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Effect on muscle activity of lower extremities during squat and lunge exercises on unstable support surfaces

Jae-Young Park
Division of Physical Therapy, Kyungwoon University

불안정한 지지면에서의 스쿼트와 런지운동이 하지 근활성도에 미치는 영향

박재영
경운대학교 물리치료학과

Abstract The purpose of this study was to examine the effect of unstable support on muscle activities of the lower extremities during squat and lunge exercises. Muscle activities of the VL, VM, and RF were measured by surface S-EMG. During the lunge exercise on an unstable support surface, VL and VM muscle activities were significantly greater than those of the RF. In addition, during squat exercise on an unstable support surface, RF muscle activity was significantly greater than VM and VL activities. The study shows that squat and lunge exercises on an unstable support surface effectively activate each part of the QM. These exercises could be applied in lower extremity rehabilitation programs for the elderly and adults with knee joint disease.

요 약 본 연구는 불안정한 지지면에서 스쿼트와 런지 운동 시 일부 하지 근육의 근 활성도를 분석하기 위해 건강한 성인 남녀 30명을 대상으로 넙다리곧은근, 안쪽넓은근, 가쪽넓은근의 평균 근 활성도와 최대 근 활성도를 측정하였다. 모든 자료는 SPSS window ver 23.0을 사용하여 빈도 분석 및 평균과 표준편차를 구하였고, 스쿼트와 런지 운동의 효과를 비교하기 위해 대응표본 t-test를 실시하였다. 유의수준은 $p < .05$로 설정하였으며, 그 결과는 다음과 같았다. 불안정한 지지면에서의 런지 운동 시 가쪽넓은근과 안쪽넓은근의 근 활성도가 넙다리곧은근에 비해 유의하게 높게 나타났으며, 스쿼트 운동 시 넙다리곧은근의 근 활성도가 안쪽넓은근과 가쪽넓은근에 비해 유의하게 높게 나타났다. 결론적으로 불안정한 지지면에서의 런지와 스쿼트 운동은 대상자의 상태와 목적에 맞게 적용한다면 균형 능력과 하지 근력 강화에 효과적임을 알 수 있었다. 본 연구는 불안정한 지지면을 통한 스쿼트와 런지 운동이 넙다리네갈래근의 부위별 근 활성화에 효과적임을 알 수 있었고, 다양한 무릎관절 질환을 가진 성인뿐만 아니라 노인을 대상으로 낙상 예방을 위한 다양한 하지 재활 프로그램에 적용할 수 있을 것으로 기대된다.

Keywords : S-EMG, Squat, Lunge, Vastus Medialis(VM), Vastus Lateralis(VL), Unstable Support Surfaces

1. Introduction

Recently, working from home has become prevalent due to the development of the Fourth Industrial Revolution and the influence of COVID-19, and hours spent at home are increasing due to self-isolation. This has generated problems in the form of various diseases, including muscle weakness and imbalance, due to a lack of physical activity and

*Corresponding Author : Jae-Young Park(Kyungwoon University)
email: hopi7@naver.com
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exercise[1]. As people's interest in a healthy life increased, various exercise programs people can do at home without restrictions on time and place are becoming popular[2].

Especially, lower extremity muscle strength actively regulates body movement, affects overall balance and stability, maximizes recovery of functions such as walking ability, balance, and improves the quality of life, but strengthening lower extremity muscles is very important[3]. Lower extremity muscle strength gradually decreases with age, increasing the probability of knee-related diseases[4]. The quadriceps femoris muscle(QM) is a representative muscle for strengthening the lower extremity muscle[5].

The QM protects the knee joint and contributes to stabilization and is also essential in daily life and rehabilitation. Muscle exercise of the QM is necessary for maintaining a healthy life. It helps to increase walking ability, balance, and recovery, prevent falls, and improve exercise performance. If the muscle strength of the QM decreases, the diminishing role of reducing joint load can cause stress on the joint[6].

Squat and lunge exercises are the most common ways to strengthen lower extremity muscle strength. Among them, squat maintain the lower extremities' tendons and ligaments and help strengthen lumbar and core muscles[7]. Lunge exercise is a functional multi-joint motion commonly used in lower extremity rehabilitation[8]. It has been reported to be used in clinical practice to reduce the strength of the QM and the imbalance of bilateral muscle strength[9]. In addition, it has been found that squat exercise requires little balance ability. In contrast, lunge exercise can improve balance ability with muscle strength and strengthen the VM and VL[10].

It has been reported that exercise on unstable support surfaces helps stimulate more neuromuscular systems than on stable support surfaces, promoting postural control and dynamic balance[11,12]. In addition, it is closely related to the activity of daily living (ADL) that controls posture and balance in space by increasing postural stability through muscle strengthening involved in lower extremity joint and trunk stability[13]. It is said that maintaining balance through postural stability is the most basic essential factor for humans to live their daily lives and perform purposeful activities. It is closely related to many tasks of controlling the body's posture and balance[14].

Although various studies compare the difference in lower extremity muscle activity of squat and lunge exercises according to the type of support surface, there need to be more studies comparing squat and lunge movements.

Therefore, in this study, we compare the difference in electromyographic activity between rectus femoris(RF), inner VM, and narrow VL when doing squats and lunge movements on unstable support surfaces.

2. Materials and methods

2.1 Study subjects

This study was conducted on 30 men and women at K university in the G region from May 19 to May 31, 2022. Subjects selected agreed to participate after sufficiently explaining the order of progress, research purpose, and research method. Selected subjects were those with no congenital deformity or orthopedic disease, those with no peripheral nerve or central nerve injury, and those with dominant right feet. General characteristics of subjects, such as sex, age, height, and weight, were collected before the experiment.

2.1.1 Selection criteria

The dominant foot screening criteria for all subjects was based on the first feet subjects took

when performing a timed up and go test (TUGT). The order of squats and lunge movements for each subject was random.

2.2 Lumge exercise

In the starting position of the lunge exercise for this study, subjects must keep their gaze at a point straight ahead of them, place both hands in an X-shape on the shoulder. The subject keeps the feet shoulder-width apart, sticks out the dominant foot forward about 70-100cm, and raises the heel of the left foot. With the waist and back kept straight, the right knee angle is in the 89-102° angle range, where the quadriceps muscle activity occurs the most. Bend the knee, lower the body as if the left knee touches the floor, and then return to the starting position straightening the knee and hip joint. Subjects complete 3 total sets of 10 repetitions. The posture maintenance time is 7 seconds, and the rest time is 3 minutes to minimize muscle fatigue.

2.3 Squat exercise

In the starting position of the squat exercise, subjects must keep their feet shoulder-width apart and the position the feet at 30° to 45° angle, and the gaze is kept facing forward. During the exercise, the subject must not tilt the trunk and pelvis to one side, maintaining the neutral position, and the knee angle should be at a 90° angle.

2.4 TUGT(Timed Up and Go Test)

TUGT is a test method that can measure locomotor ability and functional mobility. The subject begins sitting and stands up when the test starts, walking to a designated target point and then returning to the return point to sit back on the chair. Time is measured from start to finish, and the first foot set forward during the test is determined by the subjects' dominant foot.

2.5 TOGU

Togu jumper was used to perform exercise on unstable support surface. Togu enhances sensory motor control and improves local muscle activity and proprioceptor, providing muscle strength and postural stability(Fig. 1).

Fig. 1. TOGU

2.6 S-EMG

WEMG-8 (LXM5308) was used to measure muscle activity of the QM. This equipment measures and collects data by wirelessly transmitting and receiving frequencies. Surface electrodes were attached to the RF, the VL, and the VM of the QM using three channels. The attachment area of the RF was attached side by side with the muscle fiber in the front center of the thigh, the midpoint between the patella and the iliac spin. From the upper edge of the knee bone, the VL was attached slightly from the patella's upper edge to the knee's upper edge at about 3-5cm. The VM was attached in an oblique direction 55° from the patella's upper rim at a 2cm point inside(Fig. 2).

Fig. 2. S-EMG patch

2.7 Statistical analysis

In this study, SPSS Window ver 23.0 was used

for data analysis, and paired t-test was conducted to measure the change in the mean and maximum values of some lower extremity muscle activity. The level of significance was α =.05

3. Results and discussion

3.1 General Characteristics of Study Subjects

Table 1 shows general characteristics of study subjects.

Table 1. General characteristics of study subjects

Variables(unit)	Mean±SD	
Gender(M/W)	17/0	0/13
Age(years)	23.9±1.1	22±0.8
Height(cm)	174.7±4.9	160.4±4.1
Weight(kg)	70.2±6.4	51.8±5.5

3.2 Average muscle activity of squat and lunge on unstable support surfaces

Table 2 shows the average muscle activity during squats and lunge exercises on unstable support surface. The highest values in order were RF 53.449.9, VL 49.514.8, and VM 45.718.7 during squats, followed by VL 60.921.7, VM 56.922, and RF 50.517.2 during lunges. As a result of the analysis, the change in the average muscle activity of all lower extremity muscles showed a significant difference (p<.05).

Table 2. Average muscle activity of squat and lunge on unstable support surfaces

	Squat (Mean±SD)	Lunge (Mean±SD)	T	P
VL	49.5±14.8	60.9±21.7	-8.306	.02*
VM	45.7±18.7	56.9±22	-10.585	.04*
RF	53.4±49.9	50.5±17.2	-9.419	.01*

VL : vastus lateralis VM : vastus medialis
RF : rectus femoris

3.3 Maximum muscle activity of squat and lunge on unstable support surfaces

Table 3 shows the maximum muscle activity on unstable support surface. High values were shown in the order of RF 340.9199.7, VL 323.3132.1, and VM 231.9121.2 during squats, followed by VM 334.3147.8, VL 323.3132.1, and RF 196.5107.1 during lunges. As a result of the analysis, the change in the maximum muscle activity of all lower extremity muscles showed a significant difference (p<.05).

Table 3. Maximum muscle activity of squat and lunge on unstable support surfaces

	Squat (Mean±SD)	Lunge (Mean±SD)	T	P
VL	318.8±163.2	323.3±132.1	-8.080	.04*
VM	231.9±121.2	334.3±147.8	-10.267	.03*
RF	340.9±199.7	196.5±107.1	-9.353	.01*

VL : vastus lateralis VM : vastus medialis
RF : rectus femoris

Squats and lunges are the most suitable exercises for strengthening lower extremity muscle strength and have the advantage of being applied regardless of time and place and can be a representative quadriceps muscle strengthening exercise[15]. This increases posture stability by improving balance ability in unstable support surfaces, and lunge and squat exercises using Togu have been able to achieve the effect of preventing falls through activation of lower extremity muscles[16].

Muscle weakness of the VM can cause knee pain and instability, and activity use of the VM is considered necessary, especially in movements requiring deceleration, such as walking or stair climbing[17]. In previous studies, lunge exercises showed higher muscle activity of VL and VM than squat exercises on unstable support surfaces and closed-kinematic chain exercise also showed high muscle activity of VL and VM[18]. This led

to the same results as this study.

Pevious studies reported that the muscle activity of the VM was the highest among the QM during lunge exercises on unstable support surfaces[19]. However, in this study, the VL and VM muscle activity was similarly high during lunge exercise, but a slight difference showed higher activity in VL. It is believed that the VL and VM muscle activity was more evenly affected in maintaining balance due to the low proficiency in posture during lunge exercise on an unstable support surface and the high pressure of Togu.

In addition, it was also reported that the muscle activity of the RF during squat exercises on unstable support surfaces showed no significant difference compared to the VL and the VM[20]. This is because RF is closer to the gravitational line than the VL and is performing the action of the antagonist against gravity applied in the vertical direction. Also, it is believed that the RF was activated to maintain squat posture by hip extension along with a knee bend to overcome the instability of the anterior-posterior and left-right in the feet. In particular, the VM is reported to show weakening first in physiology among the QM[21]. This weakening of the VM will make it difficult to control the pressure of the knee joint and the positioning of the knee bone, which will increase knee instability, leading to various joint diseases.

Therefore, in terms of unstable support, lunge exercise was effective in strengthening the balanced muscle strength of VM, and squat exercise was an essential factor in enhancing muscle of RF, showing a significant effect on increasing lower extremity muscle activity.

Therefore, this study found that squats and lunge exercises on an unstable support surface effectively activate each part of the QM. The exercises can be applied in various lower extremity rehabilitation programs for the elderly and adults with knee joint diseases.

4. Conclusion

This study experimented with analyzing lower extremity muscle activity during squats and lunge exercises on an unstable support surface and, as a result, obtained the following conclusions.

1. During lunge exercise on an unstable support surface, the VL and the VM muscle activity was significantly higher than that of the RF.
2. During squat exercise on an unstable support surface, the muscle activity of the RF was significantly higher than that of the VM and the VL.

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박 재 영(Jae-Young Park) [정회원]

• 2017년 3월 : 경운대학교 물리치료학과 조교수

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