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Title Page:

VARIATIONS IN REPETITION DURATION AND REPETITION NUMBERS INFLUENCES MUSCULAR ACTIVATION AND BLOOD LACTATE RESPONSE IN PROTOCOLS EQUALIZED BY TIME UNDER TENSION.

Brief running head : REPETITION DURATION AND REPETITION NUMBERS AND MUSCULAR ACTIVATION AND BLOOD LACTATE RESPONSE.

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Abstract:

The aim of this study was to investigate the impact of protocols equalized by the time under tension (TUT), but composed of different repetition durations and repetitions numbers, on muscle activation and blood lactate concentration. Twenty-two males with previous experience in resistance training performed two training protocols (A and B) with the Smith machine bench press exercise, both with 3 sets, 3 minutes rest, and 60% of one repetition maximum (1RM). Protocol A consisted of 6 repetitions with a 6s repetition duration for each repetition, while in Protocol B the subjects performed 12 repetitions with a 3s repetition duration for each repetition. Muscular activation was measured in the anterior deltoid, pectoralis major, and triceps brachii muscles while performing the two protocols and the normalized root mean square of the electromyographic signal (EMGRMS) was calculated for each set. Blood lactate concentrations were measured during and up to 12 minutes after the completion of each protocol. The results showed that the EMGRMS of all muscles increased during the sets and was higher in Protocol B when compared to Protocol A. Likewise, blood lactate concentrations also increased throughout the sets and was higher in Protocol B both during and after the completion of each training session. The data obtained in this study show that training protocols conducted with the same TUT, but with different configurations, produce distinct neuromuscular and metabolic responses, so that, performing higher repetition numbers with shorter repetition durations might be a more appropriate strategy to increase muscle activation and blood lactate concentration.

Keywords: Time under tension. Electromyography. Blood lactate. Repetition number. Repetition

duration.

INTRODUCTION

The time under tension (TUT) has shown to be able to alter neurophysiological, hormonal, and metabolic responses (8, 18, 35), as well as to influence the strength gains and muscle hypertrophy caused by resistance training (35, 38). During resistance training, the TUT can be structured by manipulating different training variables, such as the repetition duration (time spent for the performance a concentric and eccentric muscle action) and the repetition numbers to complete the set (36, 37). Considering that these variables are often manipulated in resistance training protocols (2, 39), it would be relevant to understand the effects of performing training protocols with the same TUT, but structured with different repetition durations and repetition numbers.

The neuromuscular activity during resistance training protocols have often been evaluated by recording electromyographic activity (EMG) (8, 15, 33, 35, 36). To the best of our knowledge, only the study of Tran and Docherty (36) has analyzed EMG responses provided by different training protocols equalized by the TUT. For one of the training protocols studied by these authors, the subjects performed 3 sets of 10 repetitions with a repetition duration of 7s, while in the other experimental situation, the same subjects performed 3 sets of 5 repetitions with a repetition duration of 14s, totaling a TUT of 210s in both situations. Maximum voluntary isometric contractions were evaluated for maximal strength and muscle activation through the amplitude of the EMG signal before and after two different training protocols. Tran and Docherty (36) reported similar reductions in muscle activation for both experimental conditions; however, the protocol that used shorter repetition durations and higher numbers of repetitions (7s and 10 repetitions, respectively) produced a greater reduction in the maximal force after the training session. Although the authors manipulated the repetition duration and repetition numbers while keeping TUT equal, the EMG data was only collected before and after each experimental situation in an attempt to provide information about possible fatigue mechanisms. Collecting EMG activity during the actual training session could contribute to a better understanding of the muscle activation obtained throughout the exercise and provide insights about the chronic effects of resistance training (15, 32, 33, 35). In this sense, further studies should also investigate EMG responses during different protocols equalized by TUT.

Another aspect that should be considered is that Tran and Docherty (36) investigated two protocols with repetition durations of 7s and 14s, respectively, whereas in general, shorter repetition durations than 7s are recommended for resistance training emphasizing muscle hypertrophy (2, 39). Therefore, information about the effects of different protocols equalized by TUT, but involving lower repetition durations (shorter than 7s) still represent a gap in the resistance training literature.

Research that has manipulated the repetition duration and number of repetitions have also shown that the change of these variables alters other physiological responses, such as blood lactate concentrations (27, 29, 35, 38). It has been suggested that increasing the repetition duration, without changing the repetition numbers, could increase the metabolic response provided by resistance training (27, 38). In addition, it has also been reported that the repetition numbers per set is important in determining metabolic stress (29). However, when analyzing the training protocols which manipulated both repetition duration and repetition numbers, no differences in blood lactate concentrations were observed (7). It should be noted that the experimental designs used in these aforementioned studies did not equalize the protocols based on TUT.

Therefore, the purpose of the present investigation was to compare the muscle activation and blood lactate responses of two resistance training protocols composed of different repetition durations and repetition numbers, but equalized by TUT.

METHODS

Experimental Approach to the Problem

This study used a crossover design to examine the electromyographic and metabolic responses of resistance training protocols differentiated by repetition duration (3:3 and 1.5:1.5s) and repetitions numbers (6 and 12). Each volunteer attended the laboratory on 4 different days (Experimental Sessions 1 through 4) separated by at least 48 hours. The same data collection schedule was maintained for each subject across all sessions.

Subjects

Twenty-two males with weight training experience and aged between 18 and 30 years (mean ± SD: age 23.47; ±3.44 years; height 1.77; ±0.08 m; body mass 76.79; ±10.32 Kg; 1RM 92.95; ±17.16 Kg) participated in this study. The inclusion criteria for participation were (a) currently weight training continuously for at least 6 months before the start of the study; (b) no functional limitations with regard to performing the 1RM test or the training protocols; and (c) the ability to lift a weight corresponding to their own body mass on the 1RM Smith machine bench press. Subjects were informed about the study objectives, procedures, and risks and freely signed an informed consent form. The local ethics committee of the university approved this study, which complied with international standards. The subjects' training routines were modified during the data collection period, in order to avoid performing exercises that use the anterior deltoid, pectoralis major, or triceps brachii muscles 48 hours prior to sessions. Additionally, each subject was instructed not to do any physical activity immediately prior to the testing sessions and to maintain the same dietary practices before each session.

Procedures

Experimental Sessions 1 and 2

After assessing anthropometric measurements, subjects were positioned on the bench of the Smith press machine and hand and head positions were standardized as well as the range of motion. Subjects then performed ten repetitions without any additional weight added to the bar. Subsequently, subjects performed the 1RM test for the Smith machine bench press exercise. The 1RM test was performed during the first and second sessions to familiarize the subjects with its procedures and to determine the weight for the following sessions. The test began with an eccentric muscle action by lowering the bar to the sternum, followed by a concentric muscle action, determined by the extension of the elbows. 1

RM was determined within a maximum of 6 attempts, with 5 min rest periods between each attempt. Averages of 4.4 ± 1.0 and 3.5 ± 0.8 attempts were necessary to determine the 1RM performance for experimental sessions 1 and 2, respectively. As the last procedure of experimental sessions 1 and 2, participants were also familiarized with the use of the metronome (60 or 120 beats·min^{-1}) by randomly performing the training protocols to be implemented during experimental sessions 3 and 4.

Experimental Sessions 3 and 4

An initial pilot study was conducted to test the feasibility of the two training protocols. The protocols consisted of 3 sets at 60% 1RM, and 3 min rests between sets. In Protocol A, subjects completed each set of 6 repetitions with a 6s repetition duration (3s concentric: 3s eccentric), while in Protocol B the subjects perform each of 12 repetitions with a 3s repetition duration (1,5s concentric: 1,5s eccentric). Since we aimed to maintain the protocols configurations so that the variables above complied with recommendations for strength training for muscle hypertrophy (2, 39), neither of the protocols took subjects to momentary muscle failure during any of the sets.

An electrogoniometer was positioned on the subjects elbow, and electrodes were fixed to the anterior deltoid, pectoralis major and triceps brachii muscles as part of the first procedure during experimental sessions 3 and 4. The skin was marked using a semi-permanent pen to reposition the electrogoniometer and electrodes during each testing session by the same researcher. After the electrodes and the electrogoniometer were fixed and the subjects rested in a seated position for 10 min, the first blood sample was collected to obtain resting blood lactate concentrations. The remaining blood samples were collected from the earlobe 1 minute after each set of the training protocols and every 3 minutes up to 12 minutes after the completion of the training protocols. Electromyographic activity was recorded while performing each set of the training protocols.

More specifically, a calibrated electrogoniometer (NORAXON, USA) was fixed on the right elbow of participants using double-sided adhesive tape and elastic bands. Once stored, the electrogoniometer raw data were converted into angular displacement data and filtered through a 4th-order Butterworth low-pass filter with a cut-off frequency of 10 Hz. The electrogoniometer was also used to determine the elbow range of motion. Additionally, muscle action and repetition duration were determined through the angular displacement time. The duration of each muscle action was comprised of the time spent between the maximum (elbow flexion) and minimum (elbow extension) angular positions, thus the eccentric muscle action duration corresponded to the period between the minimum and maximum angular position, while the concentric muscle action duration corresponded to the maximum and minimum angular positions.

The surface electromyography procedure (Biovision, Wehrheim, Germany) followed the recommendations of Hermens et al. (21). Bipolar surface electrodes (Ag/AgCl) were placed parallel to the muscle fibers on the subjects right anterior deltoid, pectoralis major (sternal portion) and triceps brachii (long head portion) muscles. The skin area was shaved and cleaned with alcohol and a cotton pad prior to placing the electrodes. The electrodes were placed in pairs, 2 cm apart from their centers at the point of the greatest muscle area. The ground electrode was fixed at the olecranon.

The electromyographic data acquisition was amplified 500 times. After stored, these data were filtered (2^{nd}-order Butterworth band-pass filter of 20-500 Hz) and rectified (full-wave) to calculate the signal amplitude through the root mean square electromyography (EMG_{RMS}). Before commencing each experimental session, subjects were asked to perform two repetitions on the Smith machine bench press exercise at 60% 1RM, using a different repetition duration (4s; 2s concentric : 2s eccentric) to be used as reference for the normalization of the subsequent measurements. The EMG_{RMS} were determined for each concentric or eccentric action (31), and the average of the two actions were determined for each muscle group (normalization test). This procedure is in accordance with recommendation of Allison et al. (1) for dynamic contractions. Finally, the mean set EMG_{RMS} of both concentric and eccentric muscle actions obtained during the protocols was calculated, and these values were divided by the respective concentric and eccentric reference values previously described, generating the normalized EMG_{RMS} per set. The electrogoniometer was used to separate the muscle actions in all the situations mentioned above.

The electromyographic and electrogoniometer signals were synchronized and converted using an A/D board (Biovision, Wehrheim, Germany) and sampled at a frequency of 1,000 Hz. Appropriate software (DasyLab 11.0, Measurement Computing, MA, USA) was used to record and treat the data.

Blood samples were collected from a puncture to the subjects left earlobe using sterile disposable lancets. The earlobe was cleaned with neutral soap and water and then sterilized with 70% alcohol before puncturing. A 30 µl sample of blood was collected into heparinized capillary tubes, which were transferred into other tubes containing 60 µl of 1% sodium fluoride and then stored in a refrigerator maintained at a temperature of -20º C. Subsequently, the samples were thawed and analyzed in duplicates on the Yellow Springs Sport 1500 Lactate Analyzer device (Yellow Springs, OH, USA).

Statistical analyses

The normality and homogeneity of variances were verified using Shapiro- Wilks and Levene tests, respectively. These tests were performed using the Statistical Package for the Social Sciences (SPSS 20.0). The normalized EMG_{RMS} showed significant deviations from normality, therefore, the median was used as an indicator of central tendency, and the quartile indicated the dispersion of the normalized EMG_{RMS} across experimental sessions. A nonparametric procedure (ANOVA- type statistics) suggested by Brunner et al. (4) and Brunner and Langer (5) was used to check the response of the normalized EMG_{RMS} during the training protocols for the main effects of Protocol and Sets, as well as the interactions between these factors. The ANOVA-type statistics were performed using package nparLD in R software. Additionally, a post hoc Dunn's test was used to identify the differences reported in the nonparametric procedure. This procedure was performed using R software. The Intraclass Correlation Coefficient ($ICC_{[3,k]}$) of the concentric and eccentric EMG found in the normalization test of Experimental Sessions 3 and 4 was calculated; these inter-session values were 0.93 and 0.95 for the anterior deltoid; 0.87 and 0.91 pectoralis major; 0.81 and 0.77 for the triceps brachii, respectively. In addition, partial eta squared (η_p^2) values are reported to reflect the magnitude of the differences among each treatment (small = 0.01; medium = 0.06; and large = 0.14) (11).

A two-way (Protocol × Time) ANOVA with repeated-measures assessed lactate concentrations during and after the training (STATISTICA 7.0). Normality and homogeneity of variances were verified using Shapiro-Wilks and Levene tests, respectively. When necessary, a post hoc Tukey HSD test was used to identify the differences reported in the ANOVAs. Finally, paired-sample t-tests were used to compare repetition durations, TUT (concentric and eccentric) and ranges of motion. Probability was set at $p \leq 0.05$ for statistical significance for all tests.

RESULTS

With regard to the concentric normalized EMG_{RMS} data, ANOVA-type statistics indicated a significant main effect for protocol in the anterior deltoid ($H_1 = 48.06$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.63$), pectoralis major ($H_1 = 49.25$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.76$), and triceps brachii ($H_1 = 31.54$, $p = 0.0001$, power = 0.99, $\square_p^2 = 0.52$), so that the Protocol B showed higher muscle activation in all comparisons (Figure 1). Also, significant effects were observed for the sets in the anterior deltoid ($H_2 = 8.66$, $p = 0.0003$; power = 1.00, $\square_p^2 = 0.52$), pectoralis major ($H_2 = 17.20$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.71$), and triceps brachii ($H_2 = 5.21$, $p = 0.005$, power = 1.00, $\square_p^2 = 0.55$). The post hoc analysis results indicated the occurrence of an increase in muscle activation across the sets in all three muscles studied. Dunn's test identified differences between the first and third sets in the anterior deltoid and triceps brachii muscles, while differences were observed in concentric normalized EMG_{RMS} data between all sets in the pectoralis major. No significant interactions (protocol x sets) were observed for the anterior deltoid ($H_2 = 1.61$, $p = 0.20$), pectoralis major ($H_2 = 2.45$, $p = 0.08$) and triceps brachii ($H_2 = 1.72$, $p = 0.18$).

Figure 1 (here)

Regarding the eccentric normalized EMG_{RMS} data, ANOVA-type statistics indicated a significant main effect for protocol in the anterior deltoid ($H_1 = 15.35$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.65$), pectoralis major ($H_1 = 81.27$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.77$), and triceps brachii ($H_1 = 16.96$, $p = 0.0001$, power = 0.82, $\square_p^2 = 0.30$). Similarly to concentric normalized EMG_{RMS} data, Protocol B also showed higher muscle activation in all comparisons performed for the eccentric normalized EMG_{RMS} data (Figure 2). Also, significant effects were observed for the sets for the anterior deltoid ($H_2 = 11.98$, $p = 0.001$; power = 0.99, $\square_p^2 = 0.45$), pectoralis major ($H_2 = 21.43$, $p = 0.0001$, power = 1.00, $\square_p^2 = 0.75$), and triceps brachii ($H_2 = 6.84$, $p = 0.001$, power = 1.00, $\square_p^2 = 0.58$). The post hoc analysis results indicated the occurrence of an increase in muscle activation across the sets in all three muscles studied. Dunn's test verified that the first and second sets were different from the third set in anterior deltoid. In the triceps brachii, differences were verified between the first and second sets, whereas differences were observed in eccentric normalized EMG_{RMS} between the all sets in the pectoralis major (Figure 2). No significant interactions (protocol x sets) were observed for the anterior deltoid ($H_2 = 3.13$, $p = 0.21$), pectoralis major ($H_2 = 2.43$, $p = 0.08$) and triceps brachii ($H_2 = 3.00$, $p = 0.07$).

Figure 2 (here)

The main effects of protocol and set were significant with regard to blood lactate concentration. In addition, repeated-measures ANOVA indicated that a significant interaction effect was observed between protocol and time ($F_{7,133} = 26.97$; $P < 0.001$; power = 1.00, $\eta_p^2 = 0.59$). Figure 3 shows the blood lactate concentrations for different training protocols. Post hoc analysis indicated higher blood lactate concentrations for Protocol B in all times, except in the pre-exercise condition. In addition, the blood lactate concentrations increased for both protocols throughout the sets. Tukey post-hoc analysis also indicated that blood lactate concentrations were reduced after 3 min in Protocol A and after 6 min in Protocol B.

Figure 3 (here)

As expected, Protocol B showed shorter mean repetition duration than Protocol A (3.01; ± 0.05s vs 5.94; ± 0.07s; $p < 0.001$; coefficient of variation < 1.6% for both protocols). No differences were found on the average range of motion between Protocols A and B (76.01; ± 12.01° vs 74.24; ± 12.21°, respectively; $p = 0.148$). No differences were also found on the average concentric TUT between Protocols A and B (17.54; ± 0,63s vs 17.69; ± 0.57s, respectively; $p = 0.129$). On the other hand, differences were found on the average eccentric TUT between Protocols A and B (18.19; ± 0.41s vs 18.43; ± 0.58s, respectively; $p = 0.036$), although the magnitude of the difference between means was less than 1,4%.

DISCUSSION

This study examined whether protocols with different configurations of repetition durations and repetition numbers would result in different electromyographic and blood lactate responses in resistance training protocols equalized by TUT. The results showed that the normalized EMG_{RMS} responses for concentric and eccentric actions were greater in Protocol B than in Protocol A for the anterior deltoid, pectoralis major, and triceps brachii muscles. Furthermore, normalized EMG_{RMS} response increased across the sets for both protocols. Blood lactate concentrations were also higher in Protocol B both during and after completion of the training session. The results are in agreement with the findings of Tran and Docherty (36), since these authors have shown that when there is equivalence of TUT, protocols carried out with higher repetition numbers and shorter repetition durations led to increased levels of fatigue (reduced ability to generate force), indicating a greater physiological demand during its execution.

Previous studies have analyzed muscle activation while performing resistance training protocols characterized by different repetition durations and repetition numbers (8, 30, 31). One of these studies, which manipulated only the repetition duration (8), demonstrated that increasing the repetition duration may result in a greater EMG response. However, it must be emphasized that in their investigation the repetition numbers performed in the training protocols was kept constant, thus longer repetition durations could provide a higher TUT, a factor capable of altering EMG amplitude (23, 34). On the other hand, the present study aimed to compare the EMG responses to different protocols equalized by TUT, verifying that a shorter repetition duration added to the higher repetition numbers and provoked a greater EMG amplitude. Similar results were observed in the study of Sakamoto and Sinclair (30), although the protocols performed by the subjects in that study were carried out until lifting failure (maximum repetition number) and did not allow for the equalization of TUT. By analyzing this type of information, it is possible to understand that a combination of shorter repetition duration and higher repetition numbers in resistance training protocols play an important role for increasing the muscle activation response. This statement is based on the fact that EMG amplitude was higher in protocols with shorter repetition duration and higher repetition numbers regardless of whether the set was equalized by TUT as in the present study, or not, as in the Sakamoto and Sinclair study (30). At least in part, the higher amplitude of the EMG signal in Protocol B is indicative of the occurrence of an increased recruitment of motor units (10, 23, 34), which in turn has been pointed out as an important neuromuscular response related to an increased hypertrophy adaptation and an increase in muscle strength (26, 32). However, it should be noted that other factors, such as the increased firing frequency and synchronization of motor units, may also influence the EMG amplitude (23, 34).

The increased normalized EMG_{RMS} of Protocol B can be explained by the greater peak force generation needed to accelerate the bar when higher movement speeds are produced, thus requiring greater motor unit recruitment (30). This acceleration demand could occur at the beginning of the concentric muscle action. Regarding the normalized EMG_{RMS} eccentric action, the increased response in Protocol B may be also related to the greater requirement for force production during the braking phase of the movement, which probably was greater during faster movement velocities. Similar results were reported by Sampson et al. (31) that showed shorter eccentric actions during training protocols involving the elbow flexors exercise produced a greater EMG signal amplitude when compared with longer eccentric protocols. In fast eccentric actions, it is possible that contractile mechanisms would increase the force generation due to a higher level of activation (increase in the fraction of cross-bridges formed) during the pre-activation period (3). However, it still needs to be clarified whether movement velocities similar to those carried out during Protocol B (no ballistic condition) would potentialize the neurophysiological mechanisms (pre-activation and myotatic reflex response) and consequently, EMG responses compared to Protocol A. Additionally, the fact that Protocol B resulted in twice the repetition numbers must also be considered. Although no studies have specifically examined the effects of repetition numbers on muscle activation level while carrying out resistance training protocols, it is expected that this factor could contributed to the present results of both muscle actions. It should also be noted that Harwood and Rice (19) reported that the fast movements of human limbs would benefit from a single set of activation parameters capable of generating the greatest amount of torque in the shortest possible time. Thus, it has been suggested that there is a reduction in the motor unit recruitment threshold for faster dynamic actions (19), particularly during the eccentric phase of the movement (24). Considering the need to produce faster movements in Protocol B compared to Protocol A, a possible reduction of motor unit recruitment thresholds in this situation would have promoted an additional recruitment of fast motor units, and consequently a greater EMG. However, specific additional studies are necessary to investigate these mechanisms in resistance training protocols similar to those used in the present study.

Similar to EMG measurements obtained during the training sessions, no studies were found analyzing blood lactate responses when manipulating the repetition duration and repetition numbers while equalizing TUT. In the present study, blood lactate concentrations were greater for the protocol utilizing shorter repetition durations and higher repetition numbers (Protocol B) and these higher concentrations remained higher than Protocol A for up to 12 min after the completion of the training protocol. Only one previous study examined the effects of simultaneously manipulating the repetition duration and repetition numbers on blood lactate responses, while maintaining the same relative intensity of training (%1RM). As in the study of Sakamoto and Sinclair (30), Buitrago et al. (7) compared training protocols with different repetition durations and repetition numbers to volitional lifting failure. All protocols produced similar responses, however, as mentioned earlier, the absence of the exact equivalence of TUT for the protocols may have been a confounding factor in the results of the observed metabolic response since previous studies (27, 35) have suggested that the increased TUT in resistance training protocols produces higher blood lactate concentrations.

The blood lactate responses in the present study may also be related to the mechanical characteristics of the two protocols, considering that higher maximal forces would be expected to accelerate the bar during every repetition in Protocol B (20). With the production of higher maximal forces in Protocol B, additional motor units with higher glycolytic capacities were presumably recruited (6, 17, 28), which might promote an increase in blood lactate production compared with Protocol A. This hypothesis is supported by the EMG data from the present study. Additionally, it is important to note that the realization of higher repetition numbers in Protocol B should also be taken into account, considering that some investigations have found a greater mechanical work provides a higher metabolic response (6, 12, 22).

In the current study, the actual measurement of the changes in force applied to the bar during each protocol was not possible, which may be noted as a limitation of this investigation. It is known that the torque variation in dynamic muscle actions (13), as well as changes in the acceleration of the bar may change the EMG signal (14) and blood lactate response (9). Knowledge of the changes in force during the acceleration and deceleration phases of the bar movement in the bench press exercise could result in a better understanding of changes in EMG (31) and blood lactate responses (12). Furthermore, the data indicate a large variability in the EMG_{RMS} responses (large interquartile range values), especially for Protocol B. It is possible that during Protocol B, the higher variation in muscle activation may be due to the need for greater acceleration of the bar in a shorter time period compared to Protocol A. However, variability in the EMG responses during strength training protocols has often been reported in the literature (16, 25).

In conclusion, the data obtained in this study show that training protocols equalized by TUT, but with different configurations, produce different physiological demands. Specifically, a protocol with shorter repetition durations and higher repetition numbers produced greater neuromuscular and metabolic responses compared to a different protocol with the same TUT. Nevertheless, further studies are encouraged to compare other training protocols with different numbers of repetitions and repetition durations, as well as understand the impact of these protocols in chronic training responses.

PRACTICAL APPLICATIONS

This study showed that training protocols conducted with the same TUT, but with different configurations, produced distinct neuromuscular and metabolic responses, so that, performing higher repetition numbers with shorter repetition durations might be a more appropriate strategy to increase muscle activation and blood lactate concentration.

Although both protocols resulted in increases in muscle activation and lactate across the sets, greater responses were observed in the protocol with higher repetition numbers and shorter repetition durations Therefore, considering the importance of neuromuscular responses to chronic adaptations to resistance training, coaches could opt for this type of protocol training to obtain better results.

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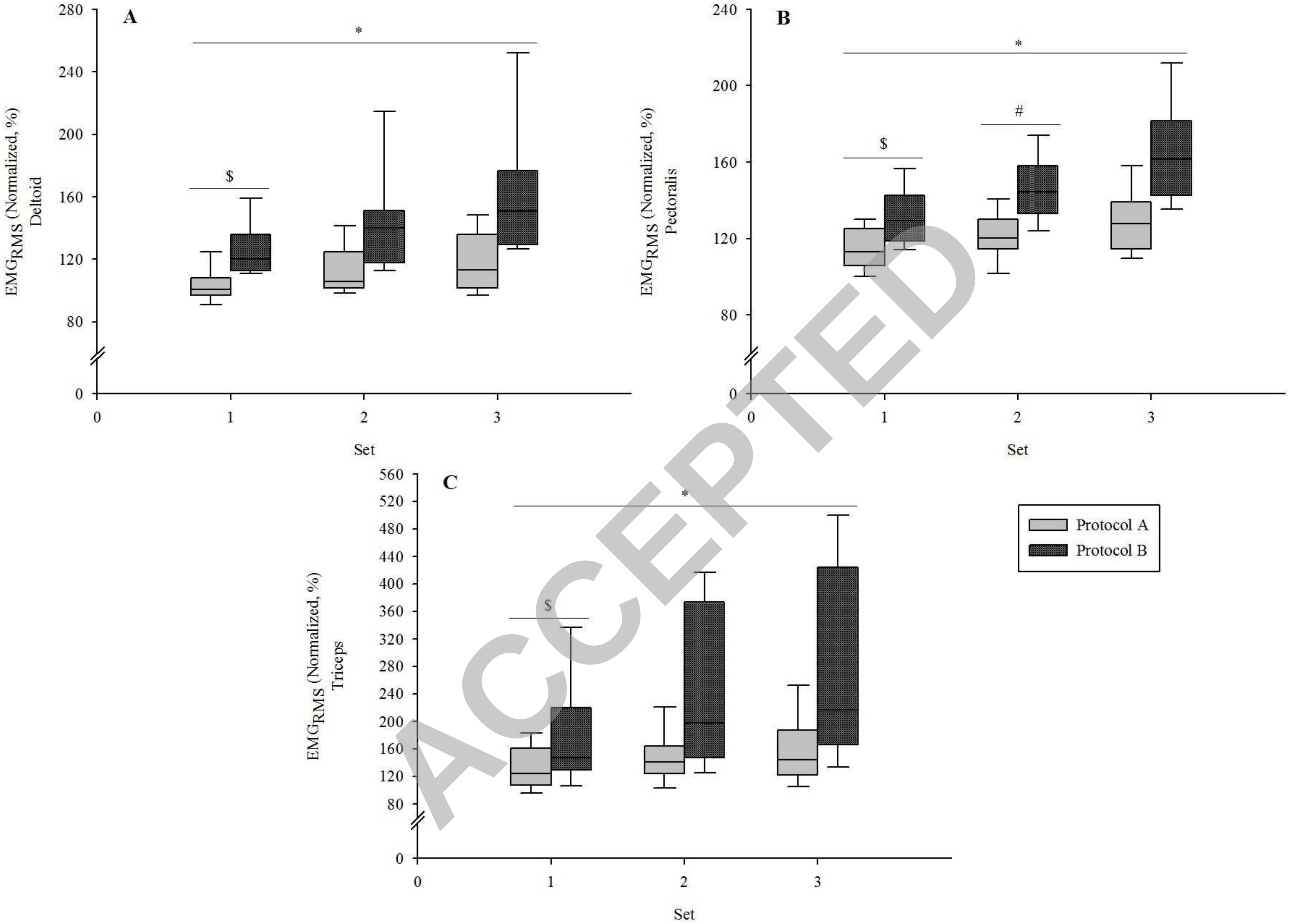
FIGURE LEGENDS

Figure 1. Median (horizontal line within the box); First Quartile and Third Quartile (lower and upper box limits); Minimum and Maximum (whiskers) concentric normalized EMG_{RMS} of the anterior deltoid (A), pectoralis major (B) and triceps brachii (C) muscles for each training protocol. * Protocol B different from the Protocol A (main effect); $ Different from sets 2 and 3 in the respective protocol; # Different from set 3 in the respective protocol; EMG_{RMS}: root mean square of electromyographic signal.

Figure 2. Median (horizontal line within the box); First Quartile and Third Quartile (lower and upper box limits); Minimum and Maximum (whiskers) eccentric normalized EMG_{RMS} of the anterior deltoid (A), pectoralis major (B) and triceps brachii (C) muscles for each training protocol. * Protocol B different from the Protocol A (main effect); $ Different from sets 2 and 3 in the respective protocol; # Different from set 3 in the respective protocol; EMG_{RMS}: root mean square of electromyographic signal.

Figure 3. Mean ± SD blood lactate concentration at rest, after each set, and up to 12 min after completing the Protocols A and B. * Different from the rest, in the respective protocol; # Protocol B different from the Protocol A, in the respective time; $ Different from the anterior moment, in the respective protocol.



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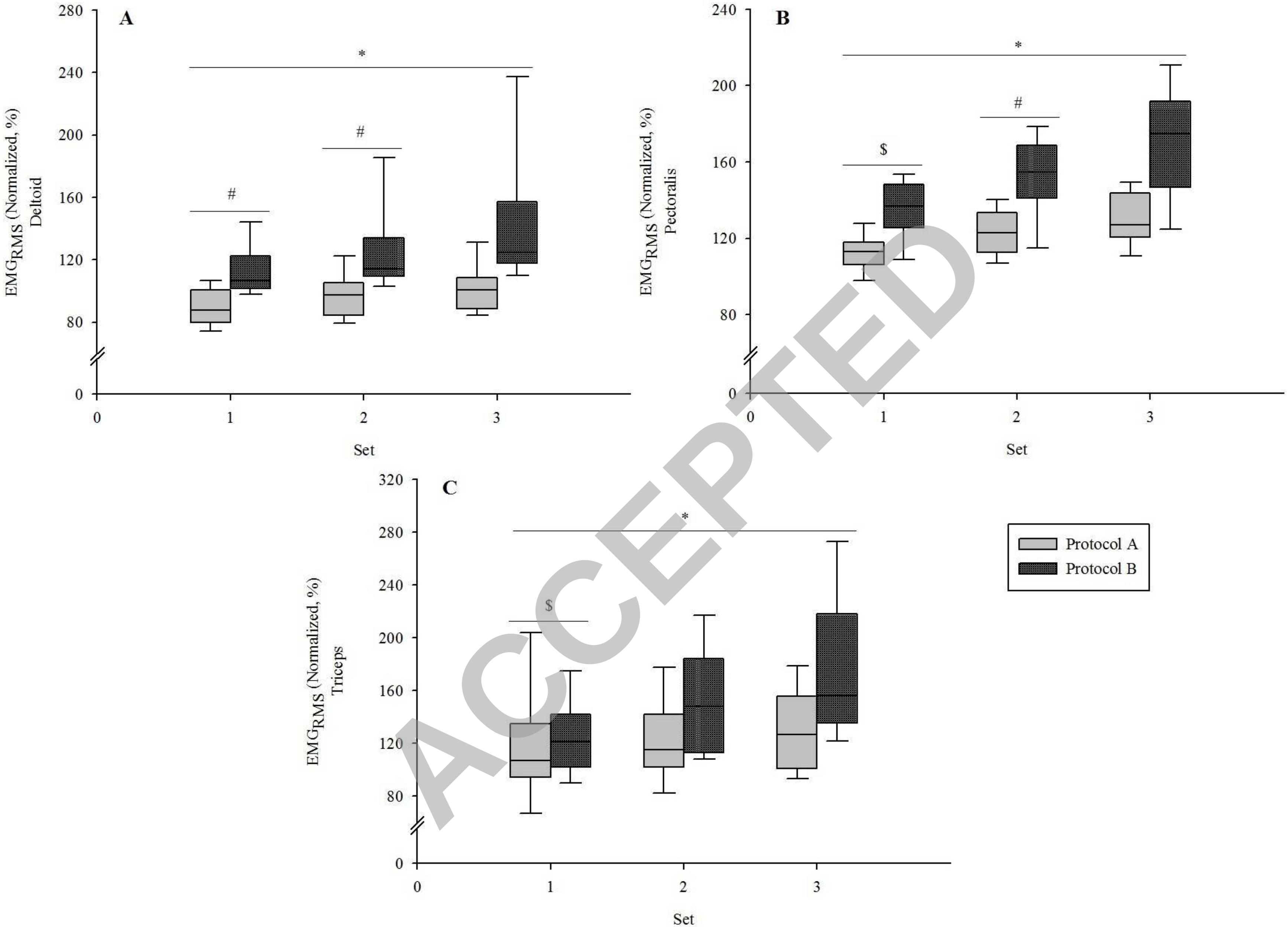

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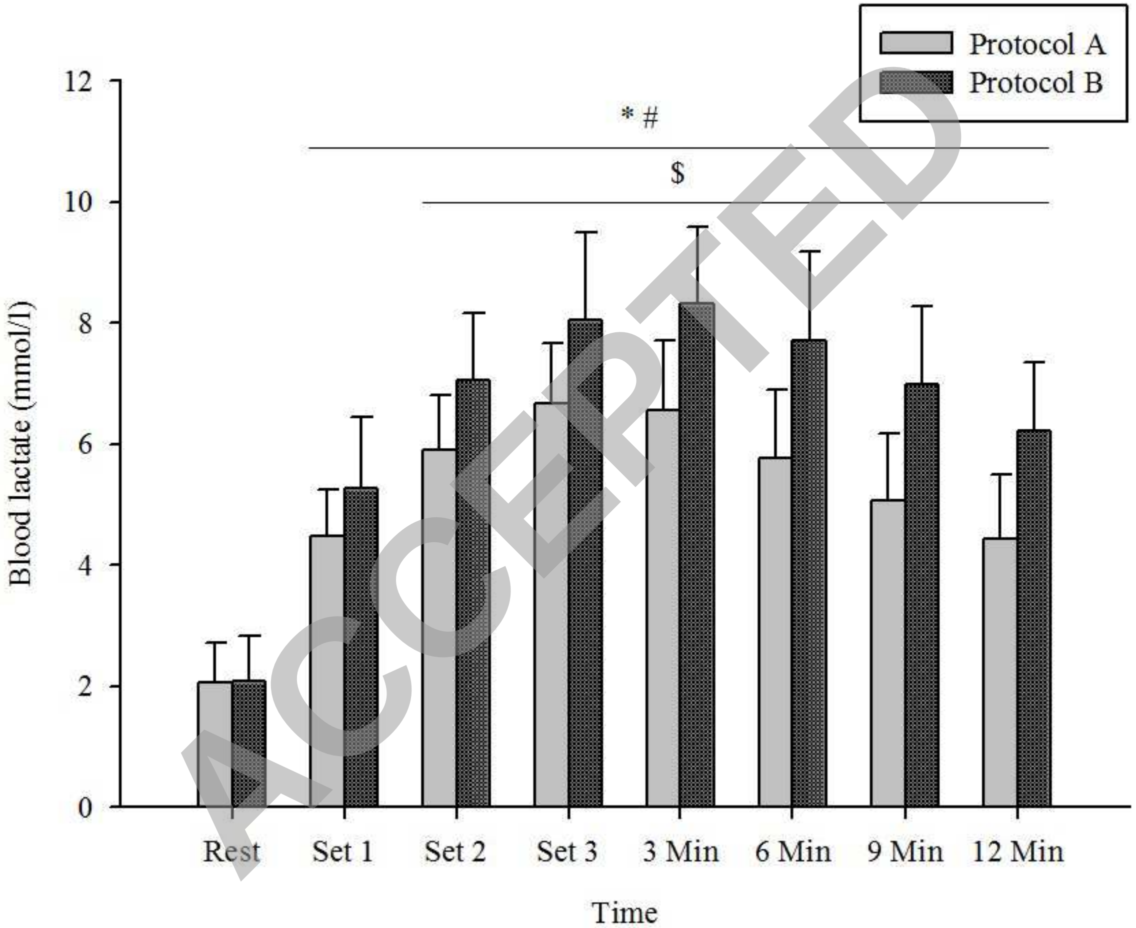

Figure 3. – Mean ± *SD* blood lactate concentration at rest, after each set, and up to 12 min after completing the Protocols A and B. * Different from the rest, in the respective protocol; # Protocol B different from the Protocol A, in the respective time; $ Different from the anterior moment, in the respective protocol.