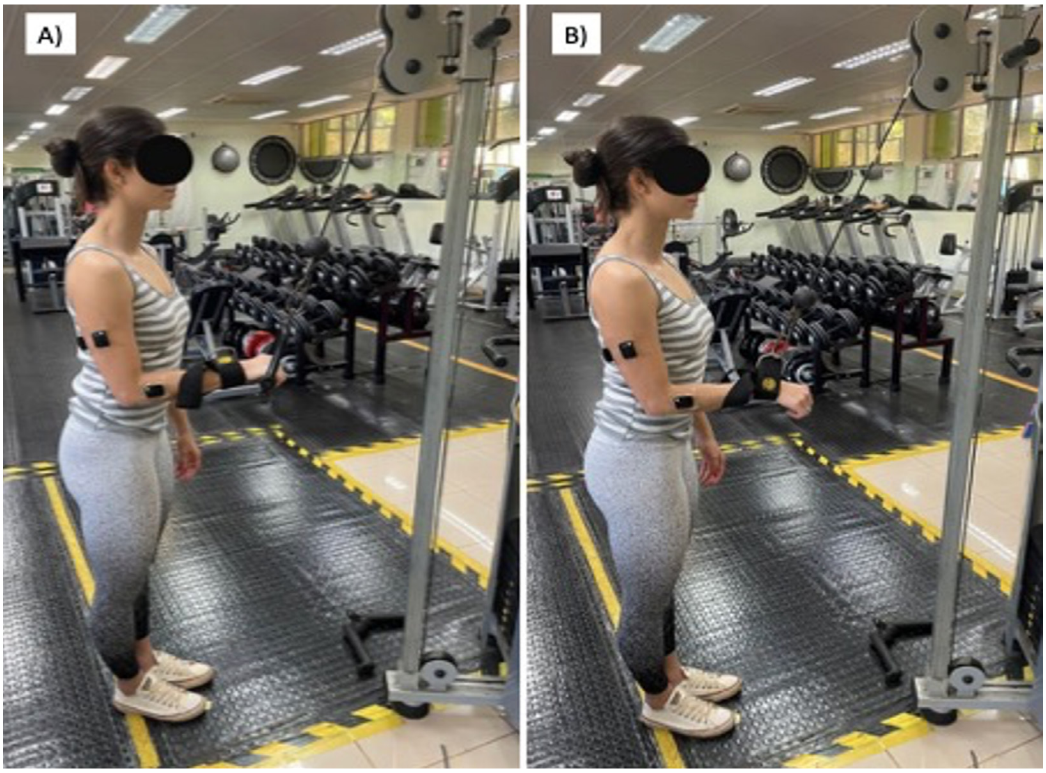

Figure 1. Participants positioning for triceps push-down exercise A) gripping the handle (PRON-H) and B) using a standard padded pulley strap (PRON-S).

Greenhouse-Geisser correction was applied. Five analyzes of variances (ANOVAs) were carried out, taking the conditions as a factor (PRON-H x SUP-H x PRON-S x SUP-S), which was treated as a repeated measure. The dependent variables were the EMG activity of the TLO, TLA, FR, ER muscles and the number of repetitions. Post hoc Bonferroni tests were performed when necessary. The magnitude of significant differences was determined by calculating the Cohen's d effect size. The significance level was maintained at $p<0.05$. All analyzes were performed using JAMOVI software (Version 2.3, the Jamovi Project 2022).

RESULTS

Twenty-two adults participated in this study, 11 women and 11 men (mean age = 25.4 ± 3.15 years; mean height = 1.69 ± 8.23 m; mean body mass = 72.4 ± 13.24 kg). Those who had more than 6 months of strength training practice in the moment of recruitment were considered trained (n = 13, 7 women and 6 men).

Our results showed effect of grip for TLO EMG activity ($F_{2.07,43.37} = 22.1$, $p<0.001$) (Figure 2). There was greater TLO activity in the SUP-H condition compared to the PRON-H (Cohen's d = 0.53, CI: 0.22, 0.89, p = 0.038), PRON-S (Cohen's d = 1.17, CI: 0.76, 1.69, $p<0.001$) and SUP-S condition (Cohen's d = 0.98, CI: 0.68, 1.38, $p<0.001$). Furthermore, there was greater TLO activity in the PRON-H condition compared to the PRON-S (Cohen's d = 0.89, CI: 0.52, 1.35, p = 0.002) and SUP-S condition (Cohen's d = 0, 61, CI: 0.34, 0.94, $p<0.001$).

Also, for TLA EMG activity, there was an effect of grip ($F_{1.73.36.30} = 7.97$, $p = 0.002$) (Figure 3). There was greater TLA activity in the SUP-H condition compared to PRON-S (Cohen's d = 0.74, CI: 0.33, 1.23, p = 0.009) and SUP-S condition (Cohen's d = 0.56, CI: 0.36, 0.81, $p<0.001$). Furthermore, there was greater TLA activity in the PRON-H condition compared to the SUP-S (Cohen's d = 0.43, CI: 0.16, 0.75, p = 0.029).

There was also an effect of grip for FR EMG activity ($F_{1.92,40.3} = 72.2$, $p<0.001$) (Figure 4). There was greater FR activity in the PRON-H condition compared to SUP-H (Cohen's d = 2.31, CI: 1.64, 3.22, $p<0.001$), PRON-S (Cohen's d = 2.71, CI: 2.13, 3.56, $p<0.001$) and SUP-S condition (Cohen's d = 2.83, CI: 2.16, 3.77, $p<0.001$).

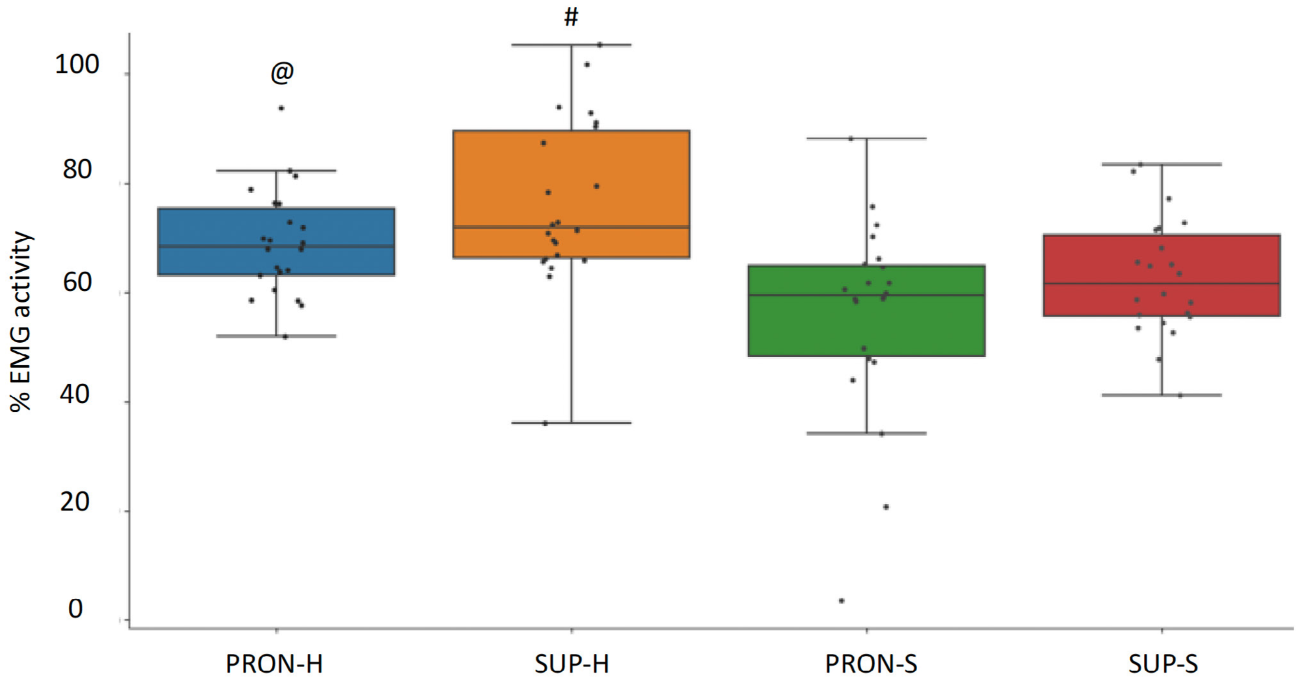

Figure 2. Boxplot and all individual values of TLO (triceps brachii longus head) electromyographic activity (%EMG) during the conditions pronated forearm with handle (PRON-H); supinated forearm with handle (SUP-H); pronated forearm with standard padded pulley strap (PRON-S); supinated forearm with standard padded pulley strap (SUP-S).
 # higher than all other conditions p<0.05
@ higher than PRON-S and SUP-S conditions p<0.05

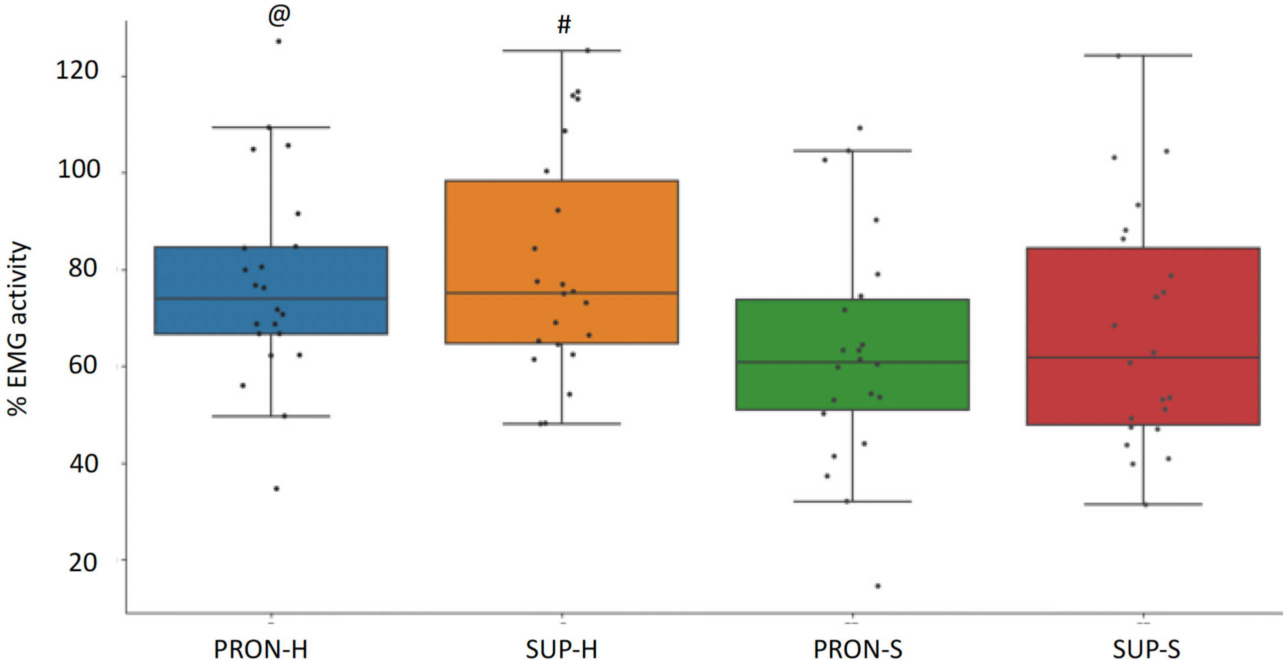

Figure 3. Boxplot and all individual values of TLA (triceps brachii lateralis head) electromyographic activity (%EMG) during the conditions pronated forearm with handle (PRON-H); supinated forearm with handle (SUP-H); pronated forearm with standard padded pulley strap (PRON-S); supinated forearm with standard padded pulley strap (SUP-S).
 # higher than PRON-S and SUP-S conditions p<0.05
@ higher than SUP-S condition p = 0.029

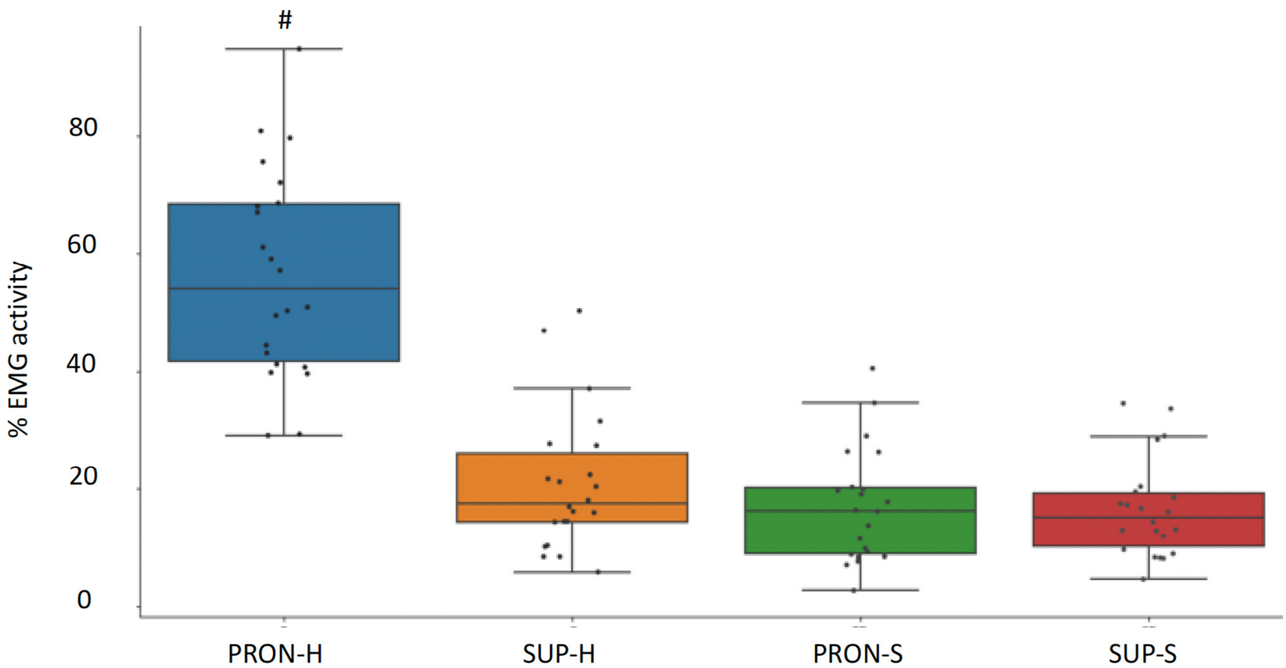

Figure 4. Boxplot and all individual values of FR (flexor carpi radialis) electromyographic activity (%EMG) during the conditions pronated forearm with handle (PRON-H); supinated forearm with handle (SUP-H); pronated forearm with standard padded pulley strap (PRON-S); supinated forearm with standard padded pulley strap (SUP-S).
 # higher than all other conditions p<0.05

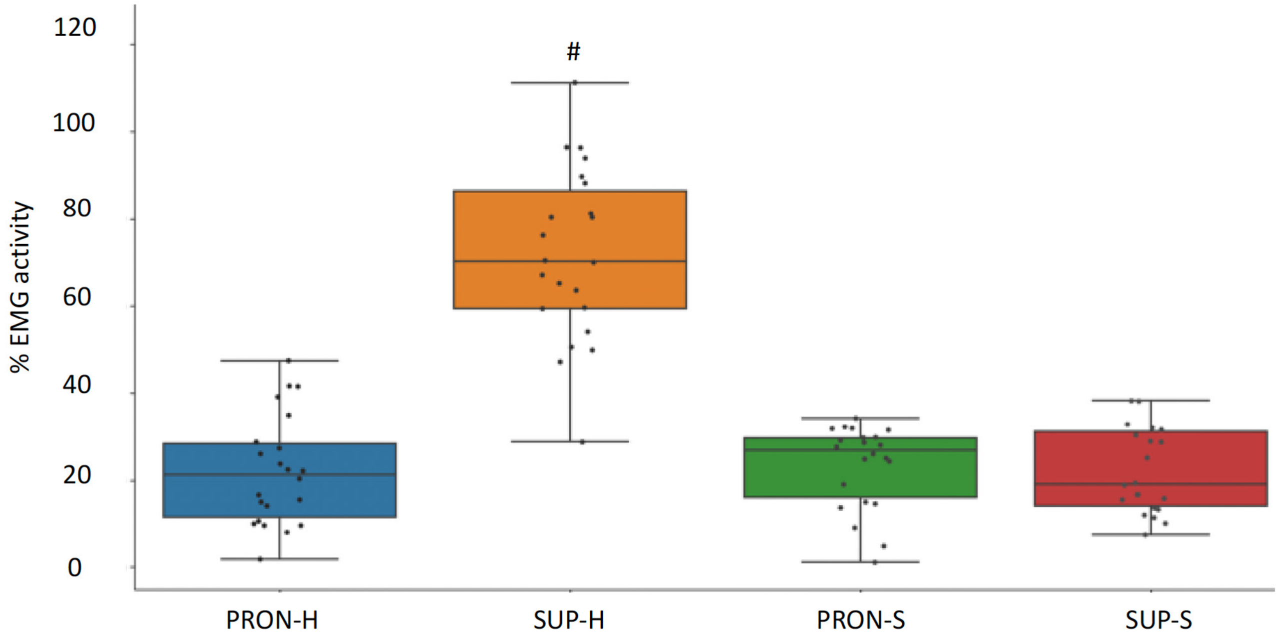

Figure 5. Boxplot and all individual values of ER (extensor carpi radialis) electromyographic activity (%EMG) during the conditions pronated forearm with handle (PRON-H); supinated forearm with handle (SUP-H); pronated forearm with standard padded pulley strap (PRON-S); supinated forearm with standard padded pulley strap (SUP-S).
 # higher than all other conditions p<0.05

For ER EMG activity, there was an effect of grip ($F2.15,45.17 = 58.4$, $p<0.001$) (Figure 5). There was greater ER activity in the SUP-H condition compared to the PRON-H (Cohen's d = 2.94, CI: 2.23, 3.94, $p<0.001$), PRON-S (Cohen's d = 3.06, CI: 2.34, 4.09, $p<0.001$) and SUP-S condition (Cohen's d = 2.00, CI: 4.41, 2.80, $p<0.001$).

Regarding the number of maximum repetitions there was also an effect of grip ($F3.63 = 26.5$, $p<0.001$) (Figure 6). Participants performed fewer repetitions in the SUP-H condition compared to the PRON-H (Cohen's d = -1.42, CI: -2.16, -0.83, $p<0.001$), PRON-S (Cohen's d = -2, 46, CI: -3.41, -1.77, $p<0.001$) and SUP-S (Cohen's d = -1.88, CI: -2.73, -1.23, $p<0.001$). In addition, the number of repetitions was lower in the PRON-H condition compared to the PRON-S condition (Cohen's d = -1.11, CI: -1.84, -0.50, p = 0.009).

DISCUSSION

Our study aimed to investigate the effect of forearm position on muscle activation during the triceps push-down exercise. Our main findings revealed that when using the same absolute load, there was greater recruitment of the triceps brachii in the supinated forearm with handle condition compared to the pronated condition and conditions using a standard padded pulley strap. Our study's findings also showed that the pronated forearm with handle condition resulted in higher EMG activity for the flexor carpi radialis muscle, compared to the other exercise conditions. Conversely, the supinated handle condition resulted in higher EMG activity for the extensor carpi radialis muscle. Furthermore, our results revealed that participants performed fewer repetitions of the triceps push-down exercise in the supinated forearm with handle condition, compared to the other three conditions.

Our initial hypothesis was that a supinated forearm position would show higher EMG activity for triceps brachii and our findings support this for thiceps brachii long head in the handle condition. A possible explanation for this result is a moment arm reduction in the pronated position. In pronation, the head of the radius turns against the lateral side of the ulna at the proximal radioulnar joint, causing the body of the radius to cross the ulna. As a result, the distal part of the radius is approximately 1.08 mm more proximal in this position (Epner et al., 1982), which reduces the moment arm and, consequently, the external torque. However, in the strap condition, the external load (i.e., strap) is located more proximally to the distal part of the radius, which can decrease this moment arm effect caused by pronation. This explains the lack of effect of forearm pronation on muscle activity in the strap condition. The difference

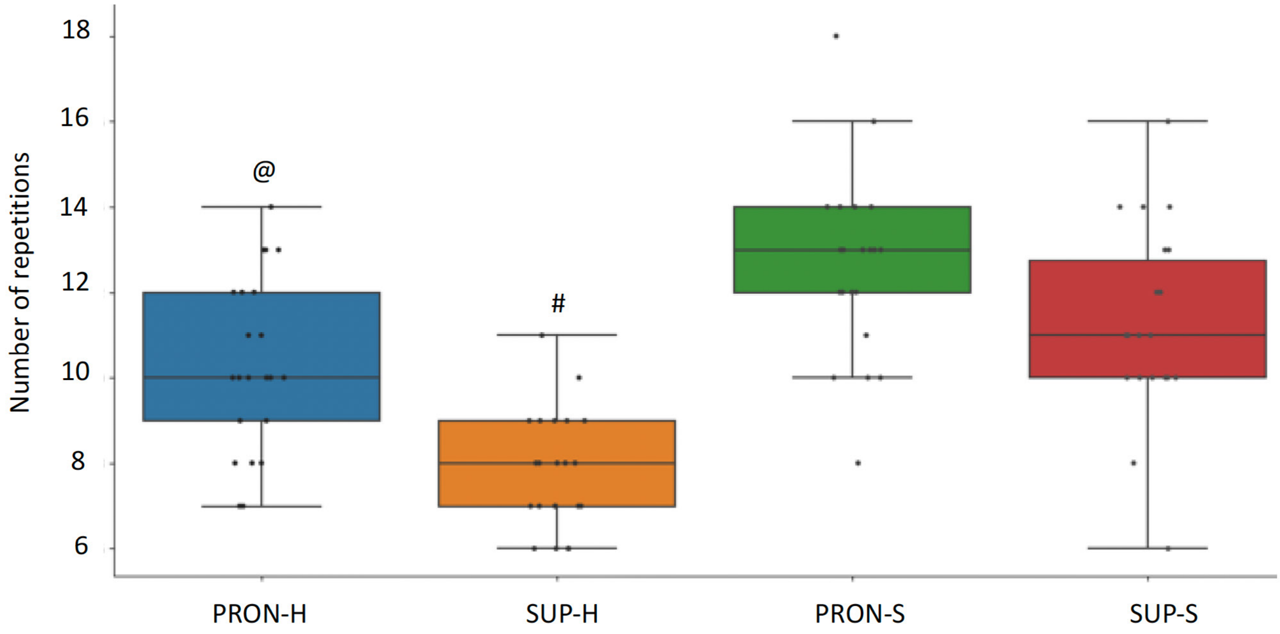

Figure 6. Boxplot and all individual values of the number of maximum repetitions during the conditions pronated forearm with handle (PRON-H); supinated forearm with handle (SUP-H); pronated forearm with standard padded pulley strap (PRON-S); supinated forearm with standard padded pulley strap (SUP-S).
 # lower than all other conditions $p<0.05$
@ lower than PRON-S condition $p = 0.009$

in triceps brachii long head activity between pronated and supinated grips may also be attributed to the involvement of the carpal flexor and extensor muscles. These muscles originate from the medial and lateral epicondyles of the humerus and cross the elbow joint, implying that they could influence elbow movement. Previous studies showed that the carpi flexor muscles can contribute to stabilization of elbow joint (Davidson et al., 1995; Hsu et al., 2008; Otoshi et al., 2014). Therefore, it is plausible that in the pronated with handle condition, the carpal flexors were recruited to prevent a carpal extension, which, in turn, affected the extension of the elbow and the triceps brachii long head EMG. Conversely, in the supinated with handle condition, the carpal extensors were recruited to prevent carpal flexion, which, in turn, possibly affected the elbow extension as well. Since the carpal flexors have greater volume and strength compared to the carpal extensors (Salonikidis et al., 2011), it is likely that the carpal flexors exert a more substantial influence on elbow extension, thus explaining the reduced demand on the triceps brachii long head in this condition. The EMG results of the carpal flexors and extensors muscles help to support this assumption. For the conditions with standard padded pulley straps (i.e., PRON-S and SUP-S), the external load was located superiorly to the wrist joint. As a result, there was no torque for flexion or extension of the wrist and, consequently, there was no need to recruit the flexor or extensor carpi muscles to counteract any external torque at the wrist. Therefore, in the conditions where there is no torque in the wrist joint (i.e., PRON-S and SUP-S), the recruitment of carpal flexors and extensors was reduced. As a result, they did not contribute to elbow extension, leading to a similar recruitment of the triceps regardless of forearm position.

Regarding the triceps brachii lateral head, although its activity was slightly higher in the supinated grip (80.7%) compared to the pronated grip (77.1%), the difference was not significant. This result is consistent with Bressel et al., (2001) study, which found no significant difference in the triceps lateral head activity with grip changes. This may suggest that the different heads of the triceps brachii function independently, meaning that one head may be more active than another in a particular joint position (as previously reported by Ali et al., 2015 and Hussain et al., 2020). In addition, Kholinne et al., (2018) demonstrated that at 0 degrees of shoulder extension (the same position used in our study), the triceps brachii long head exhibits greater activity and force production than the lateral and medial heads, which supports our findings that only the triceps brachii long head displayed a significant difference in electrical activity between the two grip positions.

Furthermore, our results revealed fewer repetitions performed with a supinated forearm position with handle compared to other conditions, suggesting an increase in difficulty level for triceps push-down exercise in this forearm position. Thus, the supinated forearm possibly provided a greater training stimulus to the triceps brachii due to less participation of the wrist flexors in this position. Also, the number of repetitions was smaller for the pronated position with handle compared to the pronated with strap. This finding may be explained by the difference in the length of the moment arm between the handle and strap conditions. Specifically, the perpendicular distance between the resistance (which is in the hand) and the elbow was greater in the handle conditions than in the strap condition. As torque is the product of strength and moment arm length, the greater moment arm length in the handle condition resulted in a larger torque required to perform the exercise. This increased torque demand could have contributed to the fewer repetitions performed in the pronated handle condition compared to the pronated strap condition.

This research has some limitations, such as, the changes in myoelectric activity were observed acutely, which does not necessarily indicate that the change in grip will cause a difference in strength gain or hypertrophy after a longitudinal training program. Also, the EMG analysis (RMS) was performed considering the whole signal (i.e. all repetitions), without considering possible differences in behavior that may occur along the series of repetitions as previous study reported (Fujita et al., 2020). Also, we did not perform separate analyzes between trained and untrained individuals. Since we used the same absolute load for all conditions (80% of the pronated condition with handle), it is important to acknowledge that the intensity may have varied between tests. In certain instances, the intensity may have been higher for some conditions (e.g. SUP-H) than others (e.g. PRON-H). Finally, although we tried to control the speed of movement using a metronome, the angular speed during repetitions was not measured. Overall, our study suggests that the position of the forearm during the triceps push-down exercise has a significant impact on the recruitment of specific muscles and overall exercise performance, providing valuable insights into the effects of forearm position on muscle activation during the triceps push-down exercise. These findings can aid exercise prescriptions for individuals looking to target specific muscles in their upper body workouts.

DISCLOSURE OF FUNDING

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