Research Paper: Ultrasonographic Comparison of Deep Lumbopelvic Muscles Activity in Plank Movements on Stable and Unstable Surface

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ABSTRACT

Purpose: The body core facilitates the transition of forces and moments between the upper and lower extremities in every movement. The present study investigated the differences in the sonographic activity of the deep lumbopelvic muscles during the implementation of plank movements on stable and unstable surfaces.

Methods: In total, 16 female athletes with the Mean±SD age of 23.69±3.57 years, Mean±SD height of 165.12±4.93 cm, and Mean±SD weight of 56.88±5.34 kg participated in this controlled laboratory study. Before the study onset, the Madison Model X8 ultrasound (Made in Korea) with Surface Linear Probe with the frequencies of 7.5 to 10.5 MHz was used to measure the thickness of the internal and external abdominal muscles, quadratus lumborum, and multifidus muscles. Moreover, their thickness was measured while performing front and side plank exercises on stable and unstable surfaces. The Paired Samples t-test was used for data analysis considering $\alpha=0.05$.

Results: There were no statistically significant differences in the mean diameter changes of the internal and external oblique, quadratus lumborum, and multifidus muscles in the front and side plank positions between the stable and unstable surfaces ($P>0.05$).

Conclusion: Probably, the shift from stable to unstable position (using Swiss ball) does not change the level of deep core muscles' activity in female athletes. Furthermore, exercising at each stable and unstable position may have no additional effects on these muscles.

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Highlights

- Shift from stable to unstable position (using Swiss ball) does not change the level of deep core muscles' activity in women athletes

- It seems that exercising at each stable and unstable position may have not additional effects on the core muscles.

Plain Language Summary

The body core refers to the total of muscles and lumbopelvic region structures including the lumbar spine, pelvic cavity, and hip joint. The body core resembles a box that the abdominal muscles lie in front of it; the gluteal and paraspinal muscles are in the back; the respiratory diaphragm is located on the top, and the pelvic floor muscles are located in the floor. This area has particular importance in sports because it provides proximal stability for distal mobility. One of the theories about the "core stability" exercises is the use of unstable surfaces in exercises. It has been suggested that decreasing stability during the core stability exercises (such as plank) may be associated with increased lumbosacral muscles activity. This study set to answer to the question whether the ultrasonographic activity of the lumbopelvic muscles in plank on stable and unstable surfaces differs or not? The current research aimed to ultrasonographically compare core muscles activity in front and side plank movements on stable (floor) and unstable (Swiss ball) surfaces. Results indicated that use of Swiss ball, as an unstable surface, cannot result in significant differences in level of activity of the core muscles in two plank movements. Therefore, simple plank and plank on Swiss ball movements can be posssibly used for strengthening abdominal muscles and generally trunk muscles. However, these two positions probably activate or strengthen these muscles in the same way.

1. Introduction

The body core refers to the total number of muscles and lumbopelvic region structures, including the lumbar spine, pelvic cavity, and hip joint. The body core resembles a box that the abdominal muscles lie in front of it; the gluteal and para-spinal muscles are in the back; the respiratory diaphragm is located on the top, and the pelvic floor muscles are located in the bottom [1]. This area has a particular importance in sports because it provides proximal stability for distal mobility [2]. Stability and the control of movement of the body core may improve one's performance and prevent further sports injuries [3]. The core muscles of body are divided into two main classes; the first class consists of the global muscles that are large and placed superficially and generate gross trunk movements. The second class includes the deep local muscles that start from one vertebral transverse processes and connect to the transverse processes of the upper or lower vertebra and provide segmental stability for the lumbar region [4].

The tendency for the core stabilization exercises or strengthening of the core trunk muscles as a growing trend in sports medicine is on the rise in the world. Furthermore, it is followed as a principle in many fitness and exercise programs [5]. Plank is a well-known static bodybuilding exercise that may increase the strength, endurance, and stability of the body's core muscles. Thus, these exercises can also be used in rehabilitation programs [5, 6]. Plank exercises may increase the activity of different muscles of the core area of the body, as well as flexibility [7]. Plank and side plank are known as core stability exercises; they are commonly-used exercises for stability and strength training [8].

A theory about the "core stability" exercises is the use of unstable surfaces in practices. Decreased stability during the core stability exercises (e.g., plank) might be associated with increased lumbosacral muscles' activity [9]. The Swiss ball has been used in different studies as an exercise tool for creating exercise surface instability [10]. Different studies using surface electromyography have generally indicated that the use of unstable surfaces could be associated with the increased Electromyographic (EMG) activity of the core stabilizing muscles. Thus, applying unstable surface is suggested for improving the core area performance [6, 11-13]. However, the use of surface EMG has some limitations, including the effect of environmental noise or the "cross-talk" effect of different muscle groups, which may affect the results [14]. Furthermore, due to the deep location of many core stabilizer muscles [1], the EMG recorded waves are more likely to interfere with surface muscles EMGs and question the results of these studies [14]. Therefore, further studies with more accurate tools are required to support the findings of surface electromyography and prescribe exercises for different athletes.

One of the valuable, non-invasive, high-reliability, relatively inexpensive, and available techniques for muscle size assessment is sonography [15]. Using ultrasonography allows the investigation of the deep tissues and internal organs, such as muscles, tendons, ligaments, bursas, and joints. In this method, the cross-sectional area and linear dimensions of muscles are measurable and have many applications in musculoskeletal evaluation [16].

Considering the limitations of surface electromyography and the deep location of most core muscles, it is unclear whether using unstable surfaces (e.g. Swiss ball) in exercises will increase muscle activity. Consequently, the activity of these muscles at two different stable and unstable surfaces was investigated in the current study using ultrasonography. Thus, this study explored whether the ultrasonographic activity of the lumbopelvic muscles in plank on stable and unstable surfaces differs.

2. Materials and Methods

In this controlled laboratory study, 16 females aged 20-30 years were selected as the sample from Tehran clubs. They had been exercising for 3 years and at least 3 days per week. Those with the following conditions were excluded: having a history of any cardiovascular and musculoskeletal disorders or disability preventing them from participating in any exercise, any injuries to the trunk and spine that resulted in 7 days of training loss during the past three months, and the inability to entirely and adequately perform any of the movements. Study samples were selected voluntarily using convenience sampling method. The research plan was explained to them orally and in writing. They then took part in an introductory session and became familiar with the methods and practices of the research. The informed consent forms were provided by the study participants. The research process was approved by the relevant research committee at Allameh Tabataba'i University in terms of ethical considerations. The study participants were announced that there was no compulsion for participation in the research and that they could leave the study at any time. They were assured that the obtained data would have remained confidential.

Next, the proper execution of plank exercise on stable and unstable surfaces was explained and illustrated to the study subjects. The order of implementing front and side plank on stable and unstable surfaces was randomly selected. Moreover, all athletes performed 4 movements by random order. Before the initiation of movements, the study participants were requested to warm up for 10 minutes.

In this study, the muscle thickness changes were measured with a Madison X8 ultrasound machine (made in Korea) with a linear probe (with a frequency of 7.5-10.5 MHz). The reliability of this method was previously reported [16]. Before performing the exercises, the location of selected muscles was specified by a radiologist at resting position on the dominant side (preferable leg for hitting the ball for at least two times of three attempts). On the midaxillary line, 2.5 cm forward at the midpoint of the line between superior edge of the iliac crest and the lowest rib, the dominant side was marked. This mark was used to determine the location of internal and external oblique muscles in supine position. To measure the thickness of the multifidus muscle at the level of fifth lumbar vertebra, a 1.5 cm outer spot from the L5 spi-

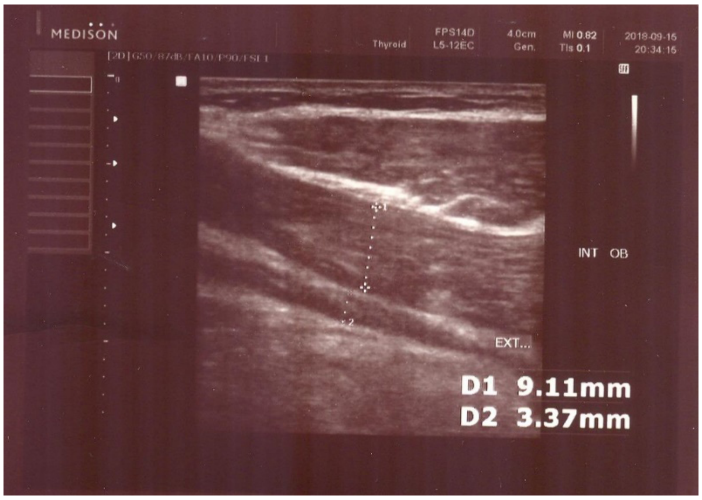

Figure 1. A sample of measurement of selected muscle thickness in resting position

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nous process was marked. For quadratus lumborum, at the level of L3 segment, the center of the paravertebral muscles was marked [17]. Then, the thickness of muscles was measured at the marked points while subjects were requested to perform front and side plank exercises on stable and unstable surfaces. To reduce measurement error and the impact of fatigue, each muscle was measured twice with a rest interval of 15 s. Additionally, the mean thickness calculated in each position was recorded. There was a 10-minute rest between each position. The maximum measurement time was specified at 30 s; thus, if the correct measurement was obtained at 30 s, the obtained value was recorded. If there was a measurement error or any other problem, the subject had to stop the movement and rest for 2 minutes. Then, respective plank movement was preserved again for measurement. The measurement unit of muscle thickness was in millimeters. Moreover, measurements were performed on the muscles of the body's dominant side. Before initiating the measurements, subjects lied toward non-dominant side in relaxed way. Next, the respective thickness of muscles was measured. The obtained values were considered as the muscle thickness in rest mode (Figure 1).

For performing front plank movement, the athlete was requested to be in a prone position. Then, the subjects had to lift their bodies, and only the forearm and toe were in contact with the ground. During the movement, the body segments should be kept as follow: a 90° elbow angle, spine and head in the neutral position, the foot in full extension, and the lumbar, hip, and trunk kept firmly in a line while preventing those from rotating. To create an unstable surface, a 75 cm diameter Swiss ball was used. In this case, the subjects took the previous position, with the forearm resting on the ball and the toe on the ground, causing inclined plank state. The subjects had to firmly hold the trunk all the time, neutralize the spine, and keep the feet in extension state.

To perform the side plank movement, the study participants lied on the dominant side and lifted their body with their forearms (90°) and legs (where the front leg was in front of the lower leg); and their spine and hip were kept in line. To perform this movement on the Swiss ball, similar to the front plank, the previous principles and position were followed; the forearm was put on the ball, and plank was performed.

Descriptive statistics were used for describing and organizing the obtained pretest-posttest data. For assessing changes in muscle thickness, the absolute magnitude of the difference in muscle thickness in each position relative to the muscle thickness at resting position was calculated. Shapiro-Wilk test was applied to investigate the normal distribution of data. Dependent Samples t-test was run to investigate the mean score difference of thickness changes between stable and unstable surfaces. All analyses were performed using SPSS at the significance level of P=0.05.

3. Results

Sixteen female athletes with the Mean±SD age of 23.69±3.57 years, Mean±SD height of 165.12±4.93 cm, and Mean±SD weight of 56.88±5.34 kg participated in this research. The Shapiro-Wilk test results suggested that all data had a normal distribution. The Independent Samples t-test results revealed no statistically significant difference

Table 1. Comparing the changes in muscle thickness in front and side plank movements on stable and unstable surfaces

Position	Muscle	Mean±SD		t	P
		Stable Surface	Unstable Surface		
Front Plank	Internal oblique	0.681±0.690	0.695±0.485	-0.114	0.911
	External oblique	0.606±0.780	0.697±0.728	-0.556	0.586
	Quadratus lumborum	0.289±2.185	0.060±2.281	0.977	0.344
	Multifidus	0.701±1.045	0.739±1.049	-0.237	0.816
Side Plank	Internal oblique	0.526±0.568	0.619±0.520	-1.063	0.304
	External oblique	0.205±0.564	0.267±0.821	-0.265	0.795
	Quadratus lumborum	0.260±2.354	0.177±2.357	0.438	0.667
	Multifidus	0.851±0.917	0.962±1.164	-0.737	0.473

N=16, P<0.05.

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between the changes in muscle thickness in plank movements on stable and unstable surfaces (Table 1).

4. Discussion

The current research aimed to ultrasonographically compare core muscle activity in front and side plank movements on stable (floor) and unstable (Swiss ball) surfaces. The obtained results indicated that the use of Swiss ball, as an unstable surface, results in no significant differences in the activity level of the core muscles in two plank movements. There was no significant difference in the thickness changes of internal and external oblique, quadratus lumborum, and lumbar multifidus muscles in plank on stable and unstable surfaces.

The use of unstable tools, including Total Resistance Exercise (TRX) and Swiss ball during various exercises, like the plank, has become increasingly popular. Numerous studies have been conducted on the use of this tool to measure muscle activity by EMG [6, 11-13]. According to Lehman et al., who recorded muscle activity using EMG, the use of a Swiss ball in the front plank increased the activity of the rectus abdominis and external oblique muscles; however, it did not affect the internal oblique and erector spinae muscles [18]. The current research findings are in line with their results regarding the internal oblique muscle. The difference in the effect of the Swiss ball on the external oblique muscle activity in Lehman's study compared with the current research may be due to the difference in the measurement instrument.

Do and Yoo investigated the abdominal and oblique muscles by ultrasonography during plank exercise in three different positions (on the ground, hands on the unstable surface, and legs on the unstable surface). According to their research, the use of unstable surfaces increased muscle activity, which is inconsistent with our results [11]. The difference in the findings of two studies might be because the present research was conducted on athletes, but their study was performed on ordinary individuals. Thus, the use of Swiss ball may not cause increased activity of deep lumbopelvic muscles in athletes; because they probably have higher muscular fitness.

Snarr and Esco investigated the electromyographic activity of the rectus abdominis, external oblique, and erector spinae muscles when performing plank movements on two unstable surfaces (Swiss ball and TRX). They concluded that the electromyographic activity of rectus abdominis, external oblique, and erector spinae muscles increased during plank movements on unstable surfaces [10]. In spite of using Swiss ball, only the front plank movement was investigated, and the results were recorded using EMG, too.

Various similar studies have indicated that the electromyographic activity of trunk muscles was significantly higher in unstable surfaces, compared to stable surfaces [12, 13, 19, 20]. However, using surface electromyography for evaluating deep muscle performance might bring about some errors, including cross-talk in muscles and noises [14]. Thus, estimating muscular activity by surface EMG may not be an accurate tool for investigating deep muscles.

The current research revealed no significant difference in the thickness of internal and external oblique, quadratus lumborum, and multifidus muscles in the front and side plank movements on stable and unstable surfaces. Therefore, simple plank and plank on Swiss ball movements can be used for strengthening abdominal muscles and trunk muscles with the same effects. However, these two positions probably activate or strengthen these muscles in the same way.

Furthermore, this study was conducted on athletes without musculoskeletal disorders; therefore, the results may not be generalizable to the public or people with low back pain. It is suggested to conduct similar research on a group with chronic nonspecific back pain. Similar research studies are required for athletes to examine the possibility of altering the activity of trunk stabilization muscles in situations that cause more perturbation (e.g., TRX). The study limitations included not selecting the sample size on the results of previous studies due to the lack of same resources.

No significant differences were found in the thickness changes of the internal and external oblique, quadratus lumborum, and multifidus muscles in front and side plank movements on stable and unstable surfaces. Therefore, simple plank and plank on Swiss ball movements can be used for strengthening abdominal muscles and trunk muscles. However, these two positions probably activate or strengthen these muscles in the same way.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles were considered in this article.

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Authors' contributions

Original idea, writing manuscript, protocol development, abstract, and data analysis: Rahman Sheikhhoseini and Roya Mirmohammad; Development of the protocol, abstracted data, and prepared the manuscript: all authors.

Conflict of interest

There were no conflict of interest to be declared.

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