# Comparison of EMG Activation of Quadriceps Femoris on Different Static Squat Exercises in Young Men with Patellofemoral Syndrome

Jin-Hyeok Yang[1], Su-Young Lee*[2]

[1] *Physical Therapist, Rehabilitation Therapy Room, Comfortable Hospital, 38 Jayang-ro, Gwangjin-gu, Seoul, 05112, Republic of Korea*

[*2] *Professor, Department of Physical Therapy, Division of Health Science, Baekseok University, 1 Baekseok University-ro, Dongnam-gu, Cheonan-si, Chungcheongnam-do, 31065, Republic of Korea*

waiwaiachi@naver.com[1], rosei118@bu.ac.kr*[2]

***Abstract***

***Background/Objectives****: This study had the purpose to test the effect of using ball, and elastic band during static squat movement through EMG activation of quadriceps femoris in patellofemoral pain syndrome (PFPS) subjects.*

***Methods/Statistical analysis****: The participants was twenty-two men with PFPS. The subjects were randomly divided into basic squat exercise group, squat exercise using ball group, or squat exercise using elastic band group. While each static squat exercise was performed, EMG activities of quadriceps femoris was measured via surface electromyography (sEMG). One-way ANOVA was used to compare EMG activation of quadriceps femoris (rectus femoris, vastus medialis oblique, and vastus lateralis) of each group.*

***Findings****: The result showed that there was significantly different in vastus medialis oblique muscle activation among the groups (p<.05), while there was not significantly different in rectus femoris and vastus lateralis (p>.05). Vastus medialis oblique muscle activity showed a significant increase in the squat exercise with ball group relative to the basic squat exercise group (p<.05). The squat exercise with ball group showed the most increase in vastus medialis oblique muscle activation than rectus femoris and vastus lateralis (p<.05). The basic squat exercise and squat exercise with elastic band group didn't have significant difference among three muscles (quadriceps femoris) (p>.05). However, in all groups, muscle activation increased in order of rectus femoris, vastus lateralis, and vastus medialis oblique.*

***Improvements/Applications****: This findings suggest that static squat exercise using ball can strengthen selective vastus medialis oblique muscle effectively that is necessary for patients with PFPS. In clinic, the use of the tool causing hip adduction during squat exercise may improve the effect.*

**Keywords:** *Ball, Electromyography, Elastic band, Patellofemoral pain syndrome, Vastus medialis oblique, Static squat exercise.*

## 1. INTRODUCTION

Patellofemoral pain syndrome (PFPS) occurs in 10 to 28% of people with high physical activity including the general population [1]. This syndrome that known as anterior knee pain causes abnormal position and movement of patella due to biomechanical alteration between the patella and the femur [2]. Young women with patellofemoral pain syndrome tend to have weak muscle strength in the hip abduction and lateral rotation muscles compared to healthy individuals [3]. In this regard, excessive pronated foot also strengthens the lateral shift of the patella, causing anterior pain in the knee joint [4].

Weakness of vastus medialis oblique is a common physiological change in patients with patellofemoral pain syndrome, and the imbalance of the muscle strength between vastus medialis oblique and vastus lateralis or delay of vastus medialis oblique contraction during knee extension has been reported as an important cause of lateral shift of the patella [5].

Closed-chain exercise has been widely performed for leg rehabilitation because it, such as squat exercise, includes simultaneous contraction of quadriceps femoris and hamstrings, reduction of anterior and posterior tibiofemoral translation, and compression force of the patellofemoral joints in lower extremities [6]. In a study of Irish et al. [7], an open kinetic chain, squat, and lunge exercise were conducted in healthy young subjects. The results showed that the EMG ratio of vastus medialis oblique and vastus lateralis muscles increased to 1.18:1 during squat exercise. Therefore squat exercise along with isometric hip contraction was effective for selective strengthening of vastus medialis oblique of quadriceps femoris muscle.

Furthermore, studies using tools have been done to enhance the effects of squat exercise. In particular, it was reported that the instability of the ball increases co-contraction of the knee joint muscle during the closed chain exercise, which maintains joint stability [8]. Previous study also has shown that the squat exercise with isometric adduction of hip joints using ball in normal subjects was more effective in improving the muscle strength of the vastus medialis oblique than other squat exercises [9].

The squat exercise using the resistance of the elastic band has also been performed in various elastic band. In the study of Hammer [10], one end of the elastic band was fixed, and the other end was wound just above the subject's knee joint so that resistance was applied backwards. That is, this caused hip joint external rotation and could then selectively strengthen the vastus medialis muscles.

Previous studies have demonstrated the effectiveness of various squat exercises, but do not compare selective vastus medialis oblique strengthening with clinically popular squat exercises. Therefore, this study aims to compares the muscle activity of the vastus lateralis and vastus medialis oblique muscles among squat exercises without any resistance and with the isometric hip adduction exercise using the elastic band and ball which are used clinically frequently in young men with patellofemoral syndrome. This study was conducted to find out the most effective leg squat to improve the vastus medialis oblique muscle selectively.

## 2. METHODS

### 2.1. *Subjects*

The subjects were twenty-two men students with PFPS at B University in South Korea. All subjects agreed to this study after fully explaining of the experimental purpose and process. And they were assigned randomly basic squat exercise group without tool, squat exercise group with ball, or squat exercise group with elastic band. The subjects were included in this study if they meet the following selection and exclusion criteria.

*The selection criteria were followed as*

1. Those whose Q angle are out of the normal range.
2. Those who sound click when bending the knee joint
3. Those who test positive for clark test
4. Anyone who has more than two pain in functional activities (such as climbing stairs, squatting, kneeling, prolonged sitting, isometric contraction, etc.)

*The exclusion criteria were followed as*

1. Those who have a history of knee surgery
2. Those who have exercised regularly within the last six months

The general characteristics of the subjects are as follows [Table 1].

**Table 1. General characteristics of subjects** (N=22)

| | SE group (n=8) | SEWB group (n=7) | SEWEB group (n=7) |
|---|---|---|---|
| Age (yrs) | 20.8±1.5* | 19.9±.4 | 21.3±.5 |
| Height (cm) | 166.1±6.6 | 176.3±4.7 | 169.6±8.2 |
| Weight (kg) | 57.3±6.7 | 64.3±7.1 | 62±12.7 |

*Mean ± Standard deviation. SE : squat exercise, SEWB : squat exercise with ball group, SEWEB : squat exercise with elastic band group.

### 2.2. *Experimental instrument*

#### *2.2.1. Surface electromyography*

Trigno (Delsys Inc, USA) surface electromyography was used to measure the maximum voluntary isometric contraction (MVIC) of the quadriceps femoris muscle (rectus femoris, vastus lateralis, vastus medialis oblique) and quadriceps femoris muscle activation during each squat exercise. The EMG signal measured by the Trigno sensor and then transmitted wirelessly to the Trigno Base Station was analyzed by EMGworks3.8.1 (Delsys Inc, USA) software.

#### *2.2.2. Electrode placement*

EMG electrodes were attached to rectus femoris, vastus lasteralis, and vastus medialis oblique muscles. The electrode on the rectus femoris was attached 20 cm above the upper outer part of the patella, and the vastus lateralis was attached to the upper 10 cm from the upper edge of the patella and to the outer 6-8 cm area, 15 degrees out of the centerline of the leg. The electrode on the vastus medialis was attached 4 cm upward and 3 cm inward from the upper inner edge of the patella.

## 2.3. *Methods*

### *2.3.1. Data collection and procedure*

*Maximal voluntary isometric contraction (MVIC)*

In order to prevent data analysis errors due to individual muscle strength differences, normalization was performed using maximum voluntary isometric contraction (MVIC) [11]. In this study, the tester had the subjects extend the knee joint by 170 ° actively after sitting on the table. They tried to keep their knee joint extension 170 ° under tester's maximal force for MVIC. MVIC of quadriceps femoris was measured three times for 5 seconds each time, and subjects rested approximately 1 minute each time to minimize muscle fatigue. The highest value for the three values obtained was used as the data value

*Quadriceps femoris muscle activation in each squat exercise group*

The signal collected through the electrode on quadriceps femoris (rectus femoris, vastus lateralis, and vastus medialis oblique) was stored as a digital signal, and the sampling rate was 1000 Hz. The data collected in each squat exercise was saved as a computer file via Root Mean Square (RMS). AcqKnowledge 3.8.1 program was used for signal storage and processing. Normalization was calculated as a percentage of the RMS to MVIC.

### *2.3.2. Squat exercise*

The subjects were assigned randomly into one to three groups, each of which consisted of ten, basic squat exercise group without tool, squat exercise with a ball group, or squat exercise with an elastic band. Since the subject's muscle recruitment ability and effort may be different, the isometric hip adduction of the ball and the resistance of the elastic band was applied as the maximum force that they can endure. Each group exercise was a total of three sets as a set of 10 seconds and 1 minute rest. A goniometer was used to control the knee joint angle.

*Basic squat exercise without tool*

The basic squat exercise group started with the knees extended and both feet as wide as shoulders and lightly folded arms. They continued to be verbally instructed to keep the gaze forward and the waist straight. Their knee was then bent slowly to 90 ° without any tool between both knees. And they maintained knee flexion 90 ° for 10 seconds.

*Squat exercise with ball*

The start position of squat exercise using the ball was the same as the basic squat exercise, and the subjects put the ball between both knees and bent the knee to 90 °. At this time, as if squeezing the ball between the legs, they pressed both knees with maximum force for 10 seconds.

*Squat exercise with elastic band*

The start position of squat exercise using the elastic band was the same as the basic squat exercise. The elastic band was tied to the knee joint and the leg of the table, respectively. A distance of 2 m was placed between the subject and the table at anterior outward 45 °. Subjects flexed their knees by 90 ° overcoming the elastic band resistance. And they maintained knee flexion 90 ° for 10 seconds.

### 2.4. *Statistical analysis*

One-way ANOVA was used to analyze quadriceps femoris muscle activity among squat exercise groups and muscle activation of squat exercise group among quadriceps femoris muscle. Tukey post hoc test was performed to compare the mean of muscle activation among exercise groups and muscles. The statistical program SPSS19.0 was used for the statistical processing of the EMG activation and the significance level α was .05 to test the statistical significance.

## 3. RESULTS AND DISCUSSION

EMG activity of vastus medialis oblique had significant difference among squat exercise groups (p<.05), while rectus femoris and vastus lateralis muscle activation had no significant difference (p>.05). Squat exercise with ball group increased significantly than basic squat exercise group in vastus medialis oblique (p<.05). Also there were increase in squat exercise group with ball than squat exercise with elastic band group but no significant difference (p>.05) [Table 2].

In squat exercise with ball group, EMG activity of vastus medialis oblique increased significantly than rectus femoris and vastus lateralis (p<.01). In squat exercise and squat exercise with elastic band, muscle activity increased in the order of rectus femoris, vastus lateralis, and vastus medialis oblique but no significant difference (p>.05) [Table 2].

**Table 2. EMG activity of quadriceps femoris on squat exercise** (Unit : %)

| Variables | SE group | SEWB group | SEWEB group | F | *p* |
|---|---|---|---|---|---|
| RF | 48.6±5.5[a] | 52.0±8.5 | 53.7±5.0 | 1.218 | .318 |
| VL | 53.7±9.1 | 57.8±9.4 | 58.2±7.4 | .622 | .547 |
| VMO | 57.6±7.8 | 71.3±5.6* ** *** | 61.2±8.5 | 6.589 | .007 |
| F | 2.806 | 10.716 | 1.981 | | |
| *p* | 0.83 | .001 | .167 | | |

[a]Mean ± Standard deviation. SE : squat exercise, SEWB : squat exercise with ball group, SEWB : squat exercise with ball group, RF : rectus femoris, VL : vastus lateralis, VMO : vastus medialis oblique,
* : significant difference between SE and SEWB in VM (p<.05),
** : significant difference between RF and VMO in SEWB (p<.05),
*** : significant difference between VL and VMO in SEWB (p<.05).

The patellofemoral joint is a joint between the patella and the femur and is located at the tip of the two long lever arms of the tibia and the femur, which is susceptible to injury due to trauma. This structural instability is supported by supportive ligaments and strong muscle function [12].

From a biomechanical point of view, the patellofemoral joint is balanced by static and dynamic factors, and the vastus medialis oblique and vastus lateralis muscles contribute to maintaining the dynamic stability of the patella. The imbalance of these two muscles causes abnormal shift of the patella, resulting in pathological changes of the patellofemoral joint. In normal people, the internal and external forces acting on the patella are in balance, whereas in patellofemoral pain syndrome patients, the relatively weak vastus medialis oblique muscles cannot cope with the external force caused by the iliotibial tract and vastus lateralis muscles. Thus the patella moves outwards [13].

Earl [14], through many studies on the muscle activity ratio (VMO / VL ratio) of the vastus medialis oblique and lateralis using EMG, reported that low muscle activity of vastus medialis oblique muscle was suggested as the most common cause of the patellofemoral pain syndrome.

Through these studies, the rehabilitation exercise for individuals with patellofemoral pain syndrome has aimed to strengthen the selective vastus medialis oblique muscle to prevent the lateral shift of the patella and has been studied in various exercise methods for this purpose.

This study was purposed to investigate the effective squat exercise for the selective muscle activation of the vastus medialis oblique in patients with patellofemoral syndrome. The result of this study was that in the vastus medialis oblique muscle squat exercise using ball showed higher muscle activation than basic squat exercise without tool. Especially in squat exercise with ball vastus medialis oblique had higher muscle activation than rectus femoris and vastus lateralis.

Irish [15] reported the squat exercise using the ball was a selective strengthening exercise of the vastus medialis oblique muscle obtained from the ratio of the medialis oblique and lateralis muscles during the squat exercise with the hip joint adduction. Miller [16] reported that, in various studies for the selective activation of vastus medialis oblique muscles, a combination of the quadriceps femoris muscle contraction and the hip joint adduction is effective for the selective activation of medial lateral muscles. This is considered to be that because some vastus medialis oblique muscle fibers are initiated at the adductor magnus and the gracillis, the contraction of these adduction muscles stabilizes the origin in the vastus medialis oblique, thus can affect its contraction.

Nam Ki-suk [17] studied the effect on the resistance direction of the elastic band on the ratio of the vastus medialis oblique and lateralis muscles during the squat exercise using the elastic band. The resistance direction was anterolateral 45°, lateral 90°, and without resistance. The result of the study showed that in anterolateral 45° the ratio of the vastus medialis oblique and lateralis muscles was greater than lateral 90° and without resistance. However the result of this study didn’t show the significant increase compared to basic squat exercise.

This study has limitation that small size of the study subjects was difficulty in generalization and the period of the exercise performance wasn’t enough to be apparent comparison between squat exercise using ball and elastic band. In future studies, it may be necessary to have more population with patellofemoral pain syndrome and enough exercise periods. And it is suggested to demonstrate the selective strengthening of the vastus medialis oblique muscle through more tools or methods used in clinic and the long periods.

**4. Conclusion**

The purpose of this study was to compare the muscle activation of quadriceps femoris on different squat exercises. This comparison can propose the most efficient selective contraction of the vastus medialis oblique on different squat exercise. As the results, when using ball on the squat exercise than basic squat exercise without tools between knees, vastus medialis oblique was strengthened the most efficiently. And during the squat exercise using the ball, the vastus medialis oblique activated also more effectively than any other quadriceps femoris muscle. This findings suggest efficient squat exercise method for the muscle balance of the vastus medialis oblique and lateralis in young men with patellofemoral syndrome. Like this, the use of the tools combining hip adduction during squat exercise will be more effective than without tools.

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