

# Comparison of Balance and Muscle Activity of Normal Male and Female in Squats Exercise According to Knee Joint Angle

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## ABSTRACT

The purpose of this study was to analysis the balance and muscle activity with squats exercise according to the knee joint knee between male and female. Before experiment, MVIC values were measured, and balance and muscle activity were measured during the squat exercise using MATLAB and EMG. Shapiro-Wilk test was used for normality test and Independent T test was used for independence test. All statistical significance levels were  $p < .05$ . The results showed that both male and female showed no significant difference between Maximum and  $140^\circ$  ( $p > .05$ ), but  $90^\circ$  showed significant difference ( $p < .05$ ). There was a significant difference in BF, VL, RA, and ES values at  $90^\circ$  between male and female ( $p < .05$ ), and VL, ES, and RA were significantly different at  $140^\circ$  ( $p < .05$ ). In order to enhance balance in various dynamic movements such as squat exercise that uses AR, the movement of the thigh muscles is required. In addition, statistics on muscle activity and balance can be used to apply a squat movement according to the knee angle. Therefore, future research suggests that research is proceeding from a more diverse angle.

**Keywords:** *squat exercise, balance, muscle activity, Knee joint angle, Normal Male and Female*

## Introduction

The squat exercise is popular because of its similarity and applicability to both activities of daily living and many athletic movements, and it is a multi-joint movement that requires many large muscle groups to function together<sup>1</sup>. Squat exercise is relatively powerful because it is more stable than other lower body exercises such as run or plank, and both legs are equally stressed. Squat exercise produces functional muscle mobilization patterns, promotes a sense of proprioception, includes the exercise of joints and muscles in closed kinetic chains, and requires many joint exercise<sup>2</sup>. Muscle activity refers to the activity of the muscle in any particular motion. Usually, muscle activity is measured in an electrocardiogram. While the muscles contract and relax, there is a tiny potential difference around them. Among the squats, there are a lot of influences on the vastus medialis, vastus lateralis, biceps femoris, and the

gastrocnemius<sup>3</sup>. At this time, the Knee extensor muscle becomes the main muscle, and the hip extensor muscle acts as an assistant to the other muscles.

Marchetti et al.(2016) reported that there was a difference in muscle activation of the vastus lateral, vastus medialis, and rectus femoris depending on the position of the knee. The isometric back squat, which produces the highest muscle activation, has an angle of  $90^\circ$ , but the vastus lateralis total muscle activation of the lateral broad muscle is said to be produced in an isometric back squat at  $140^\circ$ , and muscle activation of the hamstring were not associated with knee angle<sup>4</sup>. And Saito et al.(2013) reported the neuromuscular activation of four synergistic agents of quadratus femoris at three different knee joint angles during isometric knee extension. The activation of each of the four synergists of rectus femoris at  $150^\circ$  knee angle joint was lower than at  $90^\circ$ . vastus intermedius, vastus lateralis, vastus medialis, and Rectus femoris muscles were compared with each other. As a result, muscular activation of vastus intermedius was observed at  $150^\circ$  of knee joint angle It is said to have decreased greatly<sup>5</sup>. Park et al.(2013) also reported that the rectus femoris muscles showed an increase in activity through repetitive squat exercises only below  $100^\circ$  of the knee joint<sup>6</sup>.

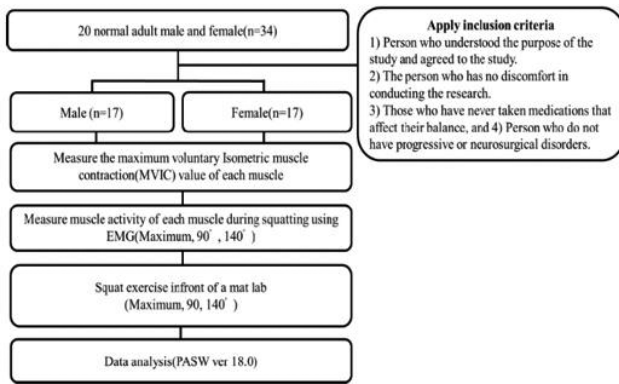
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**Figure 1: Flow diagram of subject experimental protocol**

In contrast, Caterisano et al.(2002) found that while performing squatting at three depths, the experience of ten experienced reporters, gluteus maximus, biceps femoris, vastus medialis, vastus lateralis muscles<sup>7</sup>. The results suggest that there were no significant difference in biceps femoris, vastus medialis or vastus lateralis during concentric contraction at different squatting depths.

As we have seen there have been controversial studies on the muscle activity of rectus femoris and hamstring in squat exercise according to knee angle. To conclude the controversy, there is a difference in the pelvis between male and female, so it is necessary to compare the differences because the average Q angle is different. In addition, studies to date have shown that there is a balance between the squat exercise according to the angle of the knee, and the muscle activity of the gastrocnemius, tibialis anterior, erector spine, and rectus abdominis there was little. Therefore, the purpose of this study was to compare the balance and muscle activity of normal adult male and female with squat exercise according to knee angle.

**Method**

**Participants:** This study was conducted on healthy male and female students attending S University in Asan, Chungnam. Before participating in the study, all subjects were given sufficient explanations about the purpose and method of the study to conduct the research smoothly, and the researchers conducted voluntary consent. Participants selected 17 males and 17 females. The selection criteria were: 1) Person who understood the purpose of the study and agreed to the study. 2) The person who has no discomfort in conducting the research. 3) Those who have never taken medications

that affect their balance, and 4) Person who do not have progressive or neurosurgical disorders. The exclusion criteria are those uncomfortable with the study, and that are taking supplements. This study was approved by Institutional Review Board (SM-201804-021-2) Institutional Physiological Ethics Committee.



**Figure 2: 140°, 90°, Maximum**

**Experimental Procedures:** The overall research process is shown in [Figure 1]. This study is cross sectional study and non-equivalent two group comparison test and Single blinded test. Prior to starting the study, the subjects were briefed on the purpose of the experiment and the method of study and then conducted on those who agreed to it. Before the experiment, short sleeves and shorts were worn to reduce the skin resistance of EMG attachment site. Measurements were performed on the muscles of the vastus lateralis, biceps femoris, gastrocnemius, tibialis anterior, erector spine, and rectus abdominis using an electromyography device during each squat exercise at 140°, 90°, Maximum and The muscles that were activated during the squat exercise at the angle were analyzed [Figure 2].

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We used digital goniometer for measuring angle and EMG for measuring muscle activity. To assess the balance capability, we used the Matlab program. In order to reduce the skin resistance on the legs of the subject, the hair on the attachment site was removed using a razor or the like and disinfection was carried out by inserting the area to

be examined and the EMG pad with alcohol. According to the existing study, in the case of the vastus lateralis, it was attached about 10cm above the upper corner of the knee bone and about 6~8cm toward the side<sup>8</sup>, The biceps femoris was attached at 1/2 point between the ischial tubercle and the fibular head, and the gastrocnemius was attached 1/2 between the calcaneus and the fibular head. three 3, tibialis anterior was attached at 1/3 point between fibular and medial malleolus, rectus abdominis at 5cm above the umbilicus, and erector spine was attached 2cm away from the spinous process of the 2nd lumbar. The overall attachment point is shown in [Table 1].

**Table 1: The attached location of EMG electrodes**

Muscle	Location
Vastus lateralis	About 10 cm above the upper edge of the knee bone, about 6 to 8 cm toward the edge`
Biceps femoris	1/2 point between ischial tubercle and fibular head
Gastrocnemius	1/3 point between calcaneus and fibular head
Tibialis anterior	1/3 point between fibular and medial malleolus
Rectus abdominis	About 5cm above the belly button
Erector spine	Approximately 2 cm away from the spinous process of the second lumbar

**Goniometer:** Using a Digital goniometer (Digital Absolute + Axis, 12-1027, USA, 2012), the knee joint angles were adjusted to 140°, 90°, Maximum and, respectively, and then squatting was performed [Figure 3].

**EMG (Electromyography):** The digitized signal of the EMG was subjected to 20-500 Hz bandpass filtering, full wave rectification and smoothing using root mean square (RMS). The obtained muscle activity value were calculated as the effective mean value and then mean and compared with the ratio (MVIC) of the Maximum number of muscle contractions of each muscle on the basis of the muscle strength evaluation posture<sup>9</sup>. In order to determine muscle quantization, the mean value of the root muscle, vastus lateralis, gastrocnemius, and tibialis instrument were divided by the RMS mean value of each muscle [Figure 4].

$$MVIC (%) = \frac{\text{Mean amplitude}}{MVIC} \times 100$$



**Figure 3: Goniometer**



**Figure 4: EMG(Electromyography) Matlab**

We measured the balance during squat operation using Matlab program in UINCARE (UINCARE - 82B, Korea, 2016.) MATLAB is a mathematical engineering program that allows you to measure the motion of the center of gravity(COG) in the direction of the Ant-Post, Vertical, and Medial-Lateral while the subject is moving. The method of use automatically measures the COG when the object or object is in front of the device after executing the program and shows the axis movement for the set amount of time.

**Result**

**Physical Characteristic:** The physical characteristics of the researchers are as follows [Table 2].

**Table 2: General characteristics of subjects (n = 34)**

	Male (n = 17)	Female (n = 17)	Mean
Age (year)	23.12 ± 2.28	20.94 ± 0.55	22.03 ± 1.97
Weight (kg)	73.82 ± 9.02	53.53 ± 7.62	63.68 ± 13.18
Height (cm)	173.76 ± 7.76	163.18 ± 4.47	168.47 ± 8.23
mean ± standard deviation			

**Comparison of the balance of the squat exercise:** According to the angle of the knee joint the difference in the balance when squatting according to the angle of the knee joint is as follows [Table 3].

There was no significant difference in Maximum and 140° when squatting at 140°, 90°, and Maximum, respectively ( $p > 0.05$ ), but there was a significant difference between anterior-posterior and medial-lateral at 90° ( $p < 0.05$ ). For male, there was no significant difference between  $58.14 \pm 15.99$  in the maximal Medial-Lateral ( $p > 0.05$ ) and  $95.31 \pm 236$  in the Anterior-Posterior. For 90° case, Medial-Lateral showed a significant difference of  $27.99 \pm 8.64$  ( $p < 0.05$ ) and also a significant difference of  $89.02 \pm 67.93$  Anterior-Posterior. There was no significant difference in

140° medial-Lateral ( $p > 0.05$ ), with a difference of  $101.92 \pm 8360$  at Anterior-Posterior. The maximum medial-lateral of the female was  $60.85 \pm 27.72$ , indicating no significant difference ( $p > 0.05$ ), Anterior-posterior was not significantly different from  $97.91 \pm 22.42$  ( $p > 0.05$ ). There was a significant difference between 90° mediolateral  $50.04 \pm 14.59$  and anterior-posterior  $141.02 \pm 74.66$  ( $p < 0.05$ ). There was no significant difference between 140° Medial-Lateral and  $28.29 \pm 11.58$  and anterior-posterior was also  $106.84 \pm 73.23$  ( $p > 0.05$ ).

**Table 3: Comparison of the balance of the squat exercise according to the angle of the knee joint (Unit: mm)**

		Male	Female	t
Max	overall	$342.66 \pm 32.86$	$358.43 \pm 55.49$	-1.008
	Ant-Post	$95.31 \pm 23.26$	$97.91 \pm 22.42$	-0.331
	Medio-Lateral	$58.14 \pm 15.99$	$60.85 \pm 27.72$	-0.35
90°	overall	$243.27 \pm 57.81$	$258.87 \pm 47.57$	-0.859
	Ant-Post	$89.02 \pm 67.93$	$141.02 \pm 74.66$	-2.214*
	Medio-Lateral	$27.99 \pm 8.64$	$50.04 \pm 14.59$	-5.359*
140°	overall	$159.57 \pm 43.00$	$194.77 \pm 80.10$	-1.585
	Ant-Post	$101.92 \pm 83.60$	$106.84 \pm 73.23$	-0.183
	Medio-Lateral	$24.56 \pm 12.25$	$28.29 \pm 11.58$	-0.912

mean  $\pm$  standard deviation, Max: Maximum, Ant-Post: Anterior-Posterior, Medio-Lateral: Medial-Lateral, \* $p < 0.05$

**Comparison of muscle activity of the squat exercise:** For muscle activity, there was not significant difference between male and female when the knee joint angle was Maximum, and at 90° the difference was significant at the biceps femoris at  $83.25 \pm 7.16$ ,  $62.26 \pm 4.99$ , respectively ( $p < 0.05$ ). In the vastus lateralis, there was a significant difference between males and females at  $91.94 \pm 7.26$ ,  $98.17 \pm 7.86$  ( $p < 0.05$ ). Erector spine showed a significant difference of  $86.34 \pm 7.35$ ,  $38.51 \pm 7.64$  respectively ( $p < 0.05$ ). For the rectus abdominis, there was a significant difference ( $p < 0.05$ ) with  $84.88 \pm 7.92$ ,  $34.74 \pm 8.40$  ( $p < 0.05$ ). At 140°, male and female showed a difference of  $85.61 \pm 7.55$ ,  $95.69 \pm 11.44$ ,  $37.76 \pm 5.14$ ,  $27.45 \pm 4.87$ ,  $69.91 \pm 7.2$  respectively.

**Table 4: Comparison of the muscle activity of the squat exercise according to the angle of the knee joint**

	140°			90°			Maximum		
	Male	Female	F	Male	Female	F	Male	Female	F
GCM	$34.08 \pm 6.11$	$33.26 \pm 5.16$	0.18	$65.85 \pm 6.67$	$63.18 \pm 5.47$	1.63	$77.26 \pm 8.31$	$73.21 \pm 5.59$	2.29
TA	$95.17 \pm 8.01$	$93.71 \pm 7.39$	0.31	$84.43 \pm 7.68$	$86.20 \pm 7.63$	0.45	$97.44 \pm 6.34$	$96.57 \pm 10.40$	0.09
BF	$44.35 \pm 5.40$	$93.71 \pm 7.39$	1.42	$83.25 \pm 7.16$	$62.26 \pm 4.99$	8.16*	$56.47 \pm 4.16$	$54.20 \pm 5.31$	1.92
VL	$85.61 \pm 7.55$	$95.69 \pm 11.44$	5.97*	$91.94 \pm 7.26$	$98.17 \pm 7.86$	5.76*	$72.54 \pm 8.23$	$74.89 \pm 7.42$	0.77
ES	$37.76 \pm 5.14$	$27.45 \pm 4.87$	6.64*	$86.34 \pm 7.35$	$38.51 \pm 7.64$	15.52*	$56.74 \pm 5.19$	$54.39 \pm 3.26$	2.5
RA	$69.91 \pm 7.22$	$31.21 \pm 4.61$	9.19*	$84.88 \pm 7.92$	$34.74 \pm 8.40$	19.96*	$30.03 \pm 5.20$	$28.85 \pm 5.63$	0.4

mean  $\pm$  standard deviation, GCM: Gastrocnemius, TA : Tibialis anterior, BF : Biceps femoris, VL : Vastus lateralis, ES : Erector spine, RA : Rectus abdominis, \* $p < 0.05$

## Discussion

This study compared the balance and biceps femoris, vastus lateralis, tibialis anterior, gastrocnemius, erector spine, and rectus abdominis muscle activities when normal adults were squatted according to the knee joint angle (140°, 90°, maximum). There was no significant difference between the maximum and 140° of knee joint angle ( $p>0.05$ ), but there was a significant difference at 90° ( $p<0.05$ ). Balance is the ability to maintain the center of the body on the supporting surface and base, and essential for body stability and independence<sup>10</sup>. The ability to maintain center of gravity on the base during static and dynamic movements is called balance. Sensory posture control requires visual, physical, and sensory information from the vestibular system<sup>9,11</sup>.

Balasubramanian et al.(2007) reported that balance plays a very important role in maintaining posture, maintaining posture when performing any other movement, and everyday life<sup>12</sup>. Yunwon et al.(2015) suggested that genu valgum may affect the medial-lateral balance index because the medial collateral ligament and joint capsule are elongated, the inner muscles such as semitendinosus are elongated, and the lateral joint space is lost<sup>13</sup>. Timothy et al.(2018) measured the dynamic stability index for the standard deviation of the ground reaction force and dynamic posture stability during static posture stability according to gender. As a result, female had better static postural stability than male, but no difference in dynamic postural stability<sup>14</sup>. On the other hand, Wikstrom et al.(2006) quantified dynamic postural stability during jump landing of a single leg. The results showed that female had dynamic postural stability compared to male in vertical planes<sup>15</sup>. Hollman et al.(2009) found that muscle strength of mid-ball famine suggests increased knee flexion<sup>16</sup>. Ryan et al.(2006) reported that female had a larger Q angle than male. The results showed that a cruciate ligament injury in female could be an anatomical risk factor<sup>17</sup>. In conclusion, the present study showed that the female genu valgum was increased by squatting at 90° and there was no significant difference between maximum and 140°. In the case of muscle activity, Valentina et al.(2012) Suggested that female may be exposed to the risk of anterior cruciate ligament injury by activating the quadriceps muscle because the female lacks the trunk muscle force that controls the forward displacement of the center of mass during the squatting

phase respectively<sup>18</sup>. In addition Willson et al.(2006) Using instruments suitable for a clinical setting, females were found to have greater frontal plane projection angle (FPPA) and generally decreased trunk, hip, and knee isometric torque. Hip external rotation strength was most closely associated with the frontal plane projection angle<sup>19</sup>. In this study, there was a significant difference in vastus lateralis, erector spine, and rectus abdominis at the knee joint angle of 140° between male and female.

Ebben (2009) evaluated the activity of hamstring and quadriceps muscle according to gender. As a result, female are more active in the quadriceps muscle and less active in the hamstring muscle than male. Female may require disproportionately greater training for the hamstrings compared with the quadriceps<sup>20</sup>. Therefore, in this study, the muscle activity of vastus lateralis was higher in female than in male at 90°, but it was lower in biceps femoris.

The results of this study showed that at 90° and 140° in the squat, males contributed stability to balance by activating erector spine and rectus abdominis more than females. Thus, female were more unstable than male. Also, squats at 90° can increase knee valgus stress and cause damage to knee structures. Therefore, for female who are at risk of falling, it is recommended that the knee joint angle is 140° in order to perform a stable squat.

## Conclusion

This study was intended to compare balance and muscle activity when normal male and female their squat exercise according to their knee joint angle. The study found that balance was not significantly different for both male and female at 140° and for 90°, when they had squat exercise according to the knee joint angle. Consequently, the difference in balance in knee joint angles was found to be the most unstable for female at 90° above male and relatively stable at Maximum and 140°. vastus lateralis was higher in female than in male at 90°, while biceps femoris, erector spine and rectus abdominis were lower. At 140°, females were higher in vastus lateralis than males and lower in erector spine and rectus abdominis. In the case of Maximum, there was no difference between male and female. Therefore, in the future studies will provide a comparative study of male and female according to various angles and movements.

**Ethical Clearance:** Take from Sunmoon University committee Institutional Review Board (SM-201804-021-2).

**Source of Funding:** Self

**Conflict of Interest:** Nil

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