Journal of Electromyography and Kinesiology 26 (2016) 137–142

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Delayed onset of electromyographic activity of the vastus medialis relative to the vastus lateralis may be related to physical activity levels in females with patellofemoral pain

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ARTICLE INFO

Article history:
Received 3 August 2015
Received in revised form 10 October 2015
Accepted 23 October 2015

Keywords:
Quadriceps
Knee pain
Onset
Muscle activity

ABSTRACT

The aims of this study were to examine group differences in muscle activation onset of the vastus medialis (VM) in relation to the vastus lateralis (VL) and pain level during stair ascent in females with patellofemoral pain (PFP) who maintain high and moderate levels of physical activity; to determine the association between physical activity level and muscle activation onset. Forty-three females with PFP and thirty-eight pain-free females were recruited and divided into four groups based on their level of physical activity: females with PFP ($n = 26$) and pain-free females ($n = 26$) who practiced a moderate level of physical activity and females with PFP ($n = 17$) and pain-free females ($n = 12$) who practiced an intense amount of physical activity. Participants were asked to ascend a seven-step staircase and the VM and VL activation onset was determined. Females with PFP who practiced high level of physical activity demonstrated delayed onset of VM (4.06 ms) compared to healthy females (−14.4 ms). Conversely, females with PFP who practiced moderate level of physical activity did not present VM delay (−2.48 ms) in comparison to healthy females (−9.89 ms). Furthermore, physical activity significantly correlated to the muscle activation onset difference ($p = 0.005$; $R = 0.60$). These findings may explain why controversial results regarding VM and VL muscle activation onset have been found.

1. Introduction

Patellofemoral pain (PFP) is often seen in physically active men, women and adolescents, although women are 2.23 times more likely to develop PFP than men (de Oliveira Silva et al., 2015c). PFP is characterized by anterior, retro- or peripatellar pain and aggravated by activities that increase patellofemoral joint compressive forces, such as squatting, ascending and descending stairs and prolonged sitting (Willson et al., 2014; de Oliveira Silva et al., 2015a). Although this disorder accounts for 25–40% of all knee disorders in sports medicine (Freedman et al., 2014), its etiology remains unclear.

Several contributing factors have been proposed in order to explain the mechanisms underlying PFP development. Vastus medialis (VM) delayed onset in relation to vastus lateralis (VL) has arisen as a promissory hypothesis due to the influence of these muscles on patellar stabilization (Santos et al., 2008; Uliam Kuriki et al., 2011). However, despite the apparent consolidation of this hypothesis in theoretical models, onset has yielded controversial results (Chester et al., 2008). Some studies (Cowan et al., 2002; Van Tiggelen et al., 2009) have verified an onset difference between individuals with PFP and comparison groups while others have not (Cavazzuti et al., 2010; Briani et al., 2015). Therefore, the contribution of VM delayed onset to PFP remains unclear (Sheehan et al., 2012; Toumi et al., 2013).

Recently, Rathleff et al. (2013) suggested that VM delayed onset may not always be changed in individuals with PFP due to the influence of pain on muscle motor control. Studies have shown that knee pain may alter biomechanical responses during dynamic activities (Dierks et al., 2008; Tucker and Hodges, 2010). For instance, the onset of pain in PFP may result in a decreased ability of the gluteus medius and maximus to control hip adduction and internal rotation, factors highly related to PFP (Dierks et al., 2008, 2011). As PFP is a condition related to physical activity practice and the average highest level of daily pain is associated with increased physical activity (Fairbank et al., 1984), it has been

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http://dx.doi.org/10.1016/j.jelekin.2015.10.012
1050-6411/

suggested that oscillation exists in the knee pain level according to the exposure of the individuals to pain exacerbating activities during the preceding days (Thomeé et al., 1999). Therefore, it is possible that individuals with PFP who practice higher levels of physical activity could demonstrate elevated levels of pain and, thereby, may present VM delay, while individuals who practice lower levels of physical activity may not. As the majority of studies (Brindle et al., 2003; McClinton et al., 2007; Cavazzuti et al., 2010) in this area do not discriminate the sample according to the level of physical activity, individuals with different levels of physical activity and pain may be gathered in the same sample, which could produce heterogeneous data. To the best of our knowledge, such a hypothesis has not yet been investigated and may be a reasonable explanation for the controversial results regarding this subject.

Therefore, the aims of this study were to (1) examine group differences in muscle activation onset of the VM in relation to the VL and pain level during stair ascent in females with PFP who maintain high and moderate levels of physical activity, (2) determine the association between physical activity level and muscle activation onset. We hypothesized that females with PFP who practice elevated levels of physical activity would present VM delay compared to healthy females while females with PFP who practice moderate levels of physical activity would not. In addition, higher levels of pain would be found in females who maintain high levels of physical activity than in the other group.

2. Methods

2.1. Subjects

Forty-three females with PFP and thirty-eight pain-free females were recruited from the graduate student population via advertisements placed at the university, parks and gyms. Only females were included due to the high prevalence of PFP in this population (Silva et al., 2015). Based on calculations made in sample-power using Statistical Software for Social Sciences (SPSS) Version 18.0 (SPSS Inc. Chicago, IL, USA) with data from Cowan et al. (2002), a minimum sample size of 12 females per group was indicated to evaluate VM and VL onset differences with a statistical power of 85%, observing a minimum difference of 18.42 ms between means, a standard deviation of 17.16 ms and a significance level of 5%. Prior to the data collection, all participants provided written informed consent and the experimental protocol was approved by the Institutional Review Board of the University of São Paulo State Human Ethics Committee (306.729).

Diagnosis of PFP was confirmed following consensus from two experienced clinicians (>5 years' experience) and based on definitions used in previous studies (Garcia et al., 2010; Silva et al., 2014; Briani et al., 2015). The inclusion criteria were (1) anterior knee pain during at least 2 of the following activities: prolonged sitting, squatting, kneeling, running, climbing stairs, and jumping; (2) pain during patellar palpation; (3) symptoms of insidious onset and duration of at least 1 month; (4) worst pain level in the previous month at least 3 cm on a 10 cm VAS; and (5) 3 or more positive clinical signs in the following tests: Clarke's sign, McConnell test, Noble compression, Waldron test and patellar pain on palpation. The participants were required to fulfill all five requirements to be included in the study. The presence of any of the following conditions were carefully screened as exclusion criteria: events of patellar subluxation or dislocation, lower limb inflammatory process, patellar tendon or meniscus tears, bursitis, ligament tears or the presence of neurological diseases. Those who had undergone knee surgery; or received oral steroids, opiate treatment, acupuncture or physiotherapy during the preceding 6 months were excluded from this study.

Table 1
Anthropometric data of the subjects.

	MACG mean (SD)	IACG mean (SD)	MAPFPG mean (SD)	IAPFPG mean (SD)
Age (y)	21.33 (2.62)	22.21 (3.12)	21.79 (1.01)	22.77 (2.41)
Height (m)	1.64 (0.07)	1.65 (0.05)	1.66(0.08)	1.65 (0.04)
Mass (kg)	59.48 (8.13)	63.87 (10.81)	60.01 (7.10)	61.98 (9.13)
N	26	12	26	17

Abbreviations: MACG, moderate activity control group; IACG, intense activity control group; MAPFPG, moderate activity patellofemoral pain group; IAPFPG, intense activity patellofemoral pain group; SD, standard deviation.

After the screening process, the females with PFP and pain-free females were divided into four groups based on their level of physical activity. Such separation was realized through the self-administered International Physical Activity Questionnaire long form (IPAQ), a valid and reliable form for classifying level of physical activity (Craig et al., 2003). The levels of physical activity were determined by the total amount of physical activity done in the previous week involving the lower limbs and classified according to Craig et al. (2003) and Dyrstad et al. (2014). With respect to our sample, four groups were formed: females with PFP (MAPFPG = 26) and pain-free females (MACG = 26) who practiced a moderate level of physical activity and females with PFP (IAPFPG = 17) and pain-free females (IACG = 12) who practiced an intense amount of physical activity. Anthropometric data from all groups are presented in Table 1.

2.2. Instrumentation

The experimental design included a seven step staircase, each step being 28 cm deep and 18 cm high, with a walkway in front of and at the top of it. EMG data were collected using a conditioner module (Lynx®, Sao Paulo, BRA; model 1000-8-4I) with a fourth-order, zero-lag, Butterworth digital filter with cutoff frequencies of 20–500 Hz and an amplifier with a gain of 50. The preamplifier circuit on the electrode cable had a gain of 20, a common mode rejection ratio greater than 80 dB and an impedance of 1012 Ω. The raw EMG signal was recorded at a sampling rate of 4000 Hz (Ferrari et al., 2014; Briani et al., 2015). Two pairs of bipolar surface-capture Ag/AgCl electrodes (Kendall, Mansfield, MA, USA; model Medi-Trace) with diameters of 10 mm were used to obtain VM and VL EMG data. The data were collected using AqdAnalysis software (Lynx®, Sao Paulo, SP, BRA; model EMG 1000-8-4I). An electrostimulation device (Quark®, Piracicaba, SP, BRA; model Nemesys 942) was used to find the VM and VL motor points. A force plate (AMTI, OR6, Watertown, MA, USA) was positioned in the center of the fourth step and used to obtain ground reaction force data and, thus, to establish the moment when the subject was passing over the step. The force plate acquisition sampling rate was 4000 Hz and data were collected using the same software AqdAnalysis (Lynx®, Sao Paulo, SP, BRA; model EMG 1000-8-4I) (Briani et al., 2015). The EMG and force plate data were synchronized and analog-to-digital converted into 16-bit digital format using a signal conditioner module (Lynx®, Sao Paulo, SP, BRA; model ADS 1000-AC1160).

2.3. Procedure

After finding the VM and VL motor points, the skin over the anterior portion of the thigh was cleaned with rubbing alcohol. The electrodes were placed 2 cm below the motor point in the