Comparison of the VMO/VL EMG Ratio and Onset Timing of VMO Relative to VL in Subjects with and without Patellofemoral Pain Syndrome

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Abstract. [Purpose] The purpose of our study was to measure the onset timing of the vastus medialis oblique (VMO) relative to the vastus lateralis (VL) and the VMO/VL electromyographic (EMG) ratio in subjects with and without patellofemoral pain syndrome (PFPS) while they completed a functional task (stair stepping). [Subjects] Ten patients with PFPS and ten subjects without PFPS were included in this study. [Methods] The subjects performed stair stepping while surface electrodes were used to record the EMG signal amplitude of the VMO and VL. [Results] During stair ascent and descent, significant differences in VMO/VL EMG ratios were observed between participants with and without PFPS. Significant differences were also observed for the VMO-VL timing among participants with and without PFPS while ascending and descending the stairs. [Conclusion] Our findings indicate that PFPS patients have a VMO/VL imbalance and delayed onset of VMO relative to VL.

Key words: Bridging exercise, EMG activity, Muscles

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a condition that develops in adolescents or young adults actively involved in sports1, and is more prevalent in women than in men2. PFPS is characterized by anterior and retropatellar knee pain. Symptoms typically worsen as the patients engage in daily activities such as ascending/descending stairs or sitting for prolonged periods of time3. Although the etiology of PFPS has not yet been clearly identified, two elements are commonly observed: anatomical abnormalities such as muscular imbalance around the knee joint, or an increase in Q angle and repetitive microtrauma to the soft tissue4.

Electromyographic (EMG) activity in patients with PFPS indicates an imbalance in the vastus medialis oblique (VMO) relative to the vastus lateralis (VL), and delayed onset of VMO compared to VL in their functional activity5. Ideally, the normal VMO/VL ratio of EMG activity is 1:16, but it was found that patients with PFPS have a lower ratio when performing isometric knee extension7. Differences in VMO and VL onset timing in patients with PFPS and subjects without PFPS were 22.36 ms and −61.81 ms, respectively, when ascending steps, and 50.56 ms and −56.97 ms, respectively, when descending steps8. These results indicate that VMO is more delayed than VL in individuals with PFPS.

Reduction in the EMG activity ratio and onset delay may cause abnormal tracking of the patella due to excessive lateral pulling, thereby damaging the patellofemoral joint (PFJ). Therefore, the fundamental goal of PFPS treatment should be to achieve a balanced VMO/VL ratio of the EMG activity. The VMO and VL EMG onset timing is also a crucial index of patellar stability9.

We performed the present study to measure the VMO/VL muscle activity ratios and onset timing differences in the VMO and VL of patients with PFPS and normal individuals.

SUBJECTS AND METHODS

Twenty subjects participated in this study. Ten had been diagnosed with PFPS (22.8 ± 4.3 years) and the other ten had no signs of PFPS (23.4 ± 5.1 years). For those with PFPS, the disease duration was 13.2 months on average. They had experienced anterior knee pain while performing at least two actions (sitting for a prolonged period of time, ascending/descending stairs, squatting, running, kneeling, or jumping) at least once in the previous 6 months, and had scored 80 or lower on the anterior knee pain scale (AKPS)

The average age, height, and weight of the healthy subjects were matched to those of the PFPS group. None of the subjects had any cognitive disorders. Before participating in our study, all subjects were evaluated using the visual analog scale (VAS)10, anterior knee pain scale (AKPS)10, and anterior knee pain scale (AKPS)11, and lower extremity functional scale (LEFS)12. The subjects performed a minimum of five practice trials before EMG amplitude and onset timing in the VMO and VL were measured. The average values of three test trials were used in our analysis.

The dimensions of the steps were 90 cm in width, 28 cm
in depth, and 18 cm in height (as specified by the Korea Research Institute of Standards and Technology). The subjects were asked to climb up and down the steps at a rate of 96 steps per minute. Measurements were taken of the affected legs of the PFPS patients while individuals without PFPS had their dominant leg tested.

Muscular activity was measured by using an 8-channel surface EMG apparatus (MyoSystem 1400A; Noraxon Inc., USA). Activation during stair stepping was triggered by a footswitch (Inline Foot Contact Sensor; Noraxon Inc.). The raw EMG data were saved and processed by MyoResearch XP Master Edition 1.06 software (Noraxon Inc.). EMG data were sampled at a rate of 1000 Hz and band-pass filtered between 20 and 500 Hz. EMG amplitude was then full-wave rectified and smoothed using the root mean square (RMS) at 50 ms. EMG onset timing was then full-wave rectified and low-pass filtered at 50 Hz. Onset timing was determined when the EMG signal deviated by more than 3 standard deviations for a minimum of 25 ms, above the baseline level (averaged over 200 ms prior to the commencement of the trial).

Adhesive Ag/AgCl surface electrodes (T246H; Bioprotech, South Korea), 1 cm in diameter, were used in the present study and placed 2 cm apart using hypoallergenic gel. VMO electrodes were attached 2 cm medially from the superior rim of the patella, and placed on the VL above the patella approximately 3 to 5 cm from the center line of the femur13). The VMO and VL electrodes were placed at 55 and 15 degree angles to the femur, respectively14). The common reference electrode was attached to the head of the fibula of the tested foot. Maximal voluntary isometric contraction (MVIC) was used to normalize EMG signals acquired during both ascent and descent13).

The highest average MVIC value of each evaluated muscle was adopted from three trials. Muscular activities of VMO and VL were measured relative to the footswitch trigger during stair ascent/descent. EMG amplitude of VMO and VL in the stance phase was divided by the MVIC value and multiplied by 100 to calculate the percent MVIC (% MVIC). To compare differences in VAS, AKPS, LEFS, VMO/VL EMG ratio, and VMO-VL onset timing difference between the PFPS patients and normal individuals, the independent t-test was performed; p values <0.05 were considered to be statistically significant. All data were analyzed using SPSS version 18.0 for Windows.

RESULTS

The average VAS score of the PFPS patients was 4.11 ± 0.63. This was significantly higher than that of the normal individuals (0.85 ± 0.72; p <0.05). The average AKPS of the PFPS patients was 71.40 ± 3.41. This was significantly lower than that of normal individuals (96.00 ± 6.04; p <0.05). The average LEFS of the PFPS patients was 58.70 ± 5.58. This was also significantly lower than that of the individuals without PFPS (77.90 ± 3.96; p <0.05) (Table 1).

During stair ascent, the VMO/VL EMG ratio of the PFPS patients was 0.81 ± 0.14. This was significantly lower than that of the normal individuals (1.22 ± 0.35; p <0.05). In contrast, the VMO/VL EMG ratio of the patients with PFPS in descent was 0.85 ± 0.11, significantly lower than that of normal individuals (1.11 ± 0.12; p <0.05). The VMO-VL onset difference of PFPS patients was 22.12 ± 9.82 ms during ascent, significantly greater than the value (−15.71 ± 16.59 ms) of the normal individuals (p<0.05). During descent, the VMO-VL onset difference for the PFPS patients was 19.92 ± 12.89 ms, significantly greater than that of the normal individuals (−13.10 ± 17.77 ms; p<0.05) (Table 2).

DISCUSSION

We performed the present study to determine the VMO/ VL EMG ratio and VMO-VL onset timing difference of patients with PFPS while ascending and descending stairs. These data were compared with the results of normal individuals. The VMO/VL EMG ratio is an index of the medial and lateral force on the patella. This ratio is used as an indicator of changes associated with muscular dysfunction and recruitment patterns15). A VMO/VL EMG ratio greater than 1 indicates that the normalized VMO EMG activity is greater than that of the normalized VL.

According to Cerny16), the average VMO/VL EMG ratios for patients and healthy individuals are 0.9 and 1.2, respectively, while descending stairs. Women have twice the EMG activity in VMO and VL than men when performing the same tasks. In present study, we also found that the VMO/ VL EMG ratios of patients with PFPS and normal individuals were respectively 0.81 and 1.22 during ascent, and 0.85 and 1.11 during descent, similar to preceding studies showing that VMO is lower than VL in EMG amplitude.

Ficat and Hungerford17) demonstrated that the VMO/ VL EMG ratio of patients with PFPS is lower than that of normal individuals, and that the development of PFPS can be predicted based on this ratio, even in asymptomatic cases. Exercises that increase the VMO/VL EMG ratio can reduce the pain associated with PFPS by inducing changes in the muscular activity patterns of VMO and VL during functional activities.

The VMO and VL work antagonistically to control mediolateral patellar movement, but need to be activated at the appropriate time for efficient knee joint function. According to Lieb and Perry18), VMO muscle fibers are oblique to the patella at a 55 degree angle. This structure offers a mechanical advantage over VL fibers, which stop

Table 1. Comparison of pain and functional ability

<table>
<thead>
<tr>
<th>Variable</th>
<th>aPFPS (n=10)</th>
<th>without PFPS (n=10)</th>
</tr>
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<tbody>
<tr>
<td>^VAS</td>
<td>4.11 ± 0.63</td>
<td>0.85 ± 0.72*</td>
</tr>
<tr>
<td>^AKPS</td>
<td>71.40 ± 3.41</td>
<td>96.00 ± 6.04*</td>
</tr>
<tr>
<td>^LEFS</td>
<td>58.70 ± 5.58</td>
<td>77.90 ± 3.96*</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD. Abbreviation: ^PFPS: patellofemoral pain syndrome, ^VAS: visual analog scale, ^AKPS: anterior knee pain scale, ^LEFS: lower extremity pain scale. *Statistically significant difference compared to PFPS (p<0.05)
In 33 people with PFPS, Cowan et al. 5) found that the onset between the two muscles is significant, but since it is only onset of VMO relative to VL. between VMO and VL during the tasks. Such temporal performing a functional activity (ascending or descending onset timing differences in VMO and VL in individuals ascent, similar to normal individuals (−13.70 ms).). VMO and VL in PFPS patients was −17.50 ms during Boling et al. 6) showed that the onset timing difference between the VMO and VL was 15.80 ms while ascending steps and 19.39 ms while descending steps. timing difference between the VMO and VL was 15.80 ms and 50.56 ms, respectively, and concluded that PFPS patients showed a relative delay of 22.12 ms during ascent compared to −15.71 ms for normal individuals. These results are consistent with those of previous studies examining the onset timing in PFPS patients. However, it has been noted that there is no significant onset timing difference between VMO and VL when walking on a flat surface, ascending/descending stairs, or walking up or down a slope. In contrast to the present study, Brindle et al. 21) indicated that the onset timing difference was 22.36 ms and 50.56 ms, respectively, and concluded that VMO onset was delayed. In the present study, the VMO-VL onset difference in PFPS patients showed a relative delay of 22.12 ms during ascent compared to −15.71 ms for normal individuals. The onset difference in patients with PFPS also showed a relative VMO delay of 19.92 ms during descent compared to −13.10 ms for normal individuals. These results are consistent with those of previous studies examining the onset timing in PFPS patients. However, it has been noted by Powers et al. 20) that there is no significant onset timing difference between VMO and VL when walking on a flat surface, ascending/descending stairs, or walking up or down a slope. In contrast to the present study, Brindle et al. 21) showed that the onset timing difference between the VMO and VL in PFPS patients was −17.50 ms during ascent, similar to normal individuals (−13.70 ms).

In summary, the present study was conducted to identify onset timing differences in VMO and VL in individuals performing a functional activity (ascending or descending stairs). We found a significant difference in onset timing between VMO and VL during the tasks. Such temporal factors contribute to the dysfunction in patients with PFPS. Further research on muscle re-education should be conducted since this technique seems to be effective at changing the onset of VMO relative to VL.

<table>
<thead>
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<th>Variable</th>
<th>PFPS (n=10)</th>
<th>without PFPS (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMO/VL (ms)</td>
<td>0.85 ± 0.11</td>
<td>1.11 ± 0.12*</td>
</tr>
<tr>
<td>VMO-VL (ms)</td>
<td>19.92 ± 12.89</td>
<td>13.10 ± 17.77*</td>
</tr>
</tbody>
</table>

NOTE: Values are mean±SD. Abbreviation: *PFPS: patellofemoral pain syndrome, VMO: vastus medialis oblique, VL: vastus lateralis. *Statistically significant difference compared to PFPS (p<0.05)

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