



Original Article

Changes in lower limb muscle activity based on angle of ankle abduction during lunge exercise

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Abstract. [Purpose] This study compared the activity of the quadriceps femoris muscle according to the angle of ankle abduction during a lunge exercise. [Subjects and Methods] Fifteen male healthy volunteers participated in the study. All participants performed the lunge exercise with different angles of ankle abduction (0°, 20°, 40°, 60°). The activity of the rectus femoris (RF), vastus lateralis (VL) and vastus medialis oblique (VMO) muscles were recorded for the four angles by using a surface electromyography system. [Results] There were significant differences between the rectus femoris (RF), vastus lateralis (VL) and vastus medialis oblique (VMO) with every angle of the ankle joint. The most significantly increased muscle activity was evident in the vastus medialis oblique (VMO) when the ankle abduction was 60°. [Conclusion] These findings suggest that as the ankle abduction angle increases during the lunge exercise, the muscle activity of the quadriceps femoris muscle increases and this could be helpful in the selective muscle strengthening of the vastus medialis oblique muscle (VMO) with the ankle in the 60° abduction position.

Key words: Electromyography, Lunge exercise, Abduction of ankle

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INTRODUCTION

With the increased awareness of the need to exercise if one is to live a healthy life in our modern society, the number of people who enjoy sports has increased. As a result, injuries to the knee joint resulting from excessive physical activity also occur more frequently¹⁾. Among the problems related to knee joint injury, the patellofemoral pain syndrome is common. The precise cause of this has not been established, but it refers to a situation where a weakened vastus medialis oblique (VMO) causes a muscle imbalance between the vastus lateralis (VL) and VMO and the knee bone is pulled excessively laterally. The condition frequently develops among youth between the ages of 16 and 25 and in athletes for whom the continuous stress on the knee diminishes their ability to exercise as it induces a chronic pain of the joint²⁻⁴⁾. Earlier studies have reported that among patients with patellofemoral pain syndrome, the muscle activity ratio of the VMO was remarkably lower than that of people without this condition. These studies argue that selective strengthening of the VMO should be emphasized with the aim of establishing balance and stability in the quadriceps femoris muscle^{5, 6)}. The lunge exercise is a close kinetic chain (CKC) exercise that strengthens the muscles of the lower limbs and is used for treatment of patellofemoral pain syndrome and its early rehabilitation. The lunge exercise requires a body shift technique that quickly moves the body forward at the start of the movement and then resumes the original posture by inducing a centrifugal contraction of the quadriceps femoris muscle^{7, 8)}. In a previous study, the lunge exercise was shown to activate the muscle activity of VMO by 77% as compared to other exercise schemes⁷⁾. Adduction of the hip joint and the tibia during the lunge exercise are beneficial for strengthening the VMO and the pressure on the knee joint decreases as the force delivered to the lateral patellofemoral joint diminishes during the abduction of the femur^{9, 10)}. Previous

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Table 1. Comparison of the lower-extremity muscular activity according to angle of the ankle abduction during a lunge exercise (Units: %)

Muscle	0°	20°	40°	60°
RF	23.0 ± 12.8	26.9 ± 12.7	32.5 ± 12.0	37.6 ± 14.5**
VL	41.3 ± 20.9	44.7 ± 20.5	51.1 ± 23.3	57.0 ± 28.7**
VMO	44.2 ± 24.0	48.9 ± 24.6	55.9 ± 27.3	63.6 ± 33.8**.

Values are expressed as mean ± SD.

RF: rectus femoris; VL: vastus lateralis; VMO: vastus medialis Oblique. * $p < 0.05$, ** $p < 0.01$,

** repeated ANOVA, †† post hoc of 60°

studies have been actively studied on the lower limb muscle activity of the patellofemoral pain syndrome. However, most of those studies were limited to the changes in the muscle activity of the quadriceps femoris muscle according to hip or knee angle in closed chain exercise, and there are comparatively few research studies investigated lunge exercise for muscle activation of quadriceps femoris muscle in relation to the location of the ankle abduction^{4, 11, 12}. Therefore, this study compares the muscle activity of the quadriceps femoris muscle according to the angle of ankle abduction during the lunge exercise and attempts to provide fundamental data for designing an efficient exercise program aimed at strengthening the quadriceps femoris muscle.

SUBJECTS AND METHODS

The current study was conducted on 15 healthy males (mean age=21.4 ± 3.0 years; mean weight=71.5 ± 6.8 kg; mean height=164.1 ± 7.9 cm) who were enrolled at U1 University in Chungcheongbuk-do. Subjects with nervous or cardiopulmonary system problems or with orthopedic musculoskeletal issues related to the trunk and lower limbs were excluded from study. The study purpose and methods were explained to the subjects, who provided informed consent according to the principles of the Declaration of Helsinki before participating. Ethical approval for the study was granted by the U1 University institutional review board U1UIRB 2017-17.

Measurement was conducted in the general lunge exercise posture where the subjects looked straight ahead and put their hands on their waists to prevent sway of the upper body. Muscle activity was measured while the subjects performed lunges with 0°, 20°, 40°, and 60° abductions of the ankle. Each lunge exercise lasted five seconds. Excluding 1 second each for the start and end, data for the muscle activity during the middle three seconds were used in the analysis. To prevent fatigue during the lunge exercise, there was a two minute break after each five second lunge exercise.

In this study, an MP150 system (BIOPAC system Inc., Santa Barbara, CA, USA) was used to measure the activities of the muscles of the lower limb. The muscle activity was measured three times in each of the four positions (the neutral position, and at angles of 20°, 40°, and 60°) in the abduction of the ankle joint during the lunge exercise. The electrodes were attached over the rectus femoris muscle (RF), the vastus lateralis muscle (VL) and the vastus medialis oblique muscle (VMO).

The collected data were analyzed with SPSS for Windows (Ver.18.0), and the one-way repeated measure ANOVA was employed to compare the muscle activities of the lower limbs according to the angle of the ankle abduction during the lunge exercise. As a post hoc test, the Least Significant Difference (LSD) test was applied to examine the differences. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

In the results from this study, a significant difference was observed in the muscle activity of the RF muscle, the VL, and the VMO during the lunge exercise for all angles of ankle abduction ($p < 0.05$). In the post-hoc test, the VMO showed significantly higher levels of activity when the ankle abduction was 60° ($p < 0.05$) (Table 1).

DISCUSSION

In this study, the muscle activity of the quadriceps femoris muscle gradually increased during the lunge exercise according to the increase in the angle of ankle abduction. In particular, the VMO showed the highest muscle activity when the ankle was in the 60° abduction condition. During the lunge exercise, the tibia rotates to correct the alignment of the knee bone and this changes the stability of the knee joint, which ultimately provides the optimal condition for the quadriceps femoris muscle to function at its maximum ability^{9, 10}.

Although the quadriceps femoris muscle groups cannot contract individually as they have the same dominant nerve, a previous study reported that the muscle contraction initiation time decreases when the muscle activity is higher. Based on this, the high level of muscle activity of the VMO that was observed in our study can be attributed to the fact that contraction in the VMO began earlier than in the other quadriceps femoris muscles¹³. Overall, increasing the ankle abduction angle during a lunge exercise can help to strengthen the quadriceps femoris muscle. In particular, we suggest that a selective strengthening of the VMO under the condition where ankle abduction is 60° is the most effective.

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