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ELECTROMYOGRAPHIC STUDY OF THE *FLEXOR* AND *EXTENSOR CARPI ULNARIS* MUSCLES IN FLEXION MOVEMENTS OF THE FOREARM

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ABSTRACT

In this work, the electromyographic (EMG) activity of the *flexor* and *extensor carpi ulnaris* muscles was studied in flexion movements of the forearm in the semipronation, supination and pronation positions with 50% maximum voluntary contraction. Ten untrained volunteers, (5M, 5F), 21 to 38 years old, were enrolled and requested to perform three serial movements in a double-pulley apparatus. The EMG signals were acquired with differential surface electrodes and digitalized by a 12 bit A/D converter board, using the AqDados software which provided numerical data as root mean square values. The results showed that both muscles were active in the conditions studied, independent of the forearm position. The *flexor carpi ulnaris* muscle was relatively less active than the *extensor carpi ulnaris* muscle in the semipronation position, but relatively more active in the supination position; both muscles showed similar activity in the pronation position. There were significant differences in the electromyographic activity among the semipronation, supination and pronation positions in both the *flexor* and *extensor carpi ulnaris* muscles, with the highest values obtained in the pronation position and the lowest in the supination position. However, there were no significant differences between the values obtained for the two muscles in the three positions. Although most reports neglect the action of the *flexor* and *extensor carpi ulnaris* muscles in flexing the elbow, these muscles cross this joint and can consequently, act on it as well as on the carpus.

Key words: Electromyography, kinesiology, upper limbs, muscles, elbow

INTRODUCTION

Electromyography (EMG) is the study of muscle function based on the analysis of electric signals produced during muscle contraction [14]. Prior to its discovery and application by Duchenne [5] and Beevor [2], muscle anatomy and physiology were based on the origin, insertion and position of the muscle in the skeleton [10]. However, although important, these characteristics are insufficient for determining the action of a particular muscle in a specific movement.

The use of electric stimulation by various authors [1,2,5,10] does not prove *per se* the involvement of muscle action in voluntary movements. To circumvent this difficulty, new techniques to confirm this action have been developed. Electromyography in particular has shown the need to review concepts about muscle activity.

Electric stimulation and the recording of electric signals from muscles during voluntary contraction are fundamental for kinesiologic and clinical studies of muscle activity, because of the amount of information they provide about muscle physiology [3]. Recording myoelectrical signals from the muscle skin surface is also frequently used in biomechanical studies such as pace analysis and calculations of the torque and force transmitted through an articulation.

A number of studies on elbow kinesiology have been reported. Yamazaki *et al.* [17] described the flexion and extension movements of the elbow-forearm complex and mentioned the action of some arm muscles, but made no reference to the flexion and extension actions of the *carpi ulnaris* muscles in the elbow joint. The *extensor carpi ulnaris* and the *flexor carpi ulnaris* muscles are responsible for the

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extension and the flexion of the hand, respectively; both muscles are also involved in adduction of the hand [8,11,13,16].

In this study, we used EMG to evaluate the activities of the *flexor* and *extensor carpi ulnaris* muscles, because their origins and insertions suggested that these muscles may be involved in flexion movements of the forearm-elbow complex. Although both muscles cross the elbow joint, classic descriptions of this anatomical region do not usually include them among the flexors of this articulation.

The action of the *flexor* and *extensor carpi ulnaris* muscles in flexion movements of the forearm was studied in the pronation, semipronation and supination positions, with 50% maximum voluntary contraction for each volunteer.

MATERIAL AND METHODS

The electromyographic activity of the *flexor* and *extensor carpi ulnaris* muscles in flexion movements of the forearm with 50% maximum voluntary contraction (MVC) was studied in 10 untrained volunteers (5M, 5F), 21 to 38 years old, with no history of disease or other alterations that could influence muscle activity.

The electromyographic signals were recorded using a 16-channel electromyograph (Lynx Tecnologia Eletrônica Ltda, Campinas, Brazil), fitted with a 12 bit A/D converter board. The apparatus was calibrated for 500 μV/division and the recording speed was 200 ms/division, which resulted in a total response time of 4 s. The filters were set at 10 Hz (low frequency) and 10 kHz (high frequency), with a gain of 100 and a sampling frequency of 1000 Hz. Signals were captured using differential surface electrodes with a 10 GΩ input impedance, at 130 dB CMRR/2 picofaraday, and a gain of 100. The recording surface was standardized at 10 mm x 10 mm x 1 mm, but no electro-conductive gel was applied. Surface electrodes were used because of their high precision and non-invasiveness [15].

All movements were done using a "double-pulley" apparatus designed for upper and lower limb muscle exercises, incorporated the modifications proposed by Sousa *et al.* [15] to provide the volunteer with greater comfort and safety.

Procedures

Initially, the skin where the electrodes were to be placed was shaved and cleaned with an alcohol-ether solution to remove fat and any substance that could interfere with the results. The volunteer received an explanation and underwent a simulation of the most adequate posture [15] for performing the exercises. The initial and final position of each movement, the execution speed and the verbal command given by the investigator to begin the exercises were also established so that the volunteer could perform the exercises within a predetermined time (4 seconds).

Each volunteer performed nine movements at free load and three repetitions at 50% of the MVC of each flexion movement of the forearm in the semipronation, supination and pronation positions. A total of ten records was obtained since the first movement was done with the forearm in the resting position.

The electromyographic signals were captured throughout the movement (4 s interval) using the AqDados software. This software transformed the action potential of the muscles into the root mean square (RMS), expressed in μV, thus providing a more accurate information on the electromyographic signals [1].

Statistical analysis

Since the distribution of the data was Gaussian, the results were analyzed using parametric tests. The differences among the electromyographic values obtained in the semipronation, supination and pronation positions for both muscles were compared using Student's *t* test. A p value < 0.05 indicated significance [12].

RESULTS

Table 1 shows the RMS values of the electromyographic activity of the *flexor* and *extensor carpi ulnaris* muscles in flexion movements of the forearm in semipronation, supination, and pronation positions with 50% MVC.

In the semipronation position, the highest activity was obtained for the *flexor carpi ulnaris* muscle in volunteers 1 and 5 compared to volunteer 9, independently of the MVC. In contrast, the *extensor carpi ulnaris* muscle showed highest activity in volunteers 1 and 7, and the smallest activity in volunteer 9.

In the supination position, the highest RMS values of the *flexor carpi ulnaris* muscle occurred in volunteers 1, 2, and 5 and the smallest value in volunteer 7. On the other hand, the *extensor carpi ulnaris* muscle exhibited RMS values higher than 100 μV only in volunteers 1 and 2, with the smallest value occurring in volunteer 4.

In the pronation position, high RMS values for the *flexor carpi ulnaris* muscle were recorded in volunteers 1, 2, 5, 8 and 9, indicating that the highest mean RMS values for this flexor muscle occurred in this position. Similarly, high RMS values for the *extensor carpi ulnaris* muscle were found in volunteers 1, 3, 5, 7, 8, and 10, also indicating that the highest mean RMS values for this extensor muscle occurred in this position. Some volunteers (1 and 5) showed the highest activity in the three positions, although their MVCs were similar to that of volunteer 4 who had a low RMS value.

As shown in Figure 1, the mean RMS values for the *flexor carpi ulnaris* muscle obtained in the pronation position were significantly higher than those found in the semipronation ($p < 0.01$) or supination ($p < 0.01$) positions. In contrast, the data obtained in a supination position were similar to those in a semipronation position ($p > 0.05$). For the *extensor carpi ulnaris* muscle, only the RMS values obtained in the pronation position were significantly higher than those found in the supination position ($p < 0.01$). There were no significant differences among the RMS values obtained for the two muscles in the three positions studied.

Table 1. RMS values (µV) for the electromyographic activity of the *flexor* and *extensor carpi ulnaris* muscles in flexion movements of the forearm in the semipronation, supination, and pronation positions with 50% maximum voluntary contraction (MVC).

Volunteer	50% MVC	Muscles					
		Flexor carpi ulnaris			*Extensor carpi ulnaris*		
		Semipronation	Supination	Pronation	Semipronation	Supination	Pronation
1	18	130.8 ± 8.2	127.5 ± 4.7	228.0 ± 34.1	379.4 ± 118.1	129.8 ± 36.6	142.3 ± 24.4
2	21	94.7 ± 45.3	125.3 ± 10.3	145.2 ± 36.2	50.1 ± 9.9	101.4 ± 35.4	95.4 ± 17.5
3	10	48.5 ± 2.6	44.4 ± 1.4	59.6 ± 8.8	51.8 ± 2.6	48.9 ± 4.8	103.6 ± 6.8
4	18	59.4 ± 5.2	52.2 ± 9.3	70.8 ± 9.1	73.7 ± 9.0	37.5 ± 3.2	74.1 ± 9.4
5	18	157.2 ± 18.0	118.9 ± 10.2	261.4 ± 24.8	87.2 ± 7.1	84.5 ± 17.1	159.6 ± 73.2
6	10	50.0 ± 12.1	38.9 ± 10.8	55.3 ± 12.2	70.9 ± 6.7	74.3 ± 3.3	90.5 ± 11.6
7	7	47.8 ± 5.2	26.5 ± 5.4	61.7 ± 4.6	191.6 ± 10.2	82.8 ± 22.4	201.7 ± 17.9
8	18	77.5 ± 11.6	94.1 ± 8.3	163.6 ± 3.4	44.1 ± 4.5	50.9 ± 8.1	154.6 ± 2.9
9	7	33.1 ± 6.8	60.4 ± 4.2	112.3 ± 33.2	39.3 ± 1.6	61.9 ± 12.7	64.0 ± 19.1
10	7	79.1 ± 2.8	74.7 ± 0.4	77.3 ± 7.4	63.9 ± 11.0	62.3 ± 4.4	135.7 ± 6.7

The values are the mean ± S.D. of a 3-movement series for each position.

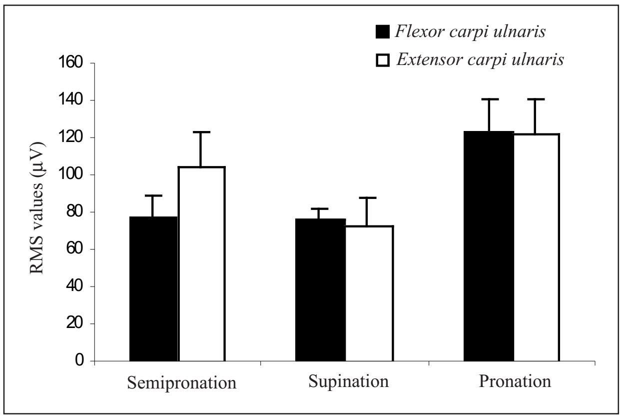

Figure 1. RMS values for the *flexor* and *extensor carpi ulnaris* muscles measured in flexion movements of the forearm in the semipronation, supination and pronation positions. The columns are the mean ± S.D. of the mean values for each position in the ten volunteers.

DISCUSSION

Little is known of the action of the forearm muscles in flexion or extension movements. Some reports have described the involvement of the *pronator teres* muscle [13,11] whereas a few authors have included the *flexor carpi ulnaris* among the muscles contributing to forearm flexion; only one report has mentioned a role for the *extensor carpi ulnaris* muscle [6].

Cunninghan [4], Gray [7] and Sobotta [13] reported a flexion action of the *flexor carpi ulnaris* muscle on the elbow. In agreement with this, we observed a relatively high electromyographic activity for this muscle in all movements, regardless of the forearm position. The highest activity of the *flexor carpi ulnaris* muscle (mean RMS 123.5 µV) was recorded with the forearm in a pronation position. This value, together with the position of the muscle in the forearm, suggests a mechanical disadvantage related to the previous shortening associated with pronation. In contrast, there would be a mechanical advantage in the other positions since in these cases the muscle would be in the process of lengthening. The previous stretching of a muscle generally, places it in a mechanical advantage. Thus, the RMS value should be smaller, as shown by the values obtained here. Based on the smallest RMS value found in the supination position, we conclude that this position would be one of greater mechanical advantage for the *flexor carpi ulnaris* muscle.

The RMS values varied considerably among muscles and among volunteers in some or all of the movements. Such variation may reflect differences in electrode positioning or may be true individual variations. There was, however, little variation for the same muscle in the three positions. The RMS values from the three movements done by each volunteer did not decrease with the movements. This behavior suggests that 50% MVC is an ideal load for kinesiologic EMG, since it does not produce fatigue in a 3-movement series.

Funk *et al.* [6], in an EMG study of the action of the eight major elbow muscles, observed that the *extensor carpi ulnaris* muscle showed moderate activity in both flexion and extension of the forearm and perhaps acted as a stabilizer for the elbow in these movements. The latter action probably reflects the fact that the origin of the *extensor carpi ulnaris* lies in the axis of rotation and can therefore participate in both movements. Since the collateral ligament is less dominant as a lateral stabilizer, some dynamic element is also implied, i.e., the *extensor carpi ulnaris* muscle.

EMG activity was detected in the *extensor carpi ulnaris* in all volunteers and positions, with the highest RMS value (mean RMS 122.1 μV) being obtained in the pronation position, followed by the semipronation (mean RMS 105.2 μV) and supination (mean RMS 73.4 μV) positions. These values showed a pattern similar to the *flexor carpi ulnaris* muscle, since both muscles are located almost parallel to each other throughout of their extension. This arrangement would subject them to similar stretching when performing supination and pronation movements.

For each muscle, there were significant differences in the EMG activity recorded in the semipronation, pronation and supination positions, but there were no significant differences between the activities of the two muscles in any of the positions.

Koshland *et al.* [9] examined muscle coordination during multijoint movements by comparing the response of wrist muscles (*flexor* and *extensor carpi ulnaris*) to perturbations around the elbow joint with their activation during a volitional elbow movement. The results confirmed that responses were elicited in non-stretched wrist muscles when the elbow joint was perturbed. Our data agree with these findings since we observed high electrical activity in these wrist muscles during flexion movements of the forearm.

Based on the RMS values recorded, we conclude that (1) the *flexor* and *extensor carpi ulnaris* muscles are active in forearm flexion, independent of the position, (2) the *flexor carpi ulnaris* muscle is relatively less active than the *extensor carpi ulnaris* muscle in the semipronation position, (3) the *flexor carpi ulnaris* muscle is relatively more active than the *extensor carpi ulnaris* muscle in the supination position, (4) both muscles show practically the same activity in the pronation position, (5) the highest EMG activity in both muscles occurred in the pronation position, (6) the smallest EMG activity occurred in the supination position, and (7) loads equivalent to 50% of the MVC do not produce muscular fatigue in a 3-movement series of kinesiologic exercises. In addition, although most of the literature neglects the flexion action of the *flexor* and *extensor carpi ulnaris* muscles on the elbow, such an action should be expected since these muscles cross this joint and consequently act on this region, as well as on the *carpus*.

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