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Activities of the Vastus Lateralis and Vastus Medialis Oblique Muscles during Squats on Different Surfaces

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Abstract. [Purpose] The purpose of the present study was to examine the effects of squat exercises performed on different surfaces on the activity of the quadriceps femoris muscle in order to provide information on support surfaces for effective squat exercises. [Subjects and Method] Fourteen healthy subjects performed squat exercises for five seconds each on three different support surfaces: hard plates, foam, and rubber air discs. Their performance was measured using electromyography. As the subjects performed the squat exercises on each surface, data on the activity of the vastus medialis oblique and the vastus lateralis, and the vastus medials oblique/vastus lateralis ratio, were collected. [Results] The activity of the vastus medialis oblique and the vastus medialis oblique/vastus lateralis ratio were found to be statistically significantly higher on rubber air discs than when the squats were performed on hard plates or foam. [Conclusion] To activate the vastus medialis obilique, and to enhance the vastus medialis oblique/vastus lateralis ratio, unstable surfaces that are highly unstable should be selected.
Key words: Support surfaces, Vastus medialis obilique, Vastus lateralis

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INTRODUCTION

Patellofemoral pain syndrome (PFPS), patellar subluxation, and patellar dislocation are factors that increase knee joint instability and are major causes of anterior knee pain (AKP)[1)]. The vastus medialis oblique (VMO) of the quadriceps is a factor that determines stress on the patellofemoral joint and stabilizes the patellar bone[2)]. In particular, selective atrophy of the VMO may break the balance of the vastus medialis oblique/vastus lateralis (VMO/VL) ratio to cause PFPS[3)]. Therefore, selective strengthening of the VMO is necessary to prevent and improve knee joint dysfunction.

Studies conducted to improve the VMO atrophy that causes PFPS have proposed strengthening of the quadriceps using open kinematic chain exercises and closed kinematic chain exercises as a possible solution[4)]. In particular, squat exercises are known to help the selective strengthening of the VMO, and many studies have investigated the optimum methods for conducting squat exercises[4, 5)]. Training using unstable surfaces results in greater joint movement and leads to more proprioceptive feedback; therefore, it can promote muscle activation[6)].

In the present study, to find the effective parameters of squat exercises, the muscle activities of the VMO, and VL, and the VMO/VL ratio were examined at different levels of instability. Support surfaces were made using hard plate surfaces, foam surfaces, and rubber air discs.

SUBJECTS AND METHODS

The subjects of the present study were 14 healthy adults (5 males, 9 females; average age 21.4 years; average height 167 cm; average weight 60.3 kg) without any musculoskeletal or neurologic disorders or any history that might have affected the experimental results. The content of this experiment was sufficiently explained to the subjects, and only those subjects who voluntarily agreed to participate in the experiment were enrolled.

The stable surface was the grounds; the unstable surfaces were 40 × 47 × 7 cm foam pads (balance-pad Elite, Germany), and 13-inch diameter, 3-inch thick rubber air discs (balance trainer, Harbinger, Canada).

The squat exercises to be performed on the different support surfaces were randomly assigned to the subjects. During the squat exercises, subjects' feet were placed apart at a distance equal to 120% of each subject's shoulder width. Feet positions were determined by foot-shaped marks at the center point of each support surface. Knee joint angles were controlled using goniometers. The subjects were instructed to keep their arms folded and their trunk upright while performing the exercises. They were also instructed to look at a point in front of them at eye level and to maintain a knee joint flexion angle of 60°[4)].

A Myotrace 400 (Noraxon Inc., USA) was used to measure muscle activity, and a Myoresearch XP master 1.07 was

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used to process the raw data obtained by the measurements. Before attaching the electrodes (T246H, Bioprotech, Korea), the skin at the attachment sites was shaved and cleaned using alcohol swabs. For VL, an electrode was placed at the two thirds of the distance along point the line connecting ASIS and the lateral side of the patellar bone. For VMO, an electrode was placed at the eight tenths of the distance along point the line connecting ASIS and the anterior joint space of the anterior border of the medial ligament, which is on the side of the superior medial margin of the patellar bone. The electrodes on the VMO and the VL formed angles of 45° and 15°, respectively, with the femur shaft. Electromyogram signals were obtained at a sampling rate of 1,000 Hz and processed by a 20–500 Hz band pass filter and a 60 Hz notch filter. The raw RMSs were divided by the value of maximal voluntary isometric contraction (MVIC) to convert them to percentage values (%MVIC).

EMG signals were collected for five seconds while the subjects maintained their knee joints at an angle of 60°. The first and last seconds of data were discarded, and only the three seconds in the middle were used in the analyses. EMGs were measured three times, and the average values were used. A ten-minute rest was given between each measuring session. The ratio of the muscle activity of the VMO to that of the VL was calculated as VMO/VL. SPSS 14.0 for Windows was used to compare EMG data obtained on the different support surfaces, with a significance level of 0.05. Measured data are presented as means and standard deviations. One-way ANOVA and Scheffe's post hoc test were used to analyze differences in EMG data between the different support surfaces.

RESULTS

The muscle activity of the VMO was the highest on the rubber air discs, and the differences from the other surfaces were statistically significant ($p<0.05$). The muscle activity of the VL was also the highest on the rubber air discs, but the differences from the other surfaces were not statistically significant ($p>0.05$). The VMO/VL ratio was the highest on the rubber air discs, and the differences from the other surfaces were statistically significant ($p<0.05$) (Table 1).

DISCUSSION

AKP occurs because of abnormal motions of the patellar while the knee is bent. The cause of such abnormal motions is the insufficient synergy of the quadriceps[1–3]. As the number of people playing sports increases, AKP has become a pathological condition that frequently occurs in young adults and athletes[7]. The subjects of the present study were young adults, who adapted well to the rubber disc training. However, elderly people may be at risk if the rubber air discs, which are highly unstable, are used. Therefore, the tools used for exercise should be carefully selected.

Kushion et al.[8] examined VMO/VL ratios in 33 normal adults and reported the VMO/VL ratios ranged from 0.99 to 1.0. Healthy adults' VMO/VL ratios are close to 1, and in normal knees, the activities of the VMO and VL are similar. In a study conducted by Mariani and Caruso[9], the normal group showed the same muscle activity levels for the VMO and the VL at the end range of knee extension, whereas the group with patellar subluxation showed lower VMO/VL ratios, since the muscle activity of the VMO was lower. In the present study, the average VMO/VL ratio on the hard surface was 0.92, which is close to 1.

Kushion et al.[8] reported that VMO/VL ratios ranged from 0.99 to 1.0 during leg raise exercises in a supine position. In the present study, a VMO/VL ratio of 0.92 was obtained in the hard plate group. The leg raise exercises in the supine position and squat exercises on hard plates showed similar levels of muscle activation. However, the rubber air disc group showed a VMO/VL ratio of 1.49. This means that squat exercises on unstable surfaces are more effective at activating the VMO than leg raise exercises.

The instability of unstable surface enhances muscle firing and recruitment[9, 10]. In a study of unilateral squat exercises using wobble boards, a VMO/VL ratio of 0.93 was shown, which was higher than the ratio obtained on stable surfaces[11].

Unstable surfaces are effective at enhancing VMO/VL ratios. In the present study, higher VMO/VL ratios were observed on the rubber air discs. These results are consistent with arguments indicating that training on unstable surfaces enhances muscle activity more than training on stable surfaces.

In the present study, squat exercises were performed on support surfaces with different levels of instability and the VMO/VL ratios were calculated. The VMO/VL ratios were 0.92 on the stable hard surface, 0.88 on the foam surface with low levels of instability, and 1.49, the highest, on the rubber air discs, which had the highest level of instability. These results mean that squat exercises performed on unstable surfaces with high levels of instability can enhance

Table 1. Differences in muscle activites of each muscle and the muscle activity ratios on the different support surfaces

Category	Support surface		
	Hard plate	Foam	Rubber air disc
VMO	44.28±18.19^a	44.50±19.39^a	69.50±17.65^b
VL	48.64±14.80	50.85±19.60	50.92±20.87
VMO/VL	0.92±.32.65^a	0.88±25.71^a	1.49±52.84^b

All data are presented as mean ± SD
The value with different letter suffixes are significantly different ($p<0.05$) by Scheffe's test unit: %MVIC

the activity of the VMO, and that squatting exercises performed on foam surfaces with low levels of instability or hard surfaces are not as effective for the selective activation of the VMO. We consider the reason why the activity of the VMO is particularly highly enhanced on rubber air discs is the fact that unstable surfaces make maintaining ankle joint positions difficult, so that more effort is required to maintain posture[6]. These characteristics of exercises on unstable surfaces are considered to better stimulate the receptors in the joints, thus increasing the afferent inputs of the proprioceptive senses and eventually leading to increased reflexive motor responses[12].

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