ELBOW FLEXION AND EXTENSION MOVEMENTS CHARACTERIZATION BY MEANS OF EMG

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Abstract: Electromyographic (EMG) signal is the electrical manifestation of neuromuscular activation associated with muscle contraction. The present work intends to characterize the behavior of the muscles biceps and triceps during elbow flexion and extension movements, without load. These movements were performed at horizontal and vertical planes. Three types of test were performed, for each plane, relating EMG signal with joint position. Five men volunteers, ages ranged between 18 and 21 years old, were selected to participate to the tests. The first test consisted to move 10 degrees for each three seconds until the allowed maximum flexion and then, to return at the same way to the initial position. For the second test, the same movement was made but continuously, without stopping at intermediate positions. And for the third test, continuously flexion and extension movements were repeated sequentially but for different amplitudes, increasing by 10 degrees each. The tests were repeated, three times each. Initially, graphical analysis of the data was made for standard behavior detection and, for a quantitative analysis, after EMG preprocessing, averages and variation coefficients were calculated from specific intervals at the beginning, middle and at the end of movement. Although an EMG signals inherent variability, results showed inter and intra subject's repeatability, but only for movements performed at the horizontal plane.

1 INTRODUCTION

The general mechanism of muscle contraction, under voluntary control, involves the following processes:

- stimulation of motor nerve by a neuronal action potential;
- secretion of neurotransmitter (acetylcholine) at the neuromuscular junction;
- propagation of a muscular action potential through the muscular fiber;
- ionic flow across the muscle membrane;
- contractile process itself (Guyton, 2002; Capucho, 2005).

The basic unit of the muscle is named motor unit and it is constituted by a motor neuron and all muscular fibers innervated by this neuron. The electrical signal that is detectable by each unit is named Motor Unit Action Potential (MUAP), and this constitutes the fundamental unit of Electromyographic (EMG) signal. The EMG signal is the electrical manifestation of neuromuscular activation associated with a muscle contraction, it is accessible at the body surface and it can be used for different purposes, as neuromuscular disease diagnoses, rehabilitation process evaluation and also to analyze muscle behavior performing specific movements.

The surface EMG signal amplitude ranged from 0 to 10 mV peak-to peak or from 0 to 1,5 mV rms, and frequency ranged from 0 to 500 Hz, with dominant energy between 50 and 150 Hz (DeLuca, 2002), but deterministic characteristics were during the initial 200 ms of the muscle contraction (DeLuca, 1979).

EMG signal detection and acquisition process need some caution due to several factors that can affect the results. The electronic apparatus used, the environment, the electrodes and the movement of the electrodes during the tests can introduce noise. This interference can be avoided or eliminated by using:

- differential electrode configuration and differential amplification;
- position of the electrodes on the midline of the muscle belly;
- rms value of the signal, for measuring the amplitude of the voluntarily elicited EMG signal

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(consists to rectify and integrate the signal in data time interval) (DeLuca, 2002).

2 MATERIAL AND METHODS

Five men volunteers, ages between 18 and 21 years agreed to the test procedures, aiming to evaluate the contribution of biceps and triceps muscles during voluntary flexion and extension elbow movements, without load. For the accomplishment of the tests, a device for arm support and joint angle monitoring was used. The right arm were accommodated and fixed, allowing free elbow movement in only one plane and hindering other movements. For EMG signal acquisition, surface electrodes and the Powerlab PTB300 kit from ADInstrumets were used.

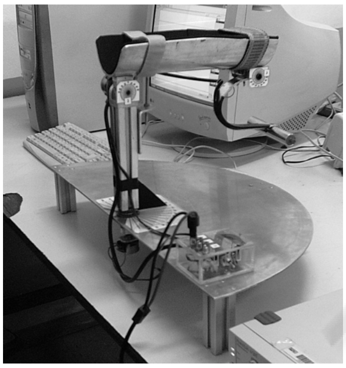

Figure 1: Device for arm support and joint angle monitoring.

The procedure consisted of three types of tests that would have to be repeated three times each for both horizontal and vertical planes.

Test 1: The volunteer had to move 10 degrees every 3 seconds, initiating in total extension and finishing with maximum flexion of 90 degrees, for the horizontal plane and 70 degrees for the vertical plane, and then had to return, to the initial position, by the same way.

Test 2: The volunteer had to repeat the amplitude of previous movement, but varying the joint position continuously, with controlled speed of 10 degrees for second, without stopping in the intermediate positions.

Test 3: The volunteer had to repeat several times elbow flexion/extension, but each time, amplitude movement was increased by 10 degrees. The initial amplitude was 10 degrees and the final amplitude was 90 degrees, for the horizontal plane and 70 degrees for the vertical plane.

The archives with the signal waveforms, obtained during the tests, were used for the result analysis, making possible the detection of standard behaviors. For the quantitative analysis, specific data intervals were fixed, considering beginning, middle and the end of movement, covering joint angles for extension and flexion positions. For these data sets, the mean and the variation coefficient were calculated for each one of the repetitions and among the three repetitions made by the same volunteer.

3 RESULTS

3.1 Movements at Horizontal Plane

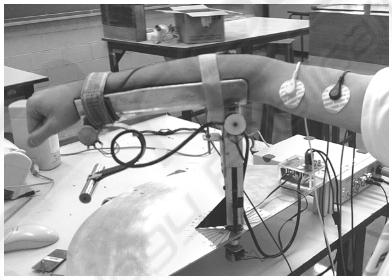

Figure 2: Arm position during movement at horizontal plane.

Figure 3 shows the signals acquired with one volunteer. From the top to the bottom, the first is the trigger signal for movement synchronism and speed control, joint angle position, biceps EMG signal, triceps EMG signal, rms of biceps EMG signal, rms of triceps EMG signal. And the columns represent each one of the repetitions of each of the three tests.

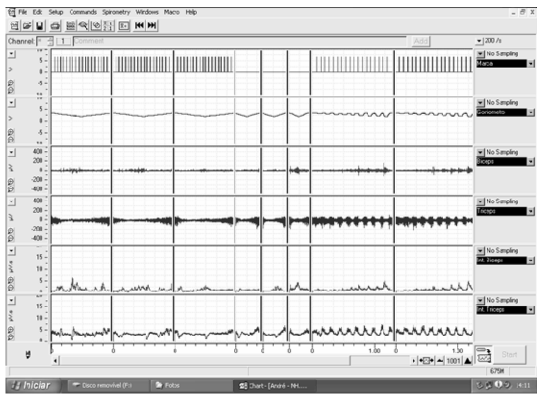

Figure 3: Waveforms obtained from the movements at horizontal plane with one volunteer.

Tests 1 and 2 showed that triceps acted more at the beginning and at the end of the movement, with the arm around extension position (joint angle varying from 0^o to 10^o and from 10^o to 0^o), while biceps acted more at the central part of the movement, between the peaks of triceps performance (around 90^o of flexion). Test 3 showed a quite constant intensity on triceps recruitment during movements, independently of the joint angle and movement amplitude. On the other hand, biceps signal showed an intensity increase as the amplitude of the movement increased.

In all the movements performed at the horizontal plane, for both muscles, were found a standard pattern at the values obtained from different volunteers, making possible the determination of representative means values as shown in table 1. The values were in accordance with the qualitative results presented before.

Table 1: Mean values obtained during muscle contraction from movements performed at horizontal plane (µV). (B.- Biceps; T. -Triceps).

Position	Test 1		Test 2		Amplitude	Test 3	
	B.	T.	B.	T.		B.	T.
Beginning 0^o–10^o Extension	1,5	3,7	1,3	3,72	Small 0^o – 10^o	1,29	3,75
Intermediate 40^o–50^o Flexion	1,71	3,26	1,72	3,21	Intermediate 0^o – 40^o	1,43	3,54
Middle 80^o–90^o Flexion	3,5	3,16	3,1	3,12	Intermediate 0^o – 50^o	1,5	3,6
End 10^o–0^o Extension	1,8	4,47	1,75	4,83	Maximum 0^o – 90^o	1,88	3,58

3.2 Movements at Vertical Plane

Tests 1 and 2 showed that the biceps had a large contribution during all the movement, but it was more requested at the beginning and at the end of the movement. Triceps acted a little more at the beginning of the movement, but its EMG signal was practically constant. In test 3, EMG signal was practically constant for both muscles, but the biceps EMG signal showed a greater intensity.

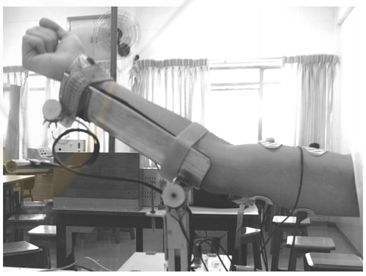

Figure 4: Arm position during movement at vertical plane.

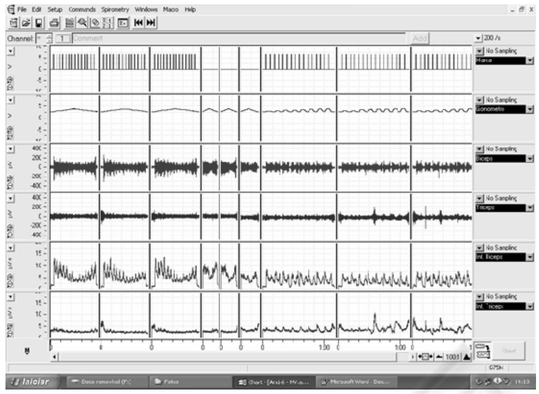

Figure 5: Waveforms obtained from the movements at vertical plane with one volunteer.

In the movements performed at the vertical plane there were no intensity pattern among volunteers for biceps recruitment as verified at horizontal plane. This indicates that each volunteer requested the muscle of different manner for the accomplishment of the same movement. By the other side, EMG signal from the triceps showed a standard pattern, making possible the determination of representative mean values as shown in table 2.

Table 2: Mean values obtained during muscle contraction from movements performed at vertical plane (µV). (B.- Biceps; T.- Triceps).

Position	Test 1		Test 2		Amplitude	Test 3	
	B.	T.	B.	T.		B.	T.
Beginning 0^o–10^o Extension	---	4,17	---	3,81	Small 0^o – 10^o	---	4,11
Intermediate 30^o–40^o Flexion	---	3,25	---	3,31	Intermediate 0^o – 30^o	---	3,88
Middle 60^o–70^o Flexion	---	2,98	---	3,04	Intermediate 0^o – 40^o	---	4,14
End 10^o–0^o Extension	---	3,32	---	3,68	Maximum 0^o – 70^o	---	4,18

4 DISCUSSION

Since the biceps acts for the flexion movement while the function of triceps is related with the elbow extension, the data obtained are consistent with the expected.

At the horizontal plane, EMG signal from the triceps had greater intensity at the beginning and at the end of the movement (intervals from 0º to 10º and from 10º to 0º). During these phases, the arm was at an extended position or near of it, needing to surpass the inertia of the movement. At the intermediate flexion position the contribution of the triceps decreased while the contribution of the biceps increased, but even so the biceps EMG signal remained smaller than the triceps EMG signal. This situation changed at half of the movement, where the elbow was in a full flexed position, requesting more of the biceps.

On the other side, for the movements performed at the vertical plane, EMG signal from the biceps showed greater intensity at the beginning and at the end of the movement (intervals from 0º to 10º and from 10º to 0º). The gravity influence is greater over the biceps at this plane. To surpass inertia the requested muscle was not triceps, as verified at the horizontal plane, but it was the biceps. Quantitative analysis showed that the intensity of EMG signal of the triceps was quite constant at this plane.

Aiming to quantify the variability of data sets during the movement and among each repetition made by the same volunteer, coefficients of variation were calculated. According to Araújo (2000), the coefficient of variation from the EMG signal is very high, being around 21.61% the average of variation of that parameter. It means that values around 20% do not indicate, necessarily, different muscular activities. This high variation can be caused by factors as position and quality of the electrodes, change of temperature and changes in the metabolism.

The coefficients of variation values obtained from the tests performed at the horizontal plane were around 25%. Therefore, it can be considered that there was repeatability of the movements performed.

Moreover the repeatability inter the several movements executions made by the same volunteer, the existence of a standard pattern of EMG intensities for both muscles, certify that there is a repeatability intra volunteers and also the existence of a recruitment pattern.

Analyzing the coefficients of variation obtained from the movements performed at vertical plane, the values related with the triceps were around 25%, indicating the same pattern analyzed previously. By the other side, although the coefficients related with the biceps, for each repetition was small, indicating little variation during the test, the values between repetitions were around 35%, indicating that there was no repeatability among recruitment for each movement performed by the same volunteer. There were cases with coefficients above 50% that probably were related with some isolated stronger muscular contraction made during the test. At vertical plane it was not possible to identify a recruitment pattern due to the variability of the data.

Besides that, it was observed small displacements of electrode positions during movements, and it must be also considered interference due the signals of adjacent muscles. These comments are in accordance with verified by DeLuca (1997), in other experiments.

5 CONCLUSIONS

During the tests, the muscle triceps showed a quite constant behavior, with repeatability of movements at both planes. The muscle biceps demonstrated this behavior only for movements performed at the horizontal plane, in which it had a little recruitment. For movements performed at the vertical plane, the biceps was more requested, resulting in a greater intensity EMG signal, but without repeatability.

There are several factors that can disturb EMG signal, but despite of the interference, it is possible to characterize movements by means of EMG, showing the intensity of muscle recruitment.

The results showed the existence of a recruitment pattern for biceps and triceps among different subjects but only for movements performed at the horizontal plane.

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