ELECTROMYOGRAPHIC ANALISYS OF BICEPS BRACHII AND ERECTOR SPINAE MUSCLES BEFORE AND AFTER A FATIGUING DYNAMIC TEST

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ABSTRACT

The increased number of musculoskeletal injuries can be caused by the lack attention to load level, as well as the posture and time of execution of an overloaded exercise. This way, the objective of this study was to analyze the effect of repetitive barbell biceps curl exercise over biceps brachii and erector spinae muscle electromyographic parameters. Ten healthy male subjects (20,91±1,37 years), without musculoskeletal diseases, performed the biceps curl exercise until fatigue, with 25%, 35% and 45% of 1 repetition maximum. The electromyographic activity of biceps brachii and erector spinae muscles was analyzed during isometric contraction performed before and immediately after fatiguing tests. The muscular fatigue was identified through the increase of root mean square and decrease of median frequency during isometric contractions. The results demonstrated these characteristics of fatigue after fatiguing test ($p<0,05$) for both muscles, showing a relationship time-load dependent for these electromyographic parameters. No significant differences were found between left and right muscles in the parameters analyzed. The experimental procedures allowed identify the muscular fatigue on biceps brachii muscles and erector spinae activity during barbell biceps curl and the dependence with load and number of repetition. These data can offer parameters to practitioners which using repetitive movement and progressive levels of load during the barbell biceps curl, because in this exercise, the trunk stabilization needs a high erector spinae activity, even in low load levels.

KEY WORDS: trunk stabilization; elbow flexion; isometric contraction; electromyography; muscular fatigue

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INTRODUÇÃO

Biceps curl exercise is frequently suggest to elbow flexor training (biceps brachii, braquialis and braquiorradialis) (AABERG, 2001), and to perform this exercise the apprentice is in standing position, and it offer an important overload in lumbar spine. Special attention should be given to this region, particularly because the postural control which the overload (AABERG, 2001; WEINECK, 1999) or even the incorrect movement (AABERG, 2001), which can cause important postural alterations (ADRIAN e COOPER, 1999).

Particularly in standing position exercises the trunk stabilization demands a higher trunk muscle action, mainly the erector spinae group, increasing the spine overload (AABERG, 2001; BONO, 2004). This activity will be more empathized in load lifting in front the body (KUMAR & MITAL, 1996; MOSELEY et al., 2002), specially in the biceps curl exercise, in long or even in short duration, but with 45% of 1 Repetition Maximum (1-RM) (OLIVEIRA et al., 2004), in which can occur a coordination in postural and in upper limbs main motors muscles activity (CORDO e NASHNER, 1982).

In sense to muscle activity understanding, the electromyography (EMG) presents as an important tool to this aim. One of the largest area to employ the EMG is the muscle fatigue, that can be defined as an increment load-dependent in the muscle electric activity during isometric and isotonic contractions (DE VRIES, 1968; MORITANI et al., 1993) and a decrease in the force output in both contraction types in isotonic movements (KUMAR e MITAL, 1996) becoming unable to perform the contraction until a failure point determine an involuntary finish in the effort.

The muscle EMG activity can be determined in the signal by amplitude parameters, as well as by the signal frequency (BASMAJIAN e

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DELUCA, 1985; DELUCA, 1997) and to biceps brachii (MORITANI et al., 1982, 1986; LINSSEN et al., 1993; MASUDA et al., 1999; MADELEINE et al., 2001; LINNAMO et al. 2003), and erector spinae muscles (DOLAN et al., 1995; KUMAR, 1997; MANNION et al., 1997; NIELSEN et al., 1998; ELFVING et al., 1999; BONATO et al., 2002) in isometric contractions, there are many papers, although a few studied the association between postural muscle activity (trunk extension) and the upper limb activity (ZEDKA et al., 1997; NIELSEN et al., 1998), verifying that the increase in trunk muscles activity can vary with the load height and level in upper limbs.

This evidences suggest the need to better understand of different muscle groups relationship during resistance exercises, as the biceps curl exercise, in which the muscle groups presents different functions in the same movement, and they are concomitantly actived to harmonic exercise performance or daily activities (ZEDKA e PROCHASKA, 1997).

In this sense, the present study will analyze the spectral and amplitude EMG profile in biceps brachii and erector spinae muscles (specially the longissimus thoracis) during the biceps curl performance, with posture limitations (adapted biceps curl), in isometric contractions performed before and immediately after the exercise conclusion.

METHODS

Subjects

Ten normal and healthy male subjects with following average and standard deviation anthropometric data volunteered for the study: mean age of 20,91±1,37 years, height of 177,3±5,61 cm and body mass of 71,77±5,69 kg. They should have a weight training practice above 12 weeks in period of the tests. All subjects related had no known history of musculoskeletal disorders in the shoulder, elbows and spine. Eight subjects were right-handed and two sinister, who reported by means of - questionnaire. The subjects read and signed an informed consent form and the local Ethics Committee approved the study.

Tasks

One week prior the test, the 1-RM of each subject was measured on three different days with interval of 24 and 72 hours between each test day according to Oliveira et al. (2005).

During these tests, the subjects were weighed and measured for their height and their ages were recorded. At the same time, they were orientated about the tasks would make in the day of fatiguing test and some movements were done to acquire the kinesthetic sense of movement.

The fatiguing tests were performed in 3 days with an interval of 24 and 72 hours between each test day (BOMPA e CORNACCHIA, 2000). In each test day the subjects performed the biceps curl exercise with a specific load level, chose randomly between 25%, 35% and 45% of 1-RM. Subjects had a time to familiarize with rhythm before the test start. These load percentages were established by means of a performance of a pilot study, where it was verified that those three percentages could be feasible to maintain for at least 1 minute of test. The subjects were encouraged during the entire test to continue performing the task. Subjects were asked to do not perform any training, which involve the studied muscles in the test.

Before the fatiguing test, it was performed a 5-seconds isometric contraction at 90º elbow flexion with the same 1 RM percentage of the fatiguing test. After 5-minutes rest, the fatiguing test consisted to perform the barbell biceps curl exercise until exhaustion, which were established my means of the impossibility of perform the movement in total amplitude of movement and in rhythm established (40 bpm). Immediately after the fatiguing test, was performed another 5-seconds isometric contraction.

Equipments and Positioning

To perform the one repetition maximum test (1-RM), barbell biceps curl and isometric contractions were used a straight weight training bar (7kg, 120cm length) and plates weights (1/2, 1, 4, 5 and 10Kg). To standardize the rhythm of the exercise execution, was used a digital metronome (Qwik Time QT-3, Beijing, China) calibrated to 40 bpm.

During the fatiguing test, as well as the isometric contractions, the subjects remained in the erect posture with feet distant 40 cm each other (AABERG, 2001). A monitor placed 130cm from the subject and 100cm height, offered visual feedback of the subject's posture (Figure 1). The image was obtained in the sagital plan by camera (JVC GR-AX910U, Tokio, Japan) positioned at 360cm perpendicular from subjects. These images allow the subjects, to identify passives joint marks placed in the joint center of shoulder, elbow and in the left part of the bar. The subjects maintained the elbow joint at 90º during the isometric contraction through the adjustment of these joint markers to

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the demarcation placed in a transparency fixed to the monitor.

With the objective of standardizing the symmetric posture and the movements during the exercise, a metallic stem system was building (FIGURE 1), which limited the arm movements antero-laterally and maintained the knees flexion at 15º. From this position, were performed the elbow flexions, extensions and isometric contractions, with the supine forearms and the hands holding the bar at distance approximately 45 cm each other.

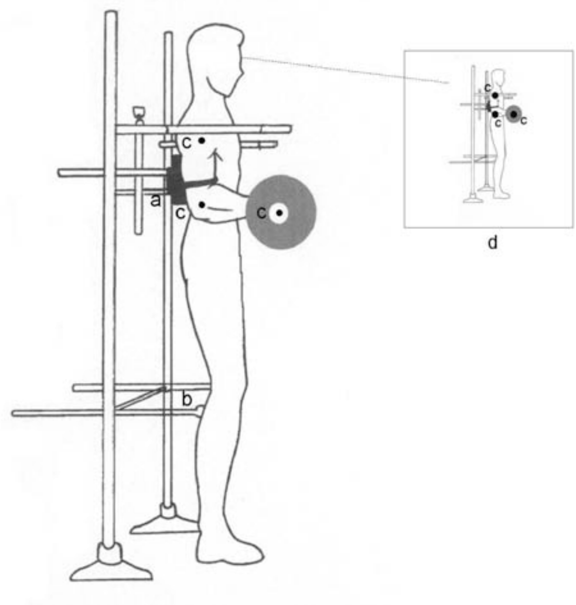

Figura 1 - Subject's positioning during the biceps curl exercise. The metallic stem system limited the arm movements antero-laterally (a) and maintained the knees flexion at 15º (b). Joint marks were placed at the shoulder, elbow and bar (c). The subject used as feedback a TV monitor, in which the exercise was displayed (d).

EMG System

A pair of disposable pre-gelled bipolar surface electrode (MediTrace 100, Chicopee, Canada) were placed in the direction of the muscle fibers. They measured 1cm of diameter and positioned with a center-to-center interelectrode distance of 3cm. The skin was shaved, abraded and alcohol-cleaned on the right biceps brachii (RB) and left biceps brachii (LB) muscle in the distal third of the arm in the common portion of muscle, according to Delagi et al. (1981) and right (RES) and left (LES) erector spinae in the level L1 (longissimus thoracis), according to Kumar (1997). A ground electrode was positioned on the stiloid process of the right wrist, after the skin preparation procedures in your surface.

The EMG signals were fed to an analog to digital (A/D) converter board (CAD 1026 - Lynx) with an input range of -5 to +5 volts and resolution of 10 bits. A gain of 1000, a high pass filter of 10Hz, the low pass filter of 500Hz and the sampling frequency rate of 1000Hz was used. The data had been acquired using a software Aqdados – Lynx - Tecnologia Eletrônica Ltda®, São Paulo, SP, Brazil. The system had a common mode rejection ratio (CMRR) of 80 dB. Once to analyze the spectral and amplitude parameters the isometric contractions are considerate more stationary, the EMG signals ware recorded in samples of 5-seconds isometric contraction duration, performed before and after the fatiguing test.

Data and statistical analysis

The RMS of the full-rectified EMG signal and the MF of biceps brachii and erector spinae isometric contractions were calculates by specific routines developed in MATLAB ambient (The MathWorks Inc., Natick, Massachusetts). The RMS and MF values were analyzed in the whole duration of isometric contractions performed before (RMSB and MFB) and after (RMSA and MFA) the fatiguing test. The RMS and MF values were normalized by the mean EMG values of the isometric contraction at 45% of 1 RM performed before the fatiguing test for each subject.

Analysis of variance (ANOVA) for $p < 0,05$ was performed to analyze the relation between independent variables (fatiguing test effect, laterality effect to biceps brachii and erector spinae, and load level effect). This same test was performed to verify the effect of the load in the execution time of the isotonic exercise. As Post Hoc test, Tukey analysis was applied.

RESULTS

The average value and standard deviation of the 1 RM test and the exhaustion time in each load percentage are presented in the Table 1, where an inverse relationship between the load intensity and the exhaustion time is presented.

The RMS values were influenced by the load level in the two pairs of muscles ($p<0,05$), with significant differences between 25%-45% and 35%-45% of 1RM, with higher value at 45%. For both muscles, the RMSA values were always higher than RMSB (FIGURES 2 and 3). Between sides, was observed no significant difference to both muscles.

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Tabela 1 - Individual values of one-repetition maximum (1-RM) of the biceps curl exercise (kg), and the respective endurance time (s) at the loads of 25%, 35% and 45% 1RM.

Subject	**1-RM**	**Endurance time**		
		25%	**35%**	**45%**
1	40	162	90	64
2	37	232	80	65
3	35	146	90	69
4	41	200	102	83
5	48	177	97	75
6	46	160	58	78
7	38	142	78	59
8	43	225	119	78
9	51	130	90	60
10	51	210	106	72
Mean	43	178,4*	91†	70,3
SD	5,77	34,4	15,96	8,21

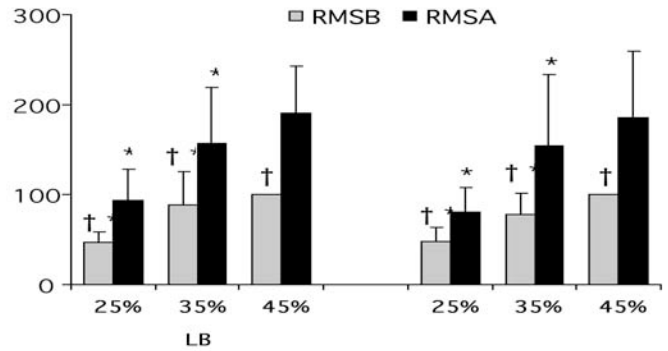

Figura 2 - Mean (SD) root mean square (RMS) of the left biceps brachii (LB) and right biceps brachii (RB). RMS values were collected before (RMSB – gray bars) and after the biceps curl exercise (RMSA – black bars) at 25%, 35% and 45% 1RM. * indicates significant difference in relation to 45%1RM ($p<0.05$); † indicates significant difference in relation to the condition after the biceps curl exercise ($p<0.05$).

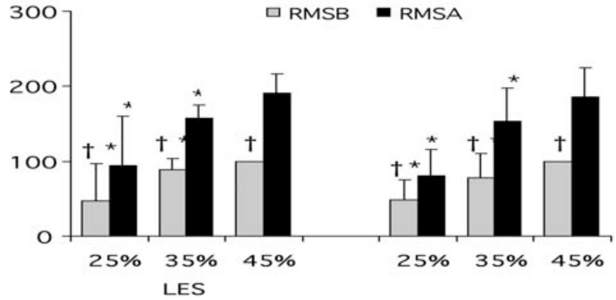

Figura 3 - Mean (SD) root mean square (RMS) of the left erector spinae (LES) and right erector spinae (RES). RMS values were collected before (RMSB – gray bars) and after the biceps curl exercise (RMSA – black bars) at 25%, 35% and 45% 1RM. * indicates significant difference in relation to 45%1RM ($p<0.05$); † indicates significant difference in relation to the condition after the biceps curl exercise ($p<0.05$).

The MF values, presented significant difference between 25%-45% of 1RM for both pairs of muscles, with lowest value at 45% of 1RM. Both pairs of muscles showed significant differences (p<0,05) between the contraction realized before and after fatiguing test, with MFA values always smaller than MFB (Figures 4 and 5). To the both muscles, MF showed not significant differences between right and left sides.

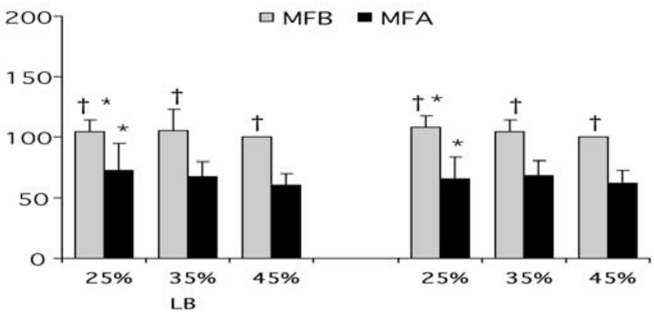

Figura 4 - Mean (SD) median frequency (MF) of the left biceps brachii (LB) and right biceps brachii (RB). RMS values were collected before (MFB – gray bars) and after the biceps curl exercise (MFA – black bars) at 25%, 35% and 45% 1RM. * indicates significant difference in relation to 45%1RM (p<0.05); † indicates significant difference in relation to the condition after the biceps curl exercise (p<0.05).

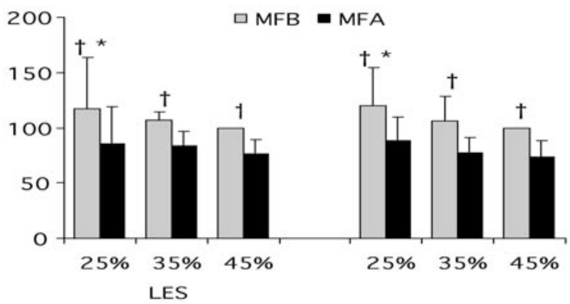

Figura 5 - Mean (SD) median frequency (MF) of the left erector spinae (LES) and right erector spinae (RES). RMS values were collected before (MFB – gray bars) and after the biceps curl exercise (MFA – black bars) at 25%, 35% and 45% 1RM. * indicates significant difference in relation to 45%1RM (p<0.05); † indicates significant difference in relation to the condition after the biceps curl exercise (p<0.05).

For both sides, the MF did not show significant differences between right and left sides.

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DISCUSSION

Studies have demonstrated an important relation between the isometric endurance of the erector spinae muscles and the maintenance of the physical and functional integrity of the vertebral column as well as its relation with the presence of pain (BIEDERMANN et al., 1991; KUMAR & GARLAND, 1992). The erector spinae muscle is considered a stabilizer of the erect posture in performance of manual tasks (ALEXANDER, 1985) and at same time, its function is vital for spinal protection (CROSSMAN et al., 2002). Repetitive tasks have become the work a risk (YOUNG et al., 1995) as well in sport as the barbell biceps curl that can promote disorder in the back because the erector spinae fatigue. Therefore, to understand the behavior of muscles during repetitive tasks can allow indicating an objective verification of local muscle fatigue commonly observed. Thereby, in this study the fact of the fatiguing test was performed with upper limbs and the load placed in front of trunk, to balance the flexor momentum, the erector spinae promoted the opposite extensor momentum and associated with the prolonged time of exertion contributed to improve the muscle fatigue.

During barbell biceps curl performed until fatigue, the load level have influenced directly the biceps brachii and erector spinae electromyographic parameters as RMS and MF (SEIDEL et al., 1987; VAN DIEËN et al., 1998) which the fatigue can be demonstrated.

The endurance time in each load percentage had an inverse relationship with the MF (ELFVING et al., 1999; BROMAN et al., 1985), and a direct relationship with EMG amplitude (LINNAMO et al., 2003). These facts have been justified by the motor units recruited to perform the task, and consequently, the type of muscle fibers can be related with the execution time. Particularly higher load levels demand the recruitment of type II fibers, which are less resistant to fatigue process (WEINECK, 1999; BOMPA e CORNACCHIA, 2000), this way, the execution time in these tasks tend to be smaller than in low load levels.

When the erector spinae RMS was analyzed it demonstrated strongly influence of load (NIELSEN et al., 1998) where, as high was the load level, as high was the RMS value for both side (BASMAJIAN e DELUCA, 1985; ROSENBURG e SEIDEL, 1989). This behavior is explained by the fact that to sustain a high load it is necessary a higher fire rate of the motor units already active followed by a recruitment of new motor units (CHRISTENSEN et al., 1995; MASUDA et al, 1999).

Many are the variables usually intervening in the EMG fatigue analysis, as the muscular length (BAZZY et al., 1986), the muscular temperature (PETROFSKY e LIND, 1980), the range of joint movement (YOUNG et al., 1995) and the load level (MORITANI et al., 1986). The electromyographic results demonstrated the clear influence of level load in the EMG parameters (ROMAN-LIU, et al., 2004), thereby, the biceps brachi (FALLENTIN et al., 1993; LINNAMO et al., 2000), and erector spinae (NIELSEN, et al. 1998) muscles demonstrated an increased RMS when the load was increased (SBRICCOLI et al., 2003), mainly at 45% of 1 RM in relation to others loads levels.

The increase in the electric activity during the biceps barbell curl during the endurance time to both muscles is a typical characteristics of fatigue process developed in the muscular fibers (MERLETTI et al., 1990; MASUDA et al., 1999). According to previous investigations the consequence is the depletion of the energy substrates and of the metabolites accumulation, resultants from the work imposed for the task performance (MORITANI et al., 1982; MASUDA et al., 1999) and because higher loads intensities causes larger need of motor unit recruitments to maintain the task execution (LINSSEN et al., 1993; LINNAMO et al., 2000).

In the present study in the maintenance of isometric contractions measured by the EMG resulted in higher significant values in the RMSA for biceps brachii and erector spinae, and this behavior as mentioned before, is related to progressive recruitment of motor units and synchronization of their firing rate (BASMAJIAN e DELUCA, 1985; CHRISTOVA e KOSSEV, 2001) during fatiguing test, to maintain the necessary useful force for the accomplishment of the imposed exercise (KUMAR e MITAL, 1996; BERNARDI et al., 1999). This phenomenon was also demonstrated by alterations in mean frequency of upper limb muscles simultaneously to lumbar muscle fatigue during the load lifting (BONATO et al., 2002). In addition, a progressive recruitment of motor units and synchronization of their firing rate concomitant to biceps brachii activation has been documented due the common efferent command for limb and trunk muscles by the central nervous system (CORDO e NASHNER, 1982; ZEDKA e PROCHASKA, 1997).

With regard to the MFA, it was significantly smaller than MFB in all muscles and in all loads used. This behavior had been also described, in ergonomic postures for the erector spinae muscles (KUMAR e MITAL, 1996), and isometric contractions of elbows flexors (CHRITOVA e KOSSEV, 2001; SEGHERS et al., 2003). All these authors agree that this decrease is due to a change in the wave shape of the action potential of MU once there is a decreasing of the

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conduction velocity of the muscular fiber stimulus because of metabolites accumulation as k+ and lactic acid (LINSSEN, et al., 1993; MASUDA et al., 1999).

There is no difference between the left and right sides for both analyzed muscles in RMS and MF parameters. Likely, this lack of difference may be occurred because of the short time of the isometric exertion (5 seconds). A longer time probably could characterize difference between both sides (ODA e MORITANI, 1995).

Despite the erector spinae at the L1 (longissimus thoracis) level has a predominance of type I fibers (MANNION et al., 1997), which are fatigue resistant (WEINECK, 1999; BOMPA e CORNACCHIA, 2000), the endurance time was long enough to change the temporal and spectral parameters in the tree load levels. Thus the barbell biceps curl performance can be considered time and load dependent, because even in low load levels, which presented endurance time significantly greater, the fatigue process was verified.

These physiological alterations are especially evident during isometric contractions, once this type of contraction induces the occlusion of capillaries responsible for both the nutrition and the metabolites removal (MASUDA, et al., 1999). Besides, the load level also influenced the MF, which presented significant differences between the load levels, presented lower values in the highest loads.

Highlight in the present study, is the efficacy of the control of subject's posture, the inexistence of compensatory movements, shoulder flexion and low back hyperextension, which possibly contributed to the inexistence of significant differences between left and right muscles in two analyzed parameters, suggesting more control during the practice of barbell biceps curl.

CONCLUSION

Despite the load levels used in this study, lower than those usually employed in weight trainings, the time of exertion demonstrated to be an important factor to promote an expressive fatigue in the biceps brachii. The control of posture, rhythm and laterality not usually controlled in weight training routines can be determinant to the biceps brachii muscle activity. The experimental procedures allowed identifying the muscular fatigue on biceps brachii muscles and erector spinae during barbell biceps curl are dependent of load and number of trials. These data can offer electromyographic parameters to practitioners, which use repetitive movement and variables load levels during the barbell biceps curl.

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