

# The effects of squatting with visual feedback on the muscle activation of the vastus medialis oblique and the vastus lateralis in young adults with an increased quadriceps angle

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**Abstract.** [Purpose] The purpose of this study was to identify the effects of performing squat exercises with visual feedback on the activation of the vastus medialis oblique (VMO) and vastus lateralis (VL) muscles in young adults with an increased quadriceps angle (Q-angle). [Subjects] This study used a motion analysis program (Dartfish, Switzerland) to select 20 young adults with an increased Q-angle, who were then divided into a squat group that received visual feedback (VSG, n=10) and a squat group that received no visual feedback (SG, n=10). [Methods] The intensity of exercises was increased every two weeks over a six-week exercise period in both groups. A visual marker was attached to the patella of the subjects in the VSG, and they then performed squat exercises with a maximum of 90° of knee flexion within a route marked on a mirror. The SG performed squat exercises with a maximum 90° of knee flexion without attaching a visual feedback device. [Results] Analysis of the muscle activation due to 90° squat exercises indicated that both groups had statistically significant increases in activation of the VL. The VSG exhibited statistically significant increases in activation of the VMO. [Conclusion] This study confirmed that squat exercises with visual feedback are effective in activation of the VMO and VL muscles. The findings are meaningful in terms of preventing the occurrence of patellofemoral pain.

**Key words:** Q-angle, Visual feedback Squat Exercise, VMO

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## INTRODUCTION

The structure of the knee joint provides a high level of resistance that enables weight support, activity control, and the bearing of heavy loads, so the knee joint is in charge of weight-bearing and has a wide range of motion (ROM)<sup>1)</sup>. From a biomechanical perspective, the quadriceps femoris group, iliotibial band, adductor magnus, adductor longus, pes anserine group, and biceps femoris work as knee joint stabilizers for the patellofemoral joint<sup>2)</sup>. Patellar alignment and tracking are determined by the amount of force and the direction of soft tissues around the patellofemoral joint. In particular, the vastus medialis oblique (VMO) muscle works as a medial patellar stabilizer<sup>3)</sup>.

An increase in the Q-angle increases the pressure on the patellofemoral joint<sup>4)</sup> and can give rise to anterior knee pain<sup>5)</sup>. An excessive Q-angle can result from imbalance between the VMO and the vastus lateralis (VL) muscles<sup>6)</sup>. This

imbalance leads to lateral gliding and incorrect tracking of the patella, thereby causing pain by increasing the pressure on the patellofemoral contact area<sup>7)</sup>. Weakening of the VMO is especially regarded as an important cause of knee imbalance<sup>8)</sup>. Women showed a greater increase in the Q-angle than in men due to their wider pelvises, which can cause malalignment of the genu valgum<sup>9)</sup>. Patellofemoral pain is also reported to be about twice as common in women than in men<sup>10)</sup>. Therefore, selective strength training for the VMO is of great importance to secure balance and stability in the VMO and VL<sup>11)</sup>.

Squat exercises are generalized lower-extremity closed kinetic chain (CKC) exercises<sup>12)</sup>. One study suggested their application as a safe and effective exercise method that minimizes stress in the patellofemoral joint within its functional range<sup>13)</sup>. McClelland et al. stated that exercises using a visual feedback device are effective for symmetrical pattern reeducation training of knee joint exercises<sup>14)</sup>. McConnell also reported that this type of real-time information delivery induced selective strengthening of the VMO<sup>15)</sup>.

Comparison and analysis of the action potentials of different muscles during muscle strengthening exercises in the knee joint are also important elements in identifying the effects of these exercises. Evaluation of exercises using an electromyogram (EMG) provides information on bioelectric activities related to the start of muscle contraction and

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muscle control actions, so the use of EMG is effective in these kinds of studies<sup>16</sup>). Several previous studies reported that EMG-based visual feedback exercises positively affect the alignment of lower extremities in young women with patellofemoral pain syndrome (PFPS), but their application has not been generalized.

The aim of the present study was to compare and analyze the muscle activation of the VMO and VL due to performance of visual feedback exercises in young adults with a large Q-angle, thereby verifying the extent of active improvement of control ability. The overall goal was to suggest a more general exercise method that can prevent pain occurring in the knee.

## SUBJECTS AND METHODS

This study used a motion analysis program (Dartfish, Switzerland) to select 20 young adults with an increased static Q-angle, who were then divided into two groups. One group underwent squat exercises with visual feedback (visual feedback squat group; VSG, n=10), and the other group performed squat exercises with no visual feedback (squat group; SG, n=10). The average age, height, weight, static Q-angle, and Kujala patellofemoral score (KPS) in the VSG were 22.60±1.83 years, 167.00±7.45 cm, 63.80±12.01 kg, 17.03±0.54°, and 83.20±2.83, respectively. The average age, height, weight, static Q-angle, and KPS in the SG were 23.20±2.14 years, 168.80±9.37 cm, 64.60±11.86 kg, 16.86±0.60°, and 84.70±2.86, respectively (Table 1).

The study's purpose and exercise methods were explained before the experiment to all subjects, who then agreed to participate. They also signed a written consent form according to the ethical principles of the Declaration of Helsinki. The subjects were young adults with a larger static Q-angle than normal as determined using a motion analysis program (Dartfish, Switzerland). In addition, they had to score at least 80 points, but below 90 points, for the KPS, and they had to have no medical history of undergoing orthopedic surgery or treatment in the lower extremities including the knee joint, no visual field defects nor abnormalities in vestibular organs, and no deformities in the knee joint, hip joint, and foot.

Before the experiment, the tester demonstrated the designed exercises to help the subjects understand the experiment's progression and procedures, and then all subjects were instructed to practice for five minutes to become familiar with the squat positions. The exercise program consisted of a warm-up, main exercises, and a cooldown. The warm-up and cool-down exercises were identical in the VSG and SG groups. For the main exercises, the VSG performed squat exercises with visual feedback, whereas the SG performed squat exercises without visual feedback. The intensity of the exercises in this progressive exercise program was increased every two weeks the course of a six-week period.

Visual feedback in the VSG consisted of marks attached to a mirror that provided a visual route that guided the ideal alignment of the lower extremities. In addition, while each subject's knee joint was extended in the sagittal plane, a visual marker was attached to the upper side of the patella. The distance between the visual marker on the subject's knee joint and the lines guiding the visual route on the mirror was

**Table 1.** General characteristics of the subjects (Mean±SD)

Group	VSG (N=10)	SG (N=10)
Gender	Male: 4	Male: 4
	Female: 6	Female: 6
Age (years)	22.60±1.83	23.20±2.14
Height (cm)	167.00±7.45	168.80±9.37
Weight (kg)	63.80±12.01	64.60±11.86
Static Q-angle (°)	17.03±0.54°	16.86±0.60°
KPS (score)	83.20±2.83	84.70±2.86

Mean±SD, mean±standard deviation; VSG: visual feedback squat group; SG: squat group, KPS: Kujala patellofemoral pain score

set as 1 m. Within the lines guiding the visual route, the subject performed squat exercises while gradually increasing the level of knee flexion, with the maximum being 90°.

In the SG, each subject performed squat exercises without wearing a visual feedback device and also gradually increased the level of knee flexion, with the maximum being 90°. For the warm-up, all subjects performed walking in the functional exercise system while maintaining a balance in the lower extremities and stretching exercises for shortened muscles related to increases in the Q-angle. For the main exercises, the VSG performed squat exercises with visual feedback, and the SG performed squat exercises without visual feedback. During weeks 1 and 2, the subjects performed one set of 20 squat exercises, which consisted of 20 squats, at 90° of knee flexion. During weeks 3 and 4, they performed two sets of squat exercises. During weeks 5 and 6, they performed three sets of squat exercises. The cooldown consisted of walking on a treadmill for five minutes.

The muscle activation of the VMO and VL was measured with each subject in a 90° squat position using a surface EMG (Noraxon Myosystem DTS, USA). The EMG signals were standardized by measuring the muscle activation of the VMO and VL during maximal voluntary isometric contraction by conducting a manual muscle test. The data values underwent RMS processing for five seconds, and the average EMG signal for three seconds, excluding the first and last second, was used as 100% MVC. For statistical analyses, comparisons of the VMO and VL within each group before and after the experiment were verified using paired t-tests. Differences between the two groups in values before and after the experiment were compared by independent t-tests. Fisher's least significant difference (LSD) was employed as a post hoc test. Data were statistically processed using SPSS 17.0 for Windows, and the statistical significance level was set at 0.05.

## RESULTS

Analysis of the muscle activation due to 90° squat exercises indicated that both groups had statistically significant increases in activation of the VL ( $p < 0.05$ ). The VSG exhibited statistically significant increases in activation of the VMO ( $p > 0.05$ ) (Table 2).

**Table 2.** Comparison of the VMO and VL within and between groups (Unit: ratio)

		Pre-test	Post-test	Difference value
VMO	VSG*	46.94±5.36	50.51±4.78	3.57±2.28
	SG	43.40±4.98	45.85±6.95	2.45±3.26
VL	VSG*	60.84±6.54	61.75±7.72	0.91±3.40
	SG*	58.37±5.72	62.43±7.18	4.06±3.66

Mean±SD, mean±standard deviation; VMO: vastus medialis oblique; VL: vastus lateralis; VSG: visual feedback squat group; SG: squat group

\*p<0.05

## DISCUSSION

This study identified the effects of the muscle activation of the VMO and VL in young adults with an increased Q-angle by dividing the subjects into a squat exercise group that was provided with visual feedback (VSG) and a squat exercise group that received no visual feedback (SG). The effects of visual feedback exercises that are easily accessible in daily life are meaningful in terms of preventive medicine. Therefore, this study was undertaken to verify the effects of new, easily accessible visual feedback exercises.

Recent relevant studies have focused on how to improve the control of the VMO, strengthen muscles functionally, and improve muscle performance with regard to the patella, rather than solely focusing on muscle strengthening<sup>17</sup>). Fehr et al. reported increases in the KPS following application of CKC exercises in a group of patients with PFPS<sup>18</sup>). Jae-Yeong Kang reported that the measurement of the Q-angle at 60° of knee flexion resulted in statistically significant decreases in a CKC exercise group that used EMG biofeedback<sup>11</sup>).

Surface EMG analysis is a useful tool for evaluating the results of treatment during treatment processes<sup>19</sup>). Hyeon-Hee Lee reported that patients with patellofemoral pain showed statistically significant declines in muscle activation of the VMO based on surface EMG readings<sup>20</sup>). In the present study, the Q-angle measurements were 17.03±2.01° in the VSG and 16.86±2.41° in the SG, which confirmed increases in the Q-angle compared with the average levels of normal adults. Raveendranath et al. reported that the average measurement values for the Q-angle in normal adult women were larger than those in men<sup>21</sup>). Another study noted that an increase in the Q-angle over normal levels led to genu valgum and could cause PFPS due to excessive pressure<sup>22</sup>). In the present study, analysis of muscle activation following 90° squat exercises showed statistically significant increases in the VMO activation in the VSG.

Grossi et al. reported statistically significant increases in muscle activation in both an PFPS group and the general groups during 60° squatting<sup>23</sup>). Seo-Yi Park also reported that, among CKC exercises, squat and step-up/down exercises yielded statistically significant increases in activation<sup>24</sup>). Gi-Cheol Kim analyzed the muscle activation ratios of the VMO and VL when subjects performed squat exercises with different angle variations, and found statistically greater effects in the group that performed biofeedback squat exercises<sup>25</sup>). They also compared the average differences between the biofeedback and general squat exercise groups and reported greater effects with biofeedback squat exercises

than with general squat exercises at all tested angles (30°, 60°, and 90°). In the present study, measurement of muscle activation before the experiment showed that the VMO had a higher level of muscle activation than the VL. Both the VSG and SG exhibited statistically significant increases in muscle activation of the VL after the treatments; however, only the VSG showed a statistically significant increase in activity of the VMO. These findings suggest that squat exercises with visual feedback are more effective in activating the VMO than squat exercises without visual feedback. Squat exercises with visual feedback are also effective in activating both the VMO and VL.

The limitation of this study is its focus on young adults with an increased Q-angle, which precluded the identification of pain reduction effects in patients who have pain. However, this study is considered meaningful in terms of helping to prevent potential patellofemoral pain using visual feedback squat exercises that activate the VMO, a primary cause of patellofemoral pain. Therefore, this study provides basic data regarding the muscle activation of the VMO and VL, but additional systematic studies should be conducted in the future using more diverse subjects and variables.

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