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Original Article

Analysis of vastus lateralis and vastus medialis oblique muscle activation during squat exercise with and without a variety of tools in normal adults

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Abstract. [Purpose] The present study investigated the effects of squat exercises with and without a variety of tools including a gym ball, wedge, and elastic band on the vastus lateralis and vastus medialis oblique muscles. [Subjects and Methods] A total of twenty healthy subjects with no history of neurological, musculoskeletal injury, or pain in the lower extremities were recruited. All subjects performed four types of exercise (conventional squat exercise, squat exercise with a gym ball, squat exercise with a wedge, squat exercise with an elastic band). [Results] There were no significant differences between exercises in comparison of the vastus lateralis muscle activity. In the squat exercise with a wedge, significantly higher activity of the vastus medialis oblique muscle was found compared with in the squat exercise with an elastic band. [Conclusion] The present study suggests that the conventional squat exercise can be one of the useful interventions for patients with patellofemoral pain syndrome.

Key words: Squat, Vastus lateralis muscle, Vastus medialis oblique muscle

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INTRODUCTION

The knee joint has the capacity to bear weight and a wide range of motion (ROM), so it plays a role in providing weight support and activity control[1)]. However, since the knee joint is constantly influenced by body-weight loading at various angles, it is vulnerable to injury[2)]. Patellofemoral pain syndrome (PFPS), an overuse injury characterized by anterior knee pain, is a condition commonly diagnosed in young individuals[3, 4)]. Although it is a very common condition, its etiology has not been clearly defined yet[5, 6)].

It has been reported that the causes for PFPS are multifactorial. Among the many risk factors including structural abnormalities, kinematic variables, and onset timing of medial and lateral vastii muscles, abnormal patellar tracking is regarded as a major precursor[3, 7, 8)]. Many studies have reported that lateralization of the patella is observed in patients with PFPS, and this abnormal tracking is caused by an imbalance between the vastus medialis oblique (VMO) muscle and the vastus lateralis (VL) muscle[6, 9)]. The ratio of the VMO muscle activity relative to the VL muscle activity in PFPS patients is less than that in healthy subjects[10)]. In the patellofemoral joint, the VMO muscle is in charge of stabilizing the medial side of the patella, so it is thought that knee imbalance may result from weakness of the VMO muscle[11)].

Selective strengthening exercises for the VMO muscle have been investigated to solve problems caused by PFPS. Among the many exercise methods, closed kinetic exercise such as squat exercise can influence on the reduction of stress in the patellofemoral joint[1, 11)]. In order to clarify the type of the exercise method that can selectively strengthen the VMO muscle, the present study investigated the effects of squat exercises with various tools including a gym ball, a wedge, and an elastic band.

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SUBJECTS AND METHODS

A total of twenty healthy subjects with no history of neurological, musculoskeletal injury, or pain in the lower limbs were recruited. The mean age, height, and weight of the participants were 21.50±1.10 years, 166.85±9.26 cm, and 57.95±8.44 kg, respectively (Table 1). The purpose and procedures of this study were explained to all subjects, and they provided written informed consent prior to their participation. This study adhered to the Declaration of Helsinki.

All subjects performed four types of squat exercise: the conventional squat exercise, the squat exercise with a gym ball, the squat exercise with a wedge, and the squat exercise with an elastic band. The conventional squat exercise (SE1) is a static posture held for 6 seconds with the legs spread shoulder-length apart and the heels planted firmly on the ground while bending the knees to a 90-degree angle. The squat exercise with a gym ball (SE2) is a static posture that is an extension of SE1 with a gym ball between the knees while adducting the hips in order to not drop the ball. The squat exercise with a wedge (SE3) is an extension of SE1 performed on a wedge board. The squat exercise with an elastic band (SE4) is also an extension of SE1 with an elastic band above the left knee to a 45 degree angle.

Electromyography (EMG) data were collected using a TeleMyo 2400 (Noraxon U.S.A., Inc., Scottsdale, AZ, USA). A sampling rate of 1,000 Hz was used for EMG signal acquisition, and the signals were full-wave rectified. Band-pass filtering at 30–500 Hz was performed using the MyoResearch XP 1.07 (Noraxon U.S.A., Inc., Scottsdale, AZ, USA) software, and the signals were also notch filtered at 60 Hz to remove noise.

The maximum voluntary isometric contractions (MVIC) values of each muscle were used to normalize the values of the muscle activities. EMG electrodes were attached to the VL and VMO muscles.

Statistical analysis was performed using PASW statistics for Windows (version 18.0). In order to assess EMG activities according to squat exercises, one-way repeated measures analysis of variance was performed. All measurements were expressed as the mean± standard deviation, and significance was accepted at values of $p<0.05$.

RESULTS

The EMG activity of the VMO muscle in the squat exercise with a wedge was significantly higher than that in the squat exercise with an elastic band. There were no significant differences although VMO muscle activity in the conventional squat exercise and the squat exercise with a wedge were higher than those in the squat exercise with a gym ball and the conventional squat exercise, respectively. There were no significant differences among the EMG activities of the VL muscle (Table 2).

DISCUSSION

PFPS is usually described as a common condition related to knee disorder, especially in young active females and athletes[8)]. The symptoms of PFPS mainly appear when ascending stairs or sitting with the knee flexed for a long period of time, and persistence of symptoms can influence the development of osteoarthritis[7, 11, 12)].

According to many studies, it has been considered that weakness of the VMO muscle results in PFPS and that this condition is caused by an imbalance in activity between the VMO and the VL muscle[13)]. In general, strengthening exercise for the quadriceps femoris muscle has been regarded as a common intervention for patients with PFPS in the field of physical therapy, and use of open kinetic chain exercise has been preferred[6)]. However, open chain knee extension produces anterior shear force that induces stress in the patellofemoral joint. It is not appropriate to strengthen the VMO muscle selectively, since the overall strength of the quadriceps femoris muscle increases through open chain knee extension[1, 11)].

It is thought that closed kinetic chain exercises are more effective than open kinetic chain exercises due to their stimulating

Table 1. General characteristics of the subjects

	Age (years)	Height (cm)	Weight (kg)
Subjects	21.5±1.1	166.9±9.3	58.0±8.4

Values are expressed as the mean±SD

Table 2. Comparison of activity in the VL and VMO muscle according to the type of the squat exercise (Unit: %MVIC)

	SE1	SE2	SE3	SE4
VL	50.6±19.3	51.9±21.4	54.1±24.6	49.8±19.7
VMO	54.7±31.3	54.3±29.9	56.5±33.2*	50.8±29.1

Values are expressed as the mean±SD.
*Significant difference vs. SE4 ($p<0.05$)

effect on structures surrounding the joint. The squat exercise, a representative lower extremity close kinetic chain exercise, can promote joint stability through co-contraction of agonist and antagonist muscles[2, 6]. Tang et al.[10] concluded that the VMO/VL ratio in the squat exercise was higher than that in open kinetic chain exercise.

Many types of squat exercise have been investigated so far. In particular, Earl et al.[11] reported that squat exercise with hip adduction may result in selective strengthening of the VMO muscle. Furthermore, it was suggested that squat exercise with a 30 degree wedge may selectively increase the VMO muscle activity[14].

The present study applied squat exercises using a gym ball, a wedge, and an elastic band. Although the level of EMG activity of the VMO muscle in SE2 and SE4 were less than that in SE1, higher activity of the VMO muscle was observed in SE3 compared with in SE1. However, SE3 did not induce selective strengthening of the VMO muscle because the activities of the VMO and VL muscle were pretty much the same. Judging from the muscle activity of the VMO muscle relative to the VL muscle, SE1 was the most effective method of strengthening the VMO muscle selectively.

In spite of these results, there are several things that need to be confirmed. Since the results of the present study did not consider the angle of the wedge, adduction induced by the gym ball, and resistance induced by the elastic band, further study should be performed to make the results more clear.

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