The effect of gender on vastus medialis oblique/vastus lateralis activation ratio during weight and non-weight bearing activities in recreationally subjects

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Abstract
Objective: To investigate the effect of gender on the activation ratio of vastus medialis oblique to vastus lateralis during straight leg raising and stepdown activities.

Method: The cross-sectional study was conducted at the College of Medical Rehabilitation Sciences, Taibah University, Medina, Kingdom of Saudi Arabia, from September 2021 to March 2022, and comprised recreationally active subjects who were distributed in 2 gender-based groups. All the participants were subjected to straight leg raising and stepdown activities thrice and the average value of each activity was noted. The vastus medialis oblique and vastus lateralis electromyographic activity of the dominant limb was recorded using surface electromyography during the activities. The normalised value of the activation ratio of vastus medialis oblique to vastus lateralis levels was calculated. Data was analysed using SPSS 25.

Results: Of the 60 subjects, there were 30(50%) males with mean age 30.00±5.91 years, mean height 167±5.63cm, mean body weight 66.76±6.14kg, and mean body mass index 23.97±3.02kg/m². There were 30(50%) females with mean age 29.03±5.34 years, mean height 186±6.20cm, mean body weight 68.5±5.6 kg and mean body mass index 23.76±3.22 kg/m². There was no significant difference in the normalized electromyography activities of the vastus medialis oblique and vastus lateralis muscles between males and females (p>0.05). Also, no significant difference was found in the activation ratio between the genders (p>0.05).

Conclusion: There were no gender-based differences in the activation ratio of vastus medialis oblique to vastus lateralis during weight-bearing and non-weight-bearing activities.

Keywords: Quadriceps muscle, Patellofemoral pain, Sex factors, Weight, Electromyography.

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Introduction
The patella, which is considered a sesamoid bone, is connected to the quadriceps muscle and acts to increase the mechanical efficiency of the knee during extension, and in turn decreases capsular tension, friction and load on the knee joint cartilage.1 Patellofemoral pain syndrome (PFPS) is twice as prevalent in females as males, and is caused by the delayed activation of the vastus medialis oblique (VMO) relative to the vastus lateralis (VL), which has been proposed as a risk factor for PFPS.2

A study reported that in runners of both genders with PFP syndrome, there was a significant decrease in the VM and rectus femoris (RF) muscle activation compared to the control group, indicating a relationship between knee pain related to PFPS and the imbalance of bioelectric activity of VM and RF muscles.3 Recently, Pavone et al.4 reported that the incidence of clinical symptoms connected to PFPS was not correlated with the amount of athletic activity in young female athletes.

Neuromuscular imbalance of the VMO in relation to the VL muscle was supposed to be a key contributing factor in PFPS3,5, which creates malt racking of the patella through the femoral trochlea.7 Patella malt racking was considered to increase load on the joint cartilage, accelerating cartilage degeneration.8 Specific exercises were recommended to restore the VMO/VL activation ratio, such as the partial lung exercise9, and sling-based closed kinetic knee extension exercise.10

Moreover, malalignment of patellofemoral joint can disturb the balance of the nearby structures, including muscles, tendons and joints.5 Subsequently, increasing the dynamic balance between knee musculature and the overall strength of lower extremity musculature can help in the prevention of knee disorders and injuries.

In both the step-up and stepdown stages of the stair-stepping exercise, the electromyographic (EMG) commencement of VL in PFPS subjects happened before that of VMO.11 In comparison to healthy participants, a review research revealed a trend towards a delayed onset of VMO relative to VL12, which was linked to a considerable
loss in the knee extension strength. However, the EMG timing of sit to stand, stand to sit, squat, step-up and stepdown activities did not differ between healthy and PFPS subjects until the peak.

Bouillon et al. reported that muscle activation among rectus abdominis (RA), external oblique (EO), erector spinae (ES), RF, tensor fascia latae (TFL), gluteus medius (GM), gluteus maximus (GMx) and biceps femoris (BF) muscles was similar in females and males during the sidestep and stepdown tasks in healthy participants. However, females demonstrated decreased VMO/VL activation ratio compared to males. During drop-landing, the mean ratio of the VMO/VL muscle was 1.07 for males and 0.78 for females. A recent review study showed that there were no significant differences between muscle activity and muscle contraction timing in both genders of all lower limb muscles except VL. Gender differences in VMO and VL activity is theoretically regarded as a contributing factor to the higher prevalence of PFPS in females.

Nevertheless, there is no agreement in literature about the presence of clear difference in VMO and VL amplitude and latency between genders and about the reasons of gender differences, if present. It was found that gender does not affect the VMO/VL activation ratio throughout execution of different forms of exercise, including closed and open-chain exercises, and the relative EMG activity should not be considered a predisposing factor to the claimed higher prevalence of PFPS in females. Bowyer et al. detected no difference in EMG intensity of VMO/VL activation ratio between one male and one female, and excluded the difference in quadriceps intensity ratio as a contributing factor in the incidence of PFPS in healthy subjects. Similar studies found that gender did not affect the activity of VM muscle during dynamic contraction.

In contrast, it has been reported that the females have lower activation in the VMO muscle and higher activation in the VL muscle than the males. The VMO motor units of females fire faster than males. Similar studies examined gender differences in the activity of major knee joint muscles without comparing VMO and VL activation, and detected some gender differences. According to a recent study, females produce muscle force in the VL muscle using distinct neuromuscular recruitment strategies different from males, which are characterised by smaller motor units discharging more quickly.

The disparity in the VMO/VL activation ratio may explain the gender variation in the occurrence of PFPS during weight-bearing and non-weight-bearing activities. Moreover, understanding the differences in the knee joint muscle activation between males and females may help health practitioners identify athletes who may be at the risk of injury.

The current study was planned to investigate the effect of gender on VMO/VL activation ratio during straight leg raising (SLR) and stepdown activities. It was hypothesised that there would be no significant differences between the genders during weight-bearing and non-weight-bearing activities.

**Subjects and Methods**

The cross-sectional study was conducted at the College of Medical Rehabilitation Sciences, Taibah University, Medina, Kingdom of Saudi Arabia from September 2021 to March 2022. After approval from the institutional ethics review committee, the sample size was calculated using G*Power 3.1.9.4. A pilot study was done on 5 males and 5 females to estimate the effect size. The sample was determined with effect size 0.75, alpha 0.05 and power 0.80. Flyers were dispersed throughout the campus and the neighbourhood to recruit subjects. The sample comprised recreationally active subjects without knee pathology. Persons were considered recreationally active if they engaged in recreational activities 3-5 times per week for at least 30 minutes each session. Those with musculoskeletal, cardiovascular, vestibular, visual, or balance issues as well as a history of back injuries, back discomfort, or back deformities requiring medical attention were excluded. After taking written informed consent from the subjects, they were divided into 2 equal gender-based groups.

Surface EMG was measured from VMO and VL using a portable EMG machine (DELSYS Myomonitor). For electrode placement on the dominant leg, each subject was requested to relax in half-lying position. First, skin cleaning was done with alcohol followed by the application of conducting gel. For VMO, recording electrode was placed 4cm above and 3cm medial to the supero-medial edge of the patella and directed 55° to the femur. For VL, the electrode was positioned 10cm above and 7cm lateral to the upper edge of the patella with 15° orientation angle to the femur with the reference electrode fixed on the contralateral tibial tuberosity (Figure 1). All measurements were taken at the same time of the day (13:00-16:00 hrs) to avoid the diurnal variations in muscle force and flexibility.

For SLR, after assuming the starting position, each participant was asked to practise SLR with keeping the knee straight and with neutral rotation of the hip. The leg was raised to the level that the heel of the exercised leg approached a guiding card with a length of 17.5cm, then holding the contraction for 3 seconds. Three trials were
completed with a 30-se rest between the trials\(^{20}\) (Figure 2).

With respect to stepdown exercise, after standing over a 19cm step with feet apart and toes just behind the edge of the step, each subject was requested to step down from the step for three trials (21) (Figure 3). The test is known to aggravate PFPS symptoms.\(^{31,32}\)

Maximal voluntary isometric contraction (MVIC) of the quadriceps was measured to help normalise EMG data.\(^{33,34}\) Rectification and smoothening of raw EMG data was done using AcqKnowledge 3.7 analysis software with 6Hz low-pass filter. EMG values of VMO and VL were averaged for each activity and the mean of the three trials was calculated. After determining the average EMG for MVIC recordings, the average EMG was determined in a similar fashion, and normalisation was obtained for SLR and stepdown activities as a percentage of MVIC.\(^{33,35}\) Utilising MVIC for normalisation has shown good reliability and permits representation of muscle activity as an expression of activity in an understandable ratio.\(^{33}\) The VMO/VL activation ratio during SLR and stepdown activities was determined by dividing the normalised value of VMO by that of VL.

Data was analysed using SPSS 25. For comparing demographic characteristics, independent t-test was used. Data normality was checked using Shapiro-Wilk test, while homogeneity between the groups was checked using Levene’s test. Independent t-test was used to compare the normalised EMG values of VMO and VL as well as VMO/VL ratio of the two groups. \(P<0.05\) was considered statistically significant with 95% confidence interval (CI).

**Results**

Of the 60 subjects, there were 30 (50%) males with mean age 30.00±5.91 years, mean height 167±5.63cm, mean body weight 66.76±6.14kg, and mean body mass index (BMI) 23.97±3.02kg/m\(^2\). There were 30 (50%) females with mean age 29.03±5.34 years, mean height 186±6.20cm, mean body weight 68.5±5.6kg and mean BMI 23.76±3.22kg/m\(^2\). There was no significant differences between the two groups in terms of age (\(p=0.540\)), weight (\(p=0.291\)), height (\(p=0.360\)) and BMI (\(p=0.801\)).

**Table** : Mean normalised values of VMO and VL muscles and the VMO/VL activation ratio.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Male group</th>
<th>Female group</th>
<th>MD (95% CI)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step down</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMO (%)</td>
<td>20.12 ± 2.71</td>
<td>19.00 ± 2.74</td>
<td>1.12 (-0.39:2.64)</td>
<td>1.48</td>
<td>0.144</td>
</tr>
<tr>
<td>VL (%)</td>
<td>25.39 ± 3.26</td>
<td>24.7 ± 3.18</td>
<td>0.69 (-1.1:2.48)</td>
<td>0.77</td>
<td>0.443</td>
</tr>
<tr>
<td>VMO/VL ratio</td>
<td>0.79 ± 0.05</td>
<td>0.77 ± 0.08</td>
<td>0.02 (-0.01:0.05)</td>
<td>1.08</td>
<td>0.283</td>
</tr>
<tr>
<td>Straight leg raise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMO (%)</td>
<td>22.31 ± 2.65</td>
<td>21.18 ± 2.68</td>
<td>1.13 (-0.36:2.61)</td>
<td>1.51</td>
<td>0.131</td>
</tr>
<tr>
<td>VL (%)</td>
<td>25.76 ± 2.26</td>
<td>25.03 ± 2.96</td>
<td>0.73 (-0.74:2.19)</td>
<td>0.99</td>
<td>0.321</td>
</tr>
<tr>
<td>VMO/VL ratio</td>
<td>0.86 ± 0.05</td>
<td>0.85 ± 0.09</td>
<td>0.01(-0.02:0.05)</td>
<td>0.71</td>
<td>0.470</td>
</tr>
</tbody>
</table>

VMO: Vastus medialis oblique, VL: Vastus lateralis, SD: Standard deviation, MD: Mean difference, CI: Confidence interval.
There was no significant difference in the normalized EMG activities of VMO and VL muscles between males and females (p>0.05). Also, no significant difference was found in the activation ratio between the genders (Table).  

Discussion  
The current study was conducted to determine if there is any gender effect on the VMO/VL activation ratio in recreational subjects during weight-bearing and non-weight-bearing activities. The results, in line with the null hypothesis, showed no differences in the VMO/VL activation ratio between males and females during SLR and stepdown. The finding was also consistent with earlier reports. Spairani et al. reported that both open and closed kinetic chain similarly activate the VMO, vastus medialis longus (VML) and VL muscles. SLR and stepdown activities aggravate the PFPS symptoms, especially the closed-chain activities, and they were commonly prescribed to strengthen the quadriceps muscle and to evaluate the efficacy of PFPS treatment. However, contrary findings have also been reported by studies that investigated the VMO/VL activation ratio during weight-bearing activity in both genders, and during isometric contraction of quadriceps. Kim et al. reported a higher ratio of VMO/VL activation ratio in males than females. The EMG normalisation data in a study was done to levels elicited with a 20-kg weight in seated knee extension. This protocol differed from the one commonly used in such circumstances in which a maximal contraction is used for the purpose. The present study adopted the maximal contraction protocol. Furthermore, a recent review concluded that all lower limb muscles except VL showed no significant difference between muscle activity and muscle contraction timing in both genders before and after foot contact.

Gender differences in EMG activities and VMO/VL activation ratio were found during vertical stepdown. EMG data was normalised to the % maximal voluntary contraction (%MVC) of knee extension executed at a combined position of 80° knee flexion and 90° hip flexion in seated position. It was concluded by a study that the likelihood of developing PFPS was higher in females than males during vertical drop-landing. The contradictory findings may have been due to limited sample size and due to differences in exercises and activities used; vertical drop-landing versus SLR and stepdown. The vertical stepdown may have excessively overloaded the quadriceps muscle. Also, the pattern of activity differed between males and females as the females did not flex their knees sufficiently during vertical landing. Additionally, during single-leg drop-landings, females had a decrease in the semitendinosus/VL pre-activation ratio, which was projected to result in an increase in knee anterior reaction force.

To determine the ideal exercises for the management of PFPS, the VMO/VL activation ratio was measured during hip abduction and terminal knee extension exercises in an open-chain design. There were no gender differences observed during hip abduction training, while EMG activity of the VL was higher than VMO activity in males during the terminal knee extension training. Moreover, Coqueiro et al. found that the VL muscle was significantly greater than that of the VMO muscle during double-leg semi-squat exercise trials without hip abduction exercises only for females with PFPS. However, no differences were found between healthy females and others with PFPS during double-leg semi-squat exercise trials with maximum hip adduction isometric contraction exercises. In line with the present findings, no gender differences were found in the EMG intensity ratio of VMO/VL activation in healthy subjects during SLR and stepdown activities. But the earlier findings should be considered with caution due to their limited sample size having one female and one male.

The average of VMO/VL activation ratio during stepdown activity was lower in participants with PFPS compared to healthy subjects. These findings may indicate that PFPS may be related to lowered activity of VMO muscle, and the authors also observed that the activity of VMO and
VL in healthy females was doubled to enable them to execute the stepdown activity compared to the males. The current study did not find gender differences in VMO/VL activation ratio in healthy subjects, but such differences may be present in subjects with PFPS. Also, there were many differences in the methodology of various studies, like normalisation protocol, placement of electrodes and type of recording electrodes. These variations may lead to contradictory results.

The current results reflected no gender differences in VMO/VL activation ratio during stepdown and SLR. In contrast, Kim et al. observed differences in the of VMO/VL activation ratio, which may be explained by adoption of other activities that overloaded the quadriceps. Also, other variables may be relevant to the higher prevalence of PFPS in females than males, such as a wider Q angle in females that affects the distance between attachments of VL muscle, smaller knee bending angle during vertical landing in females’ fat mass, or strength per body weight.

According to a recent study, the VMO/VL activation ratio was not significantly different between healthy individuals and those with PFPS. Additionally, performing the proprioception neuromuscular facilitation (PNF) patterns under load dramatically increased the activity of the VMO and VL muscles. Furthermore, it was found that the VMO/VL activation ratio values in PNF patterns were substantially higher in the PFPS group. Therefore, the PNF patterns can be said to engage the VMO muscle more than the SLR. These findings could explain the inability of SLR to elicit high activation of the VMO and VL muscles. Moreover, a study conducted on female with and without PFPS showed that backward walking increases VMO muscle activation and maintains the VMO/VL ratio in PFPS subjects, which should be considered during further weight-bearing testing of VMO/VL activation ratio.

The current study has some significant limitations, including the lack of data related to muscle strength, such as torque, and power, and the absence of functional tests. The fact that the participants did not exert their true maximum effort during the muscle testing utilised to determine the MVIC is another potential limitation. Even though both men and women were enrolled, the participants were generally young, healthy and active in their leisure time. Evaluation of other age categories was not done. Cross-talk with the use of surface EMG electrodes with nearby muscles is also a constraint as each of the muscles evaluated, standardised electrode implantation was adopted. According to some reports, placing surface EMG electrodes using a regular procedure enhances the quality of the recordings at each muscle site. Future research should investigate possible VMO/VL activation ratio gender differences in subjects with PFPS because important factors like Q angle and knee-bending, and tibiofemoral angles, which may be more associated with higher incidence of PFPS, with consideration of body position during measurement of the Q angle, where the standing position aggravates the symptoms of the PFPS more than the supine position. Future studies should evaluate the effect of gender on the VMO/VL activation ratio during backward walking, as it develops more activations of the quadriceps muscles. Finally, the leg length of the participants was not considered during normalisation of the obtained EMG data.

Conclusion

Gender differences in the VMO/VL activation ratio during weight-bearing and non-weight-bearing activities were not found.

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References


