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Pamukkale J Sport Sci, 14(3), 398-407, 2023 **Research Article**

Muscle Activation During Squat on Different Surfaces

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ABSTRACT

This study aimed to compare the vastus medialis and vastus lateralis muscle activations during squat exercises performed on different surfaces. Recreationally active 14 males (age: 20.43±1.28 years; height: 176.94±6.58 cm; body weight: 72.78±10.72 kg) participated in this study. A ground surface is used as a stable surface, a gymnastics mat and a Bosu ball are used as an unstable surface. Participants performed two sets of squats on three surfaces and ten repetitions of each set. Participants performed squat exercises with their body weight. Muscle activation measurements were made from the vastus medialis and vastus lateralis muscles during the squat movement on each surface. A one-way repeated-measures analysis of variances was used to statistically compare muscle activations between surfaces. As a result of statistical analysis, no significant differences were found in the vastus medialis and vastus lateralis muscle activations between surfaces ($p>0.05$). In conclusion, it was determined that the vastus medialis and vastus lateralis muscle activation in the squat movement was not affected by the stability of the surfaces. Therefore, it can be suggested that the surfaces used in this study can be used interchangeably for vastus medialis (VM) and vastus lateralis (VL) muscle activation in the squat exercise.

INTRODUCTION

Innovative approaches in strength training today increase the quality of resistance training by supporting the use of functional exercises to increase the effectiveness of the muscles comprehensively involved in sports skills. These exercises include gross, fine motor, and balancing movements by involving large and small muscle groups (Cook et al., 2006). Squat exercise is widely used in resistance training to increase lower extremity strength. Squat exercises are commonly performed using body weight, barbell, or machine (Escamilla, 2001). There are many studies examining neuromuscular function in resistance training (Aguilera-Castells et al., 2019; Andersen et al., 2014; Boudreau et al., 2009; Bruhn et al., 2006; Ebben et al., 2009; Ekstrom et al., 2007; Farrokhi et al., 2008; Häkkinen & Komi, 1983; Mausehund et al., 2019; Seger & Thorstensson, 2005). Resistance training on unstable surfaces has been applied by physical therapists and coaches to regain the functions lost after injury in individuals and to improve the athletic performance of athletes (Behm & Anderson, 2006; Behm et al., 2002; McBride et al., 2006; Wahl & Behm, 2008). Unstable conditions could be provided by changing the surface stability using equipment such as a Bosu ball, TRX band, balance discs, and foam pads.

Those who emphasized the importance of an unstable surface in resistance training concluded that greater instability increased neuromuscular stress (Anderson & Behm, 2005a; Anderson & Behm, 2005b; Behm & Anderson, 2006; Norwood et al., 2007). Besides, studies comparing the effects of surface stability in terms of the muscles responsible for exercise in the lower extremities reported different electromyographic activity (Hyong & Kang, 2013; Maior et al., 2009; McBride et al., 2006; McBride et al., 2010; Saeterbakken & Fimland, 2013). McBride et al. (2006) examined vastus medialis (VM) and vastus lateralis (VL) muscle activations in isometric squat movement performed on stable and unstable surfaces. They found that VM and VL muscle activations were higher on the stable surface. McBride et al. (2010) compared squat exercises with stable and unstable conditions, and they concluded that stable conditions showed the same or significantly higher value for VL muscle activity. Saeterbakken and Fimland (2013) stated that there was no significant difference between surfaces in VM and VL muscle activations during squats on stable and unstable surfaces. Although the above-mentioned studies showed no difference between surfaces in VM and VL muscle activation or that muscle activation was higher on a stable surface, Hyong and Kang (2013) stated that VM muscle activation was higher on an unstable surface. Maior et al. (2009) reported that greater

VM, VL, and rectus femoris (RF) muscle activity was observed in the unstable condition compared to the stable condition.

Considering the previously mentioned studies, various outcomes were observed regarding the impact of surface stability on muscle activation. Therefore, more studies are needed on the effects of surface stability on muscle activation using different surfaces. The aim of this study was to compare the muscle activity of the VM and VL muscles in the squat exercises performed on stable and unstable surfaces in recreationally active male individuals.

METHODS

Study Group

Fourteen recreationally active males (age: 20.43±1.28 years; height: 176.94±6.58 cm; body weight: 72.78±10.72 kg) voluntarily participated in this study. Before starting the study, the participants were informed about the study. Ethics committee approval of the study was given by the Hitit University Non-Interventional Ethics Committee (Decision No: 2022-28).

Data Collection

The study was conducted using the crossover experimental design model. Before starting the study, squat exercises were tried on three different surfaces. In this study, stable ground (S), gymnastics mat (GM), and Bosu ball (BB) were used as the surface. GM and BB were used as unstable surfaces. Throughout the study, measurements were taken for each individual on two different days. Participants' height and body weight measurements were taken in the morning on the first day. Then, the participants were randomly divided into groups, starting on three different surfaces. On the second day, participants' muscle activation measurements were taken on different surfaces during the squat exercise. Each participant exercised on all three surfaces. Measurements were made at the same time of the day and with the whole body rested. Before the measurements, participants were warned not to consume caffeine or other stimulants.

Data Collection Tools

Participants’ height was measured by using a Seca 213 stadiometer (Seca, Hamburg, Germany). Body weight was determined using Tanita BC-418 (Tanita Corporation, Tokyo, Japan). All measurements were taken while the participants wore shorts and a t-shirt and were barefoot. Muscle activation measurements were performed using the Delsys Trigno 4-channel surface electromyography device (Delsys Inc., Boston, MA, USA). A 40 cm thick and 24-density gymnastics mat was used.

Squat Exercises: Participants performed squat exercises with their thighs descending until they were parallel to the ground with their feet shoulder-width apart (parallel squat) on three different surfaces: S, GM, and BB. They performed two sets of squat exercises on each surface with their body weight, each set consisting of 10 repetitions, and a 3-minute rest was given between sets and surface changes.

Muscle Activation Measurements: Measurements were made using the Delsys Trigno 4-channel EMG device. Before the electrodes were attached to the relevant muscles, the surfaces of the muscles were shaved and cleaned with alcohol. The electrodes were placed as described by Şimşek et al. (2016) for VM and VL muscles. Muscle activation measurements were performed from the VM and VL muscles in the dominant leg. The EMG signals were sampled at 1926 Hz and bandpass filtered at 20-450 Hz. Maximum isometric voluntary contraction (MVIC) measurements were performed for each muscle before the measurements. Subjects performed MVIC measurements in a seated position with 90° knee flexion against the resistance, which was provided by using a belt around the shank (Slater & Hart, 2017). MVIC measurements were performed twice, and each trial lasted for five seconds. The first and last one-second parts of the two MVIC data were subtracted, and the average of three seconds was used in the normalization calculation (Slater & Hart, 2017).

Analysis of EMG Data: The amplitude analysis was performed using the root mean square (RMS) calculation to analyze the raw data. In the squat exercise, eight repetitions were used in the analysis by discarding the highest and lowest values from 10 repetitions in each set. The average of eight repetitions in two sets was calculated for each exercise. These mean values were normalized to the MVIC data. A 500-millisecond window length was used for RMS calculations (Earp et al., 2016; Evans et al., 2019). All EMG data analyses were performed with Delsys EMGworks Analysis software (Delsys, Boston, MA, USA).

Data Analysis

The mean and standard deviation ($\bar{X}$±SD) values of all data were used in the study. The normal distribution characteristics of the data were examined using the Shapiro-Wilk normality test. A one-way repeated-measures analysis of variances was used in the statistical analysis of the data. The significance level of $p<0.05$ was accepted for all statistical analyses. All analyses were performed using the SPSS 25 program.

RESULTS

Normalized muscle activation data obtained during squat exercises performed on different surfaces are shown in Table 1.

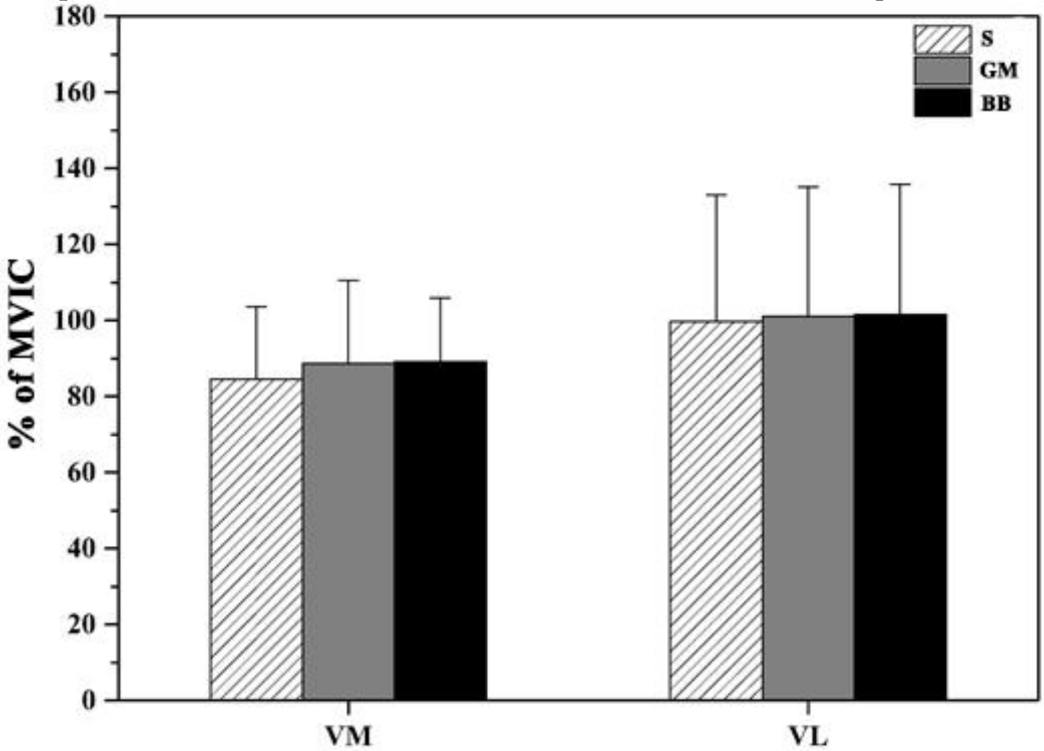
Table 1
Normalized (%MVIC) Muscle Activation Obtained During Squat Exercises Performed on Different Surfaces

Muscles	S	GM	BB	F	p
VM	84.57 ± 19.04	88.70 ± 21.92	89.16 ± 16.74	1.158	0.330
VL	99.72 ± 33.23	101.03 ± 34.01	101.52 ± 34.33	0.124	0.884

Note: S: Stable surface, GM: Gymnastics mat, BB: Bosu ball, VM: Vastus medialis, VL: Vastus lateralis

According to the result of the statistical analysis, there was no significant difference in the VM and VL muscle activations between the surfaces (p>0.05). Comparison of normalized VM and VL muscle activations according to surfaces are shown in Figure 1.

Figure 1
Comparison of normalized VM and VL muscle activations according to surfaces



VM muscle activation was 4.88% higher in GM than S and 5.43% higher in BB than S. VL muscle activation was 1.31% higher in GM than S and 1.81% higher in BB than S. However, none of these differences were statistically significant for VM and VL (p>0.05).

DISCUSSION

This study was carried out to compare the effects of stable and unstable surfaces on VM and VL muscle activations in squat exercise. As a result of this study, no significant difference was found between surfaces in VM and VL muscle activations. Performing the squat on an unstable surface did not have an additional effect on VM and VL muscle activation.

Aguilera-Castells et al. (2019) examined muscle activations using stable and unstable surfaces in the Bulgarian squat movement. They reported that there is no difference in the VM and VL muscle activations between the exercises with the stable surface, the exercise in which the back foot is on the suspension device, and the exercise in which the foot in the back is on the suspension device and the foot in the front is on the Bosu ball. Saeterbakken and Fimland (2013) investigated the electromyographic activities and force outputs of the lower extremity and some trunk muscles on surfaces with different levels of instability and on stable surfaces. In this study, a stable surface and three unstable surfaces were used, and no significant differences were found between the surfaces in VM and VL muscle activations. Andersen et al. (2014) stated there was no significant difference when comparing the VM and VL muscle activations obtained during squat exercises performed on stable and unstable surfaces. Monajati et al. (2019) found that VM and VL muscle activations were similar in exercises performed on a stable surface and Bosu ball. Li et al. (2013) did not detect a significant difference between the surfaces at different loads in the VM and VL muscle activations on a stable ground and an unstable ground using the Reebok core board. On the other hand, Anderson and Behm (2005b) stated that muscle activity of erector spinae and abdominal stabilizers was greater in squat performed on the unstable surface than the stable surfaces. Besides, they found that muscle activity of the soleus was greater in squat, which were performed on the unstable surface than the stable surfaces. According to the results of this study, it appears that the trunk and soleus muscles may prioritize maintaining balance. Saeterbakken and Fimland (2013) stated that although there was no significant difference between BOSU and stable surface, a tendency for more EMG activity was observed in BOSU for soleus. Besides, it has been stated that trunk muscles may be the primary muscles in maintaining balance instead of lower limb muscles (Monajati et al., 2019). Therefore, it is thought that there is no difference between the surfaces in the VM and VL muscle activations in our study.

Anderson and Behm (2005b) examined trunk and lower extremity muscle activations during squats on the Smith machine, free squats on stable ground, and free squats on balance discs. They stated that the VL muscle activation was highest in the squat with the Smith machine on stable ground. VL muscle activation in the Smith machine was 4.8% higher than on the unstable surface and 14.3% higher than on the free squat. Maior et al. (2009) stated that RF, VM, and VL muscle activations obtained during squat exercises performed on unstable ground were greater than muscle activations obtained on stable ground. McBride et al. (2010) stated that in squat exercises performed at different loads on both stable and unstable surfaces, VL muscle activation was greater in both eccentric and concentric phases on stable ground at all loads. Hyong and Kang (2013) compared the VM and VL muscle activations obtained during squat exercises performed on a hard plate, foam, and rubber air disc. They stated that the highest VM muscle activation occurred on the rubber air disc. However, no significant differences were found between the surfaces in VL muscle activation. Marín and Hazell (2014) stated that VM muscle activation was lower on unstable ground than on stable ground, and there was no difference in VL muscle activation between surfaces.

The present study had some limitations. Only recreationally active males took part in this study. The muscle activities of VM and VL were investigated in the parallel squat exercises performed by body weight, not by any external load. The gymnastics mat and Bosu ball were used as unstable surfaces.

CONCLUSION

This study compared the effects of surface stability on muscle activities of VM and VL during squat exercise. It was concluded that similar VM and VL muscle activation were obtained in squat exercises performed on stable ground and unstable surfaces. According to these results, it can be suggested that the surfaces used in this study can be used interchangeably for VM and VL muscle activation in the squat exercise.

PRACTICAL IMPLICATIONS

Squat exercise is widely used, especially for improving quadriceps muscle group strength. This exercise can be performed on different surfaces. The use of stable and unstable surfaces in squats has increased. This study has shown that using a stable ground, gymnastics mat, and Bosu ball in squat exercises performed with body weight produces similar effects on muscle activity of VM and VL muscles. Therefore, these three surfaces can be used for VM and VL muscle activation in squats with body weight. Coaches and athletes may use these three surfaces interchangeably to improve VM and VL muscle strength.

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Authors' contributions

All authors contributed to the design of the study and collection of data. The second author contributed to the interpretation of the results by analyzing the data. All authors contributed to the drafting of the article and its critical revision. All authors approved the final version of the manuscript.

Conflict of interest declaration

No conflict of interest is declared by the authors.

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