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# The Effect of Unstable Support Surface Changes on Upper and Lower Limbs on Core Stabilizing Muscle Activation during Plank Exercise

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**Purpose:** This study aims to suggest effective exercise methods for individual situations by examining changes in trunk muscle activity when plank exercise is performed using unstable support surfaces for the upper and lower limbs, respectively.
**Methods:** Thirty-six adult males were divided into 3 groups. The subjects were divided into three groups of 12 people through a lottery. The first group was the standard plank group (Plank), the second group was the Upper Unstable Plank group (UUP), which provided instability to the upper extremities, and the third group was the Lower Unstable Plank group (LUP), which provided instability to the lower extremities. To compare the activity of trunk muscles during each plank movement, EMG was used to compare the muscle activity of the external oblique (EO), rectus abdominis (RA), and erector spinae (ES) muscles. Muscle thickness of the transverse abdominis (TrA) was measured using ultrasound.
**Results:** This study showed that mean muscle activity of EO and RA was significantly increased in the UUP and LUP groups compared to the Plank group ($p < 0.05$). ES was not significantly different among the three groups. The mean muscle thickness of TrA was significantly increased in LUP ($p < 0.05$).
**Conclusion:** According to the results of this study, when providing instability in the plank posture to enhance trunk stability, it is recommended to provide instability to the lower extremities rather than the upper extremities.

**Keywords:** Abdominal muscle, Spine stabilization muscle, Biomechanics, Spinal loading, Ultrasonography

## INTRODUCTION

Lower back pain is a very common symptom, with reports indicating that 60% of the population suffers from it.[1] One of the causes of lower back pain is the weakening of the muscles around the lower back, which play a crucial role in maintaining posture and balance.[2] When the stabilizing muscles around the lower back weaken, it can lead to increased tension in the lower back and a decrease in balance perception. The muscles around the lower back are divided into deep muscles and superficial muscles. The deep muscles are developed through movements such as body swaying or walking, and the muscles around the torso and pelvis contribute to the stability of the spine.

Spinal stability is enhanced by the increase in intra-abdominal pressure and the simultaneous contraction of the synergistic muscles around the lower back. This involves superficial muscles such as the external oblique (EO) and rectus abdominis (RA), and deep muscles including the internal oblique (IO) and transverse abdominis (TrA). Additionally, posterior muscles like the erector spinae (ES) and multifidus also play a crucial role in this process.[3]

When the stabilizing muscles of the lower back are weakened, there is a higher risk of spinal disorders, lower back pain, and lower limb injuries.[4,5] This weakness can also negatively impact physical activities, limiting the strength required for daily activities. Weakness in the external oblique can reduce the ability of the spine to flex and the pelvis to tilt posteriorly, while weakness in the internal oblique similarly diminishes spinal flexion ability, thus compromising trunk stability.[6]

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To strengthen weakened trunk muscles, exercises such as crunches, bridge exercises, and plank exercises are recommended. Among these, the plank exercise, which involves supporting the body with the arms and legs, specifically targets abdominal muscles, and enhances trunk stability. The plank exercise strengthens core muscles, including superficial muscles like the external oblique and rectus abdominis, as well as deep muscles like the erector spinae and TrA, increasing overall trunk stability.

Designed to engage the core muscles, the plank exercise increases activity in the trunk flexors and abdominal muscles.[7] Additionally, it reduces lower back pain, supports the body, and improves balance. The plank exercise is considered an optimal workout for reducing spinal load when performed in a neutral lumbopelvic position. Consequently, many researchers are exploring more efficient exercise methods. However, most studies focus on how variations in leg width or posture during the plank exercise affect the efficiency of abdominal muscles. Research on how trunk muscles are activated in response to changes in support surfaces for the upper and lower limbs is relatively scarce.[8,9] According to previous studies, a sling with high instability was used on the lower limb, which has stronger muscle strength than the upper limb, and instability was controlled with a Swiss ball on the upper limb.[10] However, the Swiss ball is large, so additional support plates were used on the legs to maintain a balanced posture during plank posture, so an air cushion was applied in this study.

Therefore, this study aims to investigate changes in trunk muscle activity when performing plank exercises with unstable support surfaces for the upper and lower limbs, aiming to propose effective exercise methods tailored to individual circumstances.

## METHODS

### 1. Subjects

This study involved thirty-six male university students in their twenties from K University in Gimhae. The participants were randomly divided into three groups of 12 each. The first group was the Standard Plank group, the second group was the Upper Unstable Plank (UUP) group, and the third group was the Lower Unstable Plank (LUP) group. Prior to the experiment, the participants were thoroughly informed about the purpose and methods of the study, and their consent was obtained. Students with a history of chronic pain, such as lower back pain, trauma, or surgical conditions, were excluded from the study. General characteristics such as age, height, and weight of the study subjects are as follows (Table 1).

Table 1. General characteristics (n=36)

| Variable | Plank (n=12) | UUP (n=12) | LUP (n=12) |
|---|---|---|---|
| Age (year) | 25.1±4.2 | 23.8±2.0 | 23.6±1.3 |
| Height (cm) | 174.0±5.9 | 175.9±6.0 | 174.8±4.6 |
| Weight (kg) | 70.9±13.6 | 78.3±11.6 | 75.6±7.6 |

Mean±standard deviation. Plank: Standard plank, UUP: Upper Unstable Plank, LUP: Lower Unstable Plank.

### 2. Measurements

#### 1) Measurement methods

##### (1) Muscle activity measurement (Electromyography, EMG)

To measure the electromyographic signals of the EO, RA, and ES muscles, an Android-based Bluetooth EMG system (2EM, ReLive, Gimhae, Korea) was utilized. The analog signals collected from the three muscles were converted into digital signals and processed using the ReLive 4D-MT program on a tablet PC. The EMG data were initially bandpass filtered at 10-500Hz. Subsequently, a high-pass filter at 20Hz was applied using a dual-pass Butterworth filter to eliminate artifacts caused by cable movement. To minimize skin resistance at the EMG pad attachment sites, the areas were shaved and cleaned with alcohol swabs. The attachment sites were based on criteria from previous studies.[10] For the ES muscle, the pad was placed 2cm lateral to the spinal centerline at the L2 vertebra. For the RA muscle, the electrode was placed 3cm to the right of the umbilicus. For the EO muscle, the electrode was attached at the level of the navel above the anterior superior iliac spine. EMG pads for all muscles were attached only on the right side.

To measure the maximal voluntary isometric contraction (MVIC) of the EO and RA, participants were instructed to maintain a position with the upper body lifted at a 45° angle for 10 seconds. For the ES, the MVIC was measured with the participant lying prone, pelvis fixed, and lifting only the upper body. For each action, MVIC values were recorded by lifting the upper body up to the shoulder blades and maintaining the position for 10 seconds, using the middle 4 seconds of muscle activity data while excluding the initial and final 3 seconds.

##### (2) Muscle thickness measurement (Ultrasound, US)

To measure the muscle thickness of the TrA sonographically, an ultrasound imaging device (Prosound 2 ALOKA, Hitachi, Tokyo, Japan) was used. For the TrA, the probe was placed at the intersection of a vertical line drawn downward from the axillary line and a horizontal line drawn through the navel, with the participant in the supine position. The thickness of the TrA was measured 2.0cm inward from the attachment point (Figure 1).[11] To minimize inter-examiner measurement error, the same examiner performed all measurements. The muscle thickness using ultrasound was assessed both at rest and during plank exercises.

#### 2) Exercise methods

This study was conducted by dividing participants into three groups. The first group was the Standard Plank group, the second was the UUP group, and the third was the LUP group. All groups were thoroughly trained to maintain proper plank posture, avoiding compensatory movements such as pelvic tilting and hip flexion during the plank exercise. The plank exercise was performed three times per group, with the average values used. During the plank position, muscle activity of the EO, RA, and ES was measured using EMG, and the thickness of the TRA was assessed using ultrasound. Each plank exercise was held for 10 seconds. Participants were given a 5-minute rest period between each set.

##### (1) Standard Plank (Control group)

For the standard plank exercise, participants were in a prone position with their shoulders flexed at 90°, legs straight, and their bodies raised on their toes, maintaining a straight line from the head, back, hips, to the legs (Figure 2A).


Figure 1. Ultrasound measurement of the transverse abdominis muscle

##### (2) UUP group

For the UUP plank exercise, participants performed the elbow plank with an unstable support surface provided for the upper limbs. To introduce instability, air cushions were placed under each elbow. Participants maintained balance on the air cushions while holding the plank position for 10 seconds (Figure 2B).

##### (3) LUP group

For the LUP plank exercise, participants performed the elbow plank with an unstable support surface added to the lower limbs. Instability was introduced using slings. The slings were set at a height of 20cm from the floor and placed around the ankles. Participants maintained the plank position with their feet suspended in the slings for 10 seconds (Figure 2C).

#### 3) Statistical analysis

Data collected in this study were analyzed using SPSS Windows version 18.0 software. Paired T-test was used to compare pre- and post-results within groups. One-way analysis of variance (ANOVA) was performed to determine the between-group significance level of $\alpha = 0.05$. Post hoc analysis was performed using the Scheffe test.

## RESULTS

### 1. Comparison of muscle activity

The results of muscle activation during the plank exercise showed a significant increase in EMG values across all groups ($p < 0.05$). The effects of exercise between groups indicated that the UUP and LUP groups exhibited significantly higher EMG values for the EO and RA compared to the Standard Plank group ($p < 0.05$). Additionally, the ES also showed higher activity in the two groups with added instability, although the difference

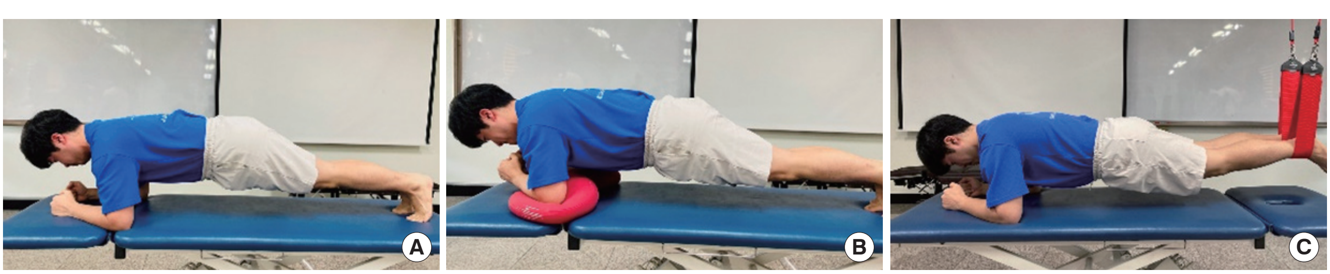


Figure 2. 3 Type of plank exercises according to differences in instability. (A) Standard Plank (B) Upper Unstable Plank (UUP) (C) Lower Unstable Plank (LUP).


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Table 2. Comparison of trunk muscle activity within the group and between the group (Unit = % MVIC)

| | | Plank (n = 12) | UUP (n = 12) | LUP (n = 12) | f (p) |
|---|---|---|---|---|---|
| EO | Pre | 9.55 ± 11.23 | 7.37 ± 3.50 | 5.76 ± 1.01 | 3.84 (0.03*) |
| | Post | 22.58 ± 13.25 | 41.36 ± 21.42 | 40.43 ± 28.69 | |
| | Post-pre | 12.57 ± 9.62 | 36.24 ± 11.47 | 33.87 ± 13.78 | |
| | t (p) | -4.44 (<0.001*) | -5.17 (<0.001*) | -3.8 (<0.001*) | |
| RA | Pre | 9.85 ± 11.21 | 6.83 ± 1.39 | 6.05 ± 1.33 | 13.24 (<0.001*) |
| | Post | 23.11 ± 11.72 | 35.01 ± 12.66 | 38.36 ± 11.12 | |
| | Post-pre | 13.14 ± 11.36 | 25.46 ± 6.54 | 32.28 ± 6.24 | |
| | t (p) | -4.39 (<0.001*) | -7.64 (<0.001*) | -9.23 (<0.001*) | |
| ES | Pre | 9.04 ± 2.10 | 9.08 ± 1.58 | 9.92 ± 1.81 | 3.33 (0.05) |
| | Post | 12.71 ± 3.43 | 21.04 ± 8.11 | 24.08 ± 9.25 | |
| | Post-pre | 3.13 ± 2.66 | 11.46 ± 4.95 | 14.77 ± 5.09 | |
| | t (p) | -3.26 (0.01*) | -4.56 (<0.001*) | -5.12 (<0.001*) | |

Mean ± standard deviation. Plank: Standard plank, UUP: Upper Unstable Plank, LUP: Lower Unstable Plank, EO: External oblique, RA: Rectus abdominis, ES: Erector Spinae. *p < 0.05.

was not statistically significant (Table 2).

### 2. Comparison of muscle thickness

The muscle thickness of the TRA during the plank exercise showed a significant increase in EMG values across all groups ($p < 0.05$). However, significant changes in TrA thickness between groups were observed only in the LUP group ($p < 0.05$)(Table 3).

## DISCUSSION

This study aimed to examine changes in trunk muscle activation when performing plank exercises with unstable support surfaces applied to the upper and lower limbs and to propose effective exercise methods tailored to individual circumstances. The results of the study showed that performing UUP and LUP exercises resulted in higher muscle activation and muscle thickness changes compared to the Standard Plank exercise. Previous studies have indicated that the application of unstable support surfaces during core stabilization exercises tends to increase muscle activation to improve stability.[12,13] However, in this study, applying instability to both the upper and lower limbs resulted in different levels of trunk muscle activation depending on the location of instability.

In the UUP group, there was a significant increase in muscle activation of the EO and RA compared to the Standard Plank. This could be attributed to the difficulty in maintaining balance in all directions when supporting the body on an air cushion or similar unstable surface, leading to greater recruitment of the EO and RA muscles. This tendency is consistent

Table 3. Comparison of muscle thickness within the group and between the group (Unit = cm)

| | | Plank (n = 12) | UUP (n = 12) | LUP (n = 12) | f (p) |
|---|---|---|---|---|---|
| TrA | Pre | 0.33 ± 0.04 | 0.39 ± 0.08 | 0.38 ± 0.04 | 17.2 (<0.001*) |
| | Post | 0.35 ± 0.04 | 0.42 ± 0.09 | 0.43 ± 0.04 | |
| | Post-pre | 0.02 ± 0.01 | 0.03 ± 0.01 | 0.05 ± 0.01 | |
| | t (p) | -7.22 (<0.001*) | -8.57 (<0.001*) | -10.78 (<0.001*) | |

Mean ± standard deviation. Plank: Standard plank, UUP: Upper Unstable Plank, LUP: Lower Unstable Plank, TrA: Transverse abdominis. *p < 0.05.

with findings from previous research, which suggested that when instability is introduced to the upper limbs using tools like a Swiss ball, the upper limbs actively engage to maintain balance, leading to simultaneous activation of multiple segments of the body.[12]

In the LUP group, besides the EO and RA muscles, the TrA also showed notably higher results. Particularly, TrA exhibited significantly higher activation compared to all other groups, which can be explained through muscle chains. The lower limbs and TrA are interconnected through muscle chains.[14] Specifically, the muscles of the lower limbs are closely linked to the TrA, a core muscle. Therefore, providing instability to the lower limbs may directly influence the activation of the TrA. This tendency is supported by previous studies that observed changes in the thickness of the TrA by providing instability to the lower limbs.[15]

For example, a study by Hodges et al.[16] showed that instability provided to the lower limbs significantly increased TrA activation during various exercises, suggesting a strong linkage between lower limb movements and core muscle responses. Similarly, Marshall et al.[17] reported that exercises involving lower limb instability resulted in greater core muscle activation, including the TrA, compared to exercises on stable surfaces. These findings are consistent with our results, indicating that incorporating lower limb instability in plank exercises can effectively enhance TrA activation.

In summary, the significantly higher activation of the TrA in the LUP group aligns with the hypothesis that lower limb instability influences core muscle activation. This is consistent with prior research demonstrating the impact of lower limb instability on TrA thickness and activation. Therefore, to maximize core muscle engagement, it is advisable to incorporate instability to the lower limbs during plank exercises.

The RA, which plays an important role in providing abdominal stability, showed high results in the LUP group compared to the Standard Plank, like the UUP. Snarr et al.[18] previous study reported that plank exercises performed with unstable support surfaces for the upper limbs (such as a Swiss ball) or with feet attached to suspension devices (like TRX) demonstrated higher muscle activation compared to traditional floor planks.

This suggests that introducing instability to plank exercises can lead to increased activation of the rectus abdominis muscle. According to these results, the UUP would be expected to be the most efficient plank exercise for strengthening the RA. However, in this study, LUP exercise emerged as the most efficient, contrary to expectations.

Upon reflection on the differences between these two studies, it can be inferred that the Swiss ball used in Snarr's study may have provided greater instability compared to the air cushion used in this study. This is because the distance from the floor to the surface of the Swiss ball supporting the arms would likely be greater than the distance to the surface of the air cushion, leading to increased instability when using the Swiss ball. Hence, the LUP in this study exhibited higher activation of the RA. The difference in the level of instability provided by the support surfaces might account for the discrepancy in results between the two studies.

A limitation of this study is that it examined the effects of temporary interventions, making it difficult to determine which plank exercise would be more effective in the long term. Additionally, since the study was conducted on healthy adults, the results may vary if conducted on patients with low back pain.

Based on the results of this study, it is recommended to provide instability to the lower limbs rather than the upper limbs when incorporating instability into plank exercises to enhance core stability. The purpose of this study was to investigate the effects of different instability conditions on muscle activation during plank exercises. Our findings indicated that lower limb instability significantly increased core muscle activation. Therefore, practitioners aiming to improve core stability should focus on creating instability in the lower limbs during plank exercises.

## REFERENCES

1. Jung JH, Kim WW, Seong IH et al. The study on effectiveness of oriental medicine treatment for lumbar disc herniation inpatients on 208 cases. J Korean Acad Rehabil Med. 2013;23(1):77-86.
2. Shumway-Cook A, Horak FB. Rehabilitation strategies for patients with vestibular deficits. Neurol Clin. 1990;8(2):441-57.
3. Mawston GA, G. Boocock M. Lumbar posture biomechanics and its influence on the functional anatomy of the erector spinae and multifidus. Phys Ther Rev. 2015;20(3):178-86.
4. Kim KH, Cho SH, Goo BO et al. Differences in transversus abdominis muscle function between chronic low back pain patients and healthy subjects at maximum expiration: measurement with real-time ultrasonography. J Phys Ther Sci. 2013;25(7):861-3.
5. Elataar FF, Salwa FA, Nasef MNA et al. Core muscles' endurance in flexible flatfeet: a cross-sectional study. J Musculoskeletal Neuronal Interact. 2020;20(3):404-10.
6. Foster DN. Fulton MN. Back pain and the exercise prescription. Clin Sports Med. 1991;10(1):197-209.
7. Kim EO, Kim TH, Roh JS et al. The influence of abdominal drawing-in maneuver on lumbar lordosis and trunk and lower extremity muscle activity during bridging exercise. Phys Ther Korea. 2009;16(1):1-9.
8. Tampier C, Janessa DMD, Jack PC et al. Progressive disc herniation: an investigation of the mechanism using radiologic, histochemical, and microscopic dissection techniques on a porcine model. Spine. 2007;32(25): 2869-74.
9. Park JC, Jeong JG. Effects of plank exercises with resistance of one-sided hip adduction on the abdominal muscle thickness. J Kor Phys Ther. 2019;31(2):82-7.
10. Topçu H, Arabaci R, Güngör A et al. Muscle activity of core muscles during plank exercise on different surfaces. Turk J Sport Exerc. 2022; 24(3):298-305.
11. Suresh S, Chan VW. Ultrasound guided transversus abdominis plane block in infants, children and adolescents: a simple procedural guidance for their performance. Pediatr Anesth. 2009;19(4):296-9.
12. Marshall PW, Murphy BA. Core stability exercises on and off a Swiss ball. Arch Phys Med Rehabil. 2005;86(2):242-9.
13. Kang KW, Son SM, Ko YM. Changes in abdominal muscle thickness and balance ability on plank exercises with various surfaces. J Korean Phys Ther. 2016;28(5):264-8.
14. Bordoni B, Myers T. A review of the theoretical fascial models: biotensegrity, fascintegrity, and myofascial chains. Cureus. 2020;12(2):e7092.
15. Do YC, Yoo WG. Comparison of the thicknesses of the transversus abdominis and internal abdominal obliques during plank exercises on different support surfaces. J Phys Ther Sci. 2015;27(1):169-70.
16. Hodges PW, Moseley GL, Gabrielsson A et al. Experimental muscle pain changes feedforward postural responses of the trunk muscles. Exp Brain Res. 2003;151(2):262-71.
17. Marshall P, Murphy B. Changes in muscle activity and perceived exertion during exercises performed on a swiss ball. Appl Physiol Nutr Metab. 2006;31(4):376-83.
18. Snarr RL, Esco MR. Electromyographical comparison of plank variations performed with and without instability devices. J Strength Cond Res. 2014;28(11):3298-305.


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