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Comparison of Age based Motor Unit Synchronization between Lower Limb Muscles during Dynamic and Isometric Squats

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Abstract

Background/Objectives: The purpose of this study is to analyze the effect of exercise by conducting three kinds of squat exercises in age-specific groups from their 10s to 60s and comparing the seven lower muscle activities.

Methods: Participants were six groups of healthy women in their 10s to 60s who have not experienced any surgical operation. In each group, bipedal squat, single leg squat, and isometric squat exercises were conducted, and muscle activity of the lower extremity was measured. Electromyography was used to measure muscle activity during three types of squats, and Two-way-ANOVA was used for comparative analysis of muscle activity.

Findings: In this study, there were significant differences in muscle activity depending on the age group and type of squats ($p<.05$), while the association between age and squats was inconsistent. However, the results of this study show that as you get old, your muscles decrease as well, and the difference in muscle activation varies depending on the type of squats. Therefore, the study will be the basis for maintaining good health through effectively strengthening the lower extremity by age.

Improvements: As age increased, muscle activity gradually decreased after the 50s. These results suggest the necessity to strengthen muscles through lower extremity exercise as you age.

Keywords : Age, Women, Dynamic squat, Static squat, Lower-extremity, Eletromyography

1. Introduction

According to the United Nations Population Report, in 1960, 5.1 percent of the population (15.35 million) were aged 65 or older. In 1980, the rate increased to 5.7 percent (25.59 million) and 6.6 percent (45 million) in 2000. Recently, the proportion of the population aged 65 and older continues to grow from 12.8 percent of the total population in 2015 to 13.2 percent in 2016, 13.8 percent in 2017, and 14.3 percent in 2018[1]. The aging process results in a significant loss in muscle mass and strength. Muscle strength decreases between 16.6 to 40.9 percent in the age of 40s[2]. After age 50, muscle mass decreases by 1 to 2 percent a year[3]. There is a popular exercise, Squat, to prevent the muscle loss of the elderly in the aging society. It strengthens the muscles of the lower extremity and improves the ability to neutralize the medial or lateral displacement of the knee[4]. Squat is one of the most frequently used exercises in strength and conditioning[5]. Therefore, this study will try to apply dynamic squats and isomeric squats by age.

Muscle strength varies depending on such factors as the joint position if the muscle serves its role as a motive force or stability, and whether the task is dynamic or static. Such dynamic squats as single leg squats and alternating leg squat, as well as isometric single leg squat naturally require high muscle activation as they should only be raised by single leg[6]. Isometric squats produce the same force and torque and are convenient to understand changes in muscle activation patterns without confusing external effects from dynamic motion[7]. There is EMG to observe the muscle activation pattern.

There was an important main effect of the knee joint and foot position, and also an interaction effect on vastus medialis oblique and vastus lateralis oblique in EMG activity. The ratio of vastus medialis oblique(VMO), vastus lateralis oblique(VLO) had significant differences depending on tibia rotation and showed interaction effects. The mid-line produced much more VMO / VLO active rates at 60 degrees of internal rotation position and external rotation position. Given the interaction effect on EMG

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activity in the quadriceps femoris, it provides a sufficient condition at a 60-degree knee angle in a neutral foot position[8]. Based on these studies, we invertigated effective squat exercises by age. According to a recent study, adolescents are more explosive and demonstrate distinct muscle adaptations compared to adults in response to conventional strength exercises[9]. In young men, it increases significantly after six minutes into the exercise, and the results support that the level of muscle activity in the lower extremity during weight-based exercise has a negative correlation to knee joint torque relative to body weight[10]. For physically weak elderly, a short-term conditioning program consisting of repetitive sit-down exercises is effective in strengthening the knee extensor and reducing the muscle effort required to lower or raise the body[11].

Based on these studies, age-specific training programs have been identified to improve stability as well as the overall functional performance. It is true that there were no age-related studies in the previous studies observing the muscle changes by squats or the effects of squats[9,10], and that there was a lack of studies covering effective types of squats by age. The purpose of this study is to measure the muscle activity of lower extremity in each age group from women in their 10s to 60s, through EMG to determine what types of squats show changes in muscle activity for each age group, and to find out the best and most effective squat.

2. Materials and Methods

2.1. *Participants*

The study design was randomized control and multiple intervention. In this study 39 healthy female and male adults attending Sun moon university in Asan. Before taking part, all subjects were given sufficient explanations about the purpose and method of this study 39 participants conducted experiments in CoN. The ESG wearing EMS and did squat exercise, SG did squat exercise and CoN did not apply any exercise. The exclusion in this study is history of ACL damage, knee damage or surgical experience. The physical characteristics of the subjects are shown in [Table 1]. This study was conducted with the approval of the Sun moon University Research by the Institutional Review Board at Sun moon University Research Ethnics Board(SM-201904-029-1).

Table 1: General characteristics of the subject (n=30)

Characteristic	Values
Gender(female)	30
Age(yr)	39.65±2.92
Height(cm)	159.26±0.75
Weight(kg)	55.87±1.26

2.2. *Experimental procedures*

In this study, Inbody 570 (Biospace, Korea) was used to measure the general characteristics of the subject and an EMG (OQUS100 Zero WIRE EMG, Noraxon) was performed to measure the target's muscles. All parts of the targeted muscles were active while measuring the groups, and the measured region was performed, where it was conducted in the previous study. Total seven muscles, vastus medialis oblique (VMO), vastus lateralis oblique (VLO), rectus femoris (RF), tibialis anterior (TA), tensor fasciae latae (TFL), gastrocnemius (GCM), and biceps femoris (BF), of all participants were measured. For objectivity of the measured values, each participant was measured 15 times, determining the mean of measured values as the final value of the muscle. After the measurement, muscle activity was assessed.

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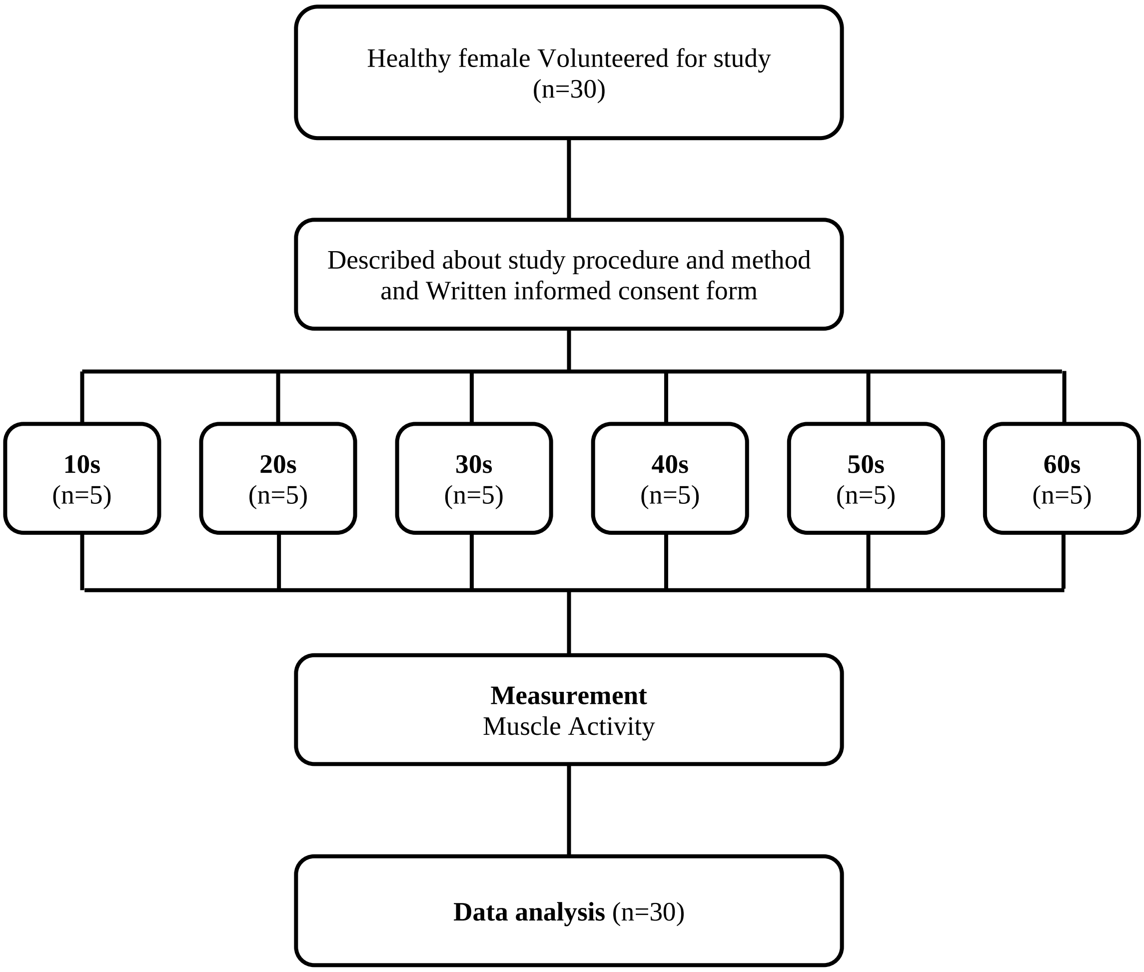

Figure 1. Experiment protocol flow chart

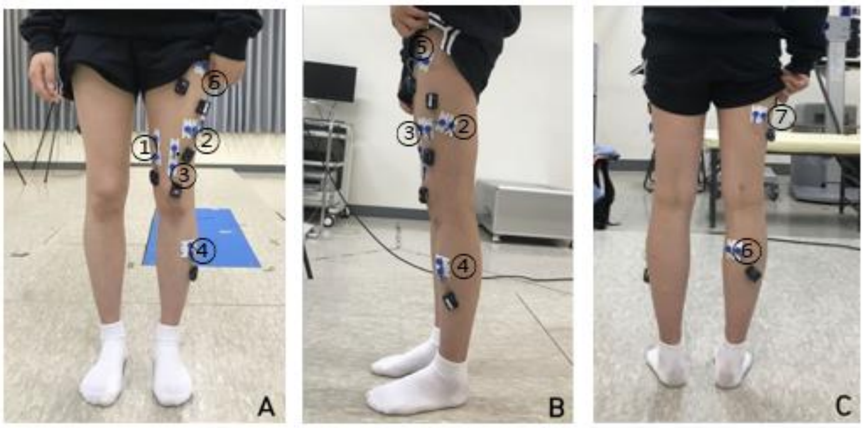

Figure 2. The attached location of EMG A : Anterior, B : Side, C : Posterior

(1) VMO, (2) VLO, (3) RF, (4) TA, (5) TFL, (6) GCM, (7) BF.

Depending on the type of squats, single leg squat was measured after performing it 15 times with knee in 45 degrees flexion and ankle supported 50~60 degrees on the ground in a straight-line position. The bipedal squat was measured after performing it 15 times with feet wider than the shoulder-width apart, knee in 90 degrees flexion, and ankle supported 70 degrees on the ground. The isometric squat was measured after performing it 15 seconds with feet wider than the shoulder-width apart, knee in 70 degrees flexion, and ankle supported 80 degrees on the ground[Table 2].

In this study, a goniometer was used to measure the range of motion (ROM) of the subject. The knee joint is measured with the head of the fibula as its axis. The ankle joint is measured by fixing parallel to the mid-line of lateral fibula with lateral malleolus as its axis and using the exercise arm parallel to the midline of the fifth metatarsal bone[Figure 3]

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Table 2: Measurement method of squats posture

Type	Measurement	Position
Single leg squat	The single leg squat was measured after performing it 15 times with knee in 45 degrees flexion and ankle supported 50~60 degrees on the ground in a straight-line position.	
Bipedal squat	The bipedal squat was measured after performing it 15 times with feet wider than the shoulder-width apart, knee in 90 degrees flexion, and ankle supported 70 degrees on the ground.	
Isometric squat	The isometric squat was measured after performing it 15 seconds with feet wider than the shoulder-width apart, knee in 70 degrees flexion, and ankle supported 80 degrees on the ground.	

Figure 3. EMG and Goniometer

2.3. *Statistical analysis*

All data measured in this study were analyzed using the SPSS 22.0 version statistical program. The chi-square test was used to verify homogeneity between groups. Two-way-ANOVA was used to identify differences in muscle thickness and angles in the ROM depending on the group, and Bonferroni and Tukey HSD analysis methods were used for post-analysis on differences between groups. The statistical significance level of this study was set at α=0.05.

3. Result

The differences in muscle activity are shown in[Table 3]. In this study, we were able to identify decreased muscle activity as the age increases between 10s and 60s. In VMO, muscle activity changed with age increases between 10s and 60s, and there were significant differences between 10s and those in their 20s, 50s, and 60s; between those in their 20s and 10s, 50s and 60s; and between those in their 30s and 40s, 50s and 60s (p<.05). The difference in muscle activity by squats in VMO was the highest in the SLS.

In VLO, muscle activity changed with age increases between 10s and 60s, and there were significant differences between 10s and those in their 20s, 50s, and 60s; between those in their 20s and 10s, 40s, 50s and 60s; and between those in their 30s and 40s, 50s and 60s (p<.05). The difference in muscle activity by squats in VLO was the highest in the SLS.

In RF, muscle activity changed with age increases between 10s and 60s, and there were no significant differences between 10s and those in their 30s; as well as those in their 40s and 50s and 60s (p>.05). The difference in muscle activity by squats in RF was the highest in the SLS.

In TFL, muscle activity decreased with age increases between 10s and 60s, but no significant differences were found (p>.05). For the difference in muscle activity by squats in TFL, SLS and BPS showed a significant difference (p>.05), and SLS was the highest in value.

In TA, muscle activity decreased with age increases between 10s and 60s, and there were significant differences between 10s and those in their 60s; those in their 20s and 40s and 60s; and those in their 30s and 40s and 60s (p<.05). For the difference in

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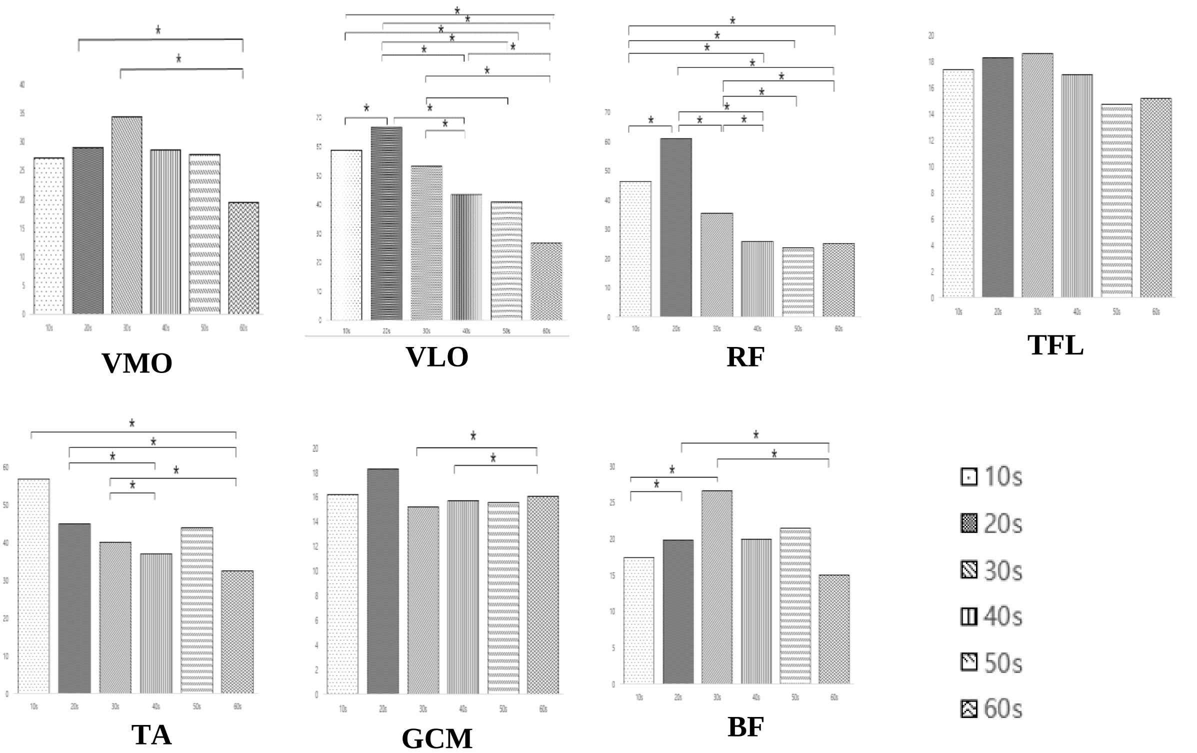
muscle activity by squats in TA, there were significant differences between SLS, BPS, and ISO (p>.05), and SLS was the highest in value while ISO was the lowest.

In GCM, muscle activity changed with age increases between 10s and 60s, and there were significant differences between those in their 60s and 30s and 40s (p<.05). The difference in muscle activity by squats in GCM was the highest in the SLS.

In BF, muscle activity changed with age increases between 10s and 60s, and there were significant differences between those in their 60s and 20s and 30s; as well as the 10s and those in their 20s and 30s (p<.05). For the difference in muscle activity by squats in BF, there were significant differences between SLS, BPS, and ISO (p>.05), and SLS was the highest in value while ISO was the lowest[Figure 4, Figure 5, Figure 6].



VMO:Vastus medialis oblique, VLO:Vastus lateralis oblique, RF:Rectus femoris, TFL:Tensor fasciae latae, TA:Tibialis anterior, GCM:Gastrocnemius, BF:Biceps femoris

Figure 4. Muscle activity multiple comparisons (BPS, 10s-each age group)

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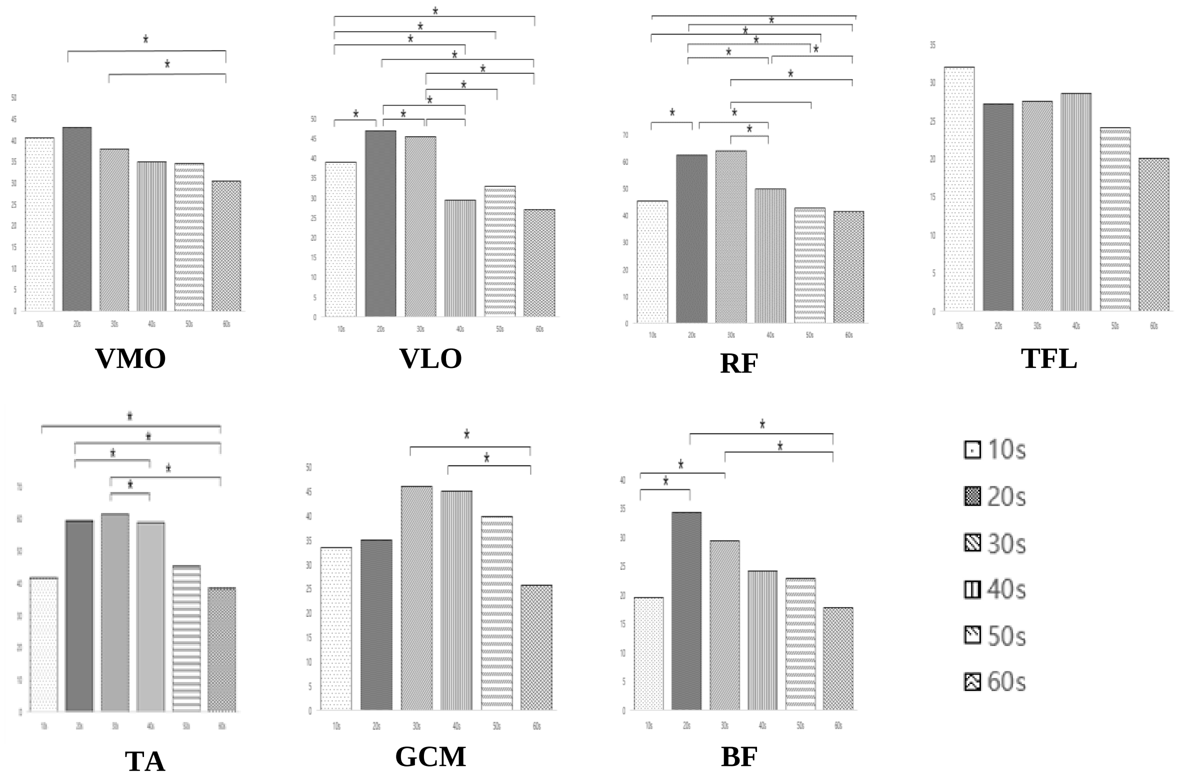
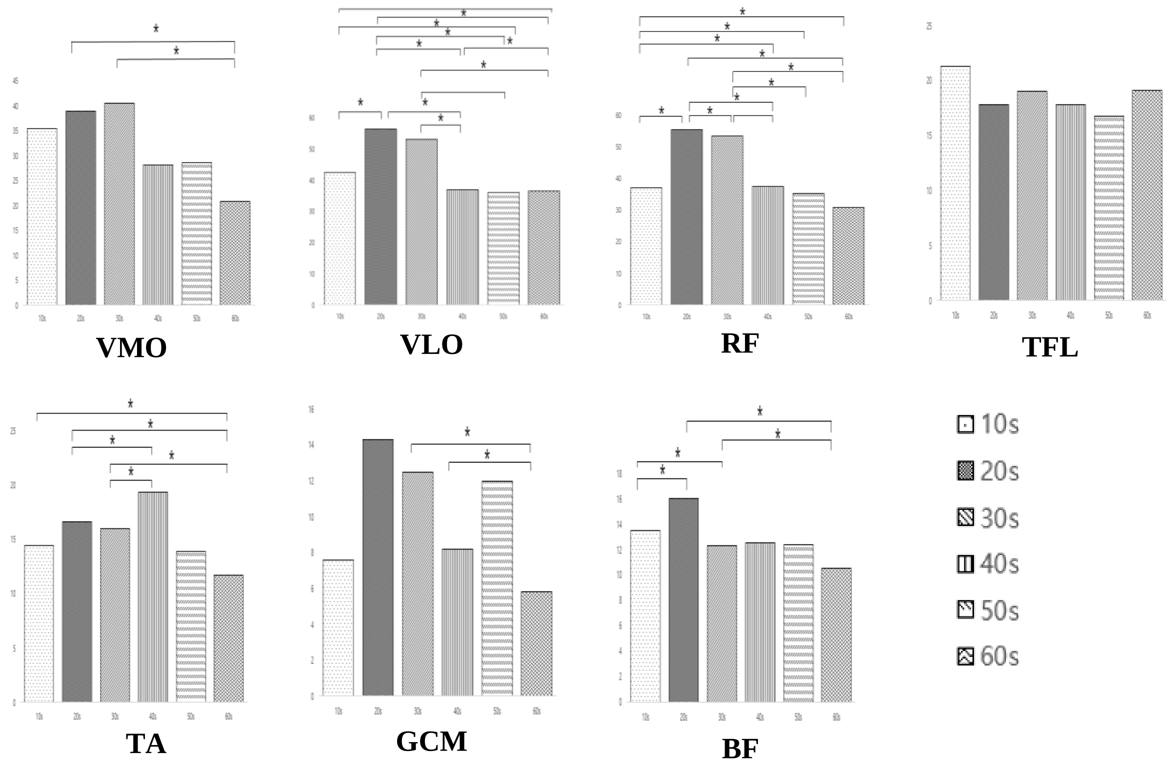


VMO:Vastus medialis oblique, VLO:Vastus lateralis oblique, RF:Rectus femoris, TFL:Tensor fasciae latae, TA:Tibialis anterior, GCM:Gastrocnemius, BF:Biceps femoris

Figure 5. Muscle activity multiple comparisons (SLS, 10s-each age group)



VMO:Vastus medialis oblique, VLO:Vastus lateralis oblique, RF:Rectus femoris, TFL:Tensor fasciae latae, TA:Tibialis anterior, GCM:Gastrocnemius, BF:Biceps femoris

Figure 6. Muscle activity multiple comparisons (ISO, 10s-each age group)

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Table 3: Lower extremity according to age and squat methods

Muscle	Type	10s	20s	30s	40s	50s	60s	F
VMO	BPS	27.10±11.17	29.04±13.32	34.32±8.26	28.64±5.34	27.84±8.09	19.40±9.20	1.263
	SLS	40.76±18.35	43.13±11.61	37.92±9.78	34.98±22.91	34.60±12.16	30.50±7.91	0.483
	ISO	35.50±11.55	39.02±6.00	40.50±5.43	28.20±5.66	28.70±14.20	20.96±3.33	3.794*
VLO	BPS	58.70±8.11	66.62±7.14	53.40±6.64	43.58±5.31	40.90±10.29	26.90±6.96	17.545*
	SLS	45.44±3.28	62.62±4.99	64.06±7.47	49.94±7.28	42.94±10.76	41.60±11.16	7.647*
	ISO	42.40±12.98	56.40±5.47	53.28±8.01	37.02±8.73	36.02±4.01	36.58±3.65	6.656*
RF	BPS	46.46±15.30	61.12±7.81	35.64±9.31	26.02±5.73	23.82±6.25	25.28±6.89	13.189*
	SLS	37.12±3.76	55.44±3.99	53.32±4.89	37.52±8.31	35.28±6.48	30.94±10.27	11.509*
	ISO	39.08±10.40	46.90±7.27	45.54±8.19	29.46±7.50	33.06±4.43	27.18±3.88	6.461*
TFL	BPS	17.46±4.70	18.30±11.62	18.64±5.18	17.08±3.01	14.78±5.12	15.20±3.97	0.323
	SLS	32.08±8.10	27.20±7.27	27.66±3.64	28.64±6.49	24.16±4.73	20.16±5.41	2.207
	ISO	21.34±6.30	17.82±2.96	19.04±2.73	17.80±3.81	16.86±5.44	19.12±4.71	0.598
TA	BPS	56.82±9.78	45.00±5.54	40.12±5.80	26.28±7.53	43.98±8.68	32.68±12.97	4.643*
	SLS	41.66±11.07	59.42±4.77	61.66±4.87	46.78±9.84	45.30±10.71	38.68±11.28	7.158*
	ISO	14.46±6.12	16.68±7.64	16.07±7.00	13.64±10.54	13.91±5.12	11.76±3.50	0.943
GCM	BPS	16.21±5.82	18.30±6.70	15.20±6.44	15.78±7.38	15.61±4.91	16.18±4.56	0.161
	SLS	33.62±6.51	35.06±8.87	46.12±3.80	45.12±10.39	39.80±8.08	25.70±12.43	3.853*
	ISO	7.60±2.47	14.32±4.69	12.56±3.47	8.18±2.44	12.06±2.44	5.88±4.25	4.727*
BF	BPS	17.44±4.85	19.94±7.25	26.62±7.99	20.06±6.89	21.54±4.41	15.08±3.85	2.077
	SLS	19.60±3.45	34.36±4.95	29.44±5.73	24.18±6.44	22.98±4.20	17.92±2.32	8.542*
	ISO	13.52±5.77	16.00±4.06	12.38±3.85	12.56±4.46	12.40±4.36	10.52±3.31	0.852

*p<.05, mean ± standard deviation, VLO: Vastus lateralis oblique, VMO: Vastus medialis oblique, RF: Rectus femoris, TFL: Tensor fasciae latae, TA: Tibialis anterior, GCM: Gastrocnemius, BF: Biceps femoris
BPS: Bipedal squat, SLS: Single leg squat, ISO: Isometric squat

4.Discussion

This study was conducted on 30 healthy women aged between 10s and 60s to see the difference in muscle activity of seven lower extremity, VMO, VLO, RF, TFL, TA, GCM and BF, according to the squat posture and method during the three types of squats exercise by measuring their muscle activity using the EMG.

With respect to bipedal squats, McCurdy et al. reported higher activity in quadriceps femoris during single leg squat[12]. Squats do not obstruct the stability of the knee and can improve stability if performed properly. They can be effective for the hip joint, knee, and ankle muscle development because they produce moderate to high limb and hamstring activation while squatting down. In a lower position, the contribution of the foot, not the posture, leads to less hip flexion, resulting in the correct trunk position, reducing the activation of the hamstring. It has also been proven that parallel squats are not harmful to healthy knee[13]. Previous studies have shown the highest consistency was between 40 Hz and 60 Hz during BPS, SLS, and ISO. In ISO, peak consistency

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occurred at higher frequencies[6]. Therefore, we believe that ISO is effective in improving muscle endurance, given the occurrence of peak consistency.

The study of Schwanbeck et al. tried to determine whether the free weights or Smith machine squats were optimal for activating the main moving devices of the legs and trunk. The free weight squats were significantly higher in the GCM, BF, and VMO, compared to the Smith machine squats. The EMG mean for all muscles during the free weight squats was 43% higher compared to the Smith machine squats (p<.05). Free weight squats may be more advantageous than Smith's machine squats for individuals who are trying to strengthen the plantar flexion, the knee flexor, and the knee extensor[14].

This study compared the differences in muscle activities between the seven muscles among groups of different ages during the three squat exercises. VLO showed significant differences between the three squats and by age differences. VMO did not differ significantly from each other in terms of squats, and they also showed little differences by age. There was no significant difference between squats in RF, but a significant difference between ages. TFL showed significant differences between squats but no significant differences among age groups, while TA showed significant differences between both the squats and the age groups. GCM showed no significant difference between squats and significant differences in SLS by age. Neither squats nor age groups in BF displayed significant differences. Significant differences in muscle activity in these studies show that muscles decrease with age. Sarcopenia is defined as the degradation of mass and function in muscle strength due to aging and key symptoms share the characteristics of falls and fractures, including obesity, gait movement disorders, lack of muscle strength, and difficulty breathing[15]. There was a big difference in muscle thickness between young and older women in terms of sarcopenia from aging. In particular, the muscle thickness of the lower extremity including gluteus maximus, gluteus medius, gluteus minimus, psoas major, RF, VLO, VMO, BF and GCM, was significantly greater in younger groups than in older groups[16]. This is considered to be the reason why people of higher age showed low muscle activity in all postures in this study.

Quadriceps femoris refers to a group of four muscles on the anterior of the vastus, which consists of VMO, VLO, vastus intermedius and RF[17]. VMO contributes to the stability of the sliding patellar when passing through the intertubercular groove on the femur[18]. RF is on the very surface of all quadriceps femoris, and it is relevant to the flexion of the hip joint as well as the extension of the knee joint[19]. Since the RF is the only two joint muscle of the quadriceps femoris, they are the most commonly injured muscles in the quadriceps femoris, and the pathology is commonly found in short-distance races, post-jumping landings, and kicks, and is primarily related to the muscle-tendon junction[19,20]. RF plays an important role in walking or standing position as the agonist for the knee extension[21]. Impairment in stability and balance of the muscles supporting the knees can cause a reduction in contact areas of the VMO and VLO as well as the imbalance of the patellar, which can lead to various diseases[22]. Thus, in this study, we observed more activation in quadriceps femoris to compensate for the tibialis anterior after the 50s, which results in lower-cross syndrome(LCS). Lower-cross syndrome results in the rigidity of the hip joint flexor and the erector spinae, and inhibition and weakening of the gluteus and abdominal muscles[23]. LCS is also called distal or pelvic crossed syndrome. In the LCS, the thoracic and vertebral extensors are crossed with iliopsoas and RF, and weakness in deep abdominal is crossed with the weakness in gluteus maximus and gluteus medius. These unbalanced patterns include the anterior tilt of the pelvis, scoliosis, external rotation of leg, and hyper-extension. This pattern also displays an imbalance in the trunk muscles[24]. In this study, VLO showed a significant difference in muscle activity by age. Therefore, single leg squats can be an efficient way to increase the muscle activity of VLO at all ages. In the case of VMO, there was no significant difference between the squats by age. Thus the three squats cannot be a way to increase the muscle activity of the VMO. In the case of RF, there was a significant difference in muscle activity by age, so single leg squats and isometric squats can be an efficient way to increase muscle activity of leg muscles. For selective increase of RF muscle activity, isometric squats can be a more efficient method than the single leg squats.

TFL decreased with age, but no significant difference between age groups was found. As it is connected to the iliotibial band, it acts as a tendon and shows less muscle decrease. Women demonstrate relatively small abduction in the hip joints during squats, so the use of TFL is small, and we reckon the lack of hip abduction exercise in various age groups. Previous studies identified that single leg wall squat has a higher percentage of muscle activity in TFL than in a typical SLS[25]. Thus, this study acknowledges that the highest value can be found in SLS, concluding that SLS is an effective exercise method when compared with other squats.

TA refers to the muscles located in the anterior of the tibia. TA is one of the important muscles responsible for balance and a decrease in tibialis anterior results in a significant increase in the risk of falling[26]. Previous studies have shown that aging increases balance disorders and increases the risk of falling by mistake in elders, while at the same time insisting that continued physical and sports activities are efficient to improve balance control[27]. Therefore, this study considers this as the reason for low muscle activity in the TA. Thus, after checking the results of this study and the results of the previous studies, and obtained that Single leg squat can be an efficient way to improve muscle activity and balance of TA with increasing age[28].

Previous studies have shown that the contraction of the plantar flexion muscle during squats is characterized to display significantly slower torque production in an elderly group compared to young women and that the aging plantar flexion muscles have impaired their ability to produce stabilization torque for the ankle joint[29]. In the case of gastrocnemius, the significant difference between those in their 30s and their 40s and 20s is relevant to the decreased muscle activity due to the activation of quadriceps femoris in compensation for a decrease in the plantar flexion as the age increases. As a result, previous studies have confirmed that SLS is BPS more effective for muscle enhancement of TA and GCM[28]. As with the results of this study, SLS can be an efficient way to strengthen the muscle strength of GCM, which has a significant influence on the stabilization of the ankle joint, and ISO can be an efficient way to strengthen the muscle strength of GCM because it shows a significantly lower value compared to the other squats.

The hamstring is composed of biceps femoris, semimembranosus, and semitendinosus. Most of the muscles in the hamstring, which starts from the pelvis, extending backward along the length of the femur, crosses striation and knee joint[30]. The hamstring muscle group plays a prominent role in the hip joint extension (anterior movement of the femur) and knee flexion (anterior movement of the tibia and the fibula). With respect to the gait cycle [32], hamstring starts at the final 25% of the swing phase, producing resistance in the hip and exerting resistance in the knee. The hamstring also plays an essential role as a mechanical stabilizer for the knee joints. The hamstring, which works with the anterior cruciate ligament, resists the anterior translation of tibia at the heel-off stage of the gait cycle[31]. In this study, the muscle activity varies with age in the case of biceps femoris in the hamstring muscles. Therefore, a single leg squat can be an efficient way to improve muscle activity of biceps femoris and knee stability.

This study has several limitations. First, since each group organized by age from 10s to 60 was comprised of only five healthy women, it is difficult to generalize the result to typical patients or all age groups. Second, the same results may not appear in men because the experiment targeted only women. Third, it cannot be generalized to people whose use of muscles has changed due to illness. Fourth, since measurements were made only with the dominant side legs, the same results may not be seen on the non-dominant side legs. Fifth, it is believed that long-term research on the comparison of muscle activity will be necessary for the future since the study was conducted for a fairly short period of time.

4. Conclusion

This study selected 30 women from age 10s to 60s without musculoskeletal diseases and pain, to measure the muscle activity in seven lower extremity, including VMO, VLO, RF, TFL, TA, GCM and BF, while conducting three types of squats. The study has reached the following conclusions: Measuring the muscle activity of the three squat exercises SLS, BPS, and ISO resulted in significant differences between the squats, and the value was significantly higher in SLS. Measuring the muscle activity between people in their 10s and 60s by age group indicated a value higher than average for those in their 20s and 30s. and a lower activity for those in their 50s. There were differences between muscles, VLO, VMO, RF, TFL, TA, GCM and BF. As a result, muscle strength decreases as age increases, resulting in an unbalanced pattern by using the quadriceps femoris to compensate for TA during squats. Therefore, simultaneous effort in strengthening muscles for both hamstring and GCM is suggested.

6. References

1. An M, Shaughnessy M. The effects of exercise-based rehabilitation on balance and gait for stroke patients. J Neurosci Nurs. 2011 Dec;43(6): 298-307. DOI:10.1097/JNN.0b013e318234ea24.
2. Karsten K, Engelhardt M. Strength and muscle mass loss with aging process. Age and strength loss. muscles ligaments tendons J. 2014. 24(4), 346–50.
3. Nijholt W, Scafoglieri A, Harriet JW, Johannes SM, Cees P. The reliability and validity of ultrasound to quantify muscles in older adults: a systematic review. J cachexia sarcopenia muscle. 2018 Oct;8(5): 702-12. DOI:10.1002/jcsm.12210.
4. Lorenzetti S, Ostermann M, Zeidler F, Zimmer P, Jentsch L, List R, et al. How to squat? Effects of various stance widths, foot placement angles and level of experience on knee, hip and trunk motion and loading. BMC Sports Sci Med Rehabil. 2018 Jul;10(14). DOI:10.1186/s13102-018-0103-7.
5. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. J Stength Cond Res. 2010 Dec;24(12):3497-506. DOI:10.1519/JSC.0b013e3181bac2d7.
6. Mohr M, Nann M, Tscharner EB, Nigg BM. Task-dependent intermuscular motor unit synchronization between medial and lateral vastii muscles during dynamic and isometric squats. PLoS One. 2015 Nov;10(11). DOI:10.1371/journl.pone.0142048.
7. Marchetti PH, Jarbas SJ, Jon SB, Nardi PS, Pecoraro SL, et al. Muscle activation differs between three different knee joint-angle positions during a maximal isometric back squat exercise. J Sports Med. 2016 Jul;6. DOI:10.1155/3846123.
8. Kim HH, Song CH. Effects of knee and foot position on EMG activity and ratio of the vastus medialis oblique and vastus lateralis during squat exercise. J mus joint health. 2010 Oct;17(2):142-50. DOI:10.5953/JMJH.2010.17.2.142.
9. Pesta D, Thaler A, Hoppel F, Macek C, Schocke M, Burtscher M. Effects of a 10-week conventional strength training program on lower leg muscle performance in adolescent boys compared to adults. J Sports Med Phys Fitness. 2014 Dec;43(6): 298-307. DOI:10.1097/JNN.0b013e318234ea24.
10. Haramura M, Takai Y, Yoshimoto T, Yamamoto M, Kanehisa H. Cardiorespiratory and metabolic responses to body mass-based squat exercise in young men. J Physiol Anthropol. 2017 Feb;36(1). DOI:10.1186/s40101-017-0127-9.
11. Mcneil CJ, Doherty TJ, Stashuk DW, Rice CL. Motor unit number estimates in the tibialis anterior muscle of young, old, and very old men. Muscle Nerve. 2005 Apr;31(4):461-7. DOI:10.1002/mus.20276.
12. Mccurdy K, O’Kelley E, Kutz M, Langford G, Ernest J, Torres M. Comparison of lower extremity EMG between the 2-leg squat and modified single-leg squat in female athletes. J sport rehabil. 2010 Feb;19(1):57-70. DOI:10.1123/jsr.19.1.57.
13. Escamilla RF. Knee biomechanics of the dynamic squat exercise. Med Sci Exerc. 2010. Jan;33(1):127-41.
14. Schwanbeck S, Chilibeck PD, Binsted G. A comparison of free weight squat to smith machine squat using electromyography. J Strength Cond Res. 2009 Dec;23(9):2588-91. DOI:10.1519/JSC.0b013e3181b1b181.
15. McNeil CJ, Doherty TJ, Stashuk DW., Rice CL. Motor unit number estimates in the tibialis anterior muscle of young,

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 895 - 904
Received 15 December 2020; Accepted 05 January 2021.

old, and very old men. Muscle Nerve. 2005 Apr;31(4):461-7. DOI:10.1002/mus.20276.

16. Abe T, Sakamaki M, Yasuda T, Bemben MG, Kondo M, Kawakami Y, et al. Age-related, site-specific muscle loss in 1507 Japanese men and women aged 20 to 95 years. J Sports Sci Med. 2011 Mar; 10(1):145-50.
17. Lieb Fj, Perry J. Quadriceps function. An anatomical and mechanical study using amputated limbs. J Bone Joint Surg Am. 1968 Dec;50(8):1535-48.
18. Irish SE, Millward AJ, Wride J, Haas BH, Shum GL. The effect of closed-kinetic chain exercises and open-kinetic chain exercise on the muscle activity of vastus medialis oblique and vastus lateralis. J Strength Cond Res. 2010 May;24(5):1256-62. DOI:10.1519/JSC.0b013e3181cf749f.
19. Pesquer L, Poussange N, Sonnery CB, Graveleau N, Meyer P, Dallaudiere B, et al. Imaging of rectus femoris proximal tendinopathies. Skeletal Radiol. 2016 Jul;45(7):889-97. DOI:10.1007/s00256-016-2345-3
20. Hughes C, Hasselman CT, Best TM, Martinez S, Garrett S. Incomplete, intrasubstance strain injuries of the rectus femoris muscle. Am J sports Med. 1995 Jul-Aug;23(4):500-6. DOI:10.1177/036354659502300422.
21. Grabiner MD, Koh TJ, Draganich LF. Neuromechanics of the patellofemoral joint. Med sci sports Exerc. 1994 Jan;26(1):10-21.
22. Fitzgerald GK. Open versus closed kinetic chain exercise: issues in rehabilitation after anterior cruciate ligament reconstructive surgery. Phys Ther. 1997 Dec;77(12):1747-54 DOI:10.1093/pti/77.12.1747.
23. Tang SF, Chen CK, Hsu R, Chou SW, Hong WH, Lew HL. Vastus medialis obliquus and vastus lateralis activity in open and closed kinetic chain exercises in patients with patellofemoral pain syndrome: an electromyographic study. Arch Phys Med Rehabil, 2001 Oct;82(10):1441-5. DOI:10.1053/apmr.2001.26252.
24. Mendiguchia J, Alentorn-Geli E, Idoate F, Myer GD. Rectus femoris muscle injuries in football: a clinically relevant review of mechanisms of injury, risk factors and preventive strategies. Br J Sports Med. 2013 Apr;47(6):359-66. DOI:10.1136/bjsports-2012-091250.
25. Han HR, Yi CH, You SH, Cynn HS, Lim OB, Son JI. Comparative effects of 4 single-leg squat exercises in subjects with gluteus medius weakness. J Sport Rehabil. 2018 Nov;27(6):513-9. DOI:10.1123/jsr.2016-0193.
26. Chris J, Mcneil BS, Timothy J, Doherty MD, Daniel W. Stashuk P, et al. Motor unit number estimates in the tibialis anterior muscle of young, old, and very old men. Muscle Nerve. 2005 Apr;31(4):461-7. DOI:10.1002/mus.20276.
27. Perrin PP, Gauchard GC, Perrot C, Jeandel C. Effects of physical and sporting activities on balance control in elderly people. Br J Sports Med. 1999 Apr;33(2):112-6. DOI:10.1136/bjsm.33.2.121.
28. Vandervoort AA, Hayes KC. Plantarflexor muscle function in young and elderly women. Eur J Appl Physiol. 1989 Jan;58(4):389-394. DOI:10.1007/BF00643514.
29. Reeder A. Ankle muscle activation during unilateral and bilateral lower body strength exercise. 2014 May.
30. Rodgers CD, Raja A. Anatomy, bony pelvis and lower limb, hamstring muscle. StatPearls, 2019 Sep;3.
31. Koulouris G, Connell D. Hamstring muscle complex: an imaging review. Radiographics, 2005 May;25(3):571-86. DOI:10.1148/rg.253045711.
32. Bhoi, A. K. (2017). Classification and Clustering of Parkinson's and Healthy Control Gait Dynamics Using LDA and K-means. International Journal Bioautomation, 21(1).