ORIGINAL ARTICLE

Activation level of vastus medialis muscle in different rehabilitation exercises

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ABSTRACT

Excessive lateralization, which often occurs by the weakening of Vastus Medialis (VM) muscle of the patella, is one of the causes of Patellofemoral Pain Syndrome (PFPS) For prevention and rehabilitation of PFPS, the VM strength is essential. **Objective:** The aim of the study was to compare the VM activation level in four different exercises used in the prevention and rehabilitation of PFPS that are isometric knee extension at 30° and 60° and isometric squat at 60° with or without hip adduction. **Methods:** A sample of 14 sedentary healthy subjects, aged between 20 and 40 years was included. The EMG signal of VM muscle was collected during Maximal Voluntary Isometric Contraction with duration of five seconds for each exercise. From the captured EMG signal, a period of three seconds was cut and thereafter the Root Mean Square value for each exercise was obtained. **Results:** The results showed that there was significantly greater activation in VM extension exercises compared to squat exercises. However, there was no significant difference between the two extension exercises, as well as between squat exercises. **Conclusion:** It can be concluded that the best exercises to maximize the activation of the VM are the isometric knee extension, regardless of the rated angle, since they have greater VM activation level, essential for the prevention and rehabilitation of PFPS.

Keywords: Patellofemoral Pain Syndrome, Quadriceps Muscle, Electromyography

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Received on August 29, 2016.
Accepted on October 21, 2016.

DOI: 10.5935/0104-7795.20160025

INTRODUCTION

The knee joint undergoes countless injuries and the Patellofemoral Pain Syndrome (PFPS) is among them. This syndrome affects especially young adults and it is one of the most common Musculoskeletal Disorders at a physiotherapy rehabilitation service.[1,2] It is defined as knee or retropatellar pain caused by structural and biomechanics alterations of the joint.[3] The etiology of the injury is still not well defined, however the excessive lateral movement of the patella is the most acknowledged aspect.[4,5]

One of the reasons for the lateralization is the muscular imbalance between the Vastus Lateralis (VL), which should draw the patella lateralward, and the Vastus Medialis which should draw the patella medialward.[1,6-10] During the knee extension, all portions of the quadriceps, rectus femoris, vastus intermedius, and vastus lateralis, except the vastus medialis, provide lateralization trends in the patella.[8] The fibers of the VM, however, stands at a medial inclination of 55° in relation to the femoral diaphysis drawing the patella medialward.[11,12] The VM insufficiency causes a prevalence of VL draw, the principal claim of patellar lateralization, therefore a predictor of PFPS.[9]

The conservative treatment for this injury is the best choice, and the physiotherapeutic intervention, either in rehabilitation or in prevention, must include a training for strengthening the weakened muscle, especially the VM, aiming to achieve muscular balance of the joint and patellar alignment.[5,13-15] For this purpose, the physiotherapeutic program includes opened kinetic chain exercises (OKC), as knee extension, and closed kinetic chain exercises (CKC), as squat.[3,16] However, in both types of exercises, the quadriceps group muscle is recruited and, therefore, the VM and VL are active.

The squat exercises are the most referred in the literature, once they promote considerable activation of the VM and provide safety to the joint, given that the subject performs a co-contraction of the quadriceps and hamstring muscles, dynamically stabilizing the knee joint.[17-19] Among the squat exercises, Felício et al.[20] verified that the squat combined with hip adduction yields greater electrical activation of the vastus medialis oblique. Oppositely, Gramani-Say et al.[21], Bevilaqua-Grossi et al.[18] and Tang et al.[16] found bigger activation of the VM during squat performed at 60° of knee flexion when compared to a 45° of knee flexion.

Other studies have shown bigger activation of the VM in different monoarticular exercises of knee extension. Bevilaqua-Grossi et al.[22] found that the VM had greater activation in the isometric contraction at 90° of knee flexion when compared to the positions of 15° and 30° of knee flexion. Stensdotter et al.[23] reported that an exercise of isometric knee extension at 30° yields greater activation of the VM and Ribeiro et al.[24] reassures this finding. The study of Santos et al.[25], however, found that the isometric exercise of knee extension at 60° may provide greater activation of the VM.

Although different studies are being executed for identifying the best exercises for activating the VM, there is still a need for studies which compare exercises reported in the literature as good activators of VM and their use in the rehabilitation and prevention of PFPS.

OBJECTIVE

Compare the level of muscle activation of VM with different exercises used in the prevention and rehabilitation of PFPS.

METHODS

This is a quantitative, comparative, cross sectional, quasi-experimental study. A sample of 14 sedentary subjects of both sex, without history of pain, injuries or knee surgeries, aging 20-40 years were included in the study. The sample size estimation was established based on the article of Bevilaqua-Grossi et al.[18] who analyzed the VM activation during exercises used in the physiotherapeutic rehabilitation. The significance level was 0.05 and the standard error was 10% for infinite population, and the standard deviation was (75.38 ± 13.65).

All subjects were previously informed about the objectives of the research and signed the Informed Consent Form. The study was approved by the Ethics Review Board of the University under registration number 317.791.

The data was collected at the *Laboratório de Pesquisa do Exercício* (Lapex) of the *Escola de Educação Física (ESEF)* of *Universidade Federal do Rio Grande do Sul (UFRGS)* - Brazil. The subjects performed a Maximum Voluntary Isometric Contraction (MVIC) for five seconds in four exercises applied at the physiotherapeutic rehabilitation, when the electromyographic signal was simultaneously collected.

The four proposed exercises were knee extension at 30° and at 60°, squat at 60° combined and not combined with hip adduction, performed with the patient squeezing a 15cm rubber ball between the knees. The order of the exercises was randomly assigned by opaque envelopes.

The two knee extension exercises were performed in an isokinetic dynamometer Cybex Norm (Ronkokoma, New York, USA), in which the subject lied down with the back supported as to form a 90° angle with the hip. The subject was adequately positioned so that the knee join axis coincide with the rotational axis of the isokinetic dynamometer. Belts and straps were used for avoiding muscular compensations. After adjusting the position, the leg weight was measured and the angles were stablished for the tests (30° or 60°), and 0° was considered the complete knee extension. After the positioning, the subject received the instructions for executing the test, and performed a warmup at submaximal force so that the quality of the electromyographic signal (EMG) was tried and the correct realization of the exercise checked. After 30 seconds, the test was performed by the subject who executed the maximum isometric force against the equipment resistance, at angles of 30° or 60°, per the randomization.

The two squats sessions were performed when the subject was standing, with feet apart at hip width. Along the exercise, the trunk would remain perpendicular to the ground as to avoid mechanical advantage of the hip extensor muscles, which happens with the increase of the spinal flexion angle.[21] The knee flexion at 60° was measured by an acrylic goniometer by Trident® (*Itapuí*, *São Paulo* - Brazil). At this position, the subject executed the extension of the lower limbs against a fixed bar supported by the shoulders. The 60° squat combined with hip adduction was performed with the same position described above, but with a 15cm rubber ball pressed between the knees.

During the four exercises, with verbal stimulation, the positions and contractions were maintained for five seconds. The interval between each exercise was three minutes. The activation level of the VM of the patient's dominating limb was analyzed by the EMG signal collected during the MVIC of each exercise.

For the collection of the EMG signal, a Miotool 400® electromyographer was used, with collection frequency of 2000Hz per channel. The electrical signal from the VM muscle was registered by pairs of skin electrodes, each one with 15mm radius, slightly overlapped, 20mm distanced from each other, and pre-amplified with bipolar configuration. For minimizing the skin impedance, at the electrodes spots, the skin was shaved and rubbed with cotton soaked in alcohol.

After this process, the electrodes were positioned according to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM).[26] For the VM muscle, the position is at 80% of the line between the anterior superior iliac spine and the space of the joint at the anterior edge of the medial ligament, over the muscular venter of VM.

After the collection, the EMG signal was, via USB, recorded saved in a computer with the software Miograph. The stored data were imported to the SAD32 software which filtered the data so that the possible noise was eliminated and did not interfere the data collection. The filtration was done with 5th order Butterworth passband filter, and frequency cut between 20 and 500Hz.

The maximum percentage of Root Mean Square (RMS) was used for normalizing the data, which was calculated during a second of MVIC of the 60° knee extension exercise, between the third and the forth seconds of execution. This exercise was chosen for normalizing the data once it yielded greater gross value of VM muscle activation.

The normality of the data was verified with the Shapiro-Wilk statistics test and the data was presented as mean and standard deviation. For comparing the activation level of the VM in the four exercises, the analysis of variance for repeated measures (one-way ANOVA) was used, followed by the Bonferroni post-hoc analysis when applicable. The data was analyzed by Statistical Package for Social Sciences (SPSS), version 14.0. In all the analysis, the accepted alpha was 0.05.

RESULTS

The results collected in this study (Figure 1), have shown there is no statistically significant difference in the activation of the VM muscle between the knee extension exercise at 30° (100.14 ± 22.21) and at 60° (55.82 ± 32.15), nor between the squat at 60° (55.82 ± 32.15) and the squat at 60° combined with hip adduction (63.09 ± 37.45).

The knee extension exercises at 30° and 60°, however, have resulted in significantly greater values of VM muscle activation when compared to squat at 60° (p = 0.001 and p < 0.001, respectively), and when compared to the squat at 60° combined with hip adduction (p = 0.003 and p = 0.002, respectively).

DISCUSSION

The findings of this study have shown that the knee extension exercises yield significantly different results of VM muscle activation when compared to squat exercises. However, no significant difference was found in the activation between the squat and the knee extension exercises.

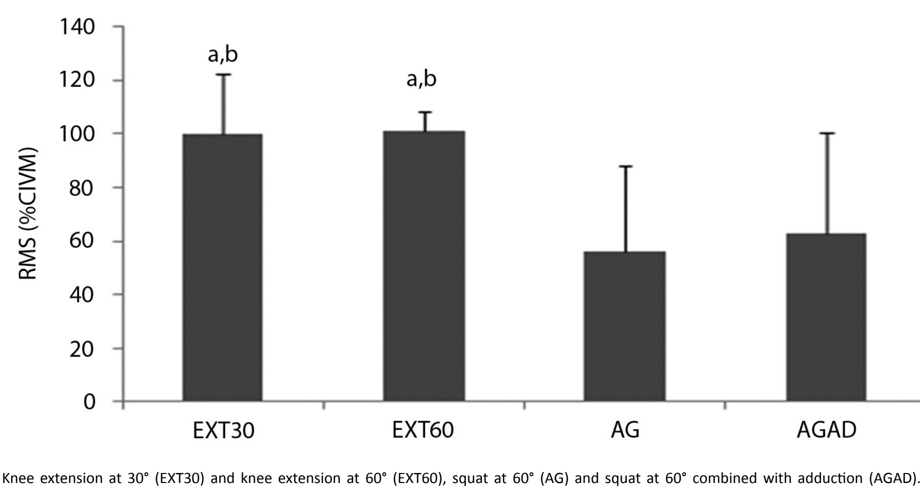
These findings on the squat exercises differ from what is suggested by Gramani-Say et al.[21], that the squat exercise combined with hip adduction should yield greater activation of VM, due to the anatomical position. According to the authors, some fibers of the VM muscle are inserted in the distal portion of the magnus adductor muscle, enhancing the muscle activation of VM when combined with hip adduction. Felício et al.[20], compared the traditional squat, squat with abduction, and squat with adduction and found that the squat combined with adduction resulted in greater activation of the VM muscle. Both studies assessed samples of similar sedentary and healthy subjects. Felício et al.[20], however, performed the tests only with women, what can justify the results due to the valgus characteristic found among women.[27]

Nonetheless, Coqueiro et al.[28] agree with the results of the present study. The authors performed a similar research, attempting to find how the VM muscle activation occurred during semi-squat isometric exercises with and without the hip adduction. They found no selective activation of VM. However, they also analyzed the ratio of the RMS between VM and VL, finding that during the squat combined with hip adduction, the ratio was closer to 1, suggesting greater activation balance of these muscles.

In the present study, both extension exercises were more effective for the VM activation when compared to the squat exercises. It can be explained since along the isometric knee extension exercise, no other joint is recruited to execute the movement, whereas during the squat exercise, the hip extensor muscles and the plantar flexor muscles of the ankle also contribute to the muscle torque of the knee, minimizing its electrical activation.[21]

Still, there are limited studies executing similar comparisons. Two studies Cabral et al.[10] and Stensdotter et al.[23] compared the knee extension exercises with leg press exercises. The study of Cabral et al.[10] used the knee extension exercise at 90° and 45° in the extensor chair, and leg press from 0° to 45°.

In their results, no difference in VM activation was observed in both exercises.[10] The contrast in results with the present study comparing OKC and CKC can be explained once those authors used the leg press instead of the vertical squat as well as dynamic exercises instead of isometric, hindering the direct comparison of both studies. In the study of Stensdotter et al.,[23] however, the extension exercise at 30° and the leg press from 30° to 0° were used, and their results have shown a greater activation of the VM muscle in the 30° extension exercise, consonantly with the present study.



Knee extension at 30° (EXT30) and knee extension at 60° (EXT60), squat at 60° (AG) and squat at 60° combined with adduction (AGAD). “a” represents significant difference of AG and “b” represents significant difference of AGAD ($p \leq 0.05$).

Figure 1. VM muscle activation percentage in the four rehabilitation exercises

The extension exercise at 30° is also a guideline for rehabilitation and prevention of PFPS by Ribeiro et al.[24] for yielding considerable activation of VM. Gramani-Say et al.[21] agree by suggesting that the VM function in the dynamic stabilization of the knee joint is more effective in flexion angles from 0° to 30°. The present study, although having found greater activation of VM muscle at the 30° extension when compared to squat, failed to find significant differences between the knee extension at 30° and at 60°, a finding that is consonant with Santos et al.[25] who suggests that isometric knee extension at 60° is an exercise with good VM muscle activation.

Santos et al.[25] compared the muscle activation of VM and VL in ten different exercises, and those which yielded greater activation of VM were isometric knee extension at 60°, isometric knee extension from 60° to 0°, and squat from standing position to 45° of knee flexion. However, the authors did not assess whether there were differences among the three exercises that promoted greater VM activation.

Even though Correa et al.,[29] suggested that the extension angle of 60° provides greater mechanical advantage in the execution of muscular force, their results did not show significant differences in the activation of VM among the angles they studied (0°, 60° and 90°). Another study that compared different knee extension angles (15° and 90°) was done by Bevilaqua-Grossi et al.[22] who also did not observe significant differences in the activation of VM.

In both studies, Bevilaqua-Grossi et al.[22] and Correa et al.,[29] the knee extension angles were different from the ones assessed in the present study. Nonetheless, it is possible to observe that, independently of the extension angle of the knee, the activation of the VM muscle does not significantly change, causing the knee extension exercise, at any angle, to be used in the prevention and rehabilitation of PFPS.

Although some authors suggest that CKC, such as squat, can be safer for patients with PFPS, since they provide dynamic stabilization of the joint, causing a closer relation between the activations levels of VM and VL,[20,30] and that studies like Fehr et al.[31] consider that CKC is more efficient for improving functionality when compared to OKC exercises, Escamilla[32] emphasizes that the squat is a functional activity which bears complaints among the patients with PFPS, and Escamilla et al.[33] concluded that the OKC produce lower compressive forces when compared to CKC, which generates bigger compressive forces, especially in angles above 85°.

Considering the results of the present study, of greater activation of VM muscle in the knee extension exercises as compared to squat, and the inconsistency about the use of squat for patients with PFPS, the knee extension exercise seems to be the most suitable.

It is relevant to emphasize that the present study only assessed one muscle of the quadriceps, the VM, for the execution of the tests. No other quadriceps muscles were analyzed, like the VL, not allowing a comparison of all patella stabilizers. Some studies performed this comparison demonstrating that, along an exercise, a greater activation of VL as compared to VM may occur, causing suspicions on the use of such exercises for patients with PFPS, once it would increase the preexisting muscle imbalance.[18,20,24,25,28,34] Another possible limitation is the sample of healthy subjects, once patients with PFPS could present different results. Some studies suggest that PFPS patients may bear imbalances between the quadriceps muscles, promoting the VM to present less activation.[24,25,28,34] Nevertheless, there are studies which compared these exercises in healthy subjects and PFPS patients, finding no significant differences in their results.[15,16,18]

A substantial aspect of the present study is the comparison of four maximal isometric exercise, which enhance the analysis and the interpretation of the collected data. There are studies which compared isometric and isotonic exercises hindering the proper interpretation of the results.[25,35]

New studies, however, are necessary for the analysis of EMG of VM and VL in these four isometric exercises as to verify how the relation between this muscles occur, as well as to compare whether there are any differences in the activation of VM and VL between healthy subjects and PFPS patients.

CONCLUSION

By means of this study, it was possible to conclude that the best exercises for maximizing the VM muscle activation in healthy subjects are isometric knee extension at 30° and 60°, once they present higher levels of VM activation, crucial for the prevention and rehabilitation PFPS.

Nonetheless, there is no consensus in the literature about which is the safest exercise to be used in the treatment of PFPS. Therefore, other studies are still necessary before the safe use of extension exercises in the clinical practice.

ACKNOWLEDGMENTS

We acknowledge the participation of the collaborator Felipe Minozzo by his relevant help in the data collection.

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