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ELECTROMYOGRAPHIC BEHAVIOR OF THE *BICEPS FEMORIS (CAPUT LONGUM)* AND *SEMITENDINOSUS* MUSCLES IN THE ISOMETRIC CONTRACTION TEST

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ABSTRACT

The purpose of this investigation was to examine the correlation between the maximal isometric strength of the *biceps femoris (caput longum)* and *semitendinosus* muscles measured through a dynamometer fitted with a load cell and the corresponding electromyographic activity recorded for each muscle. Nine female volunteers (19-23 years old), of similar anthropometry and with no antecedents of skeletal muscle diseases were enrolled in this study. The protocol consisted of maximal isometric contractions of the *biceps femoris (caput longum)* and *semitendinosus* muscles, in which the volunteers remained in ventral decubitus with a knee flexed to 90º. Maximal isometric strength was generated against the load cell for 6 s followed by a 2 min rest. The contractions were repeated for as long as possible. The root mean square values of the *biceps femoris (caput longum)* and *semitendinosus* muscles tended to increase with decreasing force as a function of the number of repetitions. This electromyographic fatigue was confirmed by the positive correlation between these two variables. The protocol described here may provide an useful index for measuring neuromuscular fatigue.

Key words: Electromyography, fatigue, hamstring, isometric contraction, knee

INTRODUCTION

The efficiency of muscle contraction depends on factors such as the fiber cross-section, the number of muscle fibers, the degree of fiber stretching, the traction angle [16], and the type of contraction required. Isometric exercise is one of several forms of exercise used to develop muscle force in humans. Isometric contraction occurs without any appreciable change in muscle length, such that although there is tension in the muscle there is little muscle movement for most of the time, hence the term static contraction [28,29].

Another variable usually included in isometric exercises is fatigue, which can be defined as a decrease in performance. Fatigue is seen as a reduction in the maximal isometric force generated with the appearance of muscle tremors or a decrease in the levels of submaximal force and/or speed of movement. Fatigue increases almost proportionally to the intensity of muscle glycogen depletion [13].

Fatigue has been studied using electromyography (EMG) in which there is a characteristic increase in the width and duration of the action potentials due to the recruitment of additional motor units [3]. In muscle fatigued by repeated contractions [19], the width of the electromyogram increases in an attempt to maintain the level of tension in activated muscle. The active motor units also discharge with increasing speed to compensate for the fall in the force of contraction of the fatigued fibers [3,15,25].

The isometric test has a positive effect on contraction after three weekly session for eight weeks. As a result, the maximal voluntary isometric contraction (MVIC) increases 28%, with a 14.6% increase in the cross-sectional area of the extending muscle of the knee; the amplitude of electromyograms in the trained leg is unaffected [7,14]. With isometric training, there is no muscle hypertrophy and the increase in the ability to generate force results from the additional synthesis of muscle contractile proteins [1,7,14].

Balestra [2] showed that voluntary contractions of the lumbar muscle caused fatigue and significantly reduced the force generated whereas electrical stimulation had no such effects. Muscles fatigue can cause a 20-40% decrease in the force generated [26].

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In this study, we assessed the usefulness of EMG for analyzing fatigue in two muscles [*biceps femoris (caput longum)* and *semitendinosus*] in the isometric test.

MATERIAL AND METHODS

Nine female subjects (21 ± 2 yr) of similar anthropometry (Table 1) and with no history of skeletal muscle diseases were studied. All subjects provided informed consent prior to any testing. The investigation were approved by the university's local Ethics Committee.

Electromyographic signals were captures using Ag/AgCl surface electrodes (10 mm contact diameter) placed on the dominant side of the *biceps femoris (caput longum)* and *semitendinosus* muscles (Fig. 1A), as recommended by Delagi and Perotto [8]. A data acquisition module (Lynx) recorded the signals at a sampling frequency of 1024 Hz, a gain of 1000x a pass band filter of 20-500 Hz. Muscles contraction (force) was measured using a load cell (Kratos MM 100 series 2BL – 2828) with a maximum traction capacity of 100 Kg. The analogical signal were digitalized using an A/D converter card with a selection window of -5 to +5 V. Muscle contractions were measured for 6 s and the recordings converted to RMS (root mean square) values for subsequent statistical analysis.

Table 1. Anthropometric measurements in the subjects studied.

Parameter	Measurement
Height (cm)	165.2 ± 3.8
Lower limb (cm)	74.9 ± 2.1
Thigh (cm)	41.1 ± 1.9
Leg (cm)	33.5 ± 0.5
Weight (kg)	58.9 ± 1.0

The values are the mean ± SD.

The subject was positioned in ventral decubitus on a table (Fig. 1) designed for this study. The knee was flexioned to 90º and isometric contractions were done by pulling on a cable fixed to the ankle which was kept at 90º relative to the longitudinal axis of the leg. The cable length was adjusted to the size of the subject's leg. The contraletral knee was kept extended on the table.

A load cell of known weight (Fig. 1B) was attached to the cable and made it possible to correlate the voltage oscillations with the weigth of the load. The traction force generated and the electromyographic signal were recorded simultaneously. For each test, muscle contractions were done for 6 s with 2 min rest intervals until exhaustion. All tests were initiated by a verbal command.

The *Pearson* correlation coefficient was used to examine the relationships between the RMS values and the traction force, or the number of performed repetitions, and between the traction force and the maximum number of repetitions.

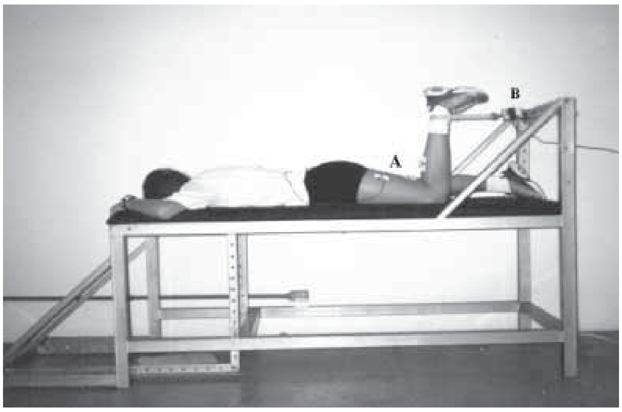

Figure 1. Position of the subject in the isometric test. A. Placement electrode. B. Load cell.

RESULTS

The RMS values correlated positively with the maximal number of repetitions, and the intensity of electromyographic signal increased in the *biceps femoris (caput longum)* (n=6) and *semitendinosus* (n=5) muscles as the maximum number of repetitions increased (Table 2), although some subjects showed a decline in the RMS values of *the biceps femoris (caput longum)* (n=3) and *semitendinosus* (n=4) (Table 2). The RMS values also increased with increasing force of contraction of the *biceps femoris (caput longum)* (n=6) and *semitendinosus* (n=8) (Table 3). Table 4 shows that the traction force decreased as the maximum number of repetitions increased (negative correlation) with a maximum reductions in the MVIC of about 40%.

Table 2. Correlation coefficients (r) between the RMS of the *biceps femoris (caput longum)* and *semitendinosus* muscles and the number of repetitions performed.

Subjects	*Biceps femoris (caput longum)*	*Semitendinosus*
1	0.21	- 0.48
2	0.43	- 0.23
3	0.44	0.09
4	- 0.83	0.51
5	- 0.61	- 0.49
6	- 0.55	- 0.74
7	0.89	0.79
8	0.06	0.05
9	0.19	0.06

Table 3. Correlation coefficients (r) between the RMS of the *biceps femoris (casput longum)* and *semitendinosus* muscles and the force measured in each number of repetitions performed.

Subjects	*Biceps femoris (caput longum)*	*Semitendinosus*
1	0.41	0.68
2	- 0.23	0.24
3	- 0.11	0.10
4	0.55	0.06
5	0.67	0.66
6	0.43	0.61
7	- 0.59	-0.61
8	0.57	0.38
9	0.28	0.43

Table 4. Correlation coefficients (r) for the traction force in the cable as a function of the number of repetitions performed (NRP).

Subjects	r (Traction vs NRP)
1	- 0.45
2	- 0.92
3	- 0.79
4	- 0.76
5	- 0.83
6	- 0.75
7	- 0.57
8	- 0.39
9	- 0.56

DISCUSSION

In muscle fatigued by repeated contractions, there is a decrease in the electromyographic signals, but an increase in the amplitude of the electromyogram. This phenomenon reflects an increase in the amplitude and duration of the potentials and in the recruitment of additional motor units [10-12,21,23,24]. Some studies have reported a decrease in the signals when the load is insufficient to produce neuromuscular fatigue, as sometimes occurs in maximal tests and isometric training [14]. This response can be explained by the presence of synergistic mechanisms [6] or other factors such as the conduction velocity of the motor unit.

Muscle traction decreased with repeated isometric contractions, in agreement with the observations of Balestra [2] and others [17,18,27,30]. These studies noted a significant reduction in force after the onset of fatigue, with the decrease corresponding to 20-40% in the normal level of force [26].

An increase in the amplitude of the EMG relative to the traction developed indicates the recruitment of motor units and/or an increase in the frequency of firing of the motor units to compensate for units that become fatigued [3-5,9,11,20,22]. This phenomenon attempts to maintain the level of contraction corresponding to the increase in electromyographic activity caused by the increase in force.

In summary, the results of this study indicate that RMS values of the *biceps femoris (caput longum)* and *semitendinosus* muscles tend to increase whereas force tends to decrease with the number of repetitions performed. Since these responses are characteristic of neuromuscular fatigue, the test described here may be useful for identifying muscle fatigue.

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