HAMSTRINGS CO-CONTRACTION IN KNEE EXTENSION DURING ISOINERTIAL STRENGTH WORK

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Resumo: O objetivo do presente estudo foi verificar a resposta eletromiográfica dos músculos antagonistas (bíceps femoral e semitendinoso) na extensão do joelho durante um trabalho de força isoinercial. Dezesseis homens (n = 16) participaram voluntariamente do estudo que foi desenvolvido em um aparelho isoinercial (YoYo\(^{TM}\) flywheel ergometer – YoYo Technology AB) específico para a extensão dos joelhos em uma ação concêntrica. Os sinais EMG foram obtidos com o uso de eletrôdos de superfície bipolar (I-330-C2) colocados 2 cm aparte no vastos lateral, reto femoral, bíceps femoral cabeça longa e semitendinoso. A parte experimental consistiu na realização de duas contrações isométricas dos isquiotibiais (2 x 6") e quatro séries de seis repetições máximas (4 x 6 com 10' intervalo) no aparelho. Não foram encontrada diferença estatisticamente significante na iEMG (p>0.05) na ativação agonista (vasto lateral-VL e reto femoral) e músculos antagonistas (bíceps femoral-BF y semitendinoso-ST) em valores absolutos. Os valores normalizados encontrados foram: Bíceps femoral - 13,52±7,03 % e Semitendinoso - 14,55±7,72%. Os músculos extensores obtiveram sua máxima ativação por volta de 48,72 ± 20,45% do aparelho de extensão enquanto os flexores em 63,22 ± 17,03%, aproximadamente 150º da extensão do joelho. O presente estudo mostrou a importância e a funcionalidade do método isoinercial no treinamento de força desde que este apresenta resultados similares quando comparados a outros, podendo auxiliar treinadores com conhecimento para seu uso no objetivo de melhor desenvolvimento do processo de treinamento.

Palavras-chave: co-ativação, eletromiografia, bíceps femoral, semitendinoso, força.

Abstract: The purpose of this research was to verify the EMG (electromyography) response of antagonist muscles (biceps femoris and semitendinosus) in the knee extension during the isoinertial strength work. Sixteen males (n = 16) voluntarily participated in this study. The study was developed in an isoinertial machine (YoYo\(^{TM}\) flywheel ergometer – YoYo Technology AB) specific to the knee extension in a concentric action. EMG signals were obtained by the use of bipolar surface electrodes (I-330-C2) placed 2cm apart on vastus lateralis, rectus femoris, biceps femoris caput longum and semitendinosus. The experimental part consisted of performing two hamstrings isometric contractions (2 x 6") and four sets of six maximum repetitions (4 x 6 repetitions with 10’ rest interval) in the quadriceps machine. It was not found significant statistical differences in the iEMG (p>0.05) in agonist Activation (vastus lateralis-VL and rectus femoris-RF) and antagonist muscles (biceps femoris-BF y semitendinosus-ST) in absolute values. The normalized values found were: Biceps femoris - 13,52±7,03 % and Semitendinosus - 14,55±7,72%. The extensor muscles obtained its maximum activation around the 48,72 ± 20,45% of the machine extension course while the flexors muscles obtained it around the 63,22 ± 17,03%, approximated to 150º of the knee extension. This present study showed the importance and the functionality of the isoinertial method in strength training since it has similar results when compared to others, helping coaches with knowledge to use it in order to reach athletes optimum development in sports training process.

Keywords: co-activation, electromyography, biceps femoris, semitendinosus, strength.
INTRODUCTION

The strength training using isoinertial machines is one of the methods that have been used for the improvement of this physical capacity. It was developed based on the inertia principle (object resistance to movement changes) and on the Maxwell pendulum concepts. The characteristics of this method allow the realization of efforts in situations in which there is no gravity effect, what gives an advantage in its use in special situations, such as in space trips. Its application allows the muscles affected to meet the inertial resistance during the concentric phases, and the kinetic energy generated is manifested as eccentric load. (1, 2)

The adequate development of the hamstrings is very important in order to guarantee the muscle balance between them and the knee extensors muscles (quadriceps), once during this action the hamstrings work as synergists (e.g. running prop phase) (3-7). Many researchers in different areas related to physical activity have exhaustively studied the process of hamstrings co-activation. (8-13, 14-18, 19, 20). Bernardi et al. (13) pointed out that the main objectives of the co-activation are related to the regulation of joint movement and the control of joint stability. The hamstrings co-activation is necessary to stabilize the knee joint, equalize the tension distribution over the joint surface and to avoid damage to the cartilage, preventing the displacement of the leg bones (10, 15-17).

From the functional point of view, it must be highlighted the level of hamstrings co-activation in the knee joint. With normalized results, Aagaard et al. (9) have found values between 15 to 35% when the normalization was done related to the agonists muscles. Other researchers presented the following values: Osternig et al. (21) between 5-40%, Nakajima et al. (22) between 10-30% of the isometric maximum contraction; Bernardi et al. (13) between 30-80% respectively. The hamstrings co-contraction during the knee extension has been extensively investigated; however, it was observed that most studies were carried out using isokinetics and traditional weight training machines and free weights.

According to the studies of Caruso and Hernández (1), isoinertial ergometer offers eccentric loads superior to the traditional methods. The same authors proved that this machine generates a caloric expenditure compared to others strength training machines used in fitness clubs. Matheson et al. (2) reaffirm the little amount of existing research about the isoinertial method for strength training and suggested a more intense EMG response to the isoinertical work once compared to others, such as free weights and elastic tubes. However, it was not clear in the reviewed literature how greater this difference would be. While the use of different strength training methods to analyze antagonist co-contracting is widespread, its relationship with the isoinertial method remains unclear. The field of strength training and physical fitness needs new methods to be used in evaluation, research and training, which shows the importance of studying different methods from the traditional ones, to allow professionals and coaches the security to use it during their activities.

Based on such information, we hypothesize that the isoinertial work on knee extension would present a greater co-activation ratio when compared with other strength training methods further studied (free weights, isokinetics etc). Moreover, we expected a similar co-activation ratio between Biceps Femoris and Semitendinosus, opposing Aagard et al. (9), who found that the biceps femoris (lateral muscle) presents a greater co-activation once compared with the semitendinosus (3 times greater).

Therefore, the purpose of the current study was to verify the EMG response of antagonist muscles (biceps femoris and semitendinosus) in the knee extension during the isoinertial strength work. In other words, we want to determine in which extension hamstrings are co-activated using this method of strength training.

METHODS

Subjects

Sixteen males (n = 16) voluntarily participated in this study. It was approved by institutional review board for use human subjects and all of them gave their written consent explaining the objectives, conditions and steps of the study prior to participation. None of the volunteers have had previous knee injuries. The group physical characteristics (mean±SD) are: mean body mass = 76,47±5,38kg, mean height = 175,3±6,34cm, mean age = 26,5 ± 4,28 years old.

Experimental Procedures

We used a group of physically active male with a history of exercise practice and/or training in different sports. All of them had previous experience in weight training. They were monitored during two days – i) familiarization and ii) testing – using a descriptive study design. The subjects, after a previous familiarization with the protocol, paid a visit to the laboratory. After a general explanation about the research and after signing the Consent Term, the subjects performed the experimental part of the study. Initially, they performed a standardized warm-up that consisted of a 10’ of a comfortable stationary cycling and three-strength exercise (2 sets x 6 repetitions x 30kg Squat; 2 set x 6 repetitions x 30kg Good Morning with 2’ rest intervals; 2 sets x 5 maximum isonertial repetitions with 5’ rest intervals). Before beginning the
Isoinertial hamstrings co-contraction

research protocol, the subjects rested 10’ while their EMG register preparation was done.

The experimental part consisted of performing two hamstrings isometric contractions (2 x 6”) and four sets of six maximum repetitions (4 x 6 repetitions with 10’ rest interval) in the quadriceps machine. In the first set, it was registered the knee extensors (vastus laterales and rectus femoris); in the second one, the knee flexors (biceps femoris and semitendinosus); in the third, the vastus laterales and the biceps femoris; and in the fourth, the same muscle registered in the third one, though emphasizing the conscious hamstrings action. All experimental procedures were supervised by the researchers and subjects were asked to stay one full day without physical activity to get rest. This research was approved by Ethics Comittee from the Universidad de Las Palmas de Gran Canaria - Spain

Electromyography

EMG signals were obtained by the use of bipolar surface electrodes (I-330-C2) placed 2cm apart on vastus laterales, rectus femoris, biceps femoris caput longum and semitendinosus. In the vastus laterales, the electrodes were fixed over the lateral aspect of the thigh, one handbreadth above the patella. The rectus femoris was registered in the midpoint between the superior border of the patella and the anterior superior iliac spine. The long head of the biceps femoris fixed the electrode at the midpoint of a line between the fibula head and the ischial tuberosity. An electrode for semitendinosus was fixed midway on a line between the medial epicondyle of the femur and ischial tuberosity. The skin of the subjects was cleaned with abrasive swabs, and subsequently rinsed with alcohol to increase conductivity and reduce electrode impedance. (input ranges: +/-10 µV; Input Impedanc: +/- 10 Gohm). The EMG signals were done in all repetitions of each set, in which it was calculated the mean values of the three repetitions that presented the lower Standard deviation. The values were normalized, in case of the hamstrings, related to the value obtained in the isometric contraction and the extensors (vastus lateralis and rectus femoris) related to the maximum isoinertial value (9). The EMG response in the isoinertial machine causes a muscular activation superior to the obtained values in an isometric contraction. (23).

Isoinertial Machine

The study was developed in an isoinertial machine (YoYo™ flywheel ergometer – YoYo Technology AB) specific to the knee extension in a concentric action. The exercise is done over a mechanism similar to the Maxwell pendulum, in a way that, when the force direction starts to be inverse (axis rotation contrarily to the extension) the subject is submitted to a force equal to the inertia created by the mass acceleration placed in the extremes of the cylinder. It is operated in a Yo-Yo principle in a mechanical flywheel device. It does not depend on the gravity and uses the inertia’s principles to provide eccentric resistance to the muscle.

Statistical Analysis

The electromyography data, for extensors and flexors, were normalized as it has been shown in the methods. The mean contraction of the extensors was considered as maximum (100%), since previous studies pointed out that maximum muscle activations were reached during the performance of this exercise. On the other hand, the hamstrings EMG were normalized from values found during the maximum isometric contraction. For the data analysis, it was used a basic descriptive statistic (mean and SD), the Student “t” test and the ANOVA, with a significance level p < 0.05.

RESULTS

Agonist Activation (vastus lateralis-VL and rectus femoris-RF) in absolute values.

Electromyography measures in knee extension agonist muscles did not present significant statistical differences in the iEMG (p>0.05) in both muscles (see values in Table 1). These results depict similar activation patterns in both muscle during isoinertial knee extension. Also, The extensor muscles obtained their maximum activation around the 48.72 ± 20.45% of the machine extension course, value that corresponds to an approximate mean 135º of knee extension. In a general way, we can consider that the extensor muscles movement pattern suggests an activation phase since the beginning of the movement, what is sustained during the whole course, although the RF reaches its maximum value a little bit before the VL. (see example in Figure1).

<table>
<thead>
<tr>
<th></th>
<th>VL</th>
<th>RF</th>
<th>BI</th>
<th>ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>80.63</td>
<td>77.62</td>
<td>12.65</td>
<td>11.76</td>
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<tr>
<td>SD</td>
<td>25.22</td>
<td>23.54</td>
<td>6.58</td>
<td>6.24</td>
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<tr>
<td>Minimum</td>
<td>42.27</td>
<td>34.54</td>
<td>4.27</td>
<td>4.90</td>
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<tr>
<td>Maximum</td>
<td>118.56</td>
<td>115.66</td>
<td>34.11</td>
<td>32.33</td>
</tr>
</tbody>
</table>

Antagonist co-contraction in absolute values.

The antagonist muscles in knee extension (biceps femoris-BF y semitendinosus-ST) also presented similar activation values (see values in
Table 1). There is no statistical differences (p>0.05) between their iEMG values. The flexor muscles obtained the maximum activation around the 63.22±17.03% of the extension machine course, what corresponds to an approximate mean of 150º of the knee extension. Comparing the behavior of both muscle groups (extensors x flexors), it is observed in this study that both presented similar EMG curves, even though the maximum flexors activation happens later, closer to the end of the movement. (Figure 2). The comparison between an extensor muscle (VL) and a flexor (BF) during knee extension is disposed in Figure 3.

![Figure 1](image1.png)

**Figure 1-** Mean contraction EMG (iEMG in µV) during knee extension of agonist muscles (vastus lateralis VL/Rectus Femoris - RF) in three repetitions in the isoinertial.

![Figure 2](image2.png)

**Figure 2-** Mean contraction EMG (iEMG in µV) during knee extension of antagonist muscles (biceps femoris BI/ Semitendinosus ST) in three repetitions in the isoinertial.

The antagonist muscles normalized values (biceps femoris and semitendinosus) are disposed in the Table 2. These values show the their normalization to the maximum isometric contraction. Biceps femoris reached 13.52±7.03 % whereas the semitendinosus reached 14.55±7.72%. Through these values, we tried to support the research hypothesis of higher co-activation in an isoinertial work when compared to other methods. At first, these data support the hypothesis that both antagonist muscles (BI/ST) present a similar activation between them, as shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>BI</th>
<th>ST</th>
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<tbody>
<tr>
<td>Mean</td>
<td>13.52 %</td>
<td>14.55 %</td>
</tr>
<tr>
<td>SD</td>
<td>7.03 %</td>
<td>7.72 %</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.56 %</td>
<td>6.06 %</td>
</tr>
<tr>
<td>Maximum</td>
<td>36.44 %</td>
<td>40.00 %</td>
</tr>
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</table>

**DISCUSSION**

The values arrived at in the current study showed that the hamstrings are co-activated during knee extension, when this movement is done in a quadriceps isoinertial machine. For this reason, it is understood that these muscles actuate during this exercise in a double function: knee extension (synergistic action) and fixation of the knee joint (protection of knee internal structures). These results are similar to the ones presented by some studies found in the specialized literature. However, these studies are related to other materials and/or research methodologies (9-11, 13, 15-18, 19). Furthermore, the researches done seem to present a high variability in the level of hamstrings activation, what can be explained by the different procedures of normalization applied in each one.
The normalized activation values obtained in the present study (BI-13.52±7.03 %/ ST-14.55±7.72%) are also similar to the ones found in other studies (6, 9, 10, 21, 22), except the one from Bernardi et al. (13), who have found higher values, even though the present study also showed a similar inter-individual range variability (5%-40%), if compared with the studies presented by other authors (6, 9, 10, 21, 22).

Baratta et al. (12) indicated that when an isokinetic action is done in low speeds, the hamstrings co-activation varies between a 5-10%, what leads to the conclusion that the action in an isoinertial machine is done in maximum intensity – the muscular action is very similar to the description done by the mentioned authors in their researches. The results found in this research oppose our first hypothesis that isoinertial work on knee extension would present a greater co-activation when compared to other methods, since isoinertial hamstrings co-activation range values are very similar to the others (6, 9, 10, 21, 22).

The moment of greater activation of extensors and flexors muscles that were analysed does not happen in the same movement range. In the present study, the higher activation of the extensor muscles happened in the 48,72± 20,45% of the course, what is equivalent to a 135°of joint extension, while the higher activation of the hamstrings is produced at 63,22 ± 17.03%, 150° of the knee extension, closer to the final part of the movement. These data are similar to the results found in Aagard et al. (9).

When the analyzed muscular structures related to the hamstrings (BI and ST) are compared among themselves, it is observed that the absolute and normalized values of both muscles did not show significant differences, what opposes to the results pointed out by Aagard et al. (9) in their study about the co-activation of the antagonist muscles during an isokinetic workout. They indicated that the ST activation is three times higher than the BI in this type of exercise. These data comparing BI and ST co-activation values support our hypothesis of similar co-activation between hamstrings muscles during isoinertial knee extension.

During sport strength training, many different methods are available to improve neuromuscular conditioning and athletic performance. Any method that is under research may be used in strength training in fitness clubs and in competitive sports context. Without appropriate research, coaches will not be able to know the real effects that such method generates in the athlete’s body.

So much so, this present study on hamstrings co-activation during knee extension in an isoinertial machine helps to show the importance and the functionality of this method in strength training since it has similar results when compared to others. We understand that the obtained data about the hamstrings, beyond the function of knee flexion and hip extension, have important functions in the knee extension and in the fixation of this joint when the isoinertial machine developed to the quadriceps training. In such a way, the current research helps coaches with specific knowledge about strength training functionality in an isoinertial machine, helping them to use this method in their training process.

REFERENCES


