

## Analysis of lower limb during squat activity using surface electromyography

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### ABSTRACT

The purpose of this research is to discuss and analyze the extent of the influence of using the bosu ball for squat activities on the lower limb. This research will use a quantitative and descriptive research approach. Surface electromyography will be used to measure different squat positions between 90° and 140°. The measurement compares the squat position without a bosu ball with the squat position using a bosu ball. The results of the surface electromyography recording on muscle activity at 90° on the four muscles indicate that the Rectus Femoris (RF) muscle experienced an increase in the percentage of 18.33%, the Vastus Medialis Oblique (VMO) was 77.92%, the Biceps Femoris (BF) was 24.88%, and the Semitendinosus was 79.63%. Meanwhile, on the 140° muscle activity, the Rectus Femoris (RF) muscle increased by 31.58%, the Vastus Medialis Oblique (VMO) by 20.19%, the Biceps Femoris (BF) by 28.07%, and the Semitendinosus by 42.93%. This study concludes is that differences in muscles will certainly provide different results as well. In the squat activity at an angle of 90°, it shows that the most dominant muscle is the Semitendinosus and the Vastus Medialis Oblique (VMO), while in the squat activity at an angle of 140°, it shows that the most dominant muscle is the Semitendinosus and the Rectus Femoris (RF). So, from the squat angle position, some muscles have their own roles and functions, with the Vastus Medialis Oblique (VMO) muscle having the most dominant result.

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### Introduction

Clinical biomechanics has a very important function; for example, it can be used to identify various problems experienced by the joints, which can be said to be biomechanical dysfunction. There are many tools used to assess lower extremity biomechanics, which can be used as a tool to assist in decision-making if injury occurs or as a way to avoid injury (Ortiz & Micheo, 2011). The advantage of biomechanical evaluation is that the evaluation results provide a very good perspective for obtaining an understanding of the mechanism of injury and rehabilitation. In principle and technically, rehabilitation is developed according to the function and technique of rehabilitation (Belda-Lois et al., 2011). In an increasingly modern and developing era like today, everyone prefers to do sports at home with the help of videos or simply by taking examples from the internet. According to the explanation, exercise is a method used by individuals to achieve a healthy body and has an impact on life (Hebestreit et al., 2014) and also becomes a condition in the continuation of life (Hulzebos et al., 2014; IJsselmuider & Faden, 1992; Martin et al., 2013; Pianosi et al., 2005). Unconsciously, sometimes people who exercise independently at home neglect the safety of their body parts. used to, without doing an assessment beforehand, directly perform heavy activities that could trigger injury to the body. Workouts, aerobic exercises, kegel exercises, and various squat activities are examples of sports that are frequently and easily performed.

A squat is a form of physical activity aimed at increasing the strength of the leg muscles. With an emphasis on the synchronization of the upper and lower muscles, a squat is a dynamic muscle-

strengthening exercise. Doing squats has several indirect benefits, including improving a person's quality of life (Marchetti et al., 2016). Squats are beneficial for increasing the strength of the lower limb and are also frequently used for the rehabilitation of injuries (Abelbeck, 2002; Rahmani et al., 2001). From a training perspective, squats are useful for those who want to increase their lower limb strength and maintain their overall health (Schoenfeld, 2010). When considering biomechanics and neuromuscular aspects, squats are an effective form of exercise because they can increase the strength of specific muscles (Escamilla, 2001; Escamilla et al., 2000; Senter et al., 2006). The theory is that the muscles used during squats may differ between individuals because there is little change in neuromuscular activity, but this theory will be broken down after this research is conducted. Although there is not much evidence to support this theory, researchers and subjects want to take advantage of the opportunity to maximize muscle activity and demonstrate it using electromyography.

Electromyography (EMG) is a useful study that provides information and knowledge about muscle and joint activity during treatment and therapy (Giancoli, 2001). To obtain recordings of lower limb muscle activity, EMG is an appropriate method for determining the extent of muscle activity (Tirosh et al., 2013). According to (Vigotsky et al., 2018), EMG is useful for reading muscle activity and does not cause pain. Meanwhile, according to (Saito & Akima, 2013), EMG provides a simple representation of neuromuscular activity in the muscles. Therefore, it can be concluded that EMG is a method of recording specific muscles using electrodes and visualizing the simple amplitude representation. In principle, EMG produces graphs and numerical values that are useful for reading muscle activity, but the position of the electrodes and the type of electrodes will affect the amplitude produced (Liou et al., 2015).

In this study, the subjects performed squat exercises at positions  $90^{\circ}$  and  $140^{\circ}$ , with a focus on four muscles: the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus. The squat exercises were performed both without and with the use of a bosu ball, as the researcher believed that balance is an important factor for anyone when performing physical activity. The purpose of this study is to perform an analysis of the measurement of lower limb activity that includes the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus during squat exercises.

## Method

### Research Design

Later on, quantitative and descriptive methods will be used in this study. The research began in July–August 2022 in the physiology laboratory of Muhammadiyah University of Surakarta.

### Participants

The total number of subjects in this study is ten, with the following inclusion criteria and standard deviations: 1) Non-athletes, 2) Average ages between  $17\pm 35$  years, 3) Heights between  $1.55\pm 1.75$  meters, 4) Weights between  $45\pm 75$  kilograms, and 5) Body Mass Index with a normal category between  $18.5\pm 22.9$ . Ethical clearance with number 218/KEPK/EC/2021 means that it has been approved to conduct the research. Ethical clearance was approved by the research ethics committee of Semarang State University, which is based on standards and guidelines for human research ethics review published by WHO in 2011 and the international ethics guidelines published by CIOMS and WHO in 2016.

### Instrument Test

The equipment supporting this research is an electromyography (EMG) system with an electromyography system (Noraxon, Inc., Scottsdale, AZ, USA) equipped with electrodes that function

to record muscle activity data. 3600-ISO goniometer that functions as a tool for measuring the degree of angle of the subject when performing squats. The balance ball, or Bosu, is the next piece of equipment, consisting of a half-circle made of rubber material that is pumped and then placed on a rigid platform that measures 24.6 x 24.6 x 6 inches (Satheesh, 2018). The procedure for carrying out this research is that before the subject performs squat activities, they first warm up and stretch their muscles, then try to perform squat movements with the introduction of each movement lasting 1-3 seconds. Then, during the actual recording of data, each subject performs 3 trials with each activity movement lasting 10 seconds (Marchetti et al., 2016). The subject's position in an extension angle ranging from 90° to 140° degrees.

### Data Analysis

The electromyography data will then be analyzed using Matlab (Mathwork, Inc., USA). The obtained electromyography data is then analyzed by calculating the Root Mean Square (RMS) that occurs during contraction with signals using the equation (Basmajian & De Luca, 1985), The Root Mean Square (RMS) formula used is :

$$RMS = \sqrt{\frac{\sum_{n=1}^N x_n^2}{n}}$$

### Results and Discussion

The four muscles to be measured using an electromyographic surface (sEMG) are the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus. The selection of muscles can be seen below.

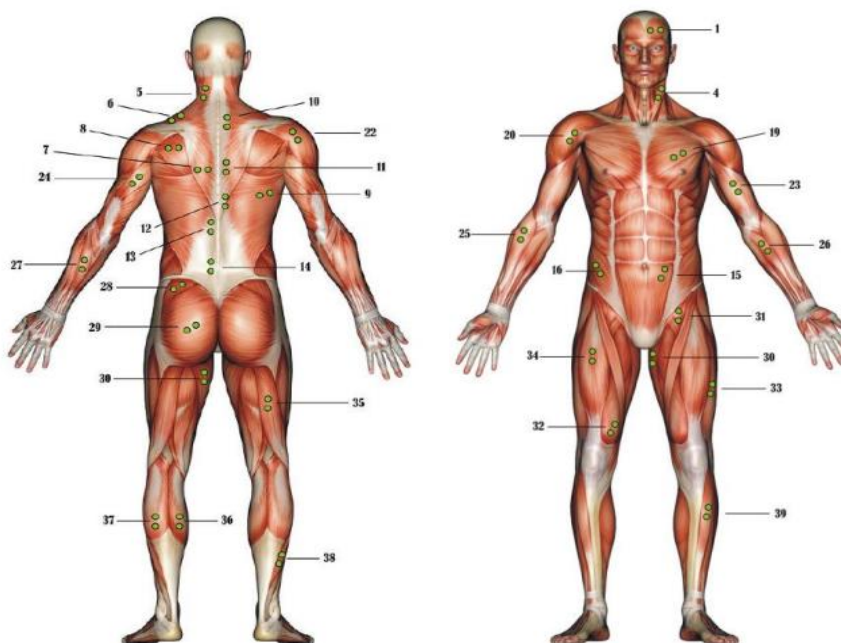


Figure 1. Overview of electrode location for electromyography recording: front view (right), rear view (left) (Adopted from (Florimond, 2010))

Tapped muscles:

- Rectus Femoris (RF) (34)
- Vastus Medialis Oblique (VMO) (32)
- Biceps Femoris (BF) (35)
- Semitendinosus (30)

The impact of the contraction that occurs in the four muscles, namely the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus, has an effect on the activity of squatting. The results of the squatting activity measurement obtained from electromyography using surface electromyography (sEMG) show an electrical image of the muscle activity of squatting. Each muscle recorded has resulted in the form of a signal that is then converted into numbers, and then further calculations of the Root Mean Square (RMS) are performed using Matlab. The results of the measurement are proven in this study at the 90° and 140° positions, both without and with a Bosu ball.

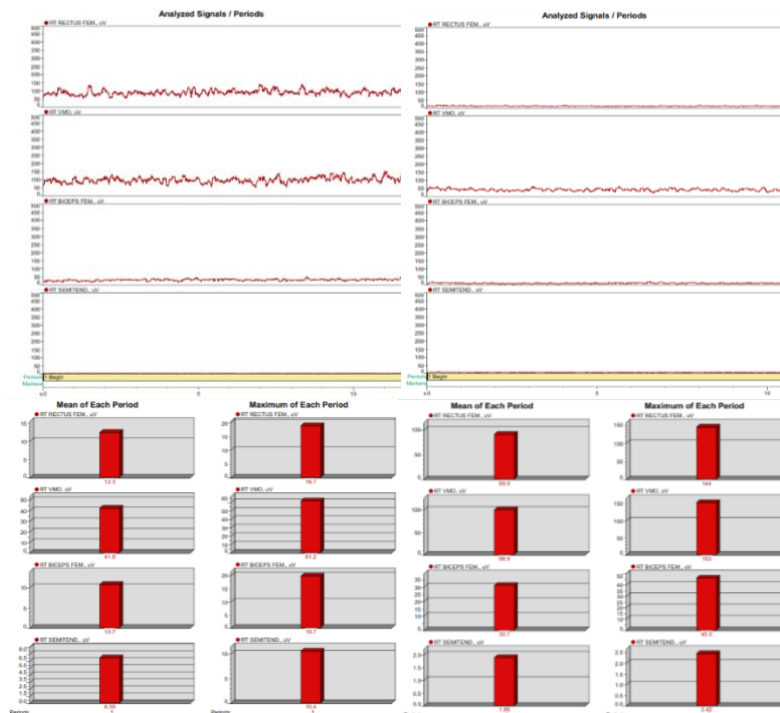


Figure 2. Report on the results of electromyographic analysis on four muscles when performing squat activities 90° and 140°

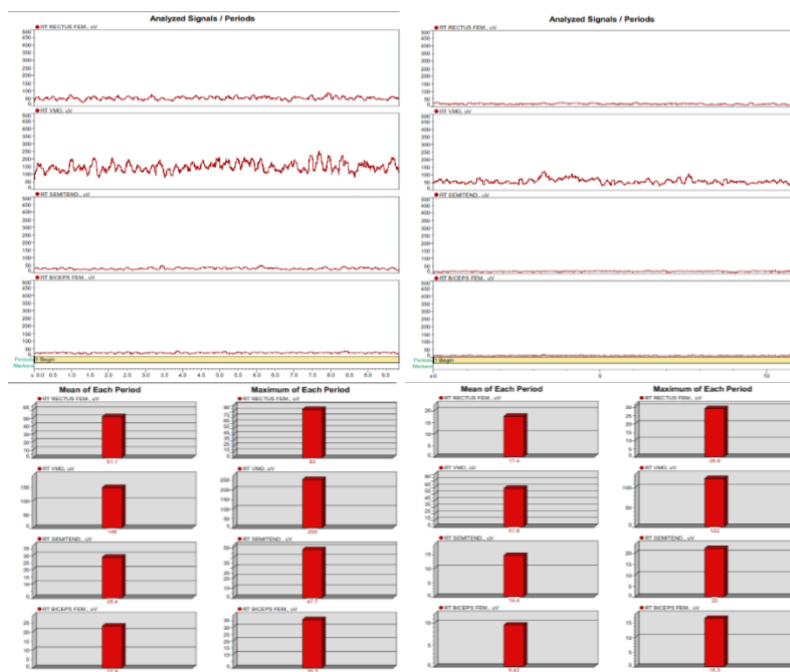


Figure 3. Report on the results of electromyographic analysis on four muscles when performing squat activities 90° and 140° using bosu balls

Figures 1 and 2 above show the recorded muscle signal data during squat activities at 90° and 140°, without using the bosu ball and with the bosu ball, respectively. It can be explained that the four muscle activities during squats are indicated by manual markers beginning at the start of the activity and ending at the end of the movement. The Noraxon MyoResearch XP device displays the average value of each muscle activity analyzed. The device can provide an overview of which muscles contribute actively when doing the activity and which muscles contribute less actively, which is then interpreted through the bar chart presented above. From the above results, the waveform signals produce data in the form of numbers, which are then calculated with the help of Matlab, and then the average Root Mean Square (RMS) value is calculated.

Table 1. RMS values at the squatting position (µV)

	Sudut	Otot				
		Otot	Rectus Femoris	Vastus Medialis Obelique	Biceps Femoris	Semitendinosus
Squat	90°		71,39	128,84*	30,06	19,57
	140°		27,69	62,56*	17,93	13,87
Squat Using Balance Ball	90°		87,42	583,48*	40,02	96,05
	140°		40,34	78,39*	24,92	24,31

Information :

\* The highest RMS value in each squat angle

Below is an explanation of the squat angle position with respect to the activity of the four muscles in the lower limb. This is done with squat angles of 90° and 140° using a bosu ball and not using a bosu ball, which is recorded in the rectus femoris (RF), vastus medialis obliques (VMO), biceps femoris (BF), and semitendinosus muscles.

a. Squat 90°

The results of surface electromyography recordings on the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus muscles with extension movements in the 90° angle position performed without using a bosu ball and using a bosu ball show RMS results that are significant. This is shown in Figure 3, with the distribution showing: the Rectus Femoris (RF) muscle increased by 18.33%, the Vastus Medialis Oblique (VMO) muscle increased by 77.92%, the Biceps Femoris (BF) muscle increased by 24.88%, and then the Semitendinosus muscle increased by 79.63%.

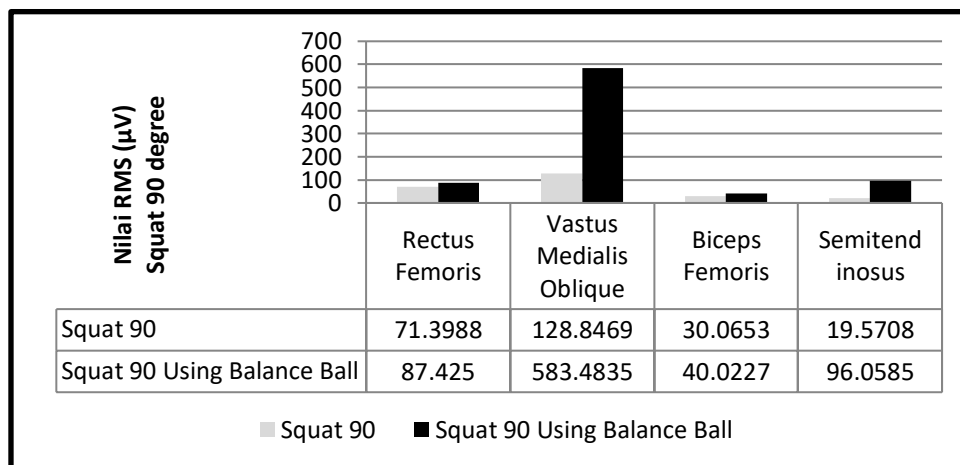


Figure 4. Root Mean Square (RMS) values for the squat 90° position

The figure above can be explained if the four muscles being examined have a significant percentage increase, starting with the highest percentage in the Semitendinosus muscle, followed by the Vastus medialis obliques (VMO), Biceps femoris (BF), and lastly the Rectus femoris (RF). Meanwhile,

if seen from the highest increase, it starts with the Vastus Medialis Oblique (VMO), Semitendinosus, Rectus Femoris (RF), and then the Biceps Femoris (BF).

b. Squat 140°

The results of surface electromyography (sEMG) recordings on the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus muscles, with extension movements in the 140° angle position performed without using a bosu ball and using a bosu ball, show RMS results in the Rectus Femoris (RF) muscle with an increase of 31.58%, the Vastus Medialis Oblique (VMO) muscle with an increase of 20.19%, the Biceps Femoris (BF) muscle with an increase of 28.07%, and the Semitendinosus 42.93%.

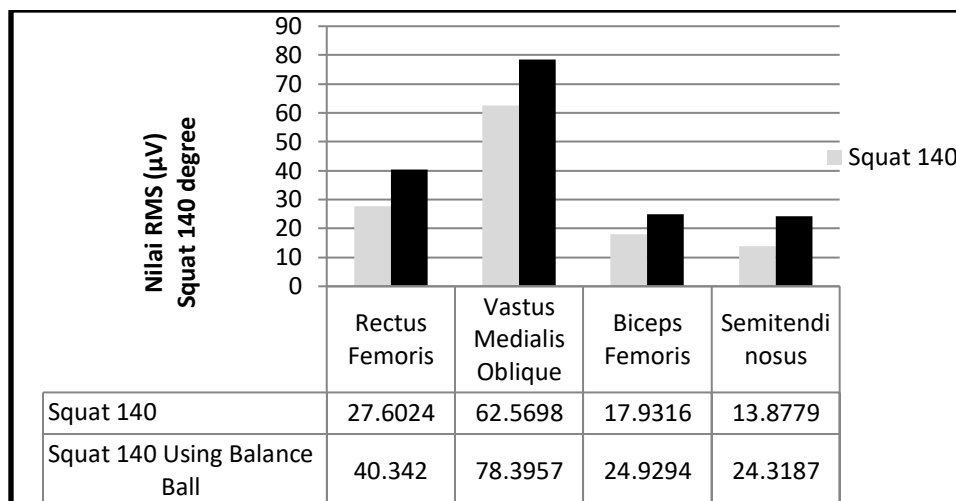


Figure 5. Root Mean Square (RMS) values for the squat 140° position

The visualization presented in Figure 5 above, it shows a significant increase in the activity of all four muscles in the squat 120° position, although the increase is not as great as in the previous squat activity. If arranged in increasing order, it starts with the Semitendinosus muscle, followed by the Rectus Femoris (RF), Biceps Femoris (BF), and lastly the Vastus Medialis Oblique (VMO).

c. Difference Test

In this difference test, the Kruskal-Wallis test is used. The purpose of this test is to perform statistical analysis using an independent test with more than two variables. The following hypothesis analysis was obtained in this study:

- H0 = The activity of the four muscles during the squat does not have a significant difference.
- H1 = The activity of the four muscles during the squat has a significant difference.

Then, after performing the Kruskal-Wallis's test, further statistical calculations were made using a table calculation, which was: If the statistics count > the statistics of the table, then H0 is rejected  
 If the statistics count < table statistics, then H0 is accepted.

The calculation result of the calculated statistic (chi-square calculation) shows a result of 104.913. The table statistic is calculated as  $df = k - 1 = 4 - 1 = 3$ , and with a significance level of 0.05%, the obtained table statistic size is 16.918. So it can be concluded that the result of the calculated statistic is greater than the table statistic ( $104.913 > 16.918$ ), and the conclusion is that H0 is rejected. Thus, it can be interpreted that the activity of the four muscles during the squat has a significant difference.

Table 2. shows the difference test for squat activity

	EMG
Chi-Square	108,313
df	3
Asymp. Sig.	.001

- a. Kruskal Walls Test
- b. Grouping variable: Posture

Several stages were carried out to obtain the final result in this research, with the hope of providing an overview and information about the electric activity in the four muscles during squatting. The recording of muscle activity in this research is divided into two stages: the first is the squat activity without using a bosu ball, and the second is the squat activity using a bosu ball. The muscles that were studied are the Rectus Femoris (RF), Vastus Medialis Oblique (VMO), Biceps Femoris (BF), and Semitendinosus. However, when the researcher has made a significant decision about the interpretation of electromyography data, they must be prepared for reintegration or new findings that will be obtained during the research (Konard, 2012). The recording was done using the MyoNoraxon XP software and an electrode support device that serves as an intermediary to describe muscle activity. Furthermore, the raw data obtained is in the form of numbers that will be the basis for obtaining information about muscle activity. The raw data was then processed using RMS on the four muscles studied. The results of the research showed a significant increase in each angle position and its muscle. At the 90° squat position, the Rectus Femoris (RF) muscle showed an increase of 18.33%, the Vastus Medialis Oblique (VMO) muscle by 77.92%, the Biceps Femoris (BF) muscle by 24.88%, and the Semitendinosus muscle by 79.62%. From the 90° degree squat angle position, each muscle showed an increase when performing a squat using a bosu ball. At the 140° squat angle position, the Rectus Femoris (RF) muscle showed an increase of 31.58%, the Vastus Medialis Oblique muscle by 20.19%, the Biceps Femoris (BF) muscle by 28.07%, and the Semitendinosus muscle by 42.93%. The results of the research showed that the results of the increase in contraction that occurred when the muscle was given additional tools to support it Especially in the 90° degree squat activity, which has a high percentage increase and almost all muscles show a high increase, as stated by (Marchetti et al., 2016), the recommended recommendation when performing squat activities is at an angle of 90° to get the most maximal muscles in the knee and hip. (Saito & Akima, 2013) explained the results of their research that confirmed that the activities of four muscles that include the Femoris (RF) and Biceps Femoris (BF) have a significant result when performing a squat at 90°, and similar findings were reported by (Watanabe & Akima, 2011), who recorded that the four parts of the muscle that include the Rectus Femoris (RF) and Biceps Femoris (BF) play a role during isometric exercises. But with this research, it will become a new reference for future researchers regarding squat activities and which muscles play a major role when performing a squat. The limitations of this research are that it only covers men, and the number is too small, so the representation of results from subjects is not sufficient to identify the knee angle during squat activities.

## Conslusions

At the beginning of its development, surface electromyography became increasingly widespread in the field of neurology and was also used as a tool for analyzing muscle electricity. However, with the rapid advancement of technology and education, surface electromyography is also frequently used in medical, rehabilitation, ergonomics, and sports science research. There is a drawback when using surface electromyography: the device can only provide information about the surface muscle to be examined. However, the benefits obtained are greater than their disadvantages; for example, it is

easier for a physiotherapist and someone knowledgeable in sports science to obtain information about the patient or subject simply through skin surface recording.

As demonstrated in this study, different muscles influence the squat position result. For example, in the 90° squat position, the two most dominant muscles were the Semitendinosus and Vastus Medialis Oblique (VMO), while in the 140° squat position, the two most dominant muscles were the Semitendinosus and Rectus Femoris (RF). Of the four muscles that were recorded, each certainly has its role and function when performing the squat activity. But there is a significant difference, namely in the Semitendinosus and Vastus Medialis Oblique (VMO) muscles during the 90° squat activity, while for the other muscles, there is a difference but only an average increase that is almost the same. The size of the result of muscle that is most noticeable is the Vastus Medialis Oblique (VMO) which shows the most significant amount in each squat position activity compared to the other muscles.

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