



Original Article

## Effect of core muscle thickness and static or dynamic balance on prone bridge exercise with sling by shoulder joint angle in healthy adults

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**Abstract.** [Purpose] To date, core muscle activity detected using ultrasonography during prone bridge exercises has not been reported. Here we investigated the effects of core muscle thickness and balance on sling exercise efficacy by shoulder joint angle in healthy individuals. [Subjects and Methods] Forty-three healthy university students were enrolled in this study. Ultrasonography thickness of external oblique, internal oblique, and transversus abdominis during sling workouts was investigated. Muscle thickness was measured on ultrasonography imaging before and after the experiment. Dynamic balance was tested using a functional reaching test. Static balance was tested using a Tetrax Interactive Balance System. [Results] Different muscle thicknesses were observed during the prone bridge exercise with the shoulder flexed at 60°, 90° or 120°. Shoulder flexion at 60° and 90° in the prone bridge exercise with a sling generated the greatest thickness of most transversus abdominis muscles. Shoulder flexion at 120° in the prone bridge exercise with a sling generated the greatest thickness of most external oblique muscles. [Conclusion] The results suggest that the prone bridge exercise with shoulder joint angle is an effective method of increasing global and local muscle strength.

**Key words:** Core muscles, Bridge exercise, Ultrasonography

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### INTRODUCTION

Use of computers by students has reportedly increased due the current information society and rapid economic growth<sup>1)</sup>. Students' lifestyle choices including computer overuse, along with a lack of health education and exercise lead to changes in physical posture and increases in pain<sup>2)</sup>. In addition, their core muscles weaken<sup>1)</sup>. Thus, studies have actively investigated trunk stabilization exercises. Trunk stability is related to the body's ability to move and involves increased activity of the core muscles and erector spinae<sup>3, 4)</sup>.

Muscles that comprise trunk stability stabilize the body and the spine irrespective of limb movements since they act like a corset. These muscles function to balance the body<sup>5)</sup>. Studies have reported that once trunk stabilization is secured, activities of the abdominal muscles, pelvis, waist, and hips harmonize and movements of the limbs occur more smoothly<sup>6)</sup>. In addition, trunk stabilization exercises are important to preventing functional movement impairment of the abdominal muscles<sup>7)</sup>. Researchers have also reported that trunk stabilization exercises increase weight bearing toward the immobile side and that they are effective for postural control and activities of daily living<sup>8, 9)</sup>.

Trunk stabilization exercises maximize spinal movement and stability through repeated reinforcement<sup>10)</sup>. A sling, which is used to enhance stability and mobility during trunk exercises, has the following advantages: The participant's own weight

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serves as the resistance and the exercises can be performed in small areas, are simple, and include a variety of motions. Thus, the use of a sling is popular<sup>11</sup>). A previous study reported on how one can maintain balance in the prone position as well as advantages of trunk stabilization exercises<sup>12</sup>). When trunk movement is parallel to the provided external resistor, transversus abdominis (TrA) contractions are activated to maintain a neutral trunk position<sup>13</sup>). When the shoulder joints are bent to a 90° horizontal alignment of the pelvis posture, abdominal internal oblique (IO) and TrA activities are high<sup>11</sup>). Oh et al. compared abdominal external oblique (EO) and abdominal IO by controlling the elbow joint angle during push-ups at 0°, 45°, and 90°. As a result, activity was higher when the angle during sling exercises was 0°. Those authors concluded that trunk stabilization exercises effectively promote stability of the trunk as well as the muscles around the proximal joint<sup>14</sup>).

As shown above, although trunk stabilization exercises have clinical therapeutic effects, there have been few formal studies on the effect of different shoulder joint angles on trunk stabilization exercises. The purpose of this study was to identify whether bending the shoulder joints with a sling strapped at an angle in the prone position effectively thickens the core muscles and increases static and dynamic balance abilities in a standing position.

## SUBJECTS AND METHODS

In this study, 91 students of both genders, all in their 20s, and who were enrolled at Sun Moon University located in Asan City were randomly selected as subjects. The study was approved by the Sun Moon University Institutional Bioethics Committee (SMU-14-07-03). All participants provided written informed consent and were informed of the study's purpose and procedures. The inclusion criteria involved 1) A full understanding of the researchers' instructions and purpose of study; 2) Good health; and 3) Written informed consent. Exclusion criteria consisted of 1) Structural abnormalities of the spine during the three months prior to the study; 2) Pain in the spine, such as back pain; 3) Drug use; 4) Regularly performing weight-training activities that may affect the mechanical structure of the abdominal muscles.

Of the initial 91 subjects, 45 met the inclusion criteria. Two Participants were eliminated later. This study used a randomized single-blind study method. Subjects were randomized into three groups: the shoulder joints 60° flexed trunk stabilization exercises group (group 1), shoulder joints 90° flexed trunk stabilization exercises group (group 2), and shoulder joints 120° flexed trunk stabilization exercises group (group 3). The experiment was conducted one by one in a separate time in order to blind subjects to the information about the angle. In group 1, the exercises were performed with a sling strapped on both ankles at the shoulder joints bending 60° in the push-up position. In group 2, the same condition at the shoulder joints bending 90° was used, while in group 3, the same condition at the shoulder joints bending 120° was used. The intervention period lasted a total of 8 weeks, after which time the thickness, static balance, and dynamic balance of the core muscles were measured to identify the pre- versus post-intervention changes.

Posture must involve both elbow joints bending in the prone state. When the measurer says "Start" in a state when a sling has been strapped, the participant must move both knees away from the floor<sup>11</sup>). Before both knees fall back to the floor, the shoulder joints bending angles (60°, 90°, and 120°) are set using an electronic goniometer.

After both knees are away from the ground, the hip joint angle must be maintained at 0°. The measurer should always observe whether the participant maintains the posture and angle in the prone state. According to each shoulder joint angles, trunk stabilization exercises were performed for 30 minutes three times a week for a total of 8 weeks (warm-up, 5 minutes; exercises, 20 minutes; cool-down, 5 minutes). After the exercises were conducted for 40 seconds, each subject rested for 20 seconds. This protocol was performed 20 times.

A 3.5-MHz convex array transducer with an ultrasonic measurement device was used to measure trunk muscle thickness. On the ultrasound images, core muscle thickness was determined using a B-mode scanner. One physical therapist skillful at measuring ultrasound images applied ultrasound gel between the transducer and the skin and placed the B-mode scanner so that the center of the transducer contacted the 2.5 cm site frontward at the midpoint between the 12th rib and the iliac spine ridge centered around the armpit<sup>15, 16</sup>). To measure muscle thickness, a horizontal line was drawn 1.5 cm away from the left. A vertical line was then drawn at the left and right ends of the image and the muscle thickness was measured in the order of TrA, abdominal IO, and abdominal EO<sup>17</sup>). For a measurement posture, abdominal throw-in was used; each measurement was taken twice. Average values were used in the analysis. For abdominal throw-operation, the participant was asked to comfortably bend the hip and knee joints in the supine position to minimize lumbar lordosis and pull the belly upward. When the participant performed an abdominal throw-operation, the therapist gave visual feedback for the abdominal muscle to contract while looking at the monitor.

A dynamic balance functional reaching test was used to measure dynamic stability<sup>18</sup>). During this inspection, the subject is asked to extend his/her legs as far as possible with heels not falling. At this time, arm movement is measured from end to end using a ruler pasted on the wall. In other words, this procedure aims to test a subject's ability to extend their legs as far as possible while stepping forward without losing their balance. The ability to stretch farther indicates a wider stability limit, suggesting better dynamic balance<sup>16</sup>). Balance measuring equipment was used to evaluate static balance. A stability index (ST) and a weight distribution index (WDI) were used. An ST base on each of the 4 force-plates for the toes and heels of the right and left feet showed the balance stability by measuring the posture fluctuation based on changes in weight, while the WDI showed a weight-loaded value using percentages<sup>19</sup>). The subject was asked to place one bare heel on the force plate where the sole-shaped heel portion was drawn. All subjects were asked to reach the same spot. Measured postures were

divided into eyes open, eyes closed, standing on a soft supportive surface, and eyes closed while standing on a soft supportive surface. For each posture, the subject was instructed to maintain it for 32 seconds. For the eyes open posture, the subject was asked to look 1 m ahead. After the operation, the ST and the WDI were comprehensively calculated and displayed on a computer screen connected to the equipment. In this study, a comprehensive ST value and a WDI value were used, for which lower values indicate good balance<sup>19)</sup>.

The data collected in this study were processed using SPSS for Windows Version 12.0. We performed the Shapiro-Wilk test to determine the distribution of the subjects. To compare pre- versus post-experimental data in each group, the paired samples t-test was used. To compare pre- versus post-experimental data of the three groups, one-way analysis of variance (ANOVA) was performed. When a significant difference was found, post hoc comparisons were performed using a Bonferroni correction. The measurement data of each item are presented as means and standard deviations. The significance level for statistical verification was set at  $p = 0.05$ .

## RESULTS

The mean age height, weight, and BMI were not significantly different among the groups (Table 1).

Group 1 and group 2 showed significantly increased TrA thickness after the experiment ( $p < 0.05$ ). Group 3 showed a significant post-experiment increase in EO thickness ( $p < 0.05$ ) (Table 2).

Changes in dynamic balance increased from  $18.00 \pm 4.51$  to  $21.98 \pm 3.86$  in group 2. The results showed a statistically significant difference ( $p < 0.05$ ). The post-test results revealed no statistical significance in the differences before and after dynamic balance at  $60^\circ$ ,  $90^\circ$ , and  $120^\circ$  of bending.

Changes in static balance showed statistical differences in eyes closed, Pillow with eyes closed, and stability index values in group 2, in which the shoulder joints were bent at  $90^\circ$  using a sling ( $p < 0.05$ ). The post-test results found no statistical significance in each difference in ST, WDI and in  $60^\circ$ ,  $90^\circ$ , and  $120^\circ$ .

**Table 1.** General characteristics

	Group 1 (n=14)	Group 2 (n=15)	Group 3 (n=14)
Age (years)	$20.6 \pm 0.9^a$	$20.5 \pm 1.1$	$20.2 \pm 0.4$
Height (cm)	$16,930 \pm 8.1$	$167.3 \pm 7.8$	$171.8 \pm 7.0$
Weight (kg)	$60.7 \pm 12.1$	$63.0 \pm 8.3$	$67.6 \pm 11.7$
BMI (kg/m <sup>2</sup> )	$22.1 \pm 2.1$	$19.6 \pm 1.2$	$21.2 \pm 2.2$

<sup>a</sup> mean $\pm$ SD, Group 1: the shoulder joints  $60^\circ$  bending trunk stabilization exercises group, Group 2: shoulder joints  $90^\circ$  bending trunk stabilization exercises group, Group 3: shoulder joints  $120^\circ$  bending trunk stabilization exercises group, BMI: body mass index

**Table 2.** Comparison of core muscle thickness pre- vs. post-interventions

(mm)		Group 1 (n=14)	Group 2 (n=15)	Group 3 (n=14)
EO	pre	$0.99 \pm 0.30^a$	$1.00 \pm 0.17$	$0.96 \pm 0.18$
	post	$0.87 \pm 0.18$	$0.86 \pm 0.16$	$0.94 \pm 0.13$ ***
IO	pre	$1.03 \pm 0.12$	$0.96 \pm 0.14$	$1.06 \pm 0.22$
	post	$1.05 \pm 0.10$	$1.08 \pm 0.20$	$1.03 \pm 0.23$
TrA	pre	$1.20 \pm 0.16$	$1.21 \pm 0.13$	$1.28 \pm 0.24$
	post	$1.43 \pm 0.26$ *	$1.58 \pm 0.31$ ***	$1.49 \pm 0.46$

<sup>a</sup> mean $\pm$ SD, Group 1: the shoulder joints  $60^\circ$  bending trunk stabilization exercises group, Group 2: shoulder joints  $90^\circ$  bending trunk stabilization exercises group, Group 3: shoulder joints  $120^\circ$  bending trunk stabilization exercises group, EO: External oblique, IO: Internal oblique, TrA: transverse abdominal, Comparison of the three groups pre- vs. post-interventions using one-way ANOVA, Comparison of differences before and after interventions in each group using a paired t-test, \* $p < 0.05$ , \*\*\* $p < 0.001$

## DISCUSSION

This study found that groups in which the shoulder joints were bent to 60° and 90° showed improved TrA strength. This finding suggests that the TrA muscle activity was increased. In previous studies, when the shoulder joints are bent at 90° or less, the closer the trunk, the more significant the activation of the TrA<sup>11, 19)</sup>. These findings correspond to the results of this study. TrA fibers run parallel around the abdominal wall, playing a role in allowing a force the same as the rim following contraction. In addition, TrA stabilizes the lumbar spine and is first activated by the weight of the torso due to the limb movement<sup>18)</sup>. This study's experimental method requires a force to align the trunk against gravity with the shoulder bent at various joints. Thus, TrA activation is believed to stabilize the body. In this regard, it is reported that shoulder joints can securely move since their bending angle is related to the activation of the follicle through the significant difference from 30° to 110° in the shoulder joint bending angle<sup>19)</sup>. Myers et al. reported that the movement of the far limbs may affect muscle activity and that the force of contracting muscles can be transferred to other connected muscles and tendons through the site of origin. In addition, Myers et al. reported that the deltoid was involved when the shoulder joint connected to the trapezius is bent<sup>20)</sup>. Based on previous research, this study also found that trunk stabilization exercises depending on the shoulder joint angle impact the contraction of the muscle belly through the myofascial meridians of the dorsal arm line, where the arm muscles deeply contract and the chest waist fascia to increasing the activity<sup>21)</sup>.

In the group in which the shoulder joint was bent to 120°, the EO strength was significantly improved compared to that in the other groups. For Stevens et al., the muscle activity of the EO in the leg lifted in a posture of lifting the arms and legs was higher because the EO on the lifted side of the torso turning direction in maintaining the spine against gravity contracts more by adjusting the body turning occurring in the lifting process<sup>22)</sup>. Additionally, it may be because the eccentric contraction of the EO resulted in increasing muscle activity to maintain trunk stability as the trunk and arms go farther.

For static balance, group 2 showed a statistically significant difference in EC, PC, and ST values. For ST, a significant difference was seen only in the eyes-closed posture. Visual and proprioceptive senses perform an important function in reflective postures and movement control<sup>23)</sup>. Static balance on a soft supportive surface is significantly reduced when vision is blocked<sup>24)</sup>. Additionally, Panjabi et al. reported that trunk stability is divided into three sub-systems: a passive system in charge of the stability provided to the non-contractile tissue in a passive tense form; the transmission of power, an active sub-system made by shrinking organizations, reducing the stress exerted on the vertebral body and spinal joint, adjusting pain, and reinforcing the joint with active stabilization; and an adjustable sub-system consisting of proprioceptive senses and the central nervous system<sup>25)</sup>. EC and PC better demonstrate the effects of balance, and an improved balance ability helps with neurological stabilization, which consists of an active sub-system of trunk muscles, proprioceptive senses, and the central nervous system. However, for WDI, no significant change was seen in EO, EC, or PO. Periyasamy et al. reported that foot pressure distribution is affected by a number of factors such as foot anatomy, body mass, gender, and joint range of motion<sup>26)</sup>. In this study, since measurements were performed three times in each standing posture and foot position, no statistically significant difference was created in WDI. Dynamic balance was improved overall in all three groups, but statistically significant differences were found only in group 2. Muscle stability and strength increase as the motor control for harmonious muscle mobilization between the large trunk muscles and the small intrinsic muscles is emphasized<sup>27)</sup>. In addition, the automatic activity of the TrA is thought to be the protective mechanism of the lumbar spine<sup>13)</sup> and has been reported as part of the deep muscle that provides the lumbar stability during functional movements. The TrA is reportedly involved in proactive attitude adjustments regardless of upper and lower limb movement direction<sup>28)</sup>. From these results, trunk stabilization exercises of the shoulder joint bent at 90° were the most effective since they provide trunk stability, which then improves one's dynamic balance sense. Such increases are considered to contribute to the dynamic stability required by functional movements.

This study has some limitations. First, subjects were limited to healthy adults in their 20s. As such, the subject cohort was small, making it difficult to generalize the results obtained. Second, compared to the 8-week intervention period, the pre- and post-intervention comparison was made and no subsequent evaluation was conducted. Thus, it was impossible to determine the long-term effect of the intervention. Third, the subjects' private lives, sex, habits, and personal athletic career were not considered. Therefore, further studies of a larger number of subjects with follow-up studies are required to evaluate the retention of the improved effects. The program applied in this study cannot be applied to all possible subjects. Thus, it is necessary to normalize the program as a more specific and structured intervention program through design improvements and modifications.

Therefore, trunk stabilization exercises according to shoulder joint angle using a sling have positive effects on core muscle strength and balance. The entire muscle was strengthened under trunk stabilization exercises applied at the shoulder joints at angles of 120° or higher. In trunk stabilization exercises using a sling according to various shoulder joints angles, the shorter distance between the arm and the trunk allows the TrA to act, whereas a longer distance contributes to trunk stability due to the contraction of the eccentricity of abdominal EO. To improve one's balance capacity for functional activities, the shoulder joints should be bent at 90° before training. This study is significant in that it has presented the orientation for muscle strengthening training involved in trunk stabilization for use in future clinical experiments. Related studies to demonstrate and systemize the effects on the core muscle are required.

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