

Original article (short paper)

Reliability of electromyography parameters during stair deambulation in patellofemoral pain syndrome

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Abstract—Reliability is essential to all aspects of the measure, as it shows the quality of the information and allows rational conclusions with regard to the data. There has been controversial results regarding the reliability of electromyographic parameters assessed during stair ascent and descent in individuals with patellofemoral pain syndrome (PFPS). Therefore, this study aims to determine the reliability of time and frequency domain electromyographic parameters on both gestures in women with PFPS. Thirty-one women with PFPS were selected to participate in this study. Data from vastus lateralis and medialis were collected during stair deambulation. The selected parameters were: automatic onset, median frequency bands of low, medium and high frequency. Reliability was determined by intraclass correlation coefficient and the standard error of measurement. The frequency domain variables have shown good reliability, with the stair ascent presenting the best rates. On the other hand, onset has proved to be inconsistent in all measures. Our findings suggest that stair ascent is more reliable than stair descent to evaluate subjects with PFPS in the most cases.

Keywords: electromyography, reproducibility of results, patellofemoral pain syndrome

Resumo—“Reprodutibilidade de parâmetros eletromiográficos durante a subida e descida de escada na síndrome da dor femoropatelar.” A reprodutibilidade é essencial para todos os aspectos da medida, uma vez que mostra a qualidade da informação e permite conclusões racionais no que diz respeito aos dados. Além disso, os resultados são controversos sobre parâmetros eletromiográficos avaliados durante a subida e descida de escada em indivíduos com síndrome da dor femoropatelar (SDFP). Portanto pretende-se determinar a reprodutibilidade de parâmetros eletromiográficos nos domínios do tempo e da frequência em ambos os gestos em mulheres com SDFP. Foram selecionadas 31 mulheres com SDFP. Os dados dos músculos vasto lateral e vasto medial foram coletados durante a subida e a descida de escada. Os parâmetros selecionados foram: o onset automático, frequência mediana, bandas de baixa, média e alta frequência. Determinou-se a reprodutibilidade através do coeficiente de correlação intraclasse e do erro padrão da medida. As variáveis no domínio da frequência apresentaram boa reprodutibilidade, com a subida apresentando os melhores índices, e o onset mostrou-se inconsistente. Os resultados sugerem que a subida de escada é mais confiável do que a descida da escada para avaliar indivíduos com SDPF na maioria dos casos.

Palavras-chave: eletromiografia, reprodutibilidade dos testes, síndrome da dor patelofemoral

Resumén—“Reproducibilidad de los parámetros electromiográficos durante ascenso y descenso de escaleras en la síndrome de dolor patelofemoral.” La reproducibilidad es esencial para todos los aspectos de la medida, ya que muestra la calidad de la información y permite conclusiones racionales con respecto a los datos. Además, los resultados son controvertidos en parámetros electromiográficos evaluados durante el ascenso y descenso escaleras en las personas con síndrome de dolor patelofemoral (SDPF). Por eso tenemos la intención de determinar la reproducibilidad de los

parámetros electromiográficos en el tiempo y la frecuencia en ambos gestos en mujeres con SDPF. 31 mujeres con SDPF fueron seleccionadas. Se recogieron datos del vasto lateral y medial durante ascenso y descenso de escaleras. Los parámetros seleccionados fueron: inicio automático, frecuencia mediana, bandas de baja, media y alta frecuencia. La reproducibilidad se determinó mediante el coeficiente de correlación intraclase y el error estándar de medición. Las variables en el dominio de la frecuencia mostraron buena reproducibilidad, el ascenso presentó los mejores índices, y el inicio demostró ser inconsistente. Estos resultados sugieren que el ascenso de la escalera es más confiable que el descenso para evaluar individuos con SDPF en la mayoría de los casos.

Palabras claves: electromiografía, reproducibilidad de resultados, síndrome de dolor patelofemoral

Introduction

Patellofemoral pain syndrome (PFPS) has been responsible for 25 to 40% of all knee problems registered in orthopedic centers (Boling *et al.*, 2010). It is a condition characterized by non-specific anterior knee pain, with an insidious onset (Grenholm, Stensdotter, & Häger-Ross, 2009). Different daily activities such as, ascending and descending stairs, squatting and running, have been pointed as a potential exacerbating factor (de Oliveira Silva *et al.*, 2015; Willson, Sharpee, Mear-don, & Kernozek, 2014).

Stair ascent or descent is a cheap and simple way to simulate a daily life activity in a laboratory environment (Garcia *et al.*, 2010; Riener, Rabuffetti, & Frigo, 2002). As stair deambulation is often used to evaluate the reproducibility of symptoms and to identify abnormal movement patterns indicative of PFPS, knowledge of lower extremity neuromuscular activity during stair deambulation is necessary to better characterize compensatory behaviors in this population (Salsich, Brechter, & Powers, 2001). The electromyography (EMG) parameters have been frequently investigated in PFPS studies during stair descent (Herrington, Malloy, & Richards, 2005; Saywell, Taylor, & Boocock, 2012) and stair ascent (Kuriki, De Azevedo, Filho, & Alves, 2012; Sung & Lee, 2009), however, data obtained during one gesture may not be applicable to the other due to different motor strategies imposed to their realization. For example, the gesture of descent is more challenging for the neuromuscular coordination system due to the need to generate eccentric forces to decelerate the movement (Leitner, Schmid, Hilfiker, & Radlinger, 2011). On the other hand, during the gesture of ascent the quadriceps muscle is more required and the vastus lateralis (VL) remains active for a longer time compared to the rectus femoris or hamstrings antagonists (McFadyen & Winter, 1988). Therefore, it seems reasonable to investigate the reliability in both gestures and compare their results to find the better functional activity to study PFPS.

Several studies aim to characterize the activation pattern of the patella stabilizers muscles during stair deambulation (Cavazzuti, Merlo, Orlandi, & Campanini, 2010; Kim & Song, 2012), however, few of them present data related to the quality of these measures (Bolglia, Malone, Umberger, & Uhl, 2010; Cowan, Bennell, & Hodges, 2000; Ferrari, Kuriki, Silva, Alves, & Micolis de Azevedo, 2014). Thereby, it is unknown which gesture has the best results of precision and reliability, yet, whether some specific EMG parameter has better accuracy depending on the gesture.

The EMG data can be analyzed in two different domains, the time and the frequency domain (Winter, 2009). The delay between vastus medialis (VM) and VL muscle onset is a classical time domain parameter investigated in individuals with PFPS due to its possible relation to the PFP etiology (Kim & Song, 2012; Pal *et al.*, 2010; Patil, Dixon, White, Jones, & Hui, 2011; Uliam Kuriki, Micolis de Azevedo, de Faria Negrão Filho, & Alves, 2011). On the other hand, frequency domain parameters have been currently used in studies with PFPS and promising results have been shown (Briani *et al.*, 2015; Ferrari *et al.*, 2014). Although some studies have evaluated the reliability of the electromyography data (Bolglia *et al.*, 2010; Briani *et al.*, 2015; Uliam Kuriki *et al.*, 2011), its results are controversial and sometimes the *intraclass correlation coefficient* (ICC) model chosen for the reliability calculation does not allow the extrapolation of the results to the general population. The comparison with respect to the reliability among these studies remains quite difficult due to differences in experimental designs. Thus, a study evaluating the reliability of EMG parameters in time and frequency domain during stair ascent and descent, with a standardized experimental design, may shed some light on our understanding about the more reliable gesture to analyze each variable.

The reliability is essential to all aspects of the measure, as it shows the quality of information and allows rational conclusions with regard the data (Weir, 2005), therefore, the aim of this study was to determine the reliability of EMG parameters on the time and frequency domain, during stair ascent and descent in women with PFPS.

Methods

Thirty-one women with PFPS were recruited via advertisements placed at universities, gyms and parks around the city. The sample size was calculated based on recommendations of Walter, Eliasziw, & Donner, (1998) using $\alpha \leq .05$, $p_0 = .56$ and $p_1 = .89$, the lowest and the highest level of reliability were found in previous studies, respectively (Bolglia *et al.*, 2010; Briani *et al.*, 2015; Ferrari *et al.*, 2014). A minimum of 22 individuals was estimated to be needed to ensure 80% power. All women were between 18 to 30 years. The study was approved by the State University of West Paraná Human Ethics Committee (096/2013), and each participant gave written informed consent prior to participation. The criteria used for the diagnosis of PFPS were based on those used in other PFPS studies (Briani *et al.*,

2015; de Oliveira Silva *et al.*, 2015; Ferrari *et al.*, 2014): (1) anterior knee pain during at least 2 of the following activities: remaining seated, squatting, kneeling, running, climbing stairs; (2) pain during patellar palpation; (3) symptoms for at least 1 month with an insidious start; (4) pain level up to 3cm on a 10-cm VAS in the previous week; and (5) at least 3 positive clinical signs of the following tests: Noble compression, McConnell, Waldron, Zohler's sign, Clarke's sign, Q angle higher than 18°, and patella in the medial or lateral position. These criteria do not indicate the severity of PFPS; they only classify as PFPS or not. The participants needed to fulfill all 5 requirements to be included.

Any condition besides PFPS was considered an exclusion criterion, such as events of patellar subluxation or dislocation, lower limb inflammatory process, osteoarthritis, patellar tendon or meniscus tears, bursitis, ligament tears or the presence of neurological diseases. Those who had knee surgery and knee treatments such as arthroscopy, steroid injections, oral steroids, opiate treatment, acupuncture or physiotherapy during the previous 6 months were excluded from this study.

All the participants were evaluated according to the exclusion and inclusion criteria by two investigators with five years of clinical practice and were only allocated into the PFPS group if these two investigators were in agreement about the criteria.

Instrumentation

The experimental design included a stair designed according to Yu and colleagues (1997) recommendations (Yu, Kienbacher, Growney, Johnson, & An, 1997) with seven steps, each step being 28cm deep, 18cm high and 1m width, with a 2m walkway in front of and at the top of it. These dimensions are according to the Brazilian Regulatory Standards for construction of stairs 9077/2001 (Brazilian Association of Technical Standards).

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 500Hz 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 80dB, and an impedance of 1012Ω. The raw EMG signal was recorded at a sampling rate of 4000Hz. Two pairs of bipolar surface-capture Ag/AgCl electrodes (Kendall, Mansfield, MA, USA; model Medi-Trace) with diameters of 10mm 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 point in painful lower limb.

To ensure a natural stair climbing pattern, participants were not aware of the force plate (AMTI, OR6, Watertown, MA, USA) which was hidden within the fourth step; only the investigator knew of its existence and position, the force plate was mechanically coupled to the ground (i.e. independent and uncoupled from the stair structure). It was 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 2000Hz.

Procedure

After finding the VM and VL motor point, the skin over the anterior portion of the thigh was cleaned with rubbing alcohol. The electrodes were placed 2cm below the motor point in the direction of the muscle belly, (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000) with a 20mm 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.

The laboratory temperature and illumination were controlled. Before data collection, participants were familiarized with the protocol and, once they felt comfortable and the investigators deemed they were ascending and descending stairs with consistent velocity and proper performance, the sEMG data collection commenced.

Each participant was asked to ascent and descent the stairs at their natural comfortable speed across the staircase and five successful trials were collected. The trial was considered valid when the participant touches the force plate with the symptomatic lower limb evaluated by EMG. As demonstrated by Jordan *et al.* (2007) (Jordan, Challis, & Newell, 2007) controlling the timing of the stair ascent and/or descent can change the sEMG signal for gait in healthy subjects, thus, the speed of stair ascent and descent was not controlled in this study. To ensure a natural stairs negotiation pattern, participants were not made aware of the force plate, which was hidden within the fourth step covered by a rubberized fabric, making it impossible to distinguish the force plate from the other steps. For the reliability analysis, the trials were performed in the same period of the day and in the same manner on 2 separate days, with an interval of 2 to 7 days between the 2 collection periods. The subjects were oriented to keep their daily life activities and routine physical activity between the two days of collect data. Studies have shown that electrode positions may be the cause of measurement variability (Smoliga, Myers, Redfern, & Lephart, 2010) and, as the collection of this study was performed on 2 different days, a template using the participants' anatomic references was developed (Ferrari *et al.*, 2014), furthermore, the electrodes were placed by the same person in both days.

EMG analysis

The analyzed EMG signals were referenced by the vertical component of ground reaction force measured by the force plate. Therefore, the EMG signal was considered only while the participant was crossing the fourth step. The vertical component of ground reaction force being a marker of the beginning and the end of the EMG data collection. All processing was performed in MATLAB® (The MathWorks, Inc, Natick, MA).

The power spectrum density (PSD) is often used to analyze EMG frequency analysis (Silva, Silva, Ferrari, *et al.*, 2014;

Table 1. Summary of subject demographics.

Data	Mean \pm SD	p-value
Age (years)	21.9 \pm 2.72	.457
Body Mass (Kg)	65.72 \pm 10.76	.523
Height (m)	1.65 \pm 0.05	.225
Lower limbs evaluated (R/L)	25/06	-

Abbreviation: R/L – number of participants with right lower limb pain/ number of participants with left lower limb pain.

Smoliga *et al.*, 2010). The filtered EMG data time series was calculated using the fast Fourier transform. From this calculation the median frequency (Fmed) was extracted, which is when the integral of the left side of the spectrum is equal to that of the right side (Solomonow *et al.*, 1990).

The intensity of the PSD was normalized as follows: (1) calculation of the spectral distribution function, which is the cumulative sum of the power spectrum divided by its maximum value and multiplied by 100, and (2) calculation of the derived spectral distribution function to obtain a PSD with intensity values normalized between 0 and 100. The mean intensity was calculated for each of the 3 frequency bands considered for analysis from the normalized PSD: low (15-45Hz) (B1), medium (45-96Hz) (B2), and high (96-400Hz) (B3) this bands were defined according to previous PFPS studies (Briani *et al.*, 2015; Ferrari *et al.*, 2014).

In relation to EMG Onset analysis, automatic algorithm method was utilized. This technique was suggested as the most prevalent onset techniques performed in muscular contraction studies (Cavazzuti *et al.*, 2010; Uliam Kuriki *et al.*, 2011; Williams, Haq, & Lee, 2013). Initially, a linear envelope was applied to the signal and data were full-wave rectified and low-pass filtered at 50Hz.

Automatic Onset muscle contraction was quantified as more than three standard-deviations of signal alteration for a minimum of 25ms above the baseline level of each muscle by another algorithm (Bolgia *et al.*, 2010; Cowan, Bennell, Hodges, Crossley, & McConnell, 2001; Kim & Song, 2012). After identifying the respective values, an algorithm subtracted the VL onset from the VM, where negative differences indicated previous activation of the VM and positive differences indicated previous activation of the VL (Uliam Kuriki *et al.*, 2011).

Statistical analysis

Statistical analysis was done using SPSS version 18 (SPSS Inc., Chicago IL). Descriptive statistics for sample characteristics were expressed using mean \pm standard deviation. Intraclass correlation coefficient (ICC) (2,k) was used to express relative reliability of the measures (Weir, 2005). ICC expresses the ratio of between-subject variance to within-subject variance and is a unitless value 24. Descriptors for reliability coefficients were used to describe the degree of reliability: .00 to .25 – little, if any correlation; .26 to .49 – low correlation; .50 to .69 – moderate correlation; .70 to .89 – high correlation and .90 to 1.00 – very high correlation (Kellis & Katis, 2008; Mathur, Eng, & MacIntyre, 2005). Standard error of the measurement (SEM) was used to express absolute reliability of the measure (Silva, Silva, Aragão, *et al.*, 2014; Weir, 2005). SEM is calculated from the square root of the error variance (i.e., mean of standard deviations from day 1 and day 2) and has the same unit as the tested variable. In addition, SEM values were normalized by mean to obtain their values on a 0 to 100 percentage scale. Smaller values of SEM reflect more reliable measures (Weir, 2005).

Results

All 31 volunteers have completed the two test days. The data related to the anthropometric measures and lower limbs evaluated are presented in Table 1.

The mean value, standard deviation, SEM and ICC of the variables in the time and frequency domain are described in Tables 2 and 3. The onset does not have to separate the VM and VL muscles values, because it is the delayed onset activation of these muscles. The results were separated according to the gestures of ascent (Table 2) and descent (Table 3).

Table 2. Stair ascent – Mean, standard deviation, ICC and SEM values to time and frequency domain sEMG parameters for VM and VL muscles.

VM	FMed(Hz)	B1(n.u.)	B2(n.u.)	B3(n.u.)	Onset(ms)
Day 1 (M \pm SD)	57.60 \pm 6.98	44.77 \pm 10.37	35.08 \pm 4.77	1.73 \pm 0.82	16.20 \pm 11.99
Day 2 (M \pm SD)	59.09 \pm 6.89	42.90 \pm 7.38	35.22 \pm 4.24	2.01 \pm 0.97	16.37 \pm 16.55
ICC (IC 95%)	0.81 (0.62; 0.91)	0.84 (0.68; 0.92)	0.85 (0.69; 0.92)	0.59 (0.17; 0.80)	-0.17 (-1.52; 0.44)
SEM(%)	3.81 (6.53%)	4.56 (10.40%)	2.30 (6.54%)	0.67 (35.82%)	21.07 (129.34%)
VL					
Day 1 (M \pm SD)	57.82 \pm 7.19	45.99 \pm 10.78	33.38 \pm 4.80	1.88 \pm 0.83	
Day 2 (M \pm SD)	57.65 \pm 6.33	44.85 \pm 10.33	33.70 \pm 4.35	0.97 \pm 0.17	
ICC	0.76 (0.50; 0.88)	0.81 (0.60; 0.90)	0.76 (0.51; 0.88)	0.26 (-0.56; 0.65)	
SEM (%)	4.25 (7.36%)	6.00 (13.21%)	2.83 (8.43%)	0.83 (58.45%)	

Abbreviation: FMed – median frequency, B1 – low frequency band, B2 – medium frequency band, B3 – high frequency band; n.u. – normalized unit; ms – milliseconds, IC 95% – 95% confidence intervals. As the onset values does not have to separate the VM and VL muscles values, because it is the delayed onset activation of these muscles.

Table 3. Stair descent – Mean, standard deviation, ICC and SEM values to time and frequency domain sEMG parameters for VM and VL muscles.

VM	FMed(Hz)	B1(n.u.)	B2(n.u.)	B3(n.u.)	Onset(ms)
Day 1 (M±SD)	55.23 ± 5.80	46.57 ± 8.51	34.12 ± 3.97	1.52 ± 0.65	132.11 ± 133.72
Day 2 (M±SD)	57.74 ± 7.34	43.78 ± 9.21	34.56 ± 4.78	1.77 ± 0.77	149.53 ± 123.04
ICC (IC 95%)	0.56 (0.12; 0.78)	0.72 (0.43; 0.86)	0.79 (0.56; 0.90)	0.71 (0.40; 0.86)	0.59 (-0.2; 0.83)
SEM (%)	5.07 (8.97%)	5.67 (12.55%)	2.59 (7.54%)	0.45 (27.43%)	142.24 (101.01%)
VL					
Day 1 (M±SD)	61.47 ± 9.97	41.59 ± 9.78	33.79 ± 3.23	2.23 ± 1.16	
Day 2 (M±SD)	60.58 ± 9.50	40.71 ± 10.87	34.99 ± 5.06	2.04 ± 1.09	
ICC	0.86 (0.71; 0.93)	0.88 (0.75; 0.94)	0.64 (0.28; 0.82)	0.74 (0.48; 0.87)	
SEM (%)	4.86 (7.96%)	4.77 (11.59%)	3.03 (8.81%)	0.71 (33.33%)	

Abbreviation: FMed – median frequency, B1 – low frequency band, B2 – medium frequency band, B3 – high frequency band; n.u. – normalized unit; ms – milliseconds, IC 95% – 95% confidence intervals. As the onset values does not have to separate the VM and VL muscles values, because it is the delayed onset activation of these muscles.

Discussion

The stairs have been placed on experimental designs in order to reproduce a functional gesture. And, in the case of subjects with PFPS, it reproduces a gesture in which the symptoms are exacerbated. However, to date, it is not known if there are and which are the EMG differences between the gestures of ascent and descent stairs. Thus, the aim of this study is to determine the reliability of EMG parameters in these two gestures and report which one presents more reliable results.

Our sample follows the same profile used in studies with similar experimental design (Bolgla *et al.*, 2010; Ferrari *et al.*, 2014; Kuriki *et al.*, 2012). Studies that evaluated parameters in the frequency domain showed moderate to high reliability during stair deambulation (Briani *et al.*, 2015; Ferrari *et al.*, 2014), corroborating with our findings. The EMG frequency parameters demonstrated to be an adequate diagnostic tool for PFPS (Ferrari *et al.*, 2014). Therefore, this experimental design can be implemented to diagnose individuals with PFPS (Yu *et al.*, 1997).

The time domain parameters continue to be investigated, however, few researches have shown the consistency of its measures. The null (-.17) and moderate (.59) reliability during stair descent and ascent, respectively, with high SEM, for the parameters in the time domain reveals that this variable is not consistent and the results are unreliable. In contrast, a research developed with healthy young individuals, revealed very high levels of reliability, being .96 on the descent and .91 on the ascent (Cowan *et al.*, 2000). Another study obtained an ICC of 0.70 during stair descent in females with PFPS (Bolgla *et al.*, 2010).

The main difference between these and our results is the statistical model used to calculate the reliability. The aforementioned research opted for the 3.5 ICC model, which should be performed when the goal is to analyze intra-rater reliability. In this case, it serves to establish the reliability of EMG equipment, exclusively used for the samples and cannot be generalized (Weir, 2005). Our study has chosen the 2.5 ICC model which provides test-retest reliability, thus, it detects the consistency of the measurement performed by an EMG equipment and also

can be extrapolated to other similar equipment (Weir, 2005). Besides, 2.5 ICC model take into account systematic and random errors, whereas, 3.5 ICC model only gets random errors (Weir, 2005).

In general, it has been seen a slight difference between the reliability of the parameters on the frequency domain during ascent and descent stairs. This can be explained by the change in the sequence of recruitment-derecruitment pattern of motor units (Gonzalez-Izal, Cadore, & Izquierdo, 2014; Howell, Fuglevand, Walsh, & Bigland-Ritchie, 1995). During concentric contraction (stair ascent) the recruitment of motor units occurs from the lower to the higher threshold level stimulation. Firstly, the low-threshold units are deflagrated (fatigue resistant), and with the overload increasing, the high-threshold units are recruited (low resistance to fatigue) (Kallio *et al.*, 2013). However, during the eccentric contraction can occur activation of stretch receptors, leading to an activation of some polysynaptic afferent pathways, although temporarily, that may inhibit low-threshold motoneurons and excite high-threshold motoneurons, leading to a different activation pattern (Howell *et al.*, 1995; Nardone, Romano, & Schieppati, 1989). Furthermore, the concentric contractions show higher EMG activation, since they require a greater number of active motor units to generate the same force compared to eccentric contractions (Kallio *et al.*, 2013; Yu, 2014).

Considering the results and the paucity of research addressing the quality of these measures, we note that in the context of the variables in the frequency domain, either in the ascent or in the descent stair, they are consistent for studying individuals with PFPS. Consequently, it can be explored as assessment and diagnosis method to PFPS. Nonetheless, it is necessary to show the results regarding reliability to show de quality of the measurements. The gesture of ascent is better to determine the pattern of muscle activation in subjects with PFPS and then compare it with asymptomatic subjects, due to a specific order of recruitment (low to high threshold). Therefore, it allows quantify strength physiologically (Silva Jr, 2013) and clearly determine other parameters such as Fmed, for example. On the other hand, stair descent is indicated to check the activity of the quadriceps as a result of higher demands muscle and

mechanical compared to concentric activities, besides being associated with higher rates of pain and joint stress (Powers, 2010). In contrast, the results for the delay in onset proved to be inconsistent and, therefore, should be cautious at the time of extracting the information pertaining to these measures due to its high rates of error.

There are some limitations of the present study that must be acknowledged. Firstly, the sample included only women. Although this subgroup is important to study, as these individuals are the most likely to be committed for PFPS, the results may not be generalizable to the entire population of people with PFPS. Secondly, the speed during stair deambulation was not controlled in any day, which does not allow to determine the speed influence on the EMG signal. Therefore, future studies should include men and to control factors that can influence the EMG, such as speed during stair deambulation.

Stair ascent has shown EMG characteristics more standard than stair descent. Moreover, it has exhibit moderate to high values of reliability in the frequency domain EMG parameters. Therefore, our results suggest that stair ascent and frequency domain EMG parameters are more reliable to evaluate EMG signals of subjects with PFPS in the most cases.

References

- Bolgia, L.A., Malone, T.R., Umberger, B.R., & Uhl, T.L. (2010). Reliability of electromyographic methods used for assessing hip and knee neuromuscular activity in females diagnosed with patellofemoral pain syndrome. *Journal of Electromyography and Kinesiology*, *20*, 142–7. doi:10.1016/j.jelekin.2008.11.008
- Boling, M., Padua, D., Marshall, S., Guskiewicz, K., Pyne, S., & Beutler, A. (2010). Gender differences in the incidence and prevalence of patellofemoral pain syndrome. *Scandinavian Journal of Medicine & Science in Sports*, *20*, 725–730. doi:10.1111/j.1600-0838.2009.00996.x.Gender
- Briani, R.V., de Oliveira Silva, D., Pazzinato, M.F., Albuquerque, C.E., Ferrari, D., Aragão, F.A., & Azevedo, F.M. (2015). Comparison of frequency and time domain electromyography parameters in women with patellofemoral pain. *Clinical Biomechanics*, *30*, 302–307. doi:10.1016/j.clinbiomech.2014.12.014
- Cavazzuti, L., Merlo, A., Orlandi, F., & Campanini, I. (2010). Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Gait & Posture*, *32*, 290–5. doi:10.1016/j.gaitpost.2010.06.025
- Cowan, S.M., Bennell, K.L., & Hodges, P.W. (2000). The test–retest reliability of the onset of concentric and eccentric vastus medialis obliquus and vastus lateralis electromyographic activity in a stair stepping task. *Physical Therapy in Sport*, *1*, 129–136. doi:10.1054/ptsp.2000.0036
- Cowan, S.M., Bennell, K.L., Hodges, P.W., Crossley, K.M., & McConnell, J. (2001). Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Archives of Physical Medicine and Rehabilitation*, *82*, 183–9. doi:10.1053/apmr.2001.19022
- De Oliveira Silva, D., Briani, R.V., Pazzinato, M.F., Ferrari, D., Aragão, F.A., de Albuquerque, C.E., ... de Azevedo, F.M. (2015). Reliability and differentiation capability of dynamic and static kinematic measurements of rearfoot eversion in patellofemoral pain. *Clinical Biomechanics*, *30*, 144–148. doi:10.1016/j.clinbiomech.2014.12.009
- Ferrari, D., Kuriki, H.U., Silva, C.R., Alves, N., & Micolis de Azevedo, F. (2014). Diagnostic Accuracy of the Electromyography Parameters Associated With Anterior Knee Pain in the Diagnosis of Patellofemoral Pain Syndrome. *Archives of Physical Medicine and Rehabilitation*, *95*, 1521–6. doi:10.1016/j.apmr.2014.03.028
- Garcia, F.R., Azevedo, F.M., Alves, N., Carvalho, A.C., Padovani, C.R., & Negrão Filho, R.F. (2010). Effects of electrical stimulation of vastus medialis obliquus muscle in patients with patellofemoral pain syndrome: an electromyographic analysis. *Revista Brasileira de Fisioterapia*, *14*, 477–82. (Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/21340241>)
- Gonzalez-Izal, M., Cadore, E.L., & Izquierdo, M. (2014). Muscle conduction velocity, surface electromyography variables, and echo intensity during concentric and eccentric fatigue. *Muscle & Nerve*, *49*, 389–397. doi:10.1002/mus.23926
- Grenholm, A., Stensdotter, A.-K., & Häger-Ross, C. (2009). Kinematic analyses during stair descent in young women with patellofemoral pain. *Clinical Biomechanics*, *24*, 88–94. doi:10.1016/j.clinbiomech.2008.09.004
- Hermens, H.J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology*, *10*, 361–374. doi:10.1016/S1050-6411(00)00027-4
- Herrington, 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 and Kinesiology*, *15*, 604–7. doi:10.1016/j.jelekin.2005.05.002
- Howell, J.N., Fuglevand, A.J., Walsh, M.L., & Bigland-Ritchie, B. (1995). Motor Unit Activity During Isometric and Concentric-Eccentric Contractions of the Human First Dorsal Interosseus Muscle. *Journal of Neurophysiology*, *74*, 0–3.
- Jordan, K., Challis, J.H., & Newell, K.M. (2007). Walking speed influences on gait cycle variability. *Gait & Posture*, *26*, 128–34. doi:10.1016/j.gaitpost.2006.08.010
- Kallio, J., Sogaard, K., Avela, J., Komi, P.V., Selänne, H., & Linnamo, V. (2013). Motor unit firing behaviour of soleus muscle in isometric and dynamic contractions. *PLoS One*, *8*, e53425. doi:10.1371/journal.pone.0053425
- Kellis, E., & Katis, A. (2008). Reliability of EMG power-spectrum and amplitude of the semitendinosus and biceps femoris muscles during ramp isometric contractions. *Journal of Electromyography and Kinesiology*, *18*, 351–8. doi:10.1016/j.jelekin.2006.12.001
- Kim, H., & Song, C.H. (2012). Comparison of VMO/VL EMG Ratio and Onset Timing of VMO Relative to VL in Subjects with and without Patellofemoral Pain Syndrome. *Journal of Physical Therapy Science*, *24*, 1315–1317. doi:10.1589/jpts.24.1315
- Kuriki, H.U., De Azevedo, F.M., Filho, R. de F.N., & Alves, N. (2012). Onset of quadriceps activation and torque variation during stair ascent in individuals with patellofemoral pain. *Conscientiae Saúde*, *11*, 642–650. doi:10.5585/ConsSaude.v11n4.3810
- Leitner, M., Schmid, S., Hilfiker, R., & Radlinger, L. (2011). Test-retest reliability of vertical ground reaction forces during stair climbing in the elderly population. *Gait & Posture*, *34*, 421–5. doi:10.1016/j.gaitpost.2011.06.014
- Mathur, S., Eng, J.J., & MacIntyre, D.L. (2005). Reliability of surface EMG during sustained contractions of the quadriceps. *Journal of Electromyography and Kinesiology*, *15*, 102–10. doi:10.1016/j.jelekin.2004.06.003
- McFadyen, B.J., & Winter, D.A. (1988). An integrated biomechanical analysis of normal stair ascent and descent. *Journal of Biomechanics*, *21*, 733–744. doi:10.1016/0021-9290(88)90282-5

- Nardone, A., Romano, C., & Schieppati, M. (1989). Selective recruitment of high-threshold human motor units during voluntary isotonic lengthening of active muscles. *Journal of Physiology*, 409, 451–471.
- Pal, S., Draper, C.E., Fredericson, M., Gold, G.E., Delp, S.L., Beaupre, G.S., & Besier, T.F. (2010). Patellar maltracking correlates with vastus medialis activation delay in patellofemoral pain patients. *The American Journal of Sports Medicine*, 39, 590–8. doi:10.1177/0363546510384233
- Patil, S., Dixon, J., White, L., Jones, A., & Hui, A. (2011). An electromyographic exploratory study comparing the difference in the onset of hamstring and quadriceps contraction in patients with anterior knee pain. *The Knee*, 18, 329–32. doi:10.1016/j.knee.2010.07.007
- Powers, C.M. (2010). The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *The Journal of Orthopaedic and Sports Physical Therapy*, 40, 42–51. doi:10.2519/jospt.2010.3337
- Riener, R., Rabuffetti, M., & Frigo, C. (2002). Stair ascent and descent at different inclinations. *Gait & Posture*, 15, 32–44.
- Salsich, G.B., Brechter, J.H., & Powers, C.M. (2001). Lower extremity kinetics during stair ambulation in patients with and without patellofemoral pain. *Clinical Biomechanics*, 16, 906–912. doi:10.1016/S0268-0033(01)00085-7
- Saywell, N., Taylor, D., & Boocock, M. (2012). During step descent, older adults exhibit decreased knee range of motion and increased vastus lateralis muscle activity. *Gait & Posture*, 36, 490–4. doi:10.1016/j.gaitpost.2012.05.007
- Silva, C.R., Silva, D.O., Aragão, F.A., Ferrari, D., Alves, N., & Azevedo, F.M. (2014). Influence of neuromuscular fatigue on co-contraction between vastus medialis and vastus lateralis during isometric contractions. *Kinesiology (Zagreb)*, 46, 179–185.
- Silva, C.R., Silva, D.O., Ferrari, D., Negrão Filho, R.F., Alves, N., & Azevedo, F.M. (2014). Exploratory study of electromyographic behavior of the vastus medialis and vastus lateralis at neuromuscular fatigue onset. *Motriz*, 20, 213–220. doi:dx.doi.org/10.1590/S1980-65742014000200012
- Silva Jr, R.A. (2013). Normalização EMG: considerações da literatura para avaliação da função muscular (EMG normalization: considerations from literature to assess the muscle function). *Conscientiae Saúde*, 12, 470–479. doi:10.5585/ConsSaude.v12n3.4362
- Smoliga, J.M., Myers, J.B., Redfern, M.S., & Lephart, S.M. (2010). Reliability and precision of EMG in leg, torso, and arm muscles during running. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, 20, e1–9. doi:10.1016/j.jelekin.2009.09.002
- Solomonow, M., Baten, C., Smit, J., Baratta, R., Hermens, H., D'Ambrosia, R., & Shoji, H. (1990). Electromyogram power spectra frequencies associated with motor unit recruitment strategies. *Journal of Applied Physiology*, 68, 1177–85.
- Sung, P.S., & Lee, D.C. (2009). Gender differences in onset timing and activation of the muscles of the dominant knee during stair climbing. *The Knee*, 16, 375–80. doi:10.1016/j.knee.2009.02.003
- Uliam Kuriki, H., Mícolis de Azevedo, F., de Faria Negrão Filho, R., & Alves, N. (2011). Comparison of different analysis techniques for the determination of muscle onset in individuals with patellofemoral pain syndrome. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, 21, 982–7. doi:10.1016/j.jelekin.2011.08.002
- Walter, S.D., Eliasziw, M., & Donner, A. (1998). Sample Size and Optimal Designs for Reliability Studies. *Statistics in Medicine*, 17, 101–110. doi:10.1002/(SICI)1097-0258(19980115)17:1<101::AID-SIM727>3.0.CO;2-E
- Weir, J.P. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *Journal of Strength and Conditioning Research*, 19, 231–240.
- Williams, J.M., Haq, I., & Lee, R.Y. (2013). An investigation into the onset, pattern, and effects of pain relief on lumbar extensor electromyography in people with acute and chronic low back pain. *Journal of Manipulative and Physiological Therapeutics*, 36, 91–100. doi:10.1016/j.jmpt.2012.12.006
- Willson, J.D., Sharpee, R., Meardon, S.A., & Kernozek, T.W. (2014). Effects of step length on patellofemoral joint stress in female runners with and without patellofemoral pain. *Clinical Biomechanics*, 29, 243–247. doi:10.1016/j.clinbiomech.2013.12.016
- Winter, D.A. (2009). *Biomechanics and motor control of human movement* (Fourth Ed.). New Jersey.
- Yu, B., Kienbacher, T., Growney, E.S., Johnson, M.E., & An, K.N. (1997). Reproducibility of the kinematics and kinetics of the lower extremity during normal stair-climbing. *Journal of Orthopaedic Research*, 15, 348–52. doi:10.1002/jor.1100150306
- Yu, J. (2014). Comparison of Lower Limb Muscle Activity during Eccentric and Concentric Exercises in Runners with Achilles Tendinopathy. *Journal of Physical Therapy Science*, 26, 1351–1353.

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Manuscript received on February 5, 2015

Manuscript accepted on March 25, 2015



Motriz. The Journal of Physical Education. UNESP. Rio Claro, SP, Brazil
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