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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Effect of shoulder position on triceps brachii heads activity in dumbbell elbow extension exercises

Daniel ALVES [1]*, Thiago MATTA [2, 3], Liliam OLIVEIRA [2, 3]

[1]Physical Education Center Admiral Adalberto Nunes, Brazilian Navy, Rio de Janeiro, Brazil; [2]Biomedical Engineering Program, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil; [3]Physical Education and Sports School, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

*Corresponding author: Daniel Alves, Exercise Sciences Research Lab, Physical Education Center Admiral Adalberto Nunes, Brazilian Navy, Avenida Brasil, 10590, 21030-001, Rio de Janeiro, Brazil. E-mail: alvesdaniel@gmail.com

ABSTRACT

BACKGROUND: Elbow extension exercises in different shoulder positions are selected to raise distinct effort levels among the triceps brachii heads. Because there are several triceps exercises, its choice is a big challenge on resistance training prescription. The present study aimed to compare the electromyographic signal of triceps brachii long and lateral heads among three different elbow ranges of motion (ROM) during two commonly prescribed elbow extension exercises: overhead dumbbell elbow extension (OD) and lying dumbbell elbow extension (LD).

METHODS: The long and lateral heads electromyographic signals were acquired from 21 resistance-trained men. One to two maximal repetitions of each exercise was performed with a 40% load of a maximal voluntary isometric contraction test. The signals of concentric and eccentric phases were divided into three equal ROMs each (initial, middle, and final).

RESULTS: Eccentric phase elicited less muscular activity than concentric in both exercises. Concentric contraction presented the same pattern during OD (long and lateral heads) and LD (lateral head). Initial and middle intervals elicited higher muscle activity than final interval. This behavior was also present in the eccentric contraction (initial demanded less activity than middle and final during both exercises).

CONCLUSIONS: Since both exercises presented similar activation patterns, the prescription of OD and LD on the same training routine should be avoided.

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Key words: Electromyography - Resistance training - Skeletal muscle - Elbow - Shoulder.

Resistance training is one of the most effective methods to increase muscle strength and volume. However, to achieve and optimize training objectives, strength coaches must consider many factors such as intensity, volume, and exercise selection.[1] Because the exercise selection plays an important role on training results,[2-4] it should be made taking also into account the mechanical characteristics such as resistance type,[5] machine features,[6] movement velocity,[7] instability conditions,[8] kinetic chain,[9] range of motion (ROM),[2, 10] and postural variations.[2, 11-13] Postural variation is an easy way to elicit different muscle activation patterns, and consequently emphasize different muscle regions.[2, 11-13]

Muscle activity during different exercises (distinct postures) is already reported for some exercises and muscles.[14, 15] Oliveira *et al.*,[2] using surface electromyography (sEMG), reported different patterns of biceps brachii activity in three common elbow flexors dumbbell exercises. In addition, the authors described distinct patterns of muscle activity among three different ROMs of concentric and eccentric phases of each exercise. The authors suggest that different shoulder positions in each exercise lead to distinct muscle lengths, explaining muscle activity variations.

As well as biceps brachii, the biarticular triceps long head length is affected by elbow and shoulder positions, whereas the other uniarticular heads (short and lateral) only by elbow angle,[16] with direct implications in the force-length characteristic of each head or torque-angle relationship of elbow extension. In practice, different elbow extension exercises (distinct shoulder positions) are selected to raise different effort levels among the triceps brachii heads. To our knowledge, triceps brachii activity characterization during different ROMs of the elbow extension exercise has not yet been reported in the literature, despite its importance in daily activities and in many sports gestures (*e.g.* tennis and volleyball serve, boxing punch, baseball pitch) that require a strong elbow extension.

Therefore, the aim of the present study was to compare the sEMG of triceps brachii long and lateral heads among three different elbow ROMs during two commonly prescribed elbow extension exercises: overhead dumbbell elbow extension (OD) and lying dumbbell elbow extension (LD). Considering the changes in load moment arm and muscle torque-angle relationship, we tested the hypotheses that different shoulder positions (exercises), contraction phases (concentric and eccentric), and ROMs could influence the triceps brachii long and lateral heads activity. It is plausible that the elbow extension with the shoulder more flexed, as in OD, should require more effort of long head (biarticular) than the less flexed shoulder position, as in LD. On the other hand, this variation is not expected for the lateral head, because it is a uniarticular muscle.

Materials and methods

Based on a sample size estimation of 20 subjects needed for a statistical power of 85% (at alpha level of 0.05), 21 males, with at least 12 months of resistance training experience (age 25.57±5.57 years, body mass 76.75±9.48 kg, and height 1.76±0.05 m) participated in the study. All participants were right handed and did not report any history of orthopedic injuries or cardiovascular diseases. They were fully informed about the possible risks and discomforts of the research and provided a written informed consent. The experiments were conducted according to the principles of the Declaration of Helsinki and were approved by the Research Ethics Committee of Clementino Fraga Filho University Hospital (44100215.6.0000.5257).

The participants executed one repetition (concentric-eccentric) of each exercise (OD and LD) using a 40% load of a 6-second maximal voluntary isometric contraction test (MVIC).[2] The 40% MVIC load was chosen, since it allowed the participants to perform no more than one or two slow speed repetitions of dumbbell elbow extension, *i.e.* similar to one or two repetition maximum. In practical situations, the load is set in accordance with the exercise; however, the use of a fixed load was required to compare the neuromuscular activity among the two protocols. Dumbbell elbow extension exercises (OD and LD) were randomly executed (two-minute interval among exercises) after a three-minute rest period following the MVIC trial. The body position during the trials were:

— MVIC: seated position with the right arm leaning against the chair's backrest, the elbow at 90° and forearm at neutral position;

— OD: seated position and right shoulder flexed at 180°;

— LD: lying on supine position and right shoulder flexed at 90° (Figure 1).

The participants were instructed to perform the movements through the full elbow ROM and to avoid compensatory movements. The sEMG signal of triceps brachii long and lateral heads was acquired in all trials.

Single differential sEMG (gain: 1000, common mode rejection ratio 106 dB, and bandwidth of 10-500 Hz) and elbow joint angle were synchronously sampled at

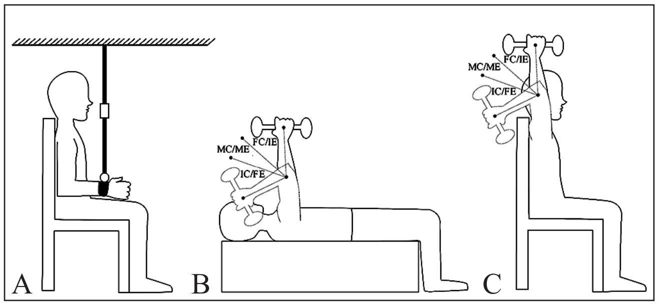

Figure 1.—Schematic illustration: A) maximal voluntary isometric contraction test; B) lying dumbbell elbow extension; C) overhead dumbbell elbow extension. Dotted lines correspond to movement partition into six equal ROMs: initial concentric (IC), middle concentric (MC), final concentric (FC), initial eccentric (IE), middle eccentric (ME), and final eccentric (FE).

1 kHz by a 16 bits A/D converter (4.8 kHz and ±10 V dynamic range; Spider8, Hottinger Baldwin Messtechnik, Darmstadt, HE, Germany). Elbow joint angle was estimated from changes in the direction of the uniaxial accelerometer (bandwidth 0-200 Hz and sensitivity 315 mV/g; ADXL202E, Analog Devices, Norwood, MA, USA), with respect to gravity acceleration vector. The accelerometer was fixed to the subject's wrist and with its normal axis orientated vertically. Two circular Ag-AgCl pre-gelled electrodes (20-mm diameter and 20-mm inter-electrode distance) were positioned on triceps brachii long and lateral heads according to SENIAM recommendations, after skin preparation.[17] A 200 kgF full-scale load cell (Kratos Dinamômetros, Cotía, Brazil) was used to measure the peak force during the MVIC trial.

The concentric and eccentric phases of the sEMG signal of triceps brachii heads were divided into three equal ROMs (initial, middle, and final) (Figure 1), according to the individual elbow joint range. The sEMG root mean square (RMS) was estimated for each ROM and phase. The main comparisons made of triceps brachii long and lateral heads $RMS_{\%}$, were among phases (same exercise, head, and ROM), among ROMs (same exercise, head, and phase), and among exercises (same head, phase, and ROM). To avoid the effect of geometrical and physiological factor on sEMG data, the RMS amplitude was normalized by the maximum RMS value estimated from the MVIC trial ($RMS_{\%}$), using equation (1) with n ranging from 1000 (1 s) to 5000 (5 s). A blind examiner performed all analyses.

$$RMS_{c;p} = \sqrt{\frac{1}{pe - ps + 1}\sum_{n=ps}^{pe} x^2[n]} \quad (1)$$

where $x[n]$ is the raw sEMG, c and p stand for contraction phase (concentric or eccentric) and ROM (1: initial, 2: middle, or 3: final), respectively, and n is the sample number ranging from the beginning (ps) to the end of the movement phase (pe).

After Shapiro-Wilk test confirmed the data distribution normality, dependent *t*-tests compared elbow extension/flexion cycles duration and joint range among exercises. Additionally, two separate two-way ANOVAs were applied to compare changes in $RMS_{\%}$ amplitude of each triceps brachii head (exercises x ROMs - for concentric and eccentric phases; and phases x ROMs - for OD and LD). HSD Tukey's *post-hoc* test was used to identify significant differences among means with a P value set to 0.05 (Statistica, StatSoft Inc., Tulsa, OK, USA).

Results

The maximal force during the MVIC trial (22.06±3.29 kg) represented 29.00±4.87% of participants body mass.

No significant changes were observed for joint amplitude between exercises. The eccentric phase of the OD exercise was performed with a statistically longer duration (P=0.002) than concentric. There was no time difference between the phases of the LD (Table I).

As can be seen in Figures 2 and 3, concentric phases elicited higher muscular activity than eccentric for both exercises, mainly for the long head. During the concentric phase of both exercises, initial and middle ROMs elicited higher triceps activity than the final interval, especially for the lateral head. The same pattern can be seen in the eccentric contraction, as the initial concentric corresponds to the same ROM of the final eccentric (IC/FE in Figure 1), final and middle ROMs presented increased activity when compared to initial.

Comparing the exercises (Figures 2, 3), there were no RMS% statistical differences between them, except for the long head during the initial eccentric, with less activity for OD than LD.

Discussion

Although some studies investigated the sEMG activity during resistance training exercises [6, 8, 15, 18] and others besides that compared different ROMs [2, 3, 10, 12-14, 19] to our knowledge, this is the first study that evaluated the triceps brachii long and lateral heads activation levels between two usual resistance exercises using high loads. The sEMG signal of the concentric and eccentric ROMs, allowed us to detect distinct levels of muscle activity.

Table I.—*Mean and standard deviation of time duration and elbow joint range of concentric and eccentric phases of overhead dumbbell elbow extension (OD) and lying dumbbell elbow extension (LD).*

Exercise	Duration (s)		Range of motion (°)
	Concentric	Eccentric	
LD	3.14±0.78	3.75±1.13	124.07±11.54
OD	2.79±0.87*	3.84±1.27	127.28±10.42

*P=0.002 between phases.

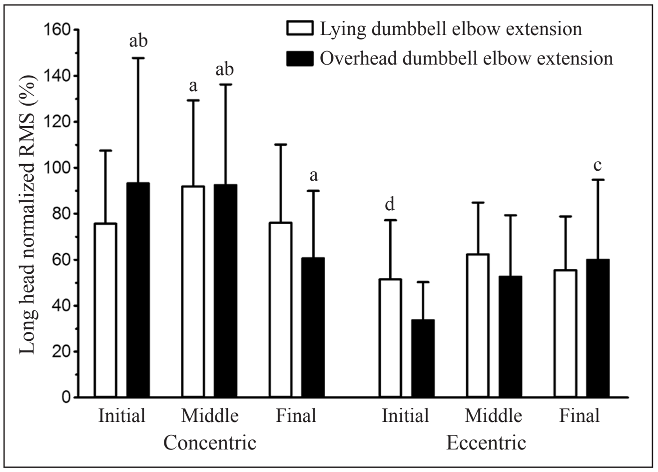

Figure 2.—Mean and standard deviation of triceps brachii long head normalized RMS ($RMS_{\%}$) of all ROMs (initial, middle, and final) of concentric and eccentric phases. Statistical differences from ($P<0.05$): a, eccentric phase (same exercise and ROM); b, final concentric (same exercise); c, initial eccentric (same exercise); d, overhead dumbbell elbow extension (same phase and ROM).

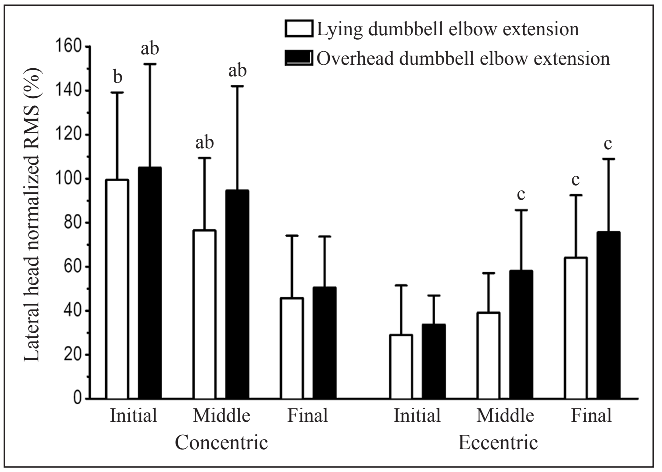

Figure 3.—Mean and standard deviation of triceps brachii lateral head normalized RMS ($RMS_{\%}$) of all ROMs (initial, middle, and final) of concentric and eccentric phases. Statistical differences from ($P<0.05$): a, eccentric phase (same exercise and ROM); b, final concentric (same exercise); c, initial eccentric (same exercise).

The MVIC test was performed with the elbow at 90° of flexion, since the maximum elbow extension torque is achieved in this position.[20] The subjects of the present study reached a mean load in MVIC of 29.00±4.87% of their body mass. In a similar MVIC protocol for the elbow flexors, the subjects reached a mean load of 43.60±7.71% of the body mass.[2] These data outcomes a flexion-extension torque relationship of approximately 66%, which is close to the values reported by Buchanan *et al.*[21] (around 60% at 90°). The load chosen for the dumbbell elbow extensions (OD and LD) were high enough to elicit a $RMS_{\%}$ around 105% for lateral head on LD exercise and the subjects could not perform more than one or two repetitions.

Lower muscle activity was detected in the eccentric phase in both triceps heads and exercises (except LD initial and final intervals of the long head and final interval of the lateral head), as expected and reported by some studies.[2, 5, 22] The concentric phase requires greater motor unit synchronicity, and consequently significantly higher sEMG amplitude than eccentric phase.[23, 24] Also, the maximum force produced by the muscle while shortening (concentric contraction) is lower than while lengthening (eccentric).[24, 25] Furthermore, higher force production on eccentric contractions has also been associated to the titin filament and its binding to calcium and actin, increasing the sarcomere stiffness.[26]

Comparing the sEMG data of different ROMs within the same phase, concentric contraction presented the same pattern during OD (long and lateral heads) and LD (lateral head). As expected, in the concentric and eccentric phases, muscle activity was less when the elbow was near full extension, where the load moment arm was minimum. This behavior was more evident for the lateral head as it is a uniarticular muscle. High variation of myoelectric activity among the 6 ROMs analyzed can be explained by the load moment arm and by the torque-angle relationship, mainly of the lateral head. This is in accordance with Murray *et al.*[27] who reported a larger variation of maximal force as a function of elbow angle for the lateral compared to the long head. This fact posits the importance of monitoring muscle activation changes throughout the total movement amplitude. According to De Luca,[28] the electromyographic analysis based on a single mean sEMG value to describe a whole movement is an important methodological limitation.

Regarding the exercises, the long head length was the key difference between LD and OD. Because the shoulder is fully flexed in OD, the biarticular head (long head) is in a longer length than in LD. Such lengthening might affect the elbow extension torque-angle relationship which has been previously reported for the shoulder in neutral position.[27, 29] Murray *et al.*[29] suggest that torque variation as a function of joint position mainly occurs because of muscle moment arm and architectural alterations. Murray *et al.*[30] demonstrated that the moment arm peaks estimated by a model [31] decreases by 25% throughout elbow extension. However, the force production capacity of the triceps brachii (mainly of the long head), when compared to elbow flexors, is relatively constant and nearly maximal along the elbow ROM, even in more flexed positions.[27] According to the authors, this is due to the relationship between the moment arm and optimal fascicle length ratio. Nevertheless, the long head force production potential, and consequently, activation pattern when lengthened (by shoulder flexion) is not clear.

Muscle force and sEMG can be correlated under certain conditions, such as isometric or non-ballistic dynamic contractions.[32] In the present study, the exercises were performed in slow velocities, resembling the above-mentioned conditions and our results showed no long head sEMG differences between the exercises, among all ROMs, except in the initial eccentric. For the lateral head, there was no statistical difference at any ROM between exercises, which was expected since it is an uniarticular muscle and its length was not changed. According to Doheny *et al.*,[29] the neural excitation level is determined by the muscle force capacity, not by the force required to perform the movement. So, as in the present study, the exercises were performed with very high loads, it is reasonable that the muscle activity did not present statistical difference between the exercises in most of the ROMs analyzed. Besides the muscle activity patterns, the mean elbow joint range and the phases duration were equal for both exercises, indicating similar muscle efforts.

The results indicate the potential of the methodology to describe muscle activity during resistance training. Therefore, other exercises should be similarly analyzed in future studies to establish guidelines for resistance training prescription. However, future studies should consider two or more visits to determine the data reliability. Nevertheless, Yang and Winter [33] reported high intraclass correlation coefficient of the muscle activation measures during submaximal isometric contractions, with the within-days coefficient of variation ranging from 8% to 10%. Another improvement could be the use of high density electromyography to provide information regarding possible nonuniform muscle activation during the exercises and also to reduce the crosstalk of medial head.[34]

Conclusions

Understanding the muscle activation among different ROMs of concentric and eccentric contractions may help strength trainers to optimize long and lateral triceps brachii heads development and performance. OD and LD are single joint exercises commonly employed in resistance training programs. Since both exercises presented similar activation patterns, the prescription of OD and LD on the same training routine should be avoided as a good strategy to provide different muscle efforts.

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