

Comparison of quadriceps muscle activation in exercises with different duration of concentric and eccentric contractions

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Summary

Aim: The objective of the present study was to compare the amplitude of the electromyographic (EMG) signal of the quadriceps muscle portions vastus medialis (VM), vastus lateralis (VL) and rectus femoris (RF) and the activation ratio (VM/VL, VM/RF and VL/RF) in protocols with different durations of concentric and eccentric muscular actions.

Material and method: Twelve female volunteers performed the knee extensor exercise with two different protocols [1s for concentric muscle action and 5s for eccentric muscle action (1:5); 5s of concentric muscle action and 1s of eccentric muscle action (5:1)] and 3 sets of 6 repetitions, 180s of pause between each sets and a intensity of 50% of 1RM. The root mean square of the amplitude of the normalized EMG signal was calculated for each repetition in each series.

Results: it was observed an increase in the activation of the VM and VL portions in equivalent repetitions of each series and for the VL portion, the 1: 5 protocol provided greater activation compared to the other protocol. No differences were found for muscles activation ratios VM/RF and VL/RF, being that for the VM/VL ratio there was only change at one repetition.

Conclusion: The results suggest that the portions of the quadriceps muscle may present different EMG responses in similar protocols, but this fact may not interfere in the synergism between them. The reduced degrees of freedom of the knee extension exercise and the characteristics of the protocols adopted may be the elements that contributed to the limited alterations that occurred in the present study.

Key words:

Resistance Training.
Electromyography.
Quadriceps muscle.

Comparación de la activación muscular del cuádriceps en ejercicios con diferente duración de las contracciones concéntricas y excéntricas

Resumen

Objetivo: El objetivo del presente estudio fue comparar la amplitud de la señal electromiográfica (EMG) de las porciones de músculo cuádriceps vasto medial (VM), vasto lateral (VL) y recto femoral (RF) y la relación de activación (VM/VL, VM/RF y VL/RF) en protocolos con diferentes duraciones de acciones musculares concéntricas y excéntricas.

Material y método: Doce mujeres voluntarias realizaron el ejercicio extensor de rodilla con dos protocolos diferentes [1 s para la acción muscular concéntrica y 5 s para la acción muscular excéntrica (1:5); 5s de acción muscular concéntrica y 1s de acción muscular excéntrica (5: 1)] y 3 series de 6 repeticiones, 180s de pausa entre cada serie y una intensidad del 50% de 1RM. La raíz media cuadrática de la amplitud de la señal electromiográfica normalizada se calculó para cada repetición en cada serie.

Resultados: se observó un aumento en la EMG de las porciones de VM y VL en repeticiones equivalentes de cada serie y para la porción de VL, el protocolo 1: 5 proporcionó una mayor activación en comparación con el otro protocolo. No se encontraron diferencias para las relaciones de activación de los músculos VM/RF y VL/RF, siendo que para la relación VM/VL solo hubo cambios en una repetición.

Conclusión: Los resultados sugieren que las partes del músculo del cuádriceps pueden presentar diferentes respuestas de EMG en protocolos similares, pero este hecho puede no interferir en el sinergismo entre ellos. Los grados reducidos de libertad del ejercicio de extensión de la rodilla y las características de los protocolos adoptados pueden ser los elementos que contribuyeron a las alteraciones limitadas que se produjeron en el presente estudio.

Palabras clave:
Entrenamiento de fuerza.
Electromiografía.
Músculo cuádriceps.

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Introduction

The vastus medialis (VM), vastus lateralis (VL) and rectus femoris (RF) are portions of the quadriceps that act synergistically to produce knee extension torque for many movements¹ and knee extensor equipment has been used both for training and for scientific research on electromyographic activation (EMG) of this muscle group in different muscle strength performances. This equipment limits the movement in its trajectory due to its rigid axis, allowing the body segment to only move in one direction, unlike other equipment such as free bars or Smith machine where knee extension is also performed.

Pincivero *et al.*² evaluated the EMG activity in a single set of knee extension at 50% of one repetition maximum 1RM with the maximum number of repetitions and verified increased activation in the concentric action without differences between portions. In the eccentric action, these authors recorded an overall reduction in activation but the activation of the VL remained greater than the other portions. Akima and Saito¹ observed a gradual increase in the EMG with time, similar to the concentric action of the study by Pincivero *et al.*², while Rabita *et al.*³ found an increase only in RF activation compared to the control group after four weeks of isometric training. Matheson *et al.*⁴ verified that different velocities produced different EMG of RF, VL and vastus medial oblique (VMO) in multiple series of isokinetic knee extension. The results of Hatzel *et al.*⁵ suggest the influence of repetition duration on quadriceps activation, with greater activation at 60°/s compared to 15°/s on eccentric action. Yavuz *et al.*⁶ pointed that different magnitudes of external load can result in different activations in the comparison between quadriceps muscle portions and Ema *et al.*⁷ recorded different EMG activations for RF at leg press and knee extensor exercises compared to VM and VL, suggesting alterations in the synergism.

Despite these different responses in studies, the results of Ribeiro *et al.*⁸ point out that when demand increases on quadriceps it is shared between the portions in synergistic action and Laine *et al.*⁹ showed that the VM and VL share the neural drive when activated synergistically.

The analysis of the activation ratios (VM/VL, VM/RF, VL/RF) can help to understand the relative contribution of each quadriceps portion compared to the others, allowing to verify how the nervous system strategy can alter synergism in the production of a specific knee extension performance. Coqueiro *et al.*¹⁰ indicate that patellar misalignment may be due to dysfunction of VMO compared to VL (VMO/VL) and other studies have suggested that changes in the activation ratio (VM/VL)^{11,12,4} may favor the onset of Patellofemoral Pain Syndrome, where individuals presenting the syndrome have a lower VMO/VL ratio than healthy individuals^{13,14}.

Wong and Ng¹¹ verified an increase in the VMO/VL ratio in both a low intensity and high volume training protocol, as well as in a higher intensity and lower volume training protocol, with no difference between them. Beyond this, VMO activation started before VL after the training period, a fact that did not occur in the pre-training period. Other studies^{4,15,16} found higher values for the VM/VL ratio with the increase in angular velocity, suggesting the interference of repetition durations; however, the methodological differences between the studies, such as the type of exercise used, limit the comparisons.

The results available keep open the different possibilities of investigating how the portions cooperate to produce movement in response to different manipulations. In addition, studies have been investigating equipment that apply external resistance in different ways and care should be taken with the transfer of results between them, for example, knee extensor and squat or leg press, due to the differences in degrees of freedom and allowed movement trajectories.

Therefore, analyzing the EMG responses of the quadriceps portions in protocols performed with different durations of muscular actions for the same repetition duration, will allow to increase the understanding of how they act synergistically in order to produce muscular strength in weight training equipments. Therefore, the present study aimed to analyze the amplitude of the electromyographic signal of the VM, VL and RF and the activation ratios VM/VL, VM/RF and VL/RF in protocols with multiple series, equal repetition duration and different durations of muscular actions in knee extension exercise.

Material and method

Sample

A experimental design of repeated measurement was used, with 12 female university students (age 21.4 ± 3.6 years, body weight 55.9 ± 7.3 kg, height 1.62 ± 0.07 meters), participating in recreational physical activities in the last six months and absence of musculoskeletal lesions in lower limbs, spine and pelvis. To participate in the study, volunteers should perform the 1RM test with, at least, 25 kg. This value refers to twice the resistance offered by the movable structure of the equipment (support of washers, mechanical arm, camus). This procedure ensured that they all performed training protocols with the determined intensity of 50% of 1RM.

The volunteers were instructed not to perform physical activities on the days of testing sessions, and on the day before the same. The sample calculation used GPower software (version 3.1.7). It was used the design of repeated measurements (ANOVA Repeated measures, within interaction), an alpha error of 0.05, a power of 0.8, a correlation between the repeated measures of 0.73 and a correction of non-sphericity of 1, considering the 2 experimental groups (1:5 and 5:1) and the 3 measures (equivalent repetitions: 1, 7 and 13, etc). For the effect size variable a value of 0.37 was, obtained through the study of Pincivero *et al.*², in the data of the rectus femoris muscle that obtained the highest coefficient of variation (CV). Through this information the software determined a sample size of 10 individuals. The study was approved by the local Research Ethics Committee.

Procedures

A knee extensor machine (Master Equipment®) was adjusted to a 110 degree angle between the backrest and the seat. A belt was placed near the iliac crest in order to minimize accessory movements in the hip. Fixed to the axis of rotation of the equipment, a linear potentiometer of 10 k Ω , with linearity error of 2%, voltage range of +10V to -10V, allowed the measurement of the angles in the equipment. To perform the Maximum voluntary isometric contraction (MVIC) at each joint

angle, a manual system was used to lift the support with weights up to the height that corresponded to the desired angle in the equipment, determined by the potentiometer.

An experimental design of repeated measurements was used and the volunteers attended 4 days at the laboratory separated by a minimum of 48 hours and a maximum of 96 hours. All testing sessions took place at the same time of the day for each volunteer.

In session 1, the volunteers were positioned with the hip at an angle of 110°, the lateral epicondyle of the femur aligned with the potentiometer and the distal support of the equipment 3 cm above the medial malleolus¹⁷; this positioning was maintained in all sessions. The 1RM test followed the guidelines of Diniz *et al.*¹⁸, with a maximum number of six attempts, five-minute pause between each attempt and gradual weight progression. The onset of concentric action was at 100° of knee flexion and the weight was progressively increased until it was not possible to reach 30° of knee flexion (0° = extended knee) in the concentric action. Ten minutes after the 1RM test, familiarization with the duration of muscle actions was performed in a series of 6 repetitions without additional weight. In session 2, the 1RM test was performed again and after 10 minutes another familiarization with the durations of muscular actions was performed.

In sessions 3 and 4, the MVIC test was performed and the EMG signal of VM, VL and RF was recorded. The electrodes on the vastus medialis were placed at 80% on the line between the upper anterior iliac spine and the joint space in front of the anterior border of the medial ligament. On the vastus lateralis the location was 2/3 on the line from the upper anterior iliac spine to the lateral side of the patella, and on the rectus femoris the electrodes were placed at 50% on the line from the upper anterior iliac spine to the superior part of the patella; these are the recommendations of Surface electromyography for the non-invasive assessment of muscles (SENIAM)¹⁹. After the placement of the electrodes, a semi-permanent pen was used to draw the edges on the patella (reference electrode) and muscles, so as to allow replication in the subsequent sessions. The electrical activity of the muscles was recorded using a surface electromyography equipment (Biovision, Germany), with the electrodes configured with a gain of 1000 times. The electromyograph information was synchronized and converted into digital signals by an A / D card (Biovision, Germany) with an input range of -5 to +5 Volts and directed to a computer. For the acquisition and treatment of the signals, a specific program (DasyLab 11.0, Ireland, Dasytech Laboratories, 12 bits), calibrated with 2000 Hz sampling frequency was used. Ag / AgCl type surface electrodes (Kobme Bio Protec, Korea), with a capture area of approximately 1 cm², were positioned in the direction of the muscle fibers according to the recommendations of SENIAM¹⁹.

Before the electrodes were placed, the area of the skin was trichotomized, hygienized with alcohol and cotton, rubbing heavily the cotton in the place in order to guarantee the cleanliness and a reduction of the impedance of the skin²⁰. The electrodes were positioned in pairs with a center-to-center distance of 2 cm. The MVIC test was performed with two 5s trials at angles of 30°, 50°, 70° and 90° of knee flexion (knee extended = 0°) and pause of three minutes between each angle and each attempt. The volunteers performed maximum force against the arm of the equipment that was fixed so that it could not be moved.

Table 1. Reliability of EMG measurements in the MVIC test.

Portion	Protocol	Mean ± SD (mV)	ICC _(3,1)	SEM (mv)
Vastus medialis	1-5	0.82 ± 0.40	0.65	0.25
	5-1	0.75 ± 0.28		
Rectus femoris	1-5	0.95 ± 0.28	0.87	0.21
	5-1	0.95 ± 0.28		
Vastus lateralis	1-5	0.68 ± 0.28	0.90	0.20
	5-1	0.69 ± 0.24		

Standard deviation (± SD); ICC - intraclass correlation coefficient; EPM – standard error of measurement. N = 12.

The MVIC was used as a reference for normalization (normalization test). Initially, a smoothing of the electromyographic signal of MVIC of each muscle was performed in each attempt at the angles of 30°, 50°, 70° and 90° through movable windows using the root mean square (RMS). EMG normalization considered the position with the highest mean value of the two trials at the respective testing session. The potentiometer data was filtered with a lowpass filter of 10 hz and EMG with a 20-500hz band pass filter, 2nd order Butterworth type. Electromyographic activity was processed in the time domain with DASYLAB 11.0. The RMS of the EMG signal during the protocols was extracted and the values were divided by the reference value previously described, resulting in normalized percentages of EMG. The reliability of the MVIC measures for each portion was determined by intraclass correlation coefficient (ICC) and standard error described in Table 1.

Protocols

After the MVIC, one of the protocols was performed, which consisted of 3 sets of 6 repetitions at 50% of 1RM, with pauses of 180s between sets. These values are in accordance with those recommended for muscle hypertrophy training²¹ and muscular actions times used were the same ones investigated by Goto *et al.*²²:

- 1: 5; concentric muscle action of 1s and eccentric of 5s.
- 5: 1; concentric muscle action of 5s and eccentric of 1s.

The order of the protocols was balanced.

Statistical analysis

Statistical packages SPSS 20.0 and SISVAR were used for data analysis and the significance level adopted was P <0.05. The EMG analysis was performed between the equivalent repetitions of the series, with 1, 7 and 13 being the first repetition of each series; 2, 8 and 14 the second repetition of each series and so on. The first repetition was also compared with the last one in each series. Initially, a descriptive analysis of the data was performed. All variables passed the normality test (Shapiro-Wilk) and homogeneity of variances (Levene). A two-way ANOVA with the protocol and repetition factors with repeated measures was used to compare the EMG mean values for the equivalent repetitions of each series in RF, VM and VL and the ratios VM/VL, VM/RF and VL/RF between the protocols and between the repetitions. When necessary, the Bonferroni post hoc was used to locate the differences.

To reflect the magnitude of the differences in each treatment the eta square was calculated by dividing the square sum of the effect by the total sums of squares. According to Cohen (1988), one can consider $\eta^2 = 0.140$ as large, $\eta^2 = 0.060$, as mean and $\eta^2 = 0.010$ as small.

Results

The durations of the concentric and eccentric muscular actions in the 1:5 and 5:1 protocols were respectively: 1:5 (1.06 ± 0.20 CONs, 4.95 ± 0.61 s EXC) and 5:1 (4.56 ± 0.31 s CON, 1.41 ± 0.33 s EXC).

In this study, 18 comparisons were performed between the equivalent repetitions in each series, with repetitions 1 to 6 located in the first series, 7 to 12 in the second and 13 to 18 in the third series. In all series, muscle EMG in the last repetition was greater than in the first one.

For the VM portion it was observed significant main effect only for the repetition factor ($F_{17,187} = 64,384, p < 0.001, \text{power} = 1.000; \text{effect size} = 0.40$), showing an increase in the activation of the equivalent repetitions in some repetitions for both protocols. There were no differences between the protocols (Figures 1 and 2).

For the VL portion, it was verified main effect of the protocol ($F_{2,222} = 5,317; p < 0.019; \text{power} = 0.721; \text{effect size} = 0.15$) and repetition ($F_{17,187} = 57,594; p < 0.001; \text{power} = 1,000; \text{effect size} = 0.37$). The 1:5 protocol had higher activation compared to the 5:1 protocol and there was an increase in activation in some equivalent repetitions in both protocols (Figures 3 and 4).

For the RF portion, a significant interaction protocol x repetition ($F_{34,374} = 2,200; p < 0.05; \text{power} = 0.775; \text{effect size} = 0.02$) was verified, showing that changes in muscle activation were different for repetitions and series between protocols (Figures 5 and 6).

For the VM/VL ratio it was verified significant effect of repetition ($F_{17,187} = 1746, p < 0.05, \text{power} = 0.523, \text{effect size} = 0.01$). Only the repetition 2 of the second series showed an increase in EMG ratio to its

Figure 1. Normalized EMG (% MVIC) in the vastus medialis portion. @ series 1 different from series 3; \$ series 2 different from the series 3; & the first repetition lower than the last repetition of each series.

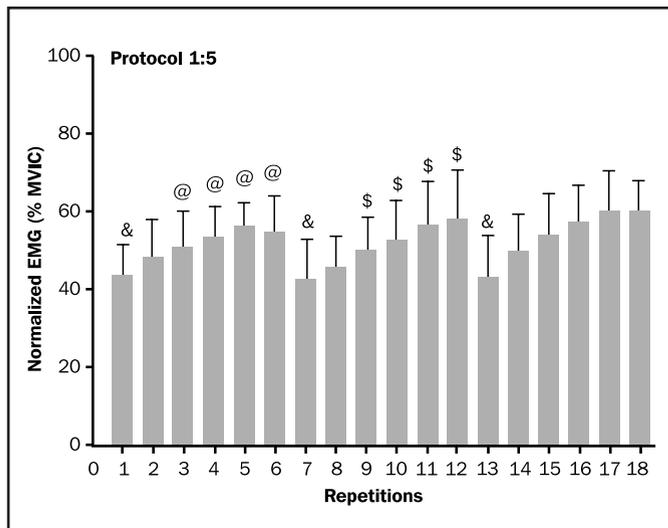


Figure 2. Normalized EMG (% MVIC) in the vastus medialis portion. @ series 1 different from series 3; \$ series 2 different from the series 3; & the first repetition lower than the last repetition of each series.

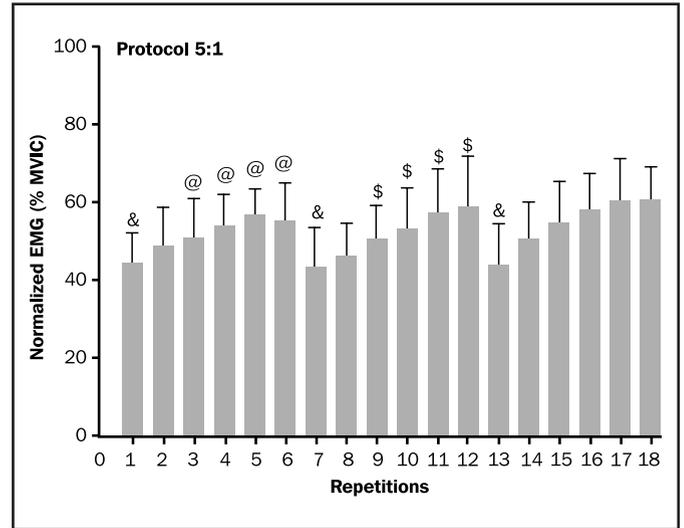
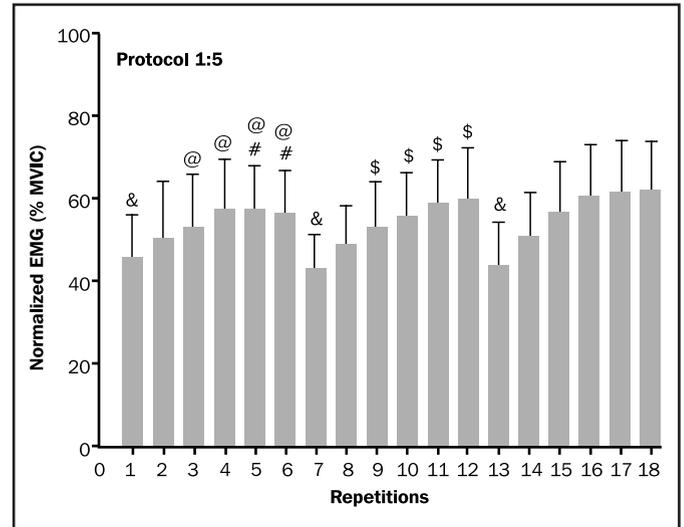


Figure 3. Normalized EMG (% CIVM) in the vastus lateralis. @ series 1 different from series 3; \$ series 2 different from the series 3; # series 1 different from series 2; & the first repetition lower than the last repetition of each series. * 1:5 protocol greater than 5:1.



equivalent in the third series, with no difference between the protocols. The VM/RF and VL/RF ratios did not present significant differences.

Discussion

This study investigated VM, VL and RF EMG in protocols with differences in muscle actions time. Differences were observed when comparing initial and final repetitions and the equivalent repetitions in second half of each series, with an increase in EMG from the beginning

Figure 4. Normalized EMG (% CIVM) in the vastus lateralis. @ series 1 different from series 3; \$ series 2 different from series 3; # series 1 different from series 2; & the first repetition lower than the last repetition of each series.

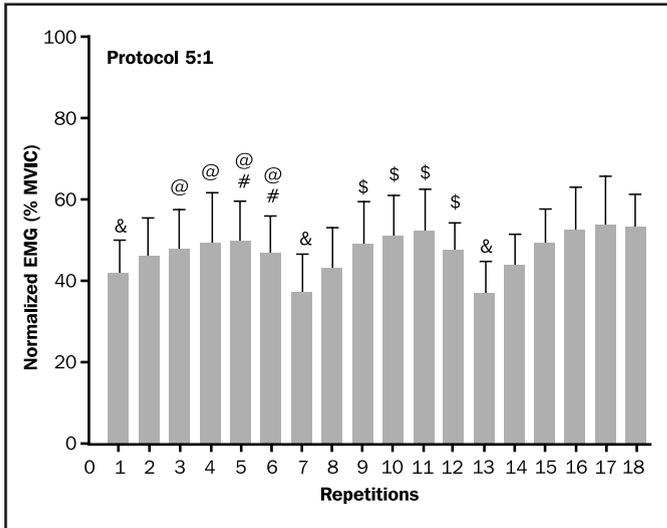


Figure 6. Normalized EMG (% MVIC) in the rectus femoris. @ series 1 different from series 3; \$ series 2 different from series 3; # series 1 different from series 2; & the first repetition lower than the last repetition of each series.

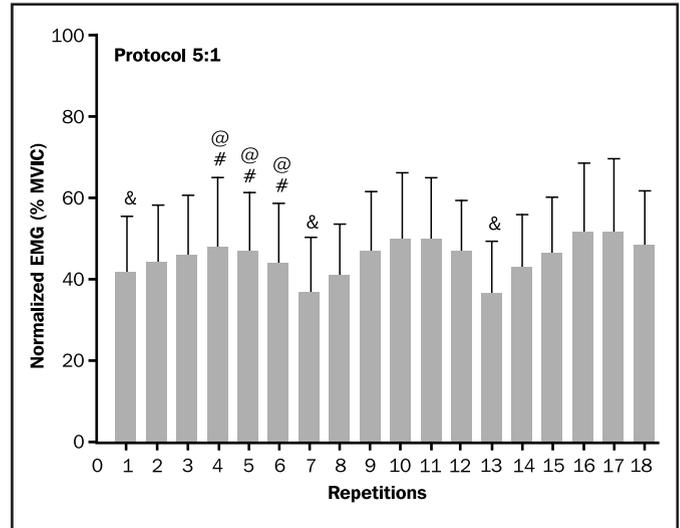
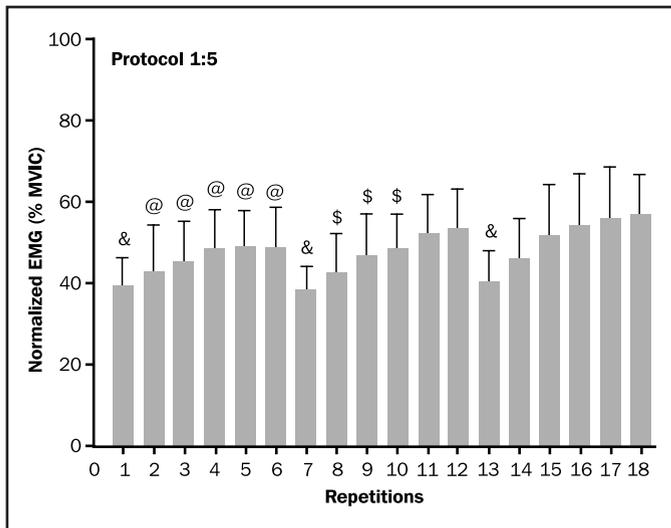


Figure 5. Normalized EMG (% MVIC) in the rectus femoris. @ series 1 different from series 3; \$ series 2 different from series 3; # series 1 different from series 2; & the first repetition lower than the last repetition of each series.



These results may reflect a characteristic of strength training, where this increase in muscle activation can be explained by the higher recruitment of motor units to produce the force required to complete the task along the protocol. However, other factors may influence the EMG amplitude as the firing frequency and/or increased synchronization of motor unit activation. On the other hand, Burd *et al.*²⁴ verified a differential increase of the EMG throughout the series between two repetition durations in the knee extensor, being that these responses were common to the VM, VL and RF, differently from our study. However, these studies did not analyze the EMG in the equivalent repetitions between series, and this was a different analysis carried out in the present study that allows adding an additional understanding of the recruitment of synergistic musculature for the production of strength.

In the present study, the results showed different activations for VM, VL and RF. An increase in EMG was observed in some equivalent repetitions between the 3 series for both protocols for the VM. For VL, the EMG for the 1:5 protocol was higher than the 5:1 protocol and the change in EMG occurred differently among protocols for RF. The 1:5 protocol had a greater EMG response than the 5:1 protocol for VL and it may be related to the need to produce larger peak forces to accelerate the weight with the concentric duration of 1s. The high effect size (0.15) and the results of the study by Sakamoto and Sinclair²⁵ reinforce this explanation. These authors verified higher EMG in concentric actions when shorter repetition durations were performed. However, it is not possible to determine why this difference occurred only in VL in our study. No differences were observed between the protocols for the VM, and for the RF it was verified protocol x repetition interaction, showing that the differences did not occur in the same equivalent repetitions in the series for each duration of the muscular actions. However, the effect size for RF was small (0.02), which reinforces the need for caution in highlighting these difference. Besides this, taking into account that the

to the end of series. Walker *et al.*²³ also observed an increase in the EMG amplitude along the repetitions for the VM and VL, with higher EMG for repetition 8 compared to repetition 2 in all series analyzed; Pincivero *et al.*² found that the portions of the quadriceps presented an increase in EMG between 10 and 20%, 20 and 30%, 40 and 50% of total time spent at single series and Akima and Saito¹ also verified larger EMG in the final repetition compared to the initial one at the knee extension exercise with intensities of 50 and 70% of 1RM and repetitions until fatigue.

RF is biarticular, such characteristic has been considered when analyzing muscle activation in the knee extensor. Cramer *et al.*²⁶ investigated the impact of eight different velocities of movement and observed a differentiated behavior for RF, suggesting that this result may be due to differences in fiber composition and muscle architecture between portions. Using isometric knee extension, Rabbita; Pérot; Lenseil-Corbeil³ showed an increase only in the RF activation after 4 weeks and justified this difference by its biarticular condition. Ebenbichler *et al.*²⁷, verified a differentiated increase in activation between the portions of quadriceps in protocols until fatigue; the VM and the VL presented increased EMG throughout the task, while the RF presented a slight increase in intensities 30 and 50%, but registered decrease with 70% of the MVIC. According to these authors, the neurophysiological control of synergism between mono and biarticular muscles can be mediated by different mechanisms of neural control in the central nervous system. There is a suggestion that the differences between the mono and bi-articular muscles may be related to the presence of two different groups of neurons in the cerebral cortex, one that encode positions²⁷ and the other that encodes the direction of the resulting force²⁸. Ebenbichler *et al.*²⁷ suggested that the organized control of different muscles acting synergistically would involve the group of neurons that control the direction of the resulting force mainly for the monoarticular muscles and both types of neurons would act for the biarticular ones; this author also point out that a monoarticular task such as knee extension would be able to stimulate these two groups of neurons, which would justify the differentiated EMG behavior of RF.

The study by Matheson *et al.*⁴ found that at 60°/s the RF was more activated than VL and VMO, at 180°/s there was no difference and at 300°/s VL and VMO activated more than RF. The authors justify these differences mainly by the absence of a thigh strap for hip stabilization and also by the fact that RF is the only biarticular portion. In the present study the volunteers were stabilized in the hip region with a belt attached to the seat to minimize accessory movements such as hip flexion and/or extension that could alter both the length and activation of the RF. However, there may have been a force application on the trunk near the back of the seat, resulting in some subtle alteration in hip joint positioning. Ema *et al.*²⁹ analysed VM, VL and RF activation at knee extension in fully extended and 80° hip flexion and no effect of hip position were observed on muscles activation, but higher activation was present at faster velocity (180°/s vs 80°/s).

The analysis of the activation ratios showed that the durations of the muscular actions adopted altered only the repetition 2 of the second series for VM/VL when compared to its equivalent in the third series, with no difference between the protocols. For the VL/RF and VM/RF, no significant differences were found. Despite the increase of the EMG verified, the synergism was not altered. To the best of our knowledge, no study investigated the VM/RF and VL/RF ratios. The studies by Matheson *et al.*⁴, Sczepanski *et al.*¹⁵ and Yoo¹⁶ investigated the impact of different velocities and suggest that higher velocities may produce higher values on the VM/VL ratio. The results of Wu *et al.*³⁰ showed that the VMO/VML activation ratio was higher than 1 at the standing unilateral knee extension, with no significant differences at nine joint ranges of motion. Other studies reported a lower VMO/VL value in individuals with patellofemoral pain syndrome (PFPS)^{12,13}

compared to healthy individuals^{12,13} and an increase in this ratio would imply a possible increase in patellar medialization¹¹, which would lead to a better distribution of the compressive forces acting on the patellar femoral joint, improving the pain symptoms

Considering the available literature, it should be emphasized that many of the results have been obtained in isokinetic equipment that does not reproduce the conditions of the resistance applied by traditional weight training equipment.

Taking into account the volume of analyzes performed, it can be pointed out that only a small number of differences were detected in EMG between the portions of the quadriceps analyzed and this can also be attributed to the characteristic of the exercise and equipment used in the experiment. The knee joint can be described as a hinge joint between the femur and the tibia and flat between the femur and the patella, and it acts on a single plane, the sagittal; this configuration does not allow a variation of the trajectory of the movement, due to the limited degrees of freedom. These degrees of freedom of the movement can not be altered by the different durations of the muscular actions adopted, not leading to changes in the characteristics of the movement that resulted in a differentiated drive despite the architectural differences between the portions analyzed, so, the synergism between the portions of the quadriceps is maintained in a stable manner. Each portion will perform its task with no possibility of changes in the trajectory of the movement that could be influenced by the durations.

Conclusions

The present study concluded that multiple series protocols with different durations of muscle action may result in a differential increase in the EMG response between the quadriceps portions. The results also indicate that despite this differentiated increase between the portions, the activation ratios between did not change, suggesting that these changes in EMG were not sufficient to alter the synergism between the portions. However, the number of differences verified was limited by the volume of comparisons. The reduced degrees of freedom of the exercise and the characteristics of the protocols may be the elements that contributed to the limited alterations that occurred in the present study.

Limitations of study

Through these results, it is not possible to suggest precise directions for the prescription of the training that guarantees a greater selective activation of some portion of the quadriceps with the manipulation of the durations of the muscular actions adopted. It should also be considered that different values for the training load volume, intensity and density may lead to another results, mainly in conditions of maximum demands of volume and/or intensity. In addition, performing knee extension on other equipment with greater degrees of freedom in the knee and hip joints may have different results from the present study.

Conflict of interest

The authors declare no conflict of interest.

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