ELECTROMYOGRAPHIC STUDY OF THE *Rectus femoris* AND *Biceps femoris* (LONG HEAD) MUSCLES DURING BILATERAL ISOTONIC CONTRACTION IN A 45º LEG PRESS APPARATUS

ESTUDO ELETROMIOGRÁFICO DOS MÚSCULOS Rectus femoris E Biceps femoris (CABEÇA LONGA) DURANTE CONTRAÇÃO ISOTÔNICA NO APARELHO LEG PRESS 45º

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ABSTRACT: The aim of this study was to compare the bilateral electric activity of the *rectus femoris* (RF) and *biceps femoris* long head (BF) muscles during flexion and extension isotonic movements of the thigh and leg. Six men and six women accomplished all movements in 45° Leg Press apparatus with 30% and 60% of the maximum voluntary load (MVL). Electromyographic signs were captured using surface electrodes, recorded in a computerized electromyograph and analyzed in a system of data acquisition (Alc-EMG). The results demonstrated that the RF muscle showed greater electric activity than BF in both loads (30% and 60% MVL) and sides, regardless the sex. It can be concluded that in spite of the RF and BF muscles are in opposite ends of the hip and knee joints and are mentioned traditionally as antagonistic muscles, both muscles seem to act with synergism between themselves with predominance of the activation of the RF muscle on the BF muscle in both genders and studied loads in leg press 45º execution. In addition, the electrical activity of these muscles is directly proportional to the load, independently of the sex.

KEYWORDS: Kinesiologic EMG. Leg Press. *Rectus femoris. Biceps femoris.*

INTRODUCTION

In the last years, several researchers have contributed to the study on effects of different types of force training in man (ALKNER; TESCH; BERG, 2000; BERTOCHI et al., 1997; ESCAMILLA et al., 2001; GRYZLO et al., 1994; KOMI et al., 2000; SOUSA et al., 2000; TASSI et al., 1998; TESCH et al., 1990).

The prescription and periodicity of resisted exercises for training, rehabilitation and improvement of the life quality request a solid knowledge with scientific basis to help in the development of advanced programs of force training and in the logical development of successive sessions of training. Therefore, techniques of measurement and processing of data have been contributing to the analysis of the human movement, prescription and periodicity of the resisted exercises.

In this context, electromyography (EMG) has been introduced to better evaluate and inform about the muscular behavior as increases or decreases of the electric activity

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Received: 08/12/05 Accept:09/06/06

in resisted exercises and identification of the individual and concomitant muscular actions during the exercises. Such evaluations can be obtained through the analysis of the performance degree of agonist and antagonist muscles during different modalities of exercises (ALKNER; TESCH; BERG, 2000; GRYZLO et al., 1994; MARKOS, 1979; MURPHEY; BLANTON; BIGGS, et al., 1971; SODERBERG et al., 1987; SODERBERG; COOK, 1983; SOUSA et al., 2000; TASSI et al., 1998).

The contraction of agonist muscles can be associated with the simultaneous contraction of its antagonists. The co-contraction of antagonists may be seen as contra-productive, particularly in a force task, because the opposite torque developed by the antagonists would decrease the production of net force in the direction intended in the movement, harming the ability in completely activating agonists by reciprocal inhibition (ALKNER; TESCH; BERG, 2000; SALE, 1988). Co-activation of the antagonist muscles is a phenomenon often observed when high levels of force are needed, being sometimes activated at a level closer to a movement in which they would be agonists. It has also been reported that practice and training would reduce the amount of co-contraction, what would allow larger agonists activation and a greater production of net force in the direction of the intended movement (ALKNER; TESCH; BERG, 2000).

Alkner, Tesch and Berg (2000) compared the electromyographic activity and the isometric force of the *quadriceps femoris* and *biceps femoris* (BF) muscles in the single-joint knee extension and the multi-joint Leg Press exercises. Their results demonstrated that the electric activity of the *rectus femoris* (RF) muscle was significantly greater than that of the BF muscle in all loads tested, having this latter an activity increased linearly with increased loads. Soderberg et al. (1987) compared the electric activity of the *vastus medialis*, *gluteus medius*, RF and BF muscles in exercises of lifting the maximally extended leg and exercises of quadriceps contraction at 0°. They found that RF was more active than the other muscles in exercises of lifting the extended leg.

Some considerations on the performance of the RF muscle in Leg Press exercises have been suggesting that additional muscles, including hip and ankle extensors, are brought into action and this might affect the EMG/force relationship (ALKNER; TESCH; BERG, 2000). Schantz et al. (1989) reported lower levels of force in the leg extension (Leg Press) when compared to the knee extension. On the other hand, the results found by Alkner, Tesch and Berg (2000) provide no evidence of failure of RF and the entire quadriceps muscle to be maximally activated because no differences were observed in the maximal EMG/force relationship between the single-joint knee extension and multi-joint Leg Press exercises. In addition, the antagonistic co-contraction of BF muscle could increase with a progressive increase of the load to stabilize the knee articulation.

Another important aspect concerning the prescription and periodicity of resisted exercises is the different performance between dominant and non-dominant limbs that can be found during the accomplishment of bilateral movements of lower limb (TASSI et al., 1998) in both maximum load and potency (SIMÃO, 2001; SIMÃO; MONTEIRO; ARAÚJO, 2001; SIMÃO et al., 2003).

The purpose of this study was to compare the bilateral simultaneous action of the RF and BF (long head) muscles during the leg press 45^{o} exercise execution with different loads and genders.

MATERIAL AND METHODS

Subjects

Twelve volunteers, six men and six women, 20-25 years old, height of 1.77 ± 0.10 m (men) and 1.62 ± 0.04 m (women), weigh of 73 ± 5 kg (men) and 54 ± 4 kg (women) were enrolled in a study to analyze the bilateral electric activity of the RF and BF muscles through the kinesiologic EMG. All volunteers were students of the Physical Education Course of the Universidade Federal de Uberlândia (UFU) and Centro Universitário do Triângulo (UNITRI), Uberlândia, MG, with training in resisted exercises for at least three months and with no history of joint or muscular diseases that could influence the results.

EMG

Electrodes - In order to capture the electric activity of the RF and BF muscles, simple differential active surface electrodes were used with two parallel metallic bars and common mode rejection ratio (CMRR) at 93dB, value considered minimum for surface EMG (PORTNEY, 1993; MATHIASSEN; WINKEL; HÄGG, 1995). A ground electrode of reference common to all channels was used to eliminate external interferences (DE LUCA, 1997) and it was positioned on the tuberosity of the volunteers' tibia. The first electrode pair was placed on the medium point of the RF muscle, in the anterior face of the thigh at 22 ± 2 cm between the patella superior border and the anterior superior iliac spine, according to Bertochi et al. (1997) and Leis; Trapani (2000). The second electrode pair was placed on the medium point of the BF muscle through an imaginary line between the ischial tuberosity and the fibula head at 22 ± 2 cm (LEIS; TRAPANI, 2000). The medium point of both muscles was chosen according De Luca (1997), who reports that the probability of detecting an interference sign can be considerably reduced placing the electrode on the medium line of the muscular belly.

The precision of the electrode position on the RF muscle was confirmed using maneuvers of activation as described by Leis and Trapani (2000), in which the volunteer sat down in a stretcher, executed the movement of leg extension against a resistance accomplished by the researcher, what evidenced the RF muscle (primary motor in this movement). For the BF muscle, movements of leg flexion were carried out with the volunteer in the ortostatic position, in which it was evidenced the BF muscle.

Electromyograph – The electromyographic signals were recorded using a computerized electromyograph developed in the Biomedical Engineer Laboratory, Faculdade de Engenharia Elétrica, UFU, Uberlândia, MG, with the following characteristics: simultaneous acquisition of up to 8 differential channels with 10 GΩ input impedance in differential mode; 12 resolution bits; filters set at 20 Hz (low pass) and 1 kHz (high pass); input range from –10 V to +10 V; ground electrode common to all channels; adjustable amplification stage, making possible gains between 100 and 4960 times; galvanic isolation (1.5 kV at 60 Hz) between the electronic circuit and the stage that is in contact with the volunteer.

An acquisition system of data (Alc-EMG) was used to quantify the electromyographic sign, transforming the action potential in numeric data of RMS (root mean square), expressed in microvolts (μV), with sample number of 8.000 and frequency of 2000 Hz, resulting in a total acquisition time of 4 seconds.

Leg Press – The exercises were carried out using an apparatus of muscular activity denominated 45º Leg Press (Righetto, São Paulo, SP, Brasil) consisting of a platform measuring 30 cm of width and 45 cm of length, and gently given by the Laboratory of Muscular Activity and Human Performance of the Centro Universitário do Triângulo (UNITRI), Uberlândia, MG. The volunteers positioned the feet in the center of the platform at a distance individually obtained by the correspondent distance between the left and right anterior superior iliac spines.

General procedures - Before the collection of data the volunteers received information on the research and an informed consent was obtained from all participants of the study according to the Ethical Committee of the UNITRI. The volunteers were submitted to explanations and simulations on the adequate posture for the execution of the exercises, the initial and final position of each movement, and the speed of execution of the exercises. A pilot test was accomplished with a short training period so that the volunteers acquired the kinesiologic sense of the movement in agreement with the proposed angle.

The volunteers were positioned in the 45º Leg Press apparatus, with the gluteal region on the seat, the trunk and head supported on the apparatus back, the feet on the platform according to pre-established measures and the two hands holding a metallic support, with the arm and forearm parallel to the trunk.

The exercise consisted of two phases of isotonic movements: (1) eccentric phase, in which the volunteer was initially positioned with total extension of the leg (180º) and then accomplished a simultaneous bilateral flexion of the thigh and leg for 2 seconds, until reaching 90º of leg flexion, what was indicated by a demarcation done in the apparatus and then a verbal command was expressed to determine the end of this phase; (2) concentric phase, in which the volunteer accomplished total extension of the leg and thigh, until reaching 180º for 2 seconds too. For the measurement of the 90º angle of leg flexion of each volunteer, a universal goniometer (Carci, Indústria e Comércio de Aparelhos Cirúrgicos e Ortopédicos Ltda., São Paulo, Brasil) was used. The screw of the goniometer was placed on the lateral condyle of femur and laterally aligned along the femur from the greater trochanter to the lateral condyle of femur and from the head of fibula to the lateral malleolus (GARY; HARRELSON, 2000).

Prior the exercise a test of maximum voluntary load (MVL) of assay-mistake in one maximum repetition was accomplished in 45º Leg Press, as suggested by Dantas (1998) in order to determine the loads to be worked (30% and 60% of MVL). Immediately before the test, a series of three active stretching with 30 second-duration and 1 minute-interval was accomplished for the *quadriceps femoris*, hamstrings and *triceps surae* muscles.

After the test of MVL, a series of three repetitions was accomplished with loads of 30% and 60% of MVL, with 3 minute-interval in order to restore the energy sources and to minimize the effects of fatigue. In this interval period, the volunteers removed the feet of the platform leaving them down on the soil, maintaining the relaxed lower limb.

Statistical analysis

In order to verify the differences among the electric activities obtained from the four muscles with loads of 30% and 60% of MVL in both masculine and feminine groups, the test of Friedman and Wilcoxon was used (SIEGEL, 1975), with a significance level established at $p < 0.05$ in a bilateral test.

RESULTS

In the total group of 12 volunteers, the electric activity of the left RF muscle was significantly greater than that obtained for the right BF muscle ($p < 0.05$) with 30% of MVL. When using 60% of MVL, significant differences were found between right BF and right RF, right BF and left RF, left BF and right RF, left BF and left RF, with the RF muscle showing greater electric activity than BF muscle in all cases ($p < 0.05$).

In the masculine group, the electric activity of the left RF was significantly greater than that of the right RF muscle in both loads (30% and 60% of MVL). For the feminine group with 30% of MVL, the left BF was significantly more active than the right BF muscle, and this latter was significantly less active than the right RF muscle. On the other hand, with 60% of MVL, the electric activity of the RF was significantly greater than that of the BF muscle in both sides (Table 1 and 2).

When comparing the results obtained with 30% and 60% of MVL, significant differences were found for the right BF, right RF and left RF muscles, with the RF muscle always showing the greatest electric activity. In addition, all muscles exhibited greater electric activity with 60% than 30% of MVL (Figure 1).

A comparison between the masculine and feminine groups revealed significant differences for the left RF muscle, which showed greater electric activity in the masculine group (Tables 1 and 2).

Table 1. RMS mean values of electric activity of the right (RFr) and left (RFl) *Rectus Femoris*, right (BFr) and left (BFl) *Biceps Femoris* muscles at 30% of the maximum voluntary load (MVL) during bilateral isotonic contraction in a 45º leg press apparatus.

Volunteers	Gender	RMS* at 30% MVL			
		Muscles			
		RFr	BFr	RFl	BFl
1	Female	198 ± 6	139 ± 32	211 ± 39	168 ± 39
2	Female	315 ± 12	151 ± 26	112 ± 33	290 ± 109
3	Female	323 ± 160	194 ± 54	236 ± 71	449 ± 70
4	Male	113 ± 7	203 ± 48	315 ± 26	344 ± 24
5	Male	321 ± 21	126 ± 21	517 ± 64	113 ± 17
6	Male	863 ± 29	296 ± 57	665 ± 31	150 ± 26
7	Male	189 ± 7	116 ± 10	221 ± 11	183 ± 23
8	Male	250 ± 35	391 ± 63	351 ± 39	281 ± 37
9	Male	244 ± 35	203 ± 69	447 ± 18	304 ± 223
10	Female	140 ± 2	116 ± 4	211 ± 16	173 ± 13
11	Female	413 ± 23	148 ± 4	404 ± 29	124 ± 6
12	Female	131 ± 14	096 ± 24	133 ± 06	138 ± 34
Mean ± SD		**292 ± 193**	**182 ± 82**	**319 ± 158**	**226 ± 101**

*RMS expressed in µV; SD: standard deviation.

Table 2. RMS mean values of electric activity of the right (RFr) and left (RFl) *Rectus Femoris*, right (BFr) and left (BFl) *Biceps Femoris* muscles at 60% of the maximum voluntary load (MVL) during bilateral isotonic contraction in a 45º leg press apparatus.

Volunteers	Gender	RMS at 60% MVL			
		Muscles			
		RFr	**BFr**	**RFl**	**BFl**
1	Female	360 ± 22	192 ± 12	316 ± 06	379 ± 147
2	Female	589 ± 51	180 ± 7	440 ± 21	139 ± 2
3	Female	471 ± 35	367 ± 21	405 ± 08	138 ±30
4	Male	493 ± 17	466 ± 41	591 ± 59	312 ± 75
5	Male	874 ± 63	217 ± 8	852 ± 09	149 ± 6
6	Male	1620 ± 69	182 ± 65	1373 ± 60	132 ± 14
7	Male	462 ± 34	160 ± 4	475 ± 32	224 ± 83
8	Male	634 ± 39	226 ± 38	651 ± 34	313 ± 182
9	Male	588 ± 18	681 ± 108	908 ± 11	503 ± 73
10	Female	346 ± 11	165 ± 1	352 ± 03	201 ± 9
11	Female	798 ± 41	224 ± 1	783 ± 43	169 ± 17
12	Female	232 ± 25	134 ± 18	228 ± 02	181 ± 28
Mean ± SD		**622 ± 348**	**266 ± 155**	**615 ± 309**	**237 ± 112**

*RMS expressed in μV; SD: standard deviation.

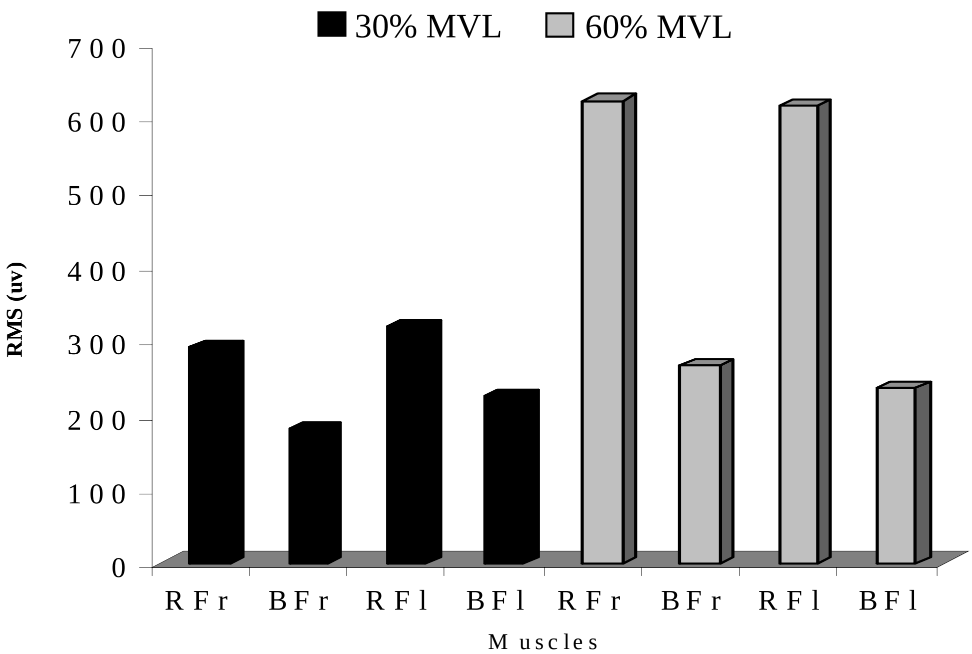

Figure 1. RMS mean values (expressed in μV) of electric activity of the right (RFr) and left (RFl) *Rectus Femoris*, right (BFr) and left (BFl) *Biceps Femoris* muscles at 30% and 60% of the maximum voluntary load (MVL) during bilateral isotonic contraction in a 45º leg press apparatus.

DISCUSSION

Differently of previous studies, the present study shows data on the dominant and non-dominant action of limbs during isotonic contractions. Concerning the isotonic exercises of flexion and extension of thigh and leg, one of the limitations was the observation of the RF and BF muscles only, making not possible to take conclusions on the global activation of the *quadriceps femoris* and hamstrings muscles.

In this study, the biarticular action of the RF and BF muscles was verified, thus confirming the anatomic and kinesiologic data previously reported (FURLANI; VITTI; BÉRZIN, 1973; JOSE; FURLANI, 1984; YAMASHITA, 1988; GONÇALVES, 1996; BERTOCHI et al., 1997; ESCAMILLA et al., 1998; GONÇALVES; BÉRZIN, 2000).

Alkner, Tesch and Berg (2000) found increased activity patterns for the BF and RF muscles in the Leg Press exercise with 20%, 40%, 60%, 80% and 100% of MVL. Although we did not use relatively high loads (30% and 60% of MVL) in this study, the significant increase of myoelectric activation in both analyzed muscles (RF and BF) was evident when the load was doubled from 30% to 60% of MVL. This might be due to some protecting mechanism that is capable to help the ligaments in the maintenance of the articular stability (BARATTA et al., 1988).

Carnaval (2001) and Delavier (2002) reported that RF and BF constitute the muscles that will be act in the 45° Leg Press exercise, what it is in agreement with the findings of this study since there was a significant electric activity of the RF and BF muscles regardless of the load and sex. In addition, studies reported by Tassi et al. (1998) also confirmed the participation of the BF muscle in both concentric and eccentric movements in the 45º Leg Press exercise. On the other hand, our findings disagree with the reports of Tesch (2000) that showed no activity of the RF ad BF muscles of subjects trained in 45° Leg Press apparatus with the feet positioned in both high and low part of the platform, although he has used the magnetic resonance instead of EMG.

Previous studies have also shown that the entire quadriceps muscle in leg extension and squat movements presents simultaneous contraction and increased activity proportional to the increase of the load (DUARTE-CINTRA; FURLANI, 1981). Such an increase might have led to the intensification of the capacity of the motor centers in mobilizing a great number of motor neurons previously still which increased the number of motor units that participated in the muscular contraction (VERKHOSHANSKI, 2001). This result is in agreement with the theory of graduation of muscular force, which affirms that a simultaneous activation of a larger number of motor units occurs with the increase of the force, as reported in other studies (ALKNER; TESCH; BERG, 2000; BILODEAU et al., 1992; SOUSA et al., 2000;) and evidenced in the present study, when 60% of MVL was used. For training such conditions are favorable due to the fact that the muscle should be submitted to the tension change in order to obtain force. According to Fleck and Kraemer (1999) the muscle should act against a resistance that usually does not exist for the physiologic changes to take place resulting in required training effects.

Escamilla et al. (2001) analyzed the dynamic unilateral activity of the quadriceps, biceps femoris long head, *semitendinosus*, *semimembranosus*, and *gastrocnemius* muscles in squat and Leg Press exercises and found significant activity of the BF and RF muscles, what is in agreement with our findings.

Tassi et al. (1998) investigated the bilateral behavior of the *biceps femoris* muscle during flexion and extension movements of the leg and thigh in the horizontal Leg Press apparatus and verified strong potentials of the dominant limb on the non-dominant one. These results are not in agreement with our findings since that no differences in the bilateral electric activity of the BF and RF muscles were found between dominant and non-dominant limbs in both loads and sexes, in spite of all volunteers were skillful. Although some studies have not used EMG (SIMÃO, 2001; SIMÃO; MONTEIRO; ARAÚJO, 2001; SIMÃO et al., 2003), their findings were similar to ours for both maximum load and muscular potency.

The exercise chosen for our study was part of the training program of the volunteers. Thus, our results can be related to the fact that these volunteers already presented a great level of inter- and intra-muscular adaptation to the analyzed exercise, favoring their motor performance.

Bilodeau et al. (1992) analyzed the EMG signs of homologous flexors and extensors of the elbow with 10%, 40% and 80% of MVL in dominant and non-dominant limbs and verified no significant differences between the right and left sides. Although the levels of force analyzed were not similar to the ones of our study, we also found minor but not significant differences between the right and left sides. These minor differences might have occurred due to a higher level of concentration in the muscles that possess lower expression of force to win the proposed resistances. It is possible that with the progress of training and the improvement of the recruitment pattern of motor units, the differences among the contralateral muscular contractions become less evident due to the transfer or crossed effect, as reported by Moritani and De Vries (1979), Sale (1988), Zhou (2000), and Munn, Herbert and Gandevia (2004).

According to Fuglsang-Frederiksen (1987), differences in the unilateral maximum force between dominant and non-dominant limbs are mainly due to the heterogeneity in the diameter of muscular fibers or in the number of fibers by motor unit or in both diameter and number of muscular fibers. For these authors a weaker muscle activates more motor units to exercise a 2 kg force than a stronger muscle, what could explain the differences found between the right and left limbs in our study. De Luca, Sabbahi and Roy (1986) also report that electromyographic differences between right and left limbs in skillful individuals provide an indication of modifications in the metabolic properties of the muscular fibers induced for a lifetime in consequence of the favorite functional use (law of the use and disuse).

Our results, although in a indirect comparison, were similar to those found by Gryzlo et al. (1994) who verified that the *rectum femoris*, *vastus lateralis oblique* and *vastus medialis* muscles were significantly more active than the *biceps femoris* and *semimembranosus* muscles during the squat in both concentric and eccentric phases of the movement.

Based on the results obtained in the present study that showed the predominant electric activity of RF on BF muscles, it can be suggested that the employment of multi-joint exercises such as 45° Leg Press should not be indicated as single training form with loads for the phase of anatomical adaptation of the thigh muscles related to the resisted training of athletes and non athletes, since these exercises make stronger muscles in disadvantage to the other ones. On the other hand, such multi-joint exercises might be indicated only when the feet are supported on the superior portion of the platform, as proposed by Tassi et.al. (1998) and Escamilla et.al. (2001). In addition, single-joint exercises should be indicated because they provide a larger strengthening and recruitment of hamstring muscles, which possess smaller electric activity and consequently poorer anatomical adaptation.

These findings could provide valuable information on the prescription of physical exercises to the sport professionals, establishing the importance of the aggregation of specific exercises for strengthening of the hamstring muscles in the basic phase of the periodicity of the sport training, in both single-joint and multi-joint characters.

CONCLUSION

According to the obtained results and the proposed methodology, it can be concluded that in spite of the RF and BF muscles are in opposite ends of the hip and knee joints and are mentioned traditionally as antagonistic muscles, both muscles seem to act with synergism between themselves with predominance of the activation of the RF muscle on the BF muscle in both genders and studied loads in leg press 45º execution.

RESUMO: O objetivo deste estudo é comparar a atividade elétrica bilateral dos músculos *rectus femoris* (RF) e cabeça longa do *biceps femoris* (BF) durante movimentos isotônicos de flexão e extensão da coxa e perna. Seis homens e seis mulheres realizaram todos os movimentos em um aparelho Leg Press 45º com 30% e 60% da carga voluntária máxima (CVM). Os sinais eletromiográficos foram captados usando eletrodos de superfície, registrados em um eletromiógrafo computadorizado e analisados em um sistema de aquisição de dados (Alc-EMG). Os resultados demonstram que o músculo RF mostra atividade elétrica maior em relação ao músculo BF em ambas as cargas (30% e 60% CVM) e lados, independente do sexo. Pode ser concluído que apesar dos músculos RF e BF estarem em extremidades opostas das articulações do quadril e joelho e serem mencionados como músculos antagônicos, ambos músculos parecem agir com sinergismo entres si, com predominância de ativação do músculo RF sobre o BF em ambos gêneros e cargas estudadas na execução do leg press 45º. Além disso, a atividade elétrica destes músculos é diretamente proporcional à carga, independente do sexo.

PALAVRAS-CHAVE: EMG cinesiológica. Leg Press. *Rectus femoris. Biceps femoris.*

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