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Original Article

Effects of squats accompanied by hip joint adduction on the selective activity of the vastus medialis oblique

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Abstract. [Purpose] This study evaluated the effective selective activation method of the vastus medialis oblique for knee joint stabilization in patients with patellofemoral pain syndrome. [Subjects and Methods] Fifteen healthy college students (9 males, 6 females); mean age, height, and weight: 22.2 years, 167.8 cm, and 61.4 kg, respectively) participated. The knee angle was held at 60°. Muscle activities were measured once each during an ordinary squat and a squat accompanied by hip joint adduction. The muscle activities of the vastus medialis oblique and vastus lateralis were measured by electromyography for five seconds while maintaining 60° knee flexion. Electromyography signals were obtained at a sampling rate of 1,000 Hz and band pass filtering at 20–50 Hz. The obtained raw root mean square was divided by the maximal voluntary isometric contraction and expressed as a percentage. The selective activity of the vastus medialis oblique was assessed according to the muscle activity ratio of the vastus medialis oblique to the vastus lateralis. [Results] The activity ratio of the vastus medialis oblique was higher during a squat with hip joint adduction than without. [Conclusion] A squat accompanied by hip joint adduction is effective for the selective activation of the vastus medialis oblique.
Key words: Patellofemoral pain syndrome, Vastus medialis oblique, Squat

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) refers to pain in the front sides of the knees when participating in sports activities, ascending stairs, or squatting[1)]; its precise etiology remains poorly understood[2)]. The causes of PFPS include an increase in Q-angles, elevation of the knee bones, excessive subtalar pronation, and anatomical misalignment such as lateral tibial rotation[3)]. As with other etiologies, PFPS is characterized by atrophy of the vastus medialis oblique (VMO) covering the inner sides of the knee joints and dysplasia as well as the resultant muscular imbalance with the vastus lateralis (VL)[4)]. A representative muscle group providing knee stability is the quadriceps femoris, among which the VMO is the muscle that stabilizes the knee joints by resisting the lateral tilting of the knee bones. Therefore, the selective activation of the VMO is essential for effective pain reduction and prevention of PFPS. For the VMO and VL, maintaining the ideal right-left balance is required for the anatomical alignment of the knee bones.

A squat, performed with the legs fixed on the floor, is a closed-chain exercise and appropriate for activating the lower limb muscles. Accordingly, previous studies have aimed to selectively activate the VMO by applying squatting. To selectively activate the VMO, Hyong and Kang[5)] applied squats on diverse bases of support, such as a hard plate, form, and rubber air disc. Meanwhile, Irish et al.[6)] observed VMO activation with a squat accompanied by hip joint adduction. However, other studies report that a squat accompanied by isometric hip joint adduction is effective for the overall activation of the quadriceps femoris muscle. However, the muscle activity ratios of the VL and VMO do not increase in this condition[4, 7)]. On the basis of the verification of the selective activity of the VMO using other methods, Davlin et al.[8)] report the selective activity of the VMO through biofeedback training using the posture of the hip joints, while Gregersen et al.[9)] observed that the VMO is selectively activated when riding a bicycle with eversion of the ankle joints. Previous studies in which the VMO was activated with a squat accompanied by isometric hip joint adduction used a pillow[10)], mechanical resistance tool[6)], and ball between the knees[11)]. However, such methods are rather inconvenient in clinical practice. Therefore, the present study examined the effects of a squat accompanied by hip joint adduction in order to maintain the isometric condition without any tools on the selective activity of the VMO.

SUBJECTS AND METHODS

The subjects were given the details of the experiment, and

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they provided informed consent to participate. The subjects were 15 healthy college students without musculoskeletal and neurologic disorders (9 males and 6 females); their mean age, height, and weight were 22.2 years, 167.8 cm, and 61.4 kg, respectively. This study was approved by the Catholic University of Pusan's Institutional Review Board (CUPIRB-2014-048).

The subjects listened to an explanation of how to perform a squat and practiced three times before the experiment. The subjects spread both feet shoulder-width apart and crossed both arms on their chest, straightened their upper body, and looked straight forward. They flexed the knees slowly and stopped when at a knee angle of 60°[12]. A goniometer was used to maintain the knee angle. Knee joint flexion was started in a standing position and stopped at 60°. Then, while the squat was maintained at 60°, the femoral lateral epicondyle was placed on the center of the goniometer and the moving arm was positioned above it; the stationary arm was placed on the center line of the lateral malleolus and fibular head. From this position, the subjects performed an ordinary squat once and a squat accompanied by hip joint adduction once. The squat accompanied by hip joint adduction was conducted with the inner side of the bilateral thighs attached to each other as the body went down into the same posture as that for a normal squat. To exclude the effects of learning, both methods were conducted in random order. In each experiment, electromyography (EMG) signals were collected for five seconds while the knee joints were flexed at 60°; the EMG signals from the middle three seconds were used for analysis. Measurements were repeated three times, and the average value was used for the analysis. The rest time between measurements was one minute.

The Myotrace 400 (Noraxon Inc., USA) was used to measure the activities of the VMO and VL, and Myoresearch XP master version 1.07 was employed to process the measured raw data. EMG sensors (T246H, Bio-protech, Korea) were attached after attachment areas were cleaned with alcohol. Activity electrodes to measure the VMO were attached from the medial 55° of the upper part of the knee bones at 4-cm intervals, and activity electrodes to measure the VL were attached on the upper part of the knee bones 8 and 10 cm located 15° from the vertical axis. The reference electrode was attached to the fibular head[6]. EMG signals were obtained at a sampling rate of 1,000 Hz, and band pass filtering was conducted at 20–50 Hz. The subjects were seated in a chair in order to measure the maximal voluntary isometric contraction (MVIC) of the quadriceps femoris. With the experimenter providing hand resistance against the ankle joint, the subject maintained knee extension. EMG data were collected for five seconds, and the middle three seconds were used; the average of three measurements was used for analysis. The obtained raw root mean square was divided by the MVIC and expressed as %MVIC. To examine the selective activity of the VMO, the ratio of VMO/VL activity was used. SPSS version 12.0 for Windows was used to compare EMG data. The level of significance was set at $p < 0.05$. The data are expressed as mean ± standard deviation. A paired t-test was used to analyze differences in the muscle activity ratios between the two types of squats.

Table 1. VMO/VL muscle activity ratio

	Squat	Squat with adduction
VMO/VL	1.06 ± 0.22	1.12 ± 0.28*

*$p < 0.05$
VMO: vastus medialis oblique; VL: vastus lateralis

RESULTS

There was a significant difference in the VMO/VL muscle activity ratio between the ordinary squat and the squat accompanied by hip joint adduction ($p < 0.05$) (Table 1).

DISCUSSION

The quadriceps femoris muscle must be activated to decrease knee pain and improve stability in athletes and ordinary people who have knee joint instability. However, the quadriceps femoris muscle should be activated selectively without failure in PFPS. In PFPS, it is important to maintain balance between activation of the VL and VMO, which provides stability and mobility in the left and right sides of the knee bones. In general, the VMO may be weakened compared to the VL. Moreover, because the delayed activity of the VMO is less than the lateral force vector produced by the VL, the iliotibial band and knee bones tend to be pulled laterally[4]. Hyong and Kang[5] observed that performing a squat on an unstable base of support, such as rubber, affects the selective activity of the VMO. Irish et al.[6] report that a squat accompanied by isometric hip joint adduction using a pillow is effective for the selective activation of the VMO. Furthermore, Koh et al.[11] note that a squat accompanied by hip joint isometric adduction is effective for the selective activation of the VMO. Finally, Macgregor et al.[13] report that the application of taping to the VMO increased VMO activity in PFPS patients to a greater extent than that in ordinary people.

As the abovementioned studies show, the selective activation of the VMO is more important than the overall activation of the quadriceps femoris muscle to obtain knee joint stability. Accordingly, the present study examined the selective activation of the VMO using the VMO/VL activity ratio. The results confirm a squat accompanied by hip joint adduction is effective in the selective activation of the VMO. This can be explained by changes in the relationship between length and tension reported in a study by Beck and Wildermuch[14] and because the concurrent contraction of the hip joint adduction and knee joint extension stretches the VMO, increasing VMO activity. In addition, the VMO starts from the tendons of the adductor magnus and adductor longus muscles, and is connected to the anteromedial intermuscular septum[15]; therefore, the concurrent contraction of the hip joint adductor and knee joint extensor provides a stable origin of the VMO[16], increasing its selective activity. In the studies of Irish et al.[6] and Koh et al.[11], a squat accompanied by isometric adduction using a pillow or a ball was effective for the selective activation of the VMO; likewise, in the present study, a squat accompanied by hip joint adduction was effective for the selective activation of the VMO.

Nonetheless, the present study involved healthy people, not PFPS patients. Therefore, the effects of pain and foot posture during squatting accompanied by hip joint adduction in PFPS patients were not evaluated. Thus, future research aiming to adjust the pain and foot posture of PFPS patients is required.

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