

## Comparison of Pennation Angle Between Vastus Intermedius and Vastus Lateralis According to the Angle of Squat

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**Abstract:** The purpose of this study is to measure the comparative analysis pennation angle of the vastus intermedius and vastus lateralis in the squat position of the knee angle. Knee angle was set as 0°, 60°, 75° and 90° the vastus intermedius and vastus lateralis of pennation angle of the knee angle was measured using ultrasonography. All measurements of the experiments were performed by one-way ANOVA. According to a study 0°, 60°, 75° and 90° that was pennation angle is greatly increased in the knee angle of 75°, all the statistical value has differences but 60° and 90° was statically significant than other values. The study found out the significant difference between the pennation angle of men and women. In conclusion, the result of experiment shows that the quadriceps muscle was most stimulated when we did a squat exercise while flexion our knee at an angle of 75°. Clinically, it is considered that the interaction between knee angle and quadriceps muscle will help to prevent injuries related to quadriceps muscle such as patellofemoral pain syndrome.

**Key words:** Knee joint, pennation angle, squat exercise, knee angle, ultrasonography, prevent

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### INTRODUCTION

The knee joint was vulnerable to injury because against strong external forces with weight bearing (Chae *et al.*, 2010). In comparison, the structure that provides the stability of the knee was weak. It aims to prevent knee injury caused by instability in knee rehabilitation (Majors and Woodfin, 1996; Neumann, 2013). The patellofemoral pain syndrome was a major cause of excessive use or abnormal movements of knee joint (LaBella, 2004). A decrease of coordination between vastus lateralis and vastus medialis oblique muscle effected stability of the knee joint. The patellofemoral pain syndrome January 17, 2018 occurred frequently among women aged 10-35 years and had higher incidence of 2-3 times compared to males (Lichota, 2003). In strength training and fitness, the squat is often used as functional exercise because of small shearing force to compare with open chain exercise (De Looze *et al.*, 1993; Grelsamer and Klein, 1998). Therefore, a squat exercise could be applied to a functional pattern of movement using various joint of lower extremity.

Ultrasonography is used to study characteristics of muscle or tendon in a non-invasive manner. The ultrasonography has the advantage of measuring the movement of joint in confined spaces and is an inexpensive alternative to different diagnostic imaging, CT and MRI (Chi-Fishman *et al.*, 2004). Pennation angle

and fascicle length was acquired by analysis of ultrasonography. The pennation angle means is the angle between the muscle and tendon and the angle varies according to the length of each muscle (Jo *et al.*, 2014). When muscle fibers are attached parallel to the tendon, the pennation angle is defined at 0°. In theory, the muscles delivered all of the contractile force to the tendons when the pennation angle was 0° (Lieber and Friden, 2001). In the 30°, muscles transferred 86% of the force to the tendons.

The study for the squat was conducted in various methods. However, the study of pennation angle was insufficient to present effective knee angles. We attempted to investigate changes of the pennation angle between vastus intermedius and vastus lateralis according to the angle of squat.

### MATERIALS AND METHODS

**Subjects and data acquisition:** Forty normal adults (20 males, 20 females; mean age 21.63±1.64 years) were recruited using the following exclusion criteria: a person who has pain or edema on his knee, someone who underwent surgery on the knee, a person with heart disease, diabetes and other medical problems. Table 1 showed physical characteristics.

The pennation angle measured the angle between vastus intermedius and vastus lateralis using



Fig. 1: Ultrasonography



Fig. 3: Squat position for data acquisition. A: 0°, B: 60°, C: 75°, D: 90°

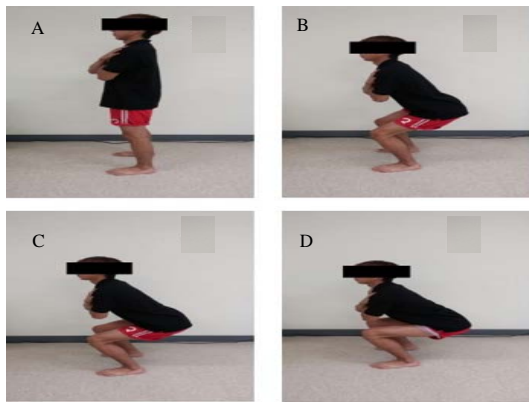


Fig. 2: The location of probe

Table 1: Subject characteristics (N = 40)

Sex	Male (N = 20)	Female (N = 20)
Age	22.35±2.36	20.9±0.91
Height (cm)	175.57±5.31	164.06±6.16
Weight (Kg)	70.2±7.33	55.95±7.42
Dominant Leg	Right: 20, Left: 0	Right: 20, Left: 0

Data are presented as mean±SD

ultrasonography with linear probe, high frequency and basic mode (Fig. 1). The method of obtaining images was applied by a longitudinal method. The location of the probe was the center of the femur with knee flexion of 10°-20° (Fig. 2).

**Measurement and analysis:** The pennation angle measured at 0°, 60°, 75° and 90° during the squat position (Fig. 3). Two min was proved between measurements to prevent muscle fatigue. The image was captured three times and was chosen as the most visible picture (Fig. 4). The pennation angle was used for performance of one-way ANOVA to determine the variances among 0°, 60°, 75° and 90° in normal subjects follows by Bonferroni

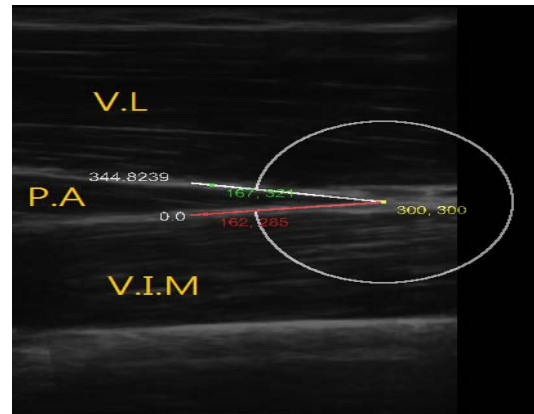


Fig. 4: Measurement method for pennation angle. V.L: Vastus Lateralis muscle, P.A: Pennation Angle, V.I.M: Vastus Intermedius

post hoc test using SPSS 18.0 for Windows (SPSS INC. Chicago. IL). The independent t-test was performed to compare the pennation angle between males and females. Significance level of all statistics were set as  $p < 0.05$ .

## RESULTS AND DISCUSSION

Table 2 shows the pennation angle by each knee angles. The pennation angle was statistically significant differences among knee angles ( $p < 0.05$ ). The largest value at 75° of knee flexion was observed to compare with other angles ( $p < 0.05$ ). There was a statistically significant difference between male and female ( $p > 0.05$ ).

In the previous studies, the muscle activity of quadriceps muscle increased to 90° during squat exercise. By contrast, it was reduced to more than 90° (Yi *et al.*, 2005). As the angle increases, the center of gravity of the

Table 2: Comparison of pennation angle

Knee angle	Male (n = 20)	Female (n = 20)	t-values
0°*	14.67±1.95	13.73±1.91	1.52
60°*	16.07±2.47	14.81±1.51	1.92
75°*	18.01±2.49	16.83±1.72	1.73
90°*	16.43±2.48	14.54±1.18	3.07

Data are presented as mean±SD. \*p<0.05

human body moved towards the back of the knee. Therefore, the increased activation of the quadriceps muscle was due to an increased moment. However, this study showed the largest pennation angle at 75°. We thought that the result had been attributed to two factors. First, the knee stability was increased due to the co-contraction between the quadriceps and gastrocnemius muscle at 90° (Kwon *et al.*, 2012). Second, an increase in the pennation angle reflected the increased muscle power. However, a decrease at the 90° might be shown because the condition of the knee joint was the most to increase the length of the muscle. This study showed difference between male and female. The absolute strength of the lower extremity of women in twenties was the average of 75% the males (Choi and Han, 2001). These difference muscle strengths increased along with the increase in age. It seems that the distinction between the sexes was caused by the muscular strength of males.

### CONCLUSION

In the current study, we attempted to find changes in the pennation angle between the vastus intermedius and vastus lateralis according to the angle of squat. A greater pennation angle was measured at 60°, 75° and 90° compared to 0°. In particular, the biggest value emerged at 75°. As the increasing flexion angle of the knee, the force required for the quadriceps muscle was increased. However, an increase in muscle tension caused an excessive load on the knee joint at 90°. Therefore, we suggested that the most effective squat exercise angle is 75°.

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