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Comparison of frequency and time domain electromyography parameters in women with patellofemoral pain

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ABSTRACT

Background: Despite its high incidence, patellofemoral pain etiology remains unclear. No prior study has compared surface electromyography frequency domain parameters and surface electromyography time domain variables, which have been used as a classic analysis of patellofemoral pain.
Methods: Thirty one women with patellofemoral pain and twenty eight pain-free women were recruited. Each participant was asked to descend a seven step staircase and data from five successful trials were collected. During the task, the vastus medialis and vastus lateralis muscle activities were monitored by surface electromyography. The data were processed and analyzed in four variables of the frequency domain (median frequency, low, medium and high frequency bands) and three time domain variables (Automatic, Cross-correlation and Visual Onset between the vastus medialis and vastus lateralis muscles). Reliability, Receiver Operating Characteristic curves and regression models were performed.
Findings: The medium frequency band was the most reliable variable and different between the groups for both muscles, also demonstrated the best values of sensitivity and sensibility, 72% and 69% for the vastus medialis and 68% and 62% for the vastus lateralis, respectively. The frequency variables predicted the pain of individuals with patellofemoral pain, 26% for the vastus medialis and 20% for the vastus lateralis, being better than the time variables, which achieved only 7%.
Interpretation: The frequency domain parameters presented greater reliability, diagnostic accuracy and capacity to predict pain than the time domain variables during stair descent and might be a useful tool to diagnose individuals with patellofemoral pain.

1. Introduction

Patellofemoral pain (PFP), described as anterior or peripatellar pain, has become one of the major knee problems in sports medicine, accounting for 25% to 40% of all knee disorders (Fagan and Delahunt, 2008). The general female population has also been affected, with reported incidences representing 10% to 28% (Ng et al., 2008). It has been shown that pain produced by this disease can limit participation in sports and daily activities, such as going up and down stairs, squatting and remaining seated (Powers et al., 2012).

Despite its high incidence, PFP etiology remains unclear. Several potential contributing factors have been cited trying to explain the mechanism responsible for developing this disorder, such as delayed onset of the vastus medialis oblique, (Cowan et al., 2001) decreased quadriceps and hip muscle strength (Bolgla et al., 2008; Rathleff et al., 2013), increased hip medial rotation (Boling et al., 2009) and knee abduction excursion (Smoliga et al., 2010), however, none of these have demonstrated a high level of diagnostic evidence.

A commonly accepted PFP etiology hypothesis is the vastus medialis (VM) and vastus lateralis (VL) contraction dysfunctions (Fulkerson, 2002). These findings are based on the quadriceps muscle being responsible for stabilizing patellar tracking (Kooiker et al., 2014; Powers et al., 1997). Consistent with the previous reports, clinical trials have verified diminished pain levels and increased functional capacity in individuals with PFP after quadriceps strengthening in both the short-term and long-term (Collins et al., 2010).

Considering the above, many studies have sought to determine VM and VL dysfunctions by analyzing their relative onset using surface electromyography (sEMG) (Cowan et al., 2001; Van Tiggelen et al., 2009). According to the literature, the main hypothesis is that VM contraction is delayed in relation to the VL leading to patellar lateralization, which could produce lateral compressive patellofemoral joint stress (Uliam Kuriki et al., 2011). Nonetheless, onset has yielded controversial results (Chester et al., 2008). Some studies (Cowan et al., 2001; Uliam Kuriki

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et al., 2011), have verified an onset difference between individuals with PFP and comparison groups while others have not (Fagan and Delahunt, 2008; Ng et al., 2008), thus, it seems that the onset of muscle activation does not provide enough information and cannot be used to diagnose PFP.

In this context, Ferrari et al. (2014) proposed a new approach to evaluate the VM and VL sEMG signals of individuals with PFP; the analysis of sEMG frequency domain parameters during stair climbing. From these analyses, it was possible to differentiate individuals with PFP with 72% sensitivity and 86% specificity, therefore, sEMG frequency domain parameters became an important tool for diagnosing PFP (Ferrari et al., 2014) whereas, according to the literature, no other biomechanical variable or clinical test was able to present the same result (Fulkerson, 2002; Nunes et al., 2013). Although the results seem to be appropriate, Powers (2010) and Pattyn et al. (2013) have indicated eccentric activities, such as stair descending, for verifying quadriceps activity as a consequence of the increased muscular and mechanical demands compared to concentric contractions. In particular, descending stairs may be associated with higher pain reports, as the stress provoked in the patellofemoral joint during this activity is higher than in ascending stairs or normal overground walking (Brechter and Powers, 2002).

To our knowledge, no prior study has compared sEMG frequency domain parameters, which is a potentially promising tool for diagnosing PFP individuals, and sEMG time domain variables, which have been used as a classic analysis of muscle contraction in PFP (Uliam Kuriki et al., 2011). As such, a study confronting these methods is necessary to better understand the diagnostic capacity of the frequency and time domain parameters. Besides, due to inconsistent evidence related to diagnosis accuracy of clinical tests (Nunes et al., 2013), which is the lack of accuracy and reliability of clinical tests used in PFP (Powers et al., 2012), a biomechanical tool with high values of reliability could be an alternative to diagnosis individuals with PFP. Also, alterations in sEMG frequency domain can be useful in inferring changes in the neuromuscular system (Farina et al., 2004), which might be used to characterize how these muscles contribute to PFP.

Thus, the purpose of this study was to determine the reliability, diagnostic accuracy and capacity to predict pain variance of two different analyses, sEMG in the frequency and time domain, on the VM and VL of individuals with PFP, compared to matched control individuals. We hypothesized that the sEMG frequency domain parameters would have (1) acceptable values of reliability, (2) the capacity to diagnose PFP in individuals with greater accuracy, and (3) better capacity to predict pain variance. On the other hand, we hypothesized that (4) EMG time domain parameters would not demonstrate the same results.

2. Methods

Thirty one women with PFP and twenty eight pain-free women were recruited from the graduate student population at the university. Mean (SD) age, height and weight for the PFP group were 21.9 (2.72) years, 1.65 (0.05) m and 65.72 (10.76) kg respectively and 22.07 (3.67) years, 1.65 (0.04) m and 62.3 (7.3) kg for the control group (CG). The sample size was calculated on the basis of previous studies (Ferrari et al., 2014; Uliam Kuriki et al., 2011) (using alpha ≤ 0.05, and an expected difference between groups of 4 normalized unit on frequency domain and 10 ms on time domain). A minimum of 25 subjects per group was estimated to be needed to ensure 80% power.

In accordance with previous PFP diagnostic studies (De Oliveira Silva et al., in press; Ferrari et al., 2014; Fulkerson, 2002), a set of clinical tests were selected for screening the individuals due to be the most used tool, in spite of the accuracy may not be enough, there is no tool more adequate available. The PFP group inclusion criteria were (1) anterior knee pain during at least 2 of the following activities: remaining seated, squatting, running, stairs negotiation and jumping; (2) pain during patellar palpation; (3) symptoms for a minimum of 1 month with an insidious beginning; (4) pain level up to 3 on a 10 cm visual analog scale (VAS) in the previous month, 0 representing no pain and 10 maximum pain; and (5) 3 or more positive clinical signs in the following tests: Clarke's sign, McConnell test, Noble compression and the patella in the medial or lateral position. To be allocated to the PFP group, participants needed to comply with all 5 requirements. Furthermore, any condition besides PFP was considered as an exclusion criterion, such as: events of patellar subluxation or dislocation, lower limb inflammatory process, osteoarthritis, patellar tendon tendinitis, meniscus tears or ligament tears. Knee surgery and treatment during the preceding 6 months, such as arthroscopy, steroid injections, acupuncture or physiotherapy were also considered exclusion criteria. CG participants, on the other hand, were excluded if they reported signs or symptoms of PFP and/or other diseases.

All participants were evaluated according to the exclusion and inclusion criteria by two investigators with five years of clinical practice and separated into the PFP or CG group only if the two investigators were in agreement about the participant's condition. Prior to participation, all subjects were given an explanation about the study and signed an informed consent form approved by the Human Ethics Committee of the State University of West Parana.

2.1. 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 to 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. 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 of 2000 Hz.

2.2. 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 direction of the muscle belly (Hermens et al., 2000), with a 20 mm interelectrode distance. This motor point method for positioning the electrodes is in accordance with the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) (Uliam Kuriki et al., 2011). The reference electrode was placed over the tibial tubercle.

Before data collection, participants rated their usual pain during the previous month on a VAS, were familiarized with the protocol and, once they felt comfortable and the investigators deemed they were descending stairs with consistent velocity and proper performance, the sEMG data collection commenced.

Each participant was asked to descend the stairs at their natural comfortable speed across the staircase, five successful trials were collected and averaged to be analyzed. As demonstrated by Jordan et al. (2007), controlling the timing of the stair descent can change the sEMG signal for gait in healthy subjects, thus, the speed of stair descent was not controlled in this study. To ensure a natural stair descent pattern, participants were not made aware of the force plate, which was