

A Study on the Selective Strengthening Exercise of the Quadriceps Muscle According to Various Squat Types

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Abstract

Background/Objectives: The purpose of this study was to identify the highest activation in Vastus Medialis (VMO), Vastus Lateralis (VL) and Rectus Femoris (RF) while performing various squat exercises to create an effective exercising method.

Method/Statistical Analysis: 40 healthy subjects (males 23, females 17) from S University were recruited. Subjects performed four different types of squats; General Squats (GS), Instability Squats on an unstable surface (IS), Knee Adduction Squats (KAS), and Wall squats (WS). The difference in the activation of VMO, VLO and RF were recorded during the various exercises were analyzed and recorded with the EMG.

Findings: Measurements of all the experiments were analyzed using one-way ANOVA. Within these results, RF showed the most activation during (WS) and the least activation during (KAS). However, there were no significant differences found between (GS) and (IS). VLO showed the most activation during (GS). On the other hand, there were no significant differences found within (IS) and (WS). In addition to our results, VMO showed the least activation during (KAS). All three muscles displayed different activation patterns during each squat exercise.

Improvements/Applications: Considering these findings, this study may help to design a more effective exercise for specific muscles when strengthening the leg muscles.

Keywords: Weight bearing exercise, Various squat, Base of support, Muscle activity, Selective Quadriceps.

Introduction

Modern science has made life convenient, but it has caused a decrease of activities resulting in an increase of health problems^[1]. Squat is the most commonly used^[2] and the best exercise for the quadriceps because it requires more movement of the joint than weightless exercises. It also stimulates the senses, functional

pattern of muscle recruitment^[3] and it equally applies force to the buttocks, thighs, and calf muscles and the trunk muscles^[4]. Closed chain movement, such as squat, is less prone to shear force due to increased compression of the femoral joint and co-contraction of the quadriceps and hamstring^[5]. It is said that it is important to keep the tibia perpendicular to the floor in order to avoid sprains^[6] and certain amount of anterior displacement in the knee can prevent excessive stress and back pain^[7].

The quadriceps play the most important role in lifting body weight^[8] and exercises that activate the quadriceps help prevent injuries. When weakened, it reduces walking speed, balance and increases the risk of knee osteoarthritis^[9-11]. It is suggested that atherapeutic approach should be developed to optimize the function of the quadriceps before muscle reintegration^[12].

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There are various method in performing the squatting exercise. Squatting on an unstable surface enhances postural orientation^[13], improve balance, and motor control while activating core muscles^[14-15]. It is also suitable for those who need to have low level training^[16-17].

Based on the anatomy that the VMO muscle reaches the distal part of Adductor Magnus^[18], it has been shown that VMO activation can be selectively obtained and strengthened through hip adduction^[19-20].

Muscle strengthening of the quadriceps through squat is considered functional because it promotes muscle mobilization, and stimulates the proprioceptive sensation^[21]. Squat has been extensively used in clinical practice but the effectiveness of the patient’s posture has not been clearly differentiated.^[22] In this study, we investigated which muscles were most active in various squats so we can design a more effective exercising method.

Method

1. Participants: [Table 1] 40 healthy adult men and women in Asan, South Chungcheong Province who did not have any musculoskeletal or any neurological diseases during the last 6 months were selected as the subjects for this study. Before participating in this study, subjects were sufficiently informed about the content and purpose of the study and filled out consent forms. This study was conducted with the approval of the Institutional Bioethics Committee of Sun Moon University (SM-201805-036-2). shows the general characteristics of the subjects. All values are mean±standard deviation

Table 1. General Characteristics (N = 40)

Types	Mean
Sex (M/F)	23/17
Age (Years)	20.8±1.43
Height (cm)	168.3±9.2

2. Procedures: [Table 2] The purpose of this study was to compare the muscle activity of RF, VLO, VMO of 40 healthy subjects according to the four types of squat exercises; General squat(GS), squats on an unstable surface(IS), squats with a ball between the knees(KAS), and wall squats with a swiss ball against their back(WS). The squat types differed between stable or unstable surfaces, knee adduction, knee abduction, and walls. Before exercise, the body

weight and height of the subjects were measured by a body composition analyzer then the subjects did warm up for 5 minutes. The squat experiment was performed after attaching the measuring pad to the location of the RF muscle, VLO muscle, and VMO muscle. During the squat, the legs were spread shoulder width with the subject facing forward. Each exercises were held in the respective order and was held for 10 seconds; GS, IS KAS, WS. The subjects took a 5-minute break upon completing each exercise. All of the squat types except the GS were guided multiple times and there was constant feedback in order to maintain the correct posture. All squat exercises were performed by bending the knee at 90° and the flexion angle was measured using a digital goniometer. [Figure 1, 2].

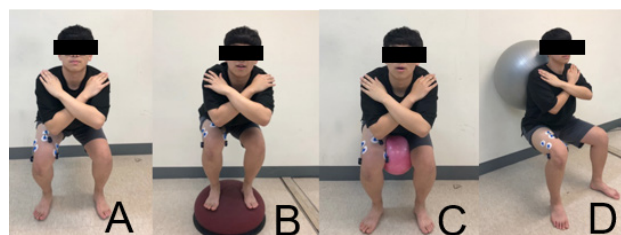


Figure 1. Types of Squats (A:General Squat, B: Instability Squat, C:Knee Adduction Squat, D: Wall Squat)

3. Measurement: In this study, EMG QUS100 (Zero wire EMG, Italy, 2009) was used to measure the muscle activity of the RF muscle, the VLO muscle, and the VMO muscle while the subjects were performing the experiment. Surface EMG, which evaluates the function of the bony muscle, can be used to electrophysiologically analyze the kinetic activity of each muscle.^[22] The pad of the VLO was attached laterally 55° and 10cm above the knee, and the VMO was attached medially 55° and 4 cm above the knee^[19]. In order to reduce the skin resistance of the electromyographic pads, the attachment site was depilated.

4. Statistical Analysis Result: [Figure 2] For data analysis, the SPSS/PC ver 22.0 for windows program was used. One-way ANOVA was used to compare the muscle activity of each exercise group. All study results were subjected to a post-test least significant difference (LSD) test, and all statistical significance levels were set at p <.05. The root mean square (RMS) value of the EMG was measured and the filtering bandwidth was 20 ~ 450Hz. And a 60Hz notch filter was used to reduce the static.

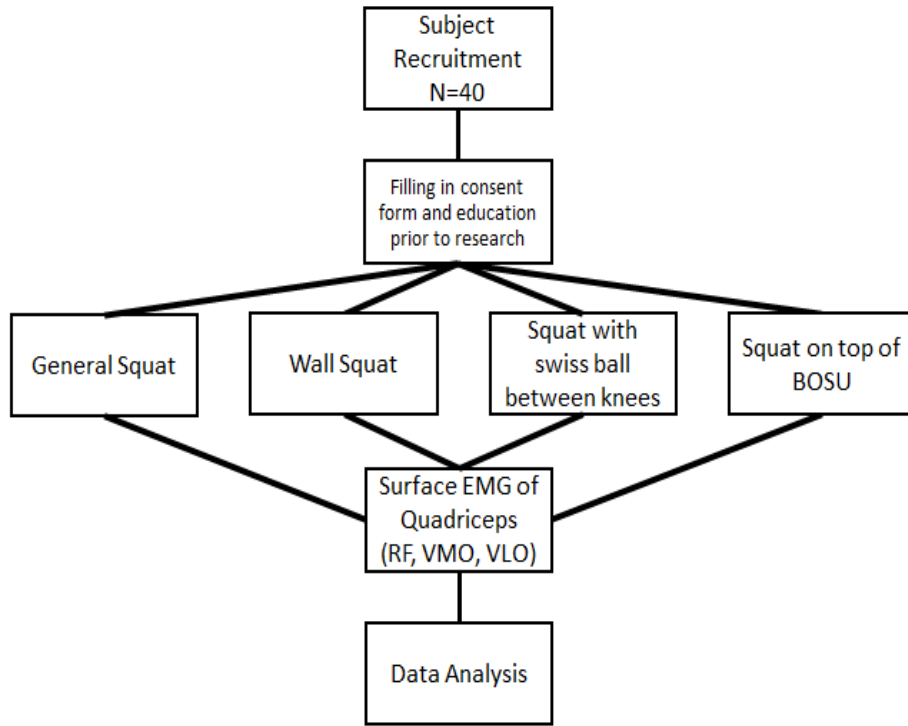


Figure 2. Flow diagram of experimental protocol

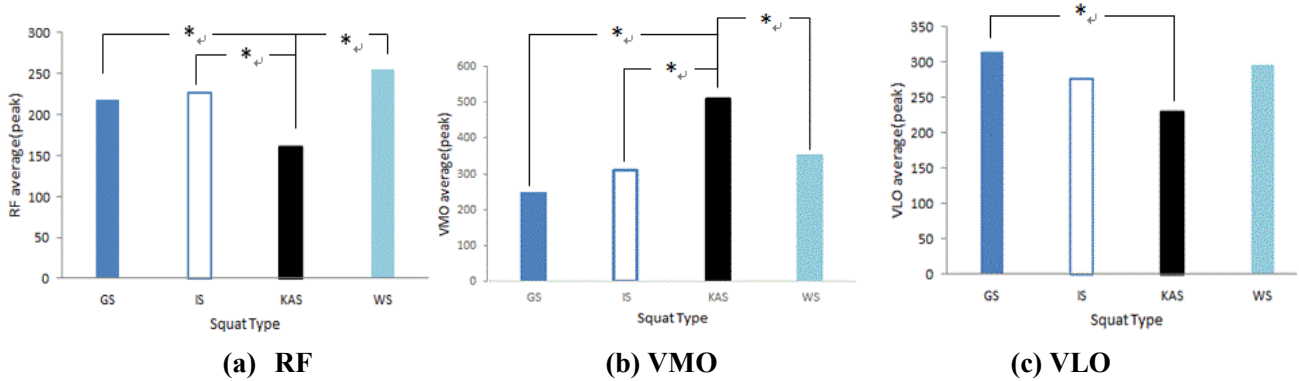


Figure 3. Muscle activation average according to type of squats for RF, VMO, VLO

Table 2. Types of Squat

Type	Squatting on a stable surface
GS	Squatting on an unstable surface
IS	Squatting on an unstable surface
KAS	Squatting while inducing knee adduction
WS	Wall squatting while leaning against a ball

GS: General Squats, IS: Instability Squats on an unstable surface, KAS: Knee Adduction Squats, WS: Wall squats.

Result

Changes in muscle activity according to the squat type were significantly different in some muscles.

- 1. RF activation average according to types of squat:** [Table 3] In the RF, when comparing the results of GS (133.92±21.18) and IS (93.54±14.79), GS and WS (183.24±28.97), IS and KAS (41.45±6.55), IS and WS, and finally, KAS and WS, there was no significant difference (p>.05). However, when comparing KAS to every squat there was a significant difference (p<.05). Considering these findings, GS, IS and WS produced the most activation within RF [Figure3 (a)].
- 2. VMO activation average according to types of squat:** [Table 3] In the VMO, when comparing the

results of GS (104.14±16.47) and IS (168.22±26.60), GS and WS (153.61±24.29), IS and WS, WS and GS, there was no significant difference ($p>.05$). However, when comparing KAS (70.68±11.18) and GS, and other squats, significant differences were found ($p<.05$). Due to these results, we have concluded that the KAS (70.68±11.18) showed the most activation in the VMO [Figure 3 (b)].

3. VLO activation average according to types of squat: [Table 3] In the VLO, when comparing the results of GS(88.67±14.02) and IS(160.01±25.30), GS and WS(195.90±30.97), IS and KAS(96.58±15.27), IS and WS, KAS and WS, there was no significant difference ($p>.05$). However, when comparing GS and KAS, there was a significant difference ($p<.05$).

Therefore, it was concluded that GS produced the most activation in the VLO [Figure 3 (c)].

Table 3. Quadriceps muscle activation according to types of squats (RMS)

Muscle	Squat Type I J		I-J	F	p
RF	GS	IS	4.34	-6.99	1.00
		KAS		67.07*	.02
		WS		-27.55	.97
	IS	GS		6.99	1.00
		KAS		74.05*	.00
		WS		-20.57	.99
	KAS	GS		-67.07*	.02
		IS		-74.05*	.00
		WS		-94.62*	.02
	WS	GS		27.55	.97
		IS		20.57	.99
		KAS		94.62*	.02
VMO	GS	IS	34.34	-75.73	.10
		KAS		-274.39*	.00
		WS		-48.87	.46
	IS	GS		75.73	.10
		KAS		-198.66*	.00
		WS		26.86	.97
	KAS	GS		274.39*	.00
		IS		198.66	.00
		WS		225.52*	.00
	WS	GS		48.87	.46
		IS		-26.86	.97
		KAS		-225.52*	.00

Muscle	Squat Type I J		I-J	F	p
VLO	GS	IS	2.38	31.72	.85
		KAS		79.56*	.00
		WS		13.59	.10
	IS	GS		-31.72	.85
		KAS		47.85	.50
		WS		-18.12	.10
	KAS	GS		-79.56*	.00
		IS		-47.85	.50
		WS		-65.97	.31
	WS	GS		-13.59	.10
		IS		18.12	.10
		KAS		65.97	.31

* $p<.05$ Mean±standard deviation, RF (Rectus Femoris), VMO (Vastus Medialis Oblique), VLO (Vastus Lateralis Oblique), GS (General Squat), IS (Instability Squat), KAS (Knee Adduction Squat), WS (Wall Squat).

Discussion

The purpose of this study was to investigate the differences in muscle activity of the RF, the VMO muscle, and the VLO muscle while performing GS, IS, KAS, and WS. Blanpied suggested that the quadriceps were required to assist the hip joint during squatting^[23]. The VMO is physiologically the weakest muscular muscle^[24] and is active during knee stabilization, knee extension and lateral movement^[25]. VMO is the first to exhibit atrophy; once weakened, it can cause an imbalance in the muscles and increase the lateral movement of the knee^[26-28] which results in various diseases^[29]. Therefore, for the purpose of this study, it was necessary to know the ratio of the muscle activity of the VMO, the VLO, and RF muscle.

There were significant differences in some muscles according to each squat type. For the RF. there was a significant difference in KAS with GS, IS, and WS. It can be seen that excluding KAS, the GS, IS, and WS approach are good exercise method for activating the RF muscle. When Shawn R (2010) performed GS body weight shifted to the tip of the toe, indicating that muscle activity was high in the RF^[30]. Nairn (2016) also supported these results by stating that squatting on an unstable support surface resulted in high muscle activity in the RF^[31]. In addition, Felipe (2011) reported that the wall squatting against a swiss ball was effective in producing muscle activity of RF.

In the VMO muscle, there was a significant difference between KAS and GS, KAS and IS, KAS and WS ($p > .05$). respectively. In HyoukHyong (2015) reported that a squat with isometric adduction using a ball was effective in selective activation of VMO^[32], which aligned with our results.

Shawn (2010) reported that there was a significant difference in muscle activity of the VLO muscles during a traditional squat^[30]. Likewise, there was significant difference in GS, IS, WS movement in the RF, and in the muscle of the VMO, the most significant difference was found in the KAS exercise.

This study has some limitations. First, it cannot be generalized to patients and all ages because it is conducted on adults in their 20's. Second, these results were done on a short-term therefore, the results of a long term test is unknown. Third, it was assumed that the signal from EMG was muscle activity. Finally, the subject's fatigue may affect the outcome by repeating the inter-experiment squat.

Conclusion

In order to investigate the muscle activity according to posture, each muscle was compared and analyzed. In the case of the RF muscle, a significant difference was found in all four squat method; GS, KAS, IS, and WS. The most significant difference in the VLO was found in the KAS. Finally, in VMO, there was a significant difference in the GS. Therefore, it was found that the squat type that is most effective for the selective strengthening of the RF is GS and IS WS, and for the VMO, the most effective exercise the KAS. In addition, we found that the maximum activation of the VLO was shown greatest during the GS.

Through the use of these results, we hope to suggest an effective exercise method for the selective muscle strengthening of the RF, VLO and VMO respectively.

Ethical Clearance: Not required

Source of Funding: Self

Conflict of Interest: Nil

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