TIBIAL ROTATIONS DURING STEP UP EXERCISE DO NOT CHANGE KNEE EXTENSOR ACTIVITY IN THE PATELLOFEMORAL PAIN SYNDROME

Juliana Moreno Carmona[1], Cristina Maria Nunes Cabral[2], Amélia Pasqual Marques[1]

[1]University of Sao Paulo, Sao Paulo SP, Brazil
[2] University of the City of Sao Paulo, Sao Paulo SP, Brazil

The purpose of this study was to compare the electromyographic activity of vastus medialis (VM) and vastus lateralis (VL) muscles during step up exercises at different tibial rotations, between individuals with and without patellofemoral pain syndrome. The electromyographic activity of the VM and VL muscles during step up exercises was evaluated in three tibial rotations: without rotation, medial and lateral rotation. Thirteen patients with patellofemoral pain syndrome and 16 control subjects performed this exercise three times. The results showed a significant lower electromyographic activity of VM muscle in both groups, compared to the electromyographic activity of VL muscle ($p<0.05$). Moreover, a significant difference in electromyographic activity between muscles for all rotations and groups ($p<0.001$) was also found. The results of the present study suggest that tibial rotations performed during step up exercise did not change the electromyographic activity of VM and VL muscles.

KEY WORDS: patellofemoral pain syndrome, EMG activity, step up exercise.

INTRODUCTION: Patellofemoral pain syndrome (PFPS) is one of the most common joint complaints in the orthopaedic practice (Powers, 1998; Davlin et al., 1999) and is frequently diagnosed in athletes (Miller et al., 1997; Tyler et al., 2006). It represents 25% to 40% of all knee problems found in sports medicine centers (Fagan et al., 2008) and affects 25% of total population (Fagan et al., 2008; Harrington et al., 2005). PFPS patients report symptoms of anterior or retropatellar pain, aggravated by functional activities as ascending and descending stairs. Considering all the etiologic factors involved, tibial rotation seems to be an important one.

In one of the first studies about the relationship between tibial rotation and quadriceps femoris muscle activation, Wheatley and Jahnke (1951) determined that lateral tibial rotation increases the vastus medialis (VM) function. On the other hand, more recent studies found that medial tibial rotation increases the activity of vastus medialis oblique muscle (VMO) and that tibial or femural rotation could contribute to decreased contact area of patellofemoral joint (PFJ). Salsich et al. (2007) concluded that the PFJ contact area can be increased by the regulators of tibial and femoral rotation, decreasing pain in PFPS patients. Miller et al. (1997) reported that VMO/vastus lateralis (VL) ratio during step up/down stairs and wall slide exercises with lateral tibial rotation was minor than in other rotations, which means that the VMO activity is bigger in this specific situation.
Thus the purpose of this study was to compare the electromyographic (EMG) activity of VM and VL muscles during step up exercises at three tibial rotations – without rotation, medial rotation and lateral rotation, between individuals with and without PFPS.

METHODS: Subjects: The population studied consisted of 13 patients with PFPS diagnosis (PFPS group – PG), 5 male and 9 female, and 16 individuals without any musculoskeletal injury in lower limbs (control group – CG), 7 male and 9 female.

The institutional review board (CAPPesq, the ethics committee for analysis of research projects of the Clinical Hospital of the University of Sao Paulo Medicine School) approved the study.
Patients were included if aged between 18 and 35, and showed a positive patellar compression test (Magee, 2002). Other inclusion criteria included symptoms of PFPS for at least six months, anterior or retropatellar pain during or after at least two of the following

activities: prolonged sitting, stepping up or down stairs, squatting, kneeling, running and jumping, and an insidious onset of symptoms unrelated to a traumatic incident (Cowan et al., 2002). Participants were excluded if they showed signs or symptoms of any other knee pathology or injury (Thomeé, 1997).

Procedures: Before the evaluation, the subjects signed an informed consent form. The EMG activity of VM and VL muscles, of the injured leg in PG and the right leg in CG, was detected using an 8-channel EMG equipment with an analogical-digital converter (EMG System do Brasil) and resolution of 12 bits, interfaced with a computer and data collection software – AqDados 5.0 (Lynx Electronics Technologies), with an acquisition frequency of 1000 Hz per channel and band pass of 20-500 Hz; active differential surface electrodes (EMG System do Brasil); and self-adhesive electrodes (Meditrace). An electrogoniometer (EMG System do Brasil) was also used.

The electrodes were placed on the muscle according to SENIAM recommendations (Hermens et al., 2006). Self-adhesive electrodes were positioned on the muscle belly, 2 cm apart, and fixed with adhesive tape. The EMG activity of the VM and VL muscles was measured during three repetitions of step up a stair with 19.5 cm-height in three tibial rotations – without rotation (WR), with 20° of medial rotation (MR) and 20° of lateral rotation (LR), controlled by positioning the foot through a piece of wood with the determined angle, in a self-selected speed. The movement amplitude during step up was controlled by an electrogoniometer, which permitted to identify the exact EMG amplitude during the exercise. An isometric knee extension contraction with the knee flexed at 90 degrees and anterior resistance applied at the distal tibia, with the subject in a sitting position, was also collected during four seconds and the volunteers were asked to extend their knee as much as possible.

EMG data analysis: The EMG signal collected during isometric contraction was processed by means of the software Origin 6.0 routines and transformed into root mean square (RMS) values as follows: the wave acquired was rectified and filtered through a 5 Hz band pass filter to obtain a linear envelope. After a visual inspection of the envelope, the 1-second period showing least variation and maximum EMG activity was selected and the RMS value of the rectified signal calculated with a band pass filter of 20 to 500 Hz in the selected period. The mean of the three attempts was analyzed. The EMG signal collected during step up exercise was then normalized by the RMS values obtained during isometric contraction.

Statistical analysis: The significance level was set at $p<0.05$. All the variables were analyzed as to normality using the Kolmogorov-Smirnov test and variance homogeneity by Levene test. Demographic variables were compared using T test for independent samples (weight, height, body mass index) and Mann Whitney test (age). EMG data presented normal distribution. In this way, three ANOVA two-way were performed, the first compared the effect of tibial rotations in the activity of VM muscles between groups, the second compared the effect of tibial rotations in the activity of VL muscles between groups and the last compared the muscles within different rotations. Tukey was the post hoc test used.

RESULTS: Comparing demographic variables between groups, a statistically significant difference in age ($p=0.0178$) was observed, while other data did not differ (age: GC- 20 (20-24.5), PG- 28 (22-30) years; weight: GC- 65±7.5, PG- 66±10.5 kg; height: GC- 1.7±0.1, PG– 1.7±0.1 m; body mass index: GC- 21.7±3, PG- 22.6±0.4 kg/m^2).

Results obtained during the evaluation showed significant difference in EMG activity between muscles for all rotations and groups ($p<0.001$). Table 1 presents the means (standard deviation) of normalized RMS values by the isometric contraction of VM and VL muscles during step up exercise in all three rotations – WR, MR and LR, which were obtained in both groups. Interactions were not observed in the two-way ANOVA, considering groups, muscles and rotations ($p>0.05$).

Table 1: Means (standard deviation) of normalized RMS values collected, in %.

Rotation	Muscles	PFPS Group (n=13)	Control Group (n=16)
Without rotation	VM	144.7 (160.4)[1]	132.1 (47.2)[4]
	VL	232.8 (221.8)[1]	190.1 (87.6)[4]
Medial rotation	VM	146.7 (159.4)[2]	134.6 (60.5)[5]
	VL	233.2 (222.7)[2]	173.8 (79.5)[5]
Lateral rotation	VM	143.8 (158.9)[3]	109.3 (138.3)[6]
	VL	233.3 (223.1)[3]	183.3 (91.3)[6]

[1]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.001$)
[2]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.001$)
[3]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.001$)
[4]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.0068$)
[5]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.0477$)
[6]Significant difference between muscles (ANOVA $p<0.001$; Tukey $p<0.0305$)

DISCUSSION: The results showed no significant difference in EMG activity of VM and VL muscles in the step up exercise with different tibial rotations between groups. The mean RMS values for VM and VL muscles in CG and PG were similar, despite previous results found in the literature (Wheatley and Jahnke, 1951; Miller et al., 1997).

One of the reasons for this difference can be the location of electrodes. In the present study, the SENIAM protocol was used, so the whole VM muscle had its EMG activity measured, not only its oblique fibers. These differences in the location of electrodes may lead to the difference of EMG data observed between this study and others found in the literature. On the other hand, Miller at al. (1997) reported EMG activity of VMO muscle, which was the dynamic stabilizer of the patella, and found fewer EMG activity of this muscle. Besides that, the authors analyzed the VMO/VL ratio, while the present study compared the normalized RMS values of VM and VL muscles separately.

Another methodological difference is that EMG data was acquired during a self-selected speed activity because our goal was to reproduce a natural movement that would not occur if the speed was controlled. This methodology was used in previous studies (Sacco et al., 2006).

Surprisingly, EMG activity of VL is bigger than VM muscle in both groups and rotations. Our supposition is that the stair height could provoke this result, because it is well known that if flexion angle of hip and/or knee increases, quadriceps femoris muscle activation is changed. When flexion angle of knee is low, the EMG activity of quadriceps femoris is low too (Cabral, 2001; Sheehy et al., 1998). But the finding about a greater activity of VL muscle in the CG needs more investigation.

Another possible reason for the differences found in this study according to the literature, is that our PG subjects perform regular sports activities, which could give more functional structure to muscles and change the personal EMG activity standard.

CONCLUSION: The results of the present study suggest that tibial rotations performed during step up exercise did not change the EMG activity of VM and VL muscles. Further studies are necessary to clarify the knee extensor function role in PFPS patients, since this study found that EMG activity of VL muscles is bigger than of VM, even in healthy subjects, suggesting that the knee extensor EMG activity may not be sufficient to predict the presence of PFPS.

REFERENCES:

Cabral CMN. (2001). Efeito dos exercícios em cadeia cinética fechada realizados no step na atividade elétrica dos componentes medial e lateral do músculo quadríceps femoral (dissertação de mestrado). São Paulo.

Cowan SM, Hodges PW, Bennell KL, Crossley KM. (2002). Altered vastii recruitment when people with patellofemoral pain syndrome complete a postural task. *Archives of Physical Medicine and Rehabilitation*, 83: 989-95.

Davlin CD, Holcomb WR, Guadagnoli MA. (1999). The effect of hip position and electromyographic biofeedback training on the vastus medialis oblique : vastus lateralis ratio. *Journal of Athletic Training.* 34 (4): 342-49.

Fagan V, Delahunt E. (2008). Patellofemoral Pain Syndrome: a review on the associated neuromuscular deficits and current treatment options. *British Journal of Sports Medicin.* Jul; 14.

Harrington L, Malloy S, Richards J. (2005). The effect of patella taping on vastus medialis oblique and vastus lateralis EMG activity and knee kinematic variables during stair descent. *Journal of Electromyography Kinesiology.* Dec; 15 (6): 604-7.

Hermens HJ, Freriks B. SENIAM. Enschede: Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles. *http://www.seniam.org*, disponível em três de dezembro de 2006.

Magee DJ (2002). *Avaliação musculoesquelética*. São Paulo: Manole.

Miller JP, Sedory D, Croce RV. (1997). Leg rotation and vastus medialis oblique/vastus lateralis electromyogram activity ratio during closed chain kinetic exercises prescribed for patellofemoral pain. *Journal of Athletic Training.* Jul; 32 (3): 216-220.

Powers CM. (1998). Rehabilitation of patellofemoral joint disorders: a critical review. *Journal of Orthopaedic and Sports Physical Therapy.* Nov; 28 (5): 345-54.

Sacco ICN, Konno GK, Rojas GB, Arnone AC, Pássaro AC, Marques AP, Cabral CMN. (2006). Functional and EMG responses to a physical treatment in patellofemoral syndrome patients. *Journal of Electromyography and Kinesiology.* 16:167-74.

Salsich GB, Perman WH. (2007). Patellofemoral joint contact area is influenced by tibiofemoral rotation alignment in individuals who have patellofemoral pain. *Journal of Orthopaedic and Sports Physical Therapy.* Sep;37(9):521-8.

Seehy P, Burdett RG, Irrgang JJ, VanSwearingen J. (1998). An electromyographic study of vastus medialis oblique and vastus lateralis activity while ascending and descending steps. *Journal of Orthopaedic and Sports Physical Therapy.* Jun;27(6):423-9.

Thomeé R. (1997). A comprehensive treatment approach for patellofemoral pain syndrome in young women. *Physical Therapy*, 77(12): 1690-703.

Tyler TF, Nicholas SJ, Mullaney MJ, McHugh MP. (2006). The role of hip muscle function in the treatment of patellofemoral pain syndrome. *American Journal of Sports Medicine*. 34 (4): 630-36.

Wheatley and Jahnke. Electromyographic study of the superficial thigh and hip muscles in normal individuals. (1951). *Archives of Physical Medicine and Rehabilitation*. Aug;32(8):508-15.

Acknowledgment: I would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support given to this study and all my laboratory group, especially Cabral CMN and Marques AP for all time spent before, during and after the execution of this project.