ORIGINAL RESEARCH

Influence of high-heeled shoes on the quadriceps electromyographic activity in women with and without patellofemoral pain syndrome during the sit-to-stand task

Influência do calçado de salto alto na atividade eletromiográfica do músculo quadríceps em mulheres com e sem síndrome da dor femoropatelar durante a tarefa de levantar e sentar

Influencia del calzado de tacón alto en la actividad electromiográfica del músculo cuádriceps en mujeres con y sin síndrome de dolor patelofemoral durante la tarea de levantarse y sentarse

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ABSTRACT | The purpose of this study was to analyze the influence of high-heeled shoes on the quadriceps electromyographic activity (EMG) during the sit-to-stand task. Ten healthy females (20.2±3.0 years) and 10 females with patellofemoral pain syndrome (PFPS) (21.3±3.4 years) participated in this study. The subjects performed a standardized sit-to-stand task under 3 conditions: barefoot, wearing sneakers and wearing 10 cm high-heeled shoes. The electromyographic (EMG) activity was recorded from the vastus medialis obliquus (VMO), vastus lateralis (VL) and rectus femoris (RF) muscles during the tasks using simple differential surface electrodes connected to an EMG system. To compare data between groups and tasks, the ANOVA test with repeated measures and the Tukey *post hoc* test were applied ($p<0{,}05$). Results demonstrated higher EMG activity for the VMO muscles during stand and sit tasks performed with high-heeled shoes in the control group. In the PFPS group, an increased EMG activity for the VL muscle during the stand task was observed, and the VMO:VL ratio decreased with the use of high heels. Results show that the use of high-heeled shoes can further increase the EMG activity of the VL muscle than the VMO in women with PFPS, a fact that may contribute to the increased joint imbalance and worsened PFPS. Therefore, the results suggest that this type of footwear should be avoided by women with PFPS.

Keywords | patellofemoral pain syndrome; knee; shoes.

RESUMO | O objetivo do estudo foi analisar a influência do calçado de salto alto na atividade eletromiográfica (EMG) do músculo quadríceps durante a tarefa de sentar e levantar. Participaram deste estudo 10 voluntárias assintomáticas com 20,2±3,0 anos e 10 voluntárias com síndrome da dor femoropatelar (SDFP) com 21,3±3,4 anos. As voluntárias executaram a tarefa de sentar e levantar em 3 diferentes condições: descalças, com tênis e com calçado de salto de 10 cm. A atividade EMG do vasto medial oblíquo (VMO), vasto lateral (VL) e reto femoral (RF) foi registrada durante a execução das tarefas por meio de eletrodos de superfície simples diferencial conectados ao eletromiógrafo. Para comparação entre grupos e tarefas, foi utilizado o teste ANOVA com medidas repetidas e o *post hoc* do teste

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de Tukey (p<0,05). Os resultados demonstraram maior atividade EMG do músculo VMO, no grupo Controle, durante as tarefas de levantar e sentar utilizando o salto alto. No grupo SDFP, foi observado aumento da atividade EMG do VL na tarefa de levantar do banco e diminuição da razão VMO:VL com o uso do salto alto. Os resultados mostraram que o uso do salto alto pode provocar um aumento da atividade do VL em relação ao VMO em mulheres com SDFP, fato esse que pode colaborar para o mau alinhamento patelar e agravamento da SDFP. Portanto, os resultados sugerem que esse tipo de calçado deve ser evitado por mulheres com SDFP.

Descritores | síndrome da dor patelofemoral; joelho; sapatos.

RESUMEN | El objetivo del estudio fue analizar la influencia del calzado de tacón alto en la actividad electromiográfica (EMG) del músculo cuadríceps durante la tarea de sentarse y levantarse. Participaron de este estudio 10 voluntarias asintomáticas con 20,2±3,0 años y 10 voluntarias con síndrome de dolor patelofemoral (SDPF) con 21,3±3,4 años. Las voluntarias ejecutaron la tarea de sentarse y levantarse en tres diferentes condiciones: descalzas, con zapatillas y con calzado de tacón de diez centímetros. La actividad EMG del vasto medial oblícuo (VMO), vasto lateral (VL) y recto femoral (RF) fue registrada durante la ejecución de las tareas por medio de electrodos de superficie diferenciales conectados al electromiógrafo. Para la comparación entre grupos y tareas fue utilizada la prueba ANOVA con medidas repetidas y *post test* de Tukey (p<.05). Los resultados demostraron más actividad EMG del músculo VMO, en el grupo Control durante las tareas de levantarse y sentarse utilizando el tacón alto. En el grupo SDPF fue observado un aumento de la actividad EMG del VL en la tarea levantarse del banco y disminución de la relación VMO:VL con el uso de tacón alto. Los resultados mostraron que el uso de tacón alto puede causar un aumento de la actividad del VL en relación al VMO en mujeres con SDPF, un hecho que puede colaborar para un mal alineamiento patelar y una agravación del SDPF. Por lo tanto, los resultados sugieren que ese tipo de calzado debe ser evitado por mujeres con SDFP.

Palabras clave | síndrome de dolor patelofemoral; rodilla; zapatos.

INTRODUCTION

The use of high-heeled shoes became a frequent habit in the past few years[1-3], being an essential accessory to the female aesthetics. However, the prolonged use can trigger biomechanical changes in the lower limb, and it may contribute for the development of musculoskeletal disorders of the knee[2]. One of the most frequent occurrences at the clinic is the patellofemoral pain syndrome (PFPS), characterized as a diffuse pain in the anterior, peripatellar or retropatellar regions[4-7], which worsens with tasks such as crouching, kneeling, going up and down the stairs[8,9].

The etiological factors of PFPS are not completely clear, and its origin may be proximal, related to changes in the mechanism of the hip, or distal, with changes in the structure and movement of the ankle and subtalar joints. Besides, the poor patellar alignment and instability, caused by the imbalance of static and dynamic stabilizing structures, have been suggested as the main causal factors[10,11].

Another proposed causal factor is the imbalance of forces and the time of activation between the vastus medialis obliquus (VMO) and the vastus lateralis (VL), which could lead to a not properly aligned patella, and consequently it would cause pain in this joint, especially during tasks that require its use, such as crouching and going up or down the stairs. Therefore, the electromyographic (EMG) activity of the VMO and VL muscles has been investigated during the performance of different functional activities and therapeutic exercises[12-18], in order to confirm or deny this hypothesis.

Besides, in literature it is possible to observe the search to better understand PFPS and the possible factors that may influence the balance of stabilizing forces. By observing the higher incidence of PFPS among females, and knowing that the use of high-heeled shoes could trigger changes in the musculoskeletal system in response to biomechanical changes in the lower limbs[3], researchers developed studies that assessed the effect of high heels in the muscular activity[3], as well as in biomechanics and kinetics variables of the lower limb[19,20].

Ho et al.[19] verified that the high-heeled shoes increase the stress of the patellofemoral joint due to the increased knee extensor moment, while Simonsen et al.[20] demonstrated that high heels cause the knee abduction moment to increase. According to these authors, the changes in the internal moments both in the sagittal and in the frontal planes would be related to the increased EMG activity of the extensor muscles of the knee, and with the greater stress over the patellofemoral joint, resulting from changes in the patellar movement.

Many studies[2,3,23] have demonstrated that the use of high heels leads to the increased EMG activity of the

VMO and VL muscles, but without causing changes or imbalance between these muscles. However, most of these studies have been conducted with asymptomatic volunteers, so it is not possible to define if this type of shoes could contribute with the imbalance of extensor muscles of the knee in women with PFPS. The knowledge about the possible influences of the high heels on symptomatic subjects is very relevant, since it can directly influence the decision making of the professionals involved in the rehabilitation process; therefore, they could include the restriction or suspension of high heels for women with PFPS.

So, the objective of this study was to investigate, by means of the surface electromyography, the influence of high-heeled shoes on the activity of the VMO, VL and rectus femoris (RF) muscles during the sit-to-stand task, with a bench, in asymptomatic women and those with PFPS. Considering that high heels can cause changes in the saggital plane, and especially in the frontal plane, the hypothesis of this study is that this type of shoe can cause changes in the activity and the balance of VMO and VL muscles.

METHODOLOGY

Sample

In this study, 20 volunteers were selected and divided into 2 groups with the same number of participants: the first one was comprised of women who presented symptoms of PFPS (PFPS group), and the second one had asymptomatic women (Control group). The anthropometric data of the volunteers are presented in Table 1. Also, there was no sample loss during the study.

In the PFPS group were included those volunteers who presented with symptoms of the dysfunction, such as previous pain in the anterior or retropatellar region in at least three of the following activities: prolonged sitting, running, going up or down the stairs, crouching, kneeling and the isometric contraction of the quadriceps; presence of at least three clinical signs observed at the functional assessment (increased Q angle, medialization of the patella, excessive subtalar pronation, sensitivity to patellar facet palpation, external tibial torsion)[18]; marking at least three for pain in the Visual Analogue Scale[22]. In the Control group, volunteers who did not present with history of pain, surgery trauma or lesion in the lower limb were included. Both groups consisted of women who wear shoes size 36 (Brazil). Besides, with the objective to ensure homogeneity among the groups, the intention was to pair volunteers according to age, body mass, height and weekly frequency of wearing high heels. This study was submitted to and approved by the Ethics Committee of *Universidade de Pernambuco*, protocol 202/09.

Table 1. Mean (standard-deviation) of the variables: age, body mass, height and dominance of the assessed groups

Characteristics	PFPS	Control	p-value
Age (years)	20.20±3.06	21.30±3.46	0.13
Body mass (kg)	53.14±3.46	53.42±3.65	0.89
Estatura (m)	1.60±0.04	1.60±0.06	0.96
Right dominance	5	7	
Left dominance	5	3	

PFPS: Patellofemoral pain syndrome

Instruments

The myoelectric signals of the RF, VMO and VL were captured by means of electrodes that were active single differential surface electrodes with gain of 20 times, composed of 2 parallel rectangular bars of pure silver (10x2x1 mm, 10 mm distance between bars), from Datahominis Tecnologia Ltda. (Uberlândia, Brazil). The reference electrode (tweezer type) was placed in the distal portion of the tibia.

In order to obtain the EMG registration, three channels from the *Myosystem Br-1* (Datahominis Tecnologia Ltda.) were used. The equipment had electrical grounding and common simultaneous acquisition for channels, 10 Hz to 5 Hz band filters, 3 amplification stages, impedance of the 10 GΩ channels in differential mode, common mode rejection ratio of 92 dB, 16 bits and dynamic resolution rendering, -10 V to +10 V amplitude range and analog digital converter. The visualization and the processing of signals were performed with the *Myosistem Br-1*, version 3.5. The raw signal was used to derive the EMG amplitude values obtained through the calculation of the Root Mean Square (RMS). Data were collected at 4000 H, and bandpass digital filters of 15,500 Hz. The RMS values were normalized by the mean value of EMG amplitude in three maximum voluntary isometric contractions (MVIC) of knee extension. Besides, the analysis of the proportion of muscle activation (VMO and VL) was performed and defined by the ratio (VMO/VL) of the normalized RMS values.

Procedures

After physical evaluation, the order of tasks was sorted out and trichotomy and skin cleansing were performed. Afterwards, the surface electrodes were fixated with adhesive plaster to the RF, VL and VMO muscles. The electrode of the RF muscle was placed according to the guidelines by SENIAM[23], and the fixation of electrodes on the VMO and VL muscles were in accordance with the procedures described by Grossi et al.[18]. The dominant limb was the criterion of muscle choice assessed by the Control group, whilst in the group with PFPS the EMG assessment was performed by the affected limb, or the most affected limb, in the case of bilateral PFPS. In order to determine the dominant limb, a ball was placed in front of the volunteers, and they were asked to kick it. The limb chosen to kick the ball was considered as the dominant one.

Afterwards, three MVIC of the leg extension muscles were performed, and the volunteers were sitting on an extension chair, with the lower limb support locked, maintaining hip and knee flexion at 90º[24]. The volunteers were asked to perform three MVIC against the support for four seconds, with a two minute interval between each contraction. After the last MVIC, there was a period of ten minutes to rest until the beginning of the tasks: standing up and sitting on the bench.

Volunteers were placed sitting on a bench that allowed height regulation, so that all of them would keep the knees flexed at 90º (Figure 1), controlled with the use of a universal goniometer, keeping the feet aligned at a distance similar to the shoulder width. Besides, the arms should be crossed in a way that the hands could touch the opposite shoulder, to avoid movements and compensations from the upper limbs. In all of the executions, the EMG collection and the

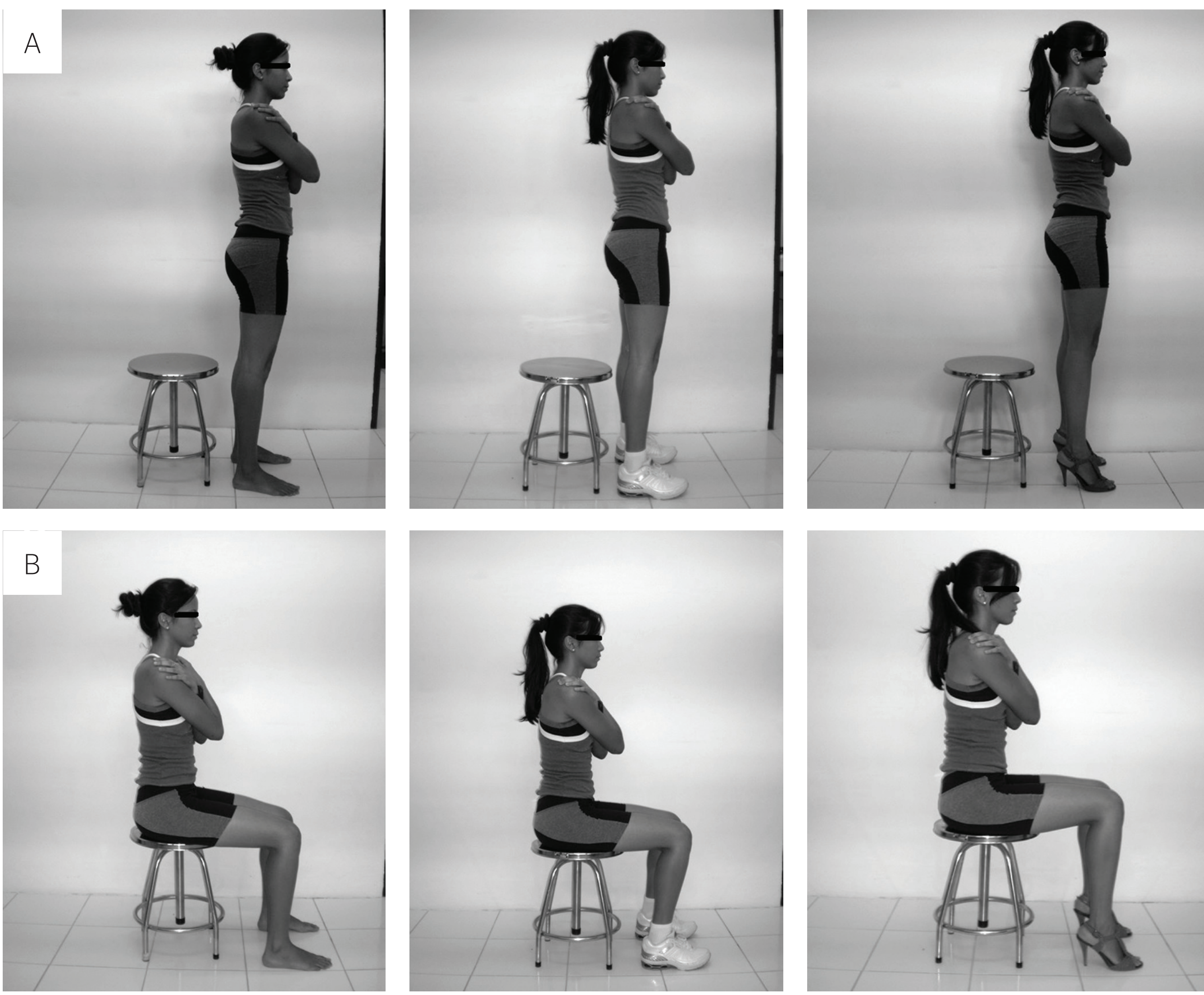

Figure 1. Initial position of the tasks sitting down (A) and standing up (B) in the conditions barefoot, with sneakers and with high heels

metronome were simultaneously activated. Volunteers were recommended to wait until the second visual and sound warning (after 1.8 second) to start the task, and then they should complete it by the second visual and sound warning (1.8 second), and keep the position for three seconds. For the EMG analysis, the gap between 1.8 and 3.6 seconds was chosen, since it represented the muscle activity rate performed during the amplitude of the knee joint movement between 90º and 180º. Before the performance of tasks, volunteers were allowed to practice and get familiar with the training, which enabled the correct performance of the task.

For the sitting down task, the volunteers were recommended to do the inverse movement in relation to the previously described task, respecting the same position of upper and lower limbs and time of execution.

Both tasks were performed three times, with a two minute interval between them. Each step was performed in three situations: wearing a 10 cm high-heeled shoe; with sneakers that had a 1 cm elevation from the sole at the midtarsus region in relation to the metatarsus and forefoot; and barefoot. For each shoe change, the volunteers had a ten minute period to adapt to the new shoe, during which they stood up and took some steps. The time of 1.8 second to perform the tasks was determined according to the data from the study by Ikeda et al.[25], which indicated the mean time of execution of 1.86 second, for young people, for the task to stand up from a chair.

Statistical analysis

All statistical tests were performed with the software SPSS, version 16.0. At first, the normality of data was checked by means of the Shapiro-Wilk test. In order to analyze the influence of the different types of shoes in the EMG activity of the studied muscles, the ANOVA test was applied with repeated measures, as well as the Tukey *post hoc* test, while for the intergroup comparisons the unpaired t test was used. All of the statistical tests considered a 5% significance level. Besides, in variables with $p<0.05$, by means of the Winpepi software, version 10.8, values of Cohen's *d* were calculated to assess the magnitude of the effect. Cohen's *d* values lower than 0.2 indicated low magnitude effect, and higher values meant high magnitude effect.

RESULTS

Standing from the bench

It was not possible to observe statistical differences between the activities of the three muscles during this task with the barefoot volunteers in the Control group ($p\geq0.08$; $d\leq0.98$) and in the PFPS group ($p\geq0.20$; $d\leq0.90$). However, it was observed that the use of sneakers and high heels provided higher EMG activity in the VMO and VL muscles when compared to the RF muscle in the Control group ($p<0.01$; $d>1.89$) and in the PFPS group ($p<0.01$; $d>1.45$). The calculation of Cohen's *d* value was higher than 0.80, and this size was considered as high magnitude effect.

In the Control group, the use of high heels increased the VMO activity in relation to the conditions of being barefoot ($p=0.01$; $d=2.74$) and with sneakers ($p=0.03$; $d=2.35$), but no statistical difference was observed for VL ($p\geq0.10$; $d\leq0.52$) and RF ($p\geq0.07$; $d\leq0.50$) (Table 2). Cohen's *d* index demonstrated a high magnitude effect in relation to the use of high heels and the increased VMO activity. No changes were shown in the VMO:VL ratio in the Control group ($p\geq0.28$; $d\leq0.30$) (Table 3).

For the PFPS group, no statistical changes were observed in the VMO ($p\geq0.06$; $d\leq0.59$) and RF activities ($p\geq0.28$; $d\leq0.66$). However, the use of high heels caused the VL activity to increase in relation to the condition of being barefoot ($p=0.01$; $d=0.72$) (Table 2) and led to the decreased ratio VMO:VL in relation to the task of standing up from the bench barefoot ($p=0.03$; $d=-0.52$) (Table 3). In this case, it was possible to observe a medium magnitude effect.

Sitting on the bench

In both groups, it was not possible to observe differences in the activities of the three muscles in the conditions

Table 2. Mean of the normalized RMS values during the activities of standing up from the bench barefoot (SUB), wearing sneakers (SUS) and wearing high heels (SUH)

	Control			PFPS		
	SUB	SUS	SUH	SUB	SUS	SUH
VMO	0.10±0.03	0.11±0.03a	0.17±0.02a*	0.10±0.04	0.12±0.05a	0.12±0.03a
VL	0.10±0.05	0.11±0.04a	0.12±0.04a	0.12±0.07	0.13±0.08a	0.15±0.05a*
RF	0.05±0.02	0.05±0.02	0.06±0.02	0.06±0.03	0.06±0.03	0.07±0.03

VMO: vastus medialis obliquus; VL: vastus lateralis; RF: rectus femoris; *Statistical difference between SUH and SUB (p=0.01) and SUH and SUS (p=0.03); a: Statistical difference between RF and VMO and VL (p=0,01) of being barefoot (control: p≥0.08; *d*≤0.68; PFPS: p≥0.21; *d*≤0.35), with sneakers (control: p≥0.08; *d*≤0.53; PFPS: p≥0.20; *d*≤0.47) and with high heels (control: p≥0.08; *d*≤0.66; PFPS: p≥0.54; *d*≤0.30) (Table 4).

In the Control group, results demonstrated a significant increase in the VMO activity when wearing high heels in relation to the conditions of being barefoot (p=0.01; *d*=1.20) and with sneakers (p=0.03; *d*=1.00), as well as the increased RF activity with high heels in relation to the conditions of being barefoot (p=0.01; *d*=0.66) and with sneakers (p=0.03; *d*=0.33). The Cohen's *d* index demonstrated a high magnitude effect for VMO and an effect that ranged from low and mean magnitude for RF. There was no significant change in the activity of the VL muscle (p≥0.12; *d*≤0.66) (Table 4). No changes were observed in the VMO:VL ratio in the Control group (p≥0.30; *d*≤0.30).

In relation to the PFPS group, no statistical differences were identified for this task in any of the analyzed situations (p>0.35; *d*≤0.34) (Tabela 4). However, the use of high heels caused the VMO:VL ratio to decrease in relation to the task of sitting down barefoot (p=0.04; *d*=-0.25) (Table 3).

Intergroup analysis

The intergroup analyses did not show statistical differences in the EMG amplitude of the VMO, VL and RF muscles during the task of sitting on the bench in any of the tested situations (p≥0.28; *d*≥0.49) (Table 4). In the task of standing up from the bench there were no significant differences in the EMG values of the three muscles in any of the tested situations (p≥0.30; *d*≥0.51) (Table 2). The values of the VMO:VL ratio did not present significant differences between the groups, both for the task of standing up (p≥0.42; *d*≥0.37) and the task of sitting down (p≥0.63; *d*≥0.32) (Table 3).

Table 3. Mean of VMO:VL ratio values during the tasks of sitting down and standing up for both groups

	VMO:VL	VMO:VL
	Control	PFPS
SUB	1.18±0.33	1.19±0.40#
SUS	1.17±0.56	1.12±0.27
SUH	1.25±0.73	1.02±0.23#
SDB	1.15±0.33	1.15±0.40ǂ
SDS	1.14±0.33	1.15±0.40
SDH	1.16±0.52	1.05±0.39ǂ

#Statistical difference between estatística entre SUB and SUS (p=0.03); ǂStatistical difference between SDB and SDH (p=0.04)

DISCUSSION

The results showed that the use of high-heeled shoes and sneakers interfered in the EMG activity of all the muscles in healthy women. In women from the PFPS group, no significant differences were registered as to the intensity of EMG activity in the RF muscle; however, the use of high heels caused changes in the activities of the VMO and VL muscles, especially in the VMO:VL ratio.

In a previous study, Edwards et al.[2] assessed the influence of different heels in the EMG activity of the VM and VL muscles of healthy women. In this study, it was observed that a 1 cm heel was not enough to cause changes in the EMG activity of the VM and VL muscles. On the other hand, the 5 cm heel led to the increased EMG activity for both muscles. However, no changes in the VM:VL ratio were found, suggesting that the heel does not cause imbalance between them. Even though in the present study, during the task of standing up, only the significant increase of the VMO muscle has been observed, it was possible to check that this fact did not influence the VMO:VL ratio. This finding corroborates the study by Edwards et al.[2], demonstrating that in the Control group there was no influence of the high heels on the VMO:VL ratio. Likewise, the use of sneakers, which would be similar to the 1 cm heel, did not influence this ratio.

Table 4. Mean of RMS normalized values during the activities of sitting down barefoot (SDB), wearing sneakers (SDS) and wearing high heels (SDH) for both groups

	Control			PFPS		
	SDB	SDS	SDH	SDB	SDS	SDH
VMO	0.10±0.05	0.11±0.05	0.16±0.05*†	0.10±0.05	0.11±0.05	0.11±0.04
VL	0.10±0.06	0.10±0.05	0.11±0.06	0.10±0.06	0.10±0.06	0.10±0.04
RF	0.05±0.03	0.06±0.03	0.07±0.03*†	0.06±0.03	0.07±0.03	0.09±0.05

VMO: vastus medialis obliquus; VL: vastus lateralis; RF: rectus femoris; *Statistical difference between SDH-SDB (p=0.01); †Statistical difference between SDH-SDS (p=0.03).

On the other hand, during the sitting down task, it was possible to observe a significant increase in the activities of the RF and VMO muscles. Anderson et al.[26] observed that, during the performance of the crouching task, the activity of the RF muscle increased while the knee flexion also increased, and that the VMO muscle also increases its activity in order to keep a proper patellar alignment. Besides, added to the fact that the increased knee flexion in a closed kinetic chain (CKC) is responsible for the increased activity of the knee extensor group, several authors[3,27,28] have reported the increased external knee flexion moment provided by the ankle inclination. These two factors contribute with the increased knee extensor moment and the higher stress of the patellofemoral joint[19].

Finally, despite being an eccentric task, unlike the concentric task analyzed by Edwards et al.[2], it was still possible to observe the concordance as to the balance aspect between VMO and VL, since the effect of high heels in the VMO:VL ratio was not observed among asymptomatic women. However, Edwards et al.[2] observed that high heels caused a significant increase in the activity of the VL muscle, which was not observed in the Control group of this study for both the tested tasks.

This divergence in relation to the VL activity can be justified by the methodological differences between the studies. This one used a 10 cm high-heeled shoe, while Edwards et al.[2] used a wooden device to simulate a 5 cm high-heeled shoe. Besides, the wooden device that simulated the high heel had a broader base, while in this study the shoes had thin heels. This could influence the position of the feet, since Foster et al.[29] demonstrated that a 9.5 cm heel significantly increases the plantarflexion angles of the ankle and inversion of the foot. This condition may have required from the volunteers some different strategies in order to keep the balance during the execution of tasks, and may have caused changes in the balance of forces not only in the sagittal plane, but also in the other planes.

Diverging from the results of the Control group, in the volunteers with PFPS the high-heeled shoes caused the decrease of the VMO:VL ratio in both tasks. This fact may be related to the increased external knee adduction moment due to the use of high heels[2,21]. With the objective to confront the external adduction moment, the quadriceps muscle, by contracting, generates an internal abduction moment[20]. However, a major increase in the internal moment caused by the muscles of the lateral side o the knee could also increase the lateral slide of the patella[2]. So, the increased activity of the VL muscle should be followed by the simultaneous increase of the VMO, in order for the balance of forces to occur and to avoid patella lateralization.

Indeed, the volunteers from the Control Group presented significant VMO increase, maintaining the VMO:VL ratio. However, the volunteers from the PFPS group presented only significant increase in the VL muscle, which consequently led to the decreased VMO:VL ratio. Some authors[30] suggest that such decrease in the VMO:VL ratio is a consequence of a neuromuscular imbalance, which could be caused by disorders of the neurophysiological mechanism. This is because the presence of pain or signals of inflammation in the knee joint have been pointed out as being responsible for causing an inhibition of the quadriceps muscle, and the VM muscle is the most affected one[31].

This inhibition mechanism of the VMO muscle could justify the differences found between the Control and PFPS groups in this study. Besides, some studies[32,33] have suggested that people with PFPS may present with decreased capacity to slow down or resist the valgus external movement during functional tasks. Thus, due to changes in the balance of forces of abductor muscles and hip external rotators, the femur could excessively adduce during functional tasks, with weight discharge, leading to the increased dynamic valgus[32], and this could lead to the lateral slide of the patella[32-34].

However, to analyze this issue it is necessary to assess the activity of the muscles that work in the hip joint, as well as to perform biomechanics and kinetics evaluations in the sagittal plane, and especially in the frontal plane. In relation to the intergroup comparisons, this study did not show statistic differences. This demonstrate that maybe the most important aspect of this dysfunction is not to assess possible changes in the levels of muscle activity between different subjects, but to consider the proportion of activation of different muscles in the same subject.

Besides, in this study it was possible to observe, in the Control Group, the increased VMO activity, which corroborates the theory of the need for greater patella stabilization, thus suggesting that the VMO would be responsible for producing an antagonistic force to the patellar lateralization. However, in the volunteers from the PFPS group, the increase in the EMG activity of the VMO muscle was not observed when the tasks were performed with high heels. Besides, it was possible to see that this type of shoe was responsible for the increased VL activity and the decreased VMO:VL ratio, which suggests that its use may lead to the imbalance of the patella stabilizing forces. Finally, the higher activity of the VMO and VL muscles in relation to RF during the task of standing up from the bench wearing high heels indicates that na action of patellar stabilization was necessary, thus confirming the stabilizing role of the VMO and VL muscles.

Even though it was a small group and two specific tasks were analyzed, the results in this study provide initial relevant information. However, this study presents some limitations, such as the small sample, the lack of kinetic and biomechanical analyses of the movement, which limits some conclusions. On the other hand, numberless questions need to be answered, thus opening possibilities for future studies to analyze the influence of the use and the time of use of different types of shoes for the activation of the stabilizing muscles of the knee and their correlation with the worsening of signs and symptoms of PFPS; then, it would be possible to create evidence that support or not the interruption of the use of shoes in patients with PFPS.

CONCLUSIONS

The results demonstrated the the use of high-heeled shoes provides different responses between groups, causing the increased VL activity in relation to VMO in women with PFPS. The decreased VMO:VL ratio suggests that the high heels may be an aggravating factor for the muscular imbalance of the stabilizers of the patellofemoral joint in women with PFPS.

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