

Research article

## Comparison of Muscle Activity and Muscle Thickness According to Knee Flexion Angle during Supine Bridge Exercises using the Abdominal Drawing-in Maneuver on an Unstable Surface

Sumin Kim<sup>1</sup>, Junhyung Park<sup>2</sup> and Jingang Her<sup>1</sup> ✉

<sup>1</sup>Department of Physical Therapy, Hallym Polytechnic University, Chuncheon-si, Republic of Korea

<sup>2</sup>Department of Physical Therapy, Dongguk University Medical Center 27, Goyang-si, Republic of Korea

### Abstract

This study evaluated changes in deep trunk muscle thickness and lower extremity muscle activities during bridge exercises with the abdominal drawing-in maneuver. Bridge exercises were conducted on an unstable surface at different knee flexion angles (60°, 90° and 120°), with the aim of identifying more effective angles for bridge exercises. This study included 21 healthy adults, aged 20–27 years. Biceps femoris (BF), rectus abdominis, and rectus femoris activity was measured using surface electromyography. The thicknesses of the transverse abdominis (TrA), external oblique (EO) and internal oblique (IO) muscles were measured. BF ( $p = 0.000$ , partial  $\eta^2 = 0.670$ ) activity increased considerably as the knee flexion angle decreased. TrA ( $p = 0.000$ , partial  $\eta^2 = 0.883$ ) and IO ( $p = 0.000$ , partial  $\eta^2 = 0.892$ ) thickness significantly increased, while EO ( $p = 0.000$ , partial  $\eta^2 = 0.893$ ) thickness decreased as the knee flexion angle decreased. When performing bridge exercises using the abdominal drawing-in maneuver on an unstable surface, the knee flexion angles should be at 120° and 60° to increase trunk stability and lower extremity muscle activity, respectively.

**Key words:** Electromyography, deep trunk muscle, lower extremity muscle, muscle activity, muscle thickness.

### Introduction

Several prior investigations have evaluated the effectiveness of bridge exercises (Dafkou et al., 2020; Ho et al., 2020; Lee et al., 2015). One study reported that the abdominal drawing-in maneuver led to increased thickness of the deep transverse abdominis (TrA) muscle, as well as reduced thickness of the rectus abdominis (RA), thus indicating that the maneuver is effective for trunk stabilization (Dafkou et al., 2020).

A study that compared various trunk muscle activities during bridge exercise between a stable surface and an unstable surface reported that exercising on an unstable surface increased trunk muscle activity (Lee et al., 2015). However, studies that investigated different knee flexion angles have reported inconsistent results regarding the ideal knee flexion angles for maximal trunk stabilization and lower extremity muscle strengthening (Ho et al., 2020; Lee et al., 2015). Ho et al. (2020) reported that the erector spinae and biceps femoris (BF) muscles had the greatest effect at a knee flexion angle of 40°, and Lee et al. (2015) reported that IO, EO, and RA activities were highest at a

knee flexion angle of 120°.

In recent years, several studies have explored the impact of incorporating variables that have been reported as significant during bridge exercises. Takahashi et al. (2021) reported that erector spinae activity significantly increased at a knee flexion angle of 90° when unstable surfaces were used. In another study, the activities of the internal oblique (IO) and TrA substantially increased when exercises were performed at 120° knee flexion (Baek et al., 2012).

Therefore, the previously reported variables should be investigated together to determine a more effective supine bridge exercise method. The effects of different knee flexion angles should also be determined. While surface electromyography (EMG) has been used in previous studies (Hirose and Tsuruike, 2018; Kim et al., 2016), ultrasound should also be used to complement the shortcomings of surface EMG and examine changes in the thickness of deep muscles.

No prior studies have reported the effects of different knee flexion angles during bridge exercises using abdominal drawing-in that are conducted on an unstable surface. Furthermore, there is a lack of data on the combined use of ultrasound and EMG to examine changes in the thickness of deep trunk muscles and lower extremity muscle activities during bridge exercises. Therefore, this study measured changes in deep trunk muscle and lower extremity muscle activities during bridge exercises with the abdominal drawing-in maneuver that were conducted on an unstable surface at different knee flexion angles, with the aim of identifying more effective angles for supine bridge exercises. We hypothesized that the activity of the muscles and muscle thickness would be different depending on the knee flexion angle during the supine bridge exercise.

### Methods

#### Participants

Twenty-one healthy adults aged 20–27 years with no history of low back pain, surgery, or neurological disease and no pain in the 6 months prior to the study were included. All patients provided informed consent to participate in the study. The study was approved by the Institutional Review Board of Hallym University (No. HIRB-2017-065) and was conducted in accordance with the Declaration of Helsinki.

## Procedures

### Supine bridge exercises

During the bridge exercises, the abdominal drawing-in maneuver was used to maintain a neutral lumbar posture. The abdominal drawing-in maneuver increases abdominal pressure by pulling the abdominal walls in and contracting the IO and TrA muscles. The participants were taught how to perform the abdominal drawing-in maneuver prior to performing the bridge exercises, and each participant practiced using a biofeedback unit (Chattanooga, Hixson, TN) and ultrasound imaging system (Acuson P300, Siemens Medical Solution, USA) (Hides et al., 2007).

The participants were in a supine position with their neck and head aligned, eyes toward the ceiling, feet shoulder-width apart on the aero-step device (Aero-step XXL, TOGU, Germany) and arms at 30° angles to the sides of the body with their hands on the ground. Prior to the measurement, the participants performed the abdominal drawing-in maneuver while lifting their hips to align their shoulders, hips, and knee joints in a straight line. The physical therapist used a goniometer to mark the points at which the knee flexion angles were 60°, 90° and 120° on the aero-step device (Figure 1). The experiment was conducted using a crossover design. When instructed, the participants lifted their hips for 5 seconds while performing the abdominal drawing-in maneuver. Each knee flexion angle was measured three times. To prevent muscle fatigue, the participants took a 1-minute break in between exercises (Baek et al., 2012).

### Muscle activity measurement

The muscle activities were measured using surface EMG (Trigno Wireless EMG system, Delsys, Boston, MA, USA). To minimize skin resistance before attaching the electrodes, the skin at the electrode attachment location was completely shaved and wiped with an alcohol pad to remove as much keratin as possible (Hermens et al., 2000). The surface electrodes were attached to the dominant side RA, rectus femoris (RF) and BF muscles (Delagi and Perotto, 1980). The maximum voluntary isometric contraction (MVIC) was measured for 5 seconds, and the procedure was repeated three times. The average muscle activity value was calculated for a 3-second period, excluding the first and last seconds of the 5-second period. The muscle activity during the bridge exercises was measured and standardized (%MVIC). Raw EMG signals were measured within the 20–450 Hz band and were full-wave rectified, high-pass filtered (fourth order, zero phase delay, Butter-

worth) to eliminate motion artifacts with a cutoff frequency of 20 Hz and subjected to a 100-millisecond root mean square (RMS) algorithm. The collected data were analyzed using Windows software (EMG Work Acquisition and Analysis, Delsys, USA) (Falla et al., 2004). The reliability of this measurement method is high (ICC = 0.67–0.90) (Marshall and Murphy, 2003).

### Ultrasonography measurement

An ultrasound system (Acuson P300, Siemens Medical Solution, USA) was employed to measure the thickness of the TrA, external oblique (EO) and IO. To ensure consistency of the measurements, a marker was placed on the anterior lateral margin of the abdomen between the right anterior iliac crest and the 11th subcostal angle. The transducer was adjusted laterally and vertically until the lateral abdominal muscles were clearly visible (Whittaker et al., 2007). To account for the effects of breathing on muscle thickness while the bridge exercises were conducted, a vertical line was drawn 2.5 cm away from the right edge of the TrA (the muscle-fascia junction) at the completion of expiration (Whittaker, 2008) (Figure 2). As muscle thickness can vary among individuals, the activation-to-rest ratio (the thickness of the muscle during the bridge exercise relative to its thickness at rest) was calculated to compare muscle activity between the resting and contracting states. The reliability of this measurement method is high (ICC = 0.90, SEM = 0.14) (Mangum et al., 2016).



**Figure 2.** Measurement of the transversus abdominis (TrA) thickness using ultrasonography.

### Statistical analysis

SPSS software (version 23.0; IBM Corp., Armonk, NY) was employed to analyze the collected data. The Kolmogorov–Smirnov test was performed to verify that the data



**Figure 1.** Supine bridge exercises with different knee flexion angles (a: 60° b: 90° c: 120°).

were normally distributed. The participants' general characteristics and measurements are presented as mean and standard deviation. The muscle activities and activation-to-rest ratio of muscle thickness were compared at three different knee flexion angles using a one-way repeated ANOVA. Post-hoc analyses were performed using the Bonferroni test. The statistical significance level was set at  $\alpha = 0.05$ . In addition, to confirm the practical significance, a partial eta-squared effect size was calculated.

## Results

Twenty-one healthy adults (11 males and 10 females) were included (mean age:  $23.51 \pm 3.30$  years; mean height:  $168.24 \pm 7.92$  cm; mean weight:  $60.62 \pm 9.34$  kg). The activities of the RA ( $p = 0.447$ , partial  $\eta^2 = 0.039$ ) and RF ( $p = 0.275$ , partial  $\eta^2 = 0.127$ ) did not significantly differ as

the knee flexion angle was changed (Table 1). The BF ( $p = 0.000$ , partial  $\eta^2 = 0.670$ ) activity considerably increased as the knee flexion angle decreased (Table 1, Figure 3). The TrA ( $p = 0.000$ , partial  $\eta^2 = 0.883$ ) and IO ( $p = 0.000$ , partial  $\eta^2 = 0.892$ ) thicknesses considerably increased as the knee flexion angle decreased (Table 2), while the EO ( $p = 0.000$ , partial  $\eta^2 = 0.893$ ) thickness considerably decreased as the knee flexion angle decreased (Figure 4).

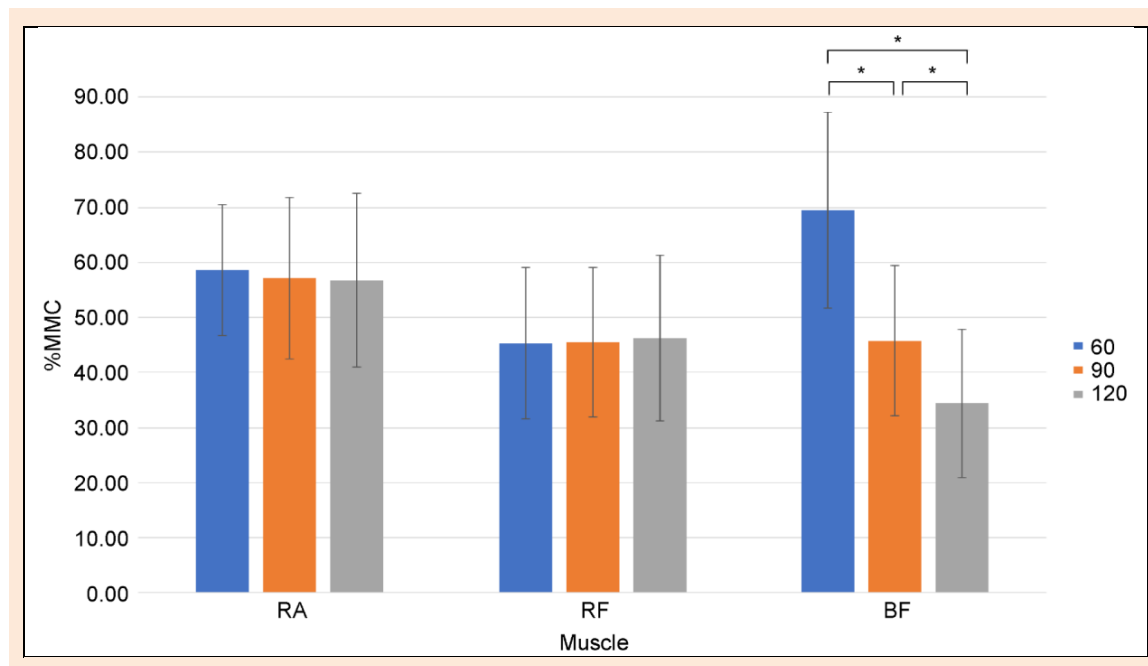
## Discussion

The BF activity considerably decreased as the knee flexion angle increased, and the IO and TrA thicknesses considerably increased as the knee flexion angle increased. The EO thickness significantly decreased as the knee flexion angle increased.

**Table 1.** Relative muscle activities (%MVIC) during bridging exercises.

Muscle	Joint angle	60°	90°	120°	F	p	partial $\eta^2$
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD				
Rectus abdominis		58.58 $\pm$ 11.83	57.05 $\pm$ 14.65	56.70 $\pm$ 15.75	0.821	0.447	0.039
Rectus femoris		45.30 $\pm$ 13.79	45.56 $\pm$ 13.57	46.25 $\pm$ 15.03	1.385	0.275	0.127
Biceps femoris		69.56 $\pm$ 17.81 <sup>a</sup>	45.76 $\pm$ 13.65 <sup>b</sup>	34.36 $\pm$ 13.41 <sup>c</sup>	31.994	0.000*	0.670

SD: Standard deviation. MVIC: maximum voluntary isometric contraction. <sup>a</sup> Significantly ( $p < 0.05$ ) different when compared to 90° and 120°. <sup>b</sup> Significantly ( $p < 0.05$ ) different when compared to 60° and 120°. <sup>c</sup> Significantly ( $p < 0.05$ ) different when compared to 60° and 90°. Effect size (partial  $\eta^2$ ): small = 0.01, medium = 0.06, large = 0.14.

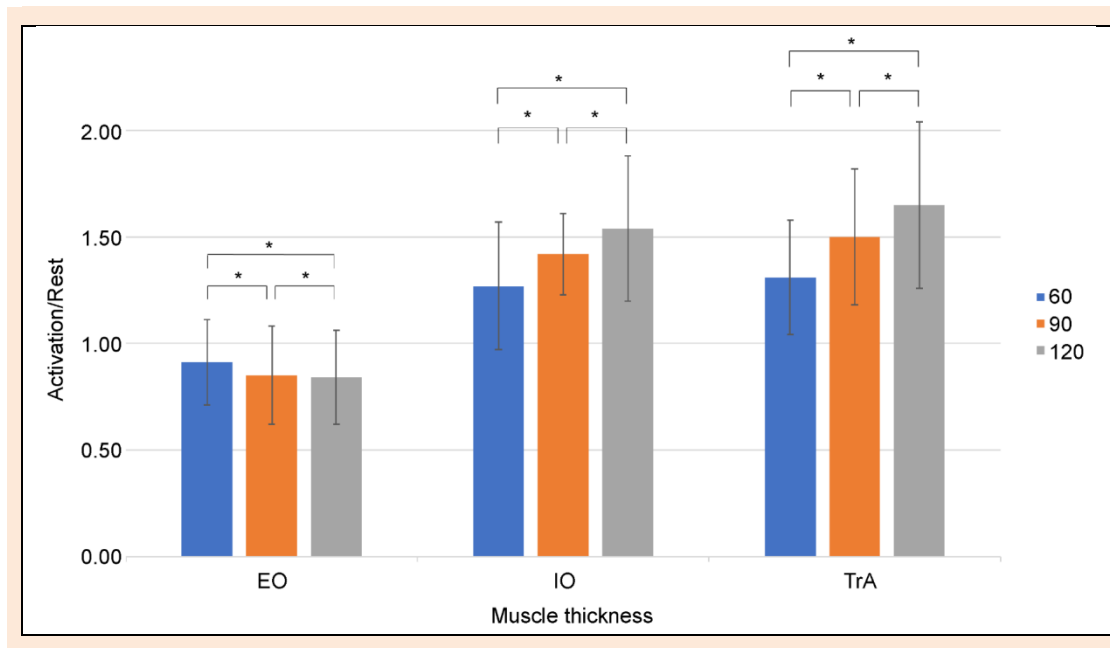


**Figure 3.** Percentage of maximum voluntary isometric contraction (%MVIC) and standard deviation for the rectus abdominis (RA), rectus femoris (RF) and biceps femoris (BF) during supine bridge exercises at knee flexion angles of 60°, 90° and 120°. \* $p < 0.05$ .

**Table 2.** Ratio of relative muscle thickness at activation and rest during bridging exercises.

Muscle	Joint angle	60°	90°	120°	F	p	partial $\eta^2$
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD				
External oblique		0.91 $\pm$ 0.20 <sup>a</sup>	0.85 $\pm$ 0.23 <sup>b</sup>	0.84 $\pm$ 0.22 <sup>c</sup>	18.091	0.000*	0.893
Internal oblique		1.27 $\pm$ 0.30 <sup>a</sup>	1.42 $\pm$ 0.19 <sup>b</sup>	1.54 $\pm$ 0.34 <sup>c</sup>	61.001	0.000*	0.892
Transverse abdominis		1.31 $\pm$ 0.27 <sup>a</sup>	1.50 $\pm$ 0.32 <sup>b</sup>	1.65 $\pm$ 0.39 <sup>c</sup>	84.652	0.000*	0.883

<sup>a</sup> Significantly ( $p < 0.05$ ) different when compared to 90° and 120°. <sup>b</sup> Significantly ( $p < 0.05$ ) different when compared to 60° and 120°. <sup>c</sup> Significantly ( $p < 0.05$ ) different when compared to 60° and 90°.



**Figure 4.** Activation/rest muscle thickness ratio of the external oblique (EO), internal oblique (IO), and transverse abdominis (TrA) during supine bridge exercises at knee flexion angles of 60°, 90° and 120°. \*  $p < 0.05$ .

The BF activity observed in this study was consistent with earlier research that reported that BF activity decreased as the knee flexion angle increased during bridge exercises (Hirose and Tsuruike, 2018). The BF generates a strong knee flexion torque during the initial phase of knee flexion movement (Onishi et al., 2002), and the knee flexion torque increases as the distance between the feet and pelvis increases during bridge exercises, thereby facilitating posture maintenance (Biscarini et al., 2017). As the distance between the legs and trunk increases, the knee flexion angle decreases, the base of support widens and the center of body pressure lowers during the bridge exercise, leading to increased activation of the BF, which is involved in knee flexion and hip extension.

IO and TrA muscle thickness values in the present study were consistent with those of Baek et al. (2012), who reported that changes in IO and TrA muscle thickness were the greatest during bridge exercises with abdominal drawing-in performed at a knee flexion angle of 120°. Furthermore, our results were consistent with the ultrasonographic findings of Dafkou et al. (2020), who reported that TrA thickness increased and RA thickness decreased during bridge exercises using the abdominal drawing-in maneuver. Similarly, Lee et al. (2015) reported that IO activity significantly increased during exercise on an unstable surface compared to that on a stable surface, and Takahashi et al. (2021) compared the results of bridge exercises using three different knee flexion angles (90°, 110°, 130°) and two different types of floor surfaces. They reported that the muscle activity of the erector spinae muscle significantly increased when the knee flexion angle was 90° on a completely unstable surface.

During the initial stages of trunk stabilization exercises that are prescribed for low back pain, the drawing-in method, also known as the abdominal hollowing exercise, is often used. The drawing-in method has been reported to be the most effective approach for promoting stabilization

of deep abdominal muscles and treating and preventing the recurrence of low back pain, regardless of its cause or outcome (Kim et al., 2018). Furthermore, bridge exercises are typically employed to strengthen back extensor muscles for low back pain (Guthrie et al., 2012). Other studies have used modified bridge exercises during the rehabilitation of athletes with hamstring injuries (Tsaklis et al., 2015) and to selectively strengthen hip muscles (Tobey and Mike, 2018). Therefore, different methods for bridge exercises should be performed depending on the purpose and goals. A limitation of this study is that the results cannot be generalized to populations beyond healthy men and women aged 20–27 years. Future studies should investigate the effects of these bridge exercise conditions in various patient populations. Moreover, interventions should be applied to patients in need of rehabilitation to confirm their effectiveness.

## Conclusion

A knee flexion angle of 120° should be used during bridge exercises on an unstable surface with the abdominal drawing-in maneuver to enhance trunk stability, and a knee flexion angle of 60° should be used to increase lower extremity muscle activities.

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### Key points

- Different methods for bridge exercises should be performed depending on the purpose and goals of rehabilitation.
- To increase trunk stability, a knee flexion angle of 120° should be used when performing supine bridge exercises using the abdominal drawing-in maneuver on an unstable surface.
- To increase lower extremity muscle activity, a knee flexion angle of 60° should be used when performing supine bridge exercises using the abdominal drawing-in maneuver on an unstable surface.

### AUTHOR BIOGRAPHY

#### Sumin KIM

##### Employment

Department of Physical Therapy, Hallym Polytechnic University

##### Degree

Ph.D. Candidate (Physical Therapy)

##### Research interests

Musculoskeletal system physical therapy, Lymphatic drainage therapy,

**E-mail:** smgreen7@nate.com

#### Junhyung PARK

##### Employment

Department of Physical Therapy, Dongguk University Medical Center

##### Degree

Ph.D.

##### Research interests

Nervous system physical therapy, musculoskeletal system physical therapy, Robot Rehabilitation

**E-mail:** potato791018@naver.com

#### Jingang HER

##### Employment

Department of Physical Therapy, Hallym Polytechnic University

##### Degree

Ph.D.

##### Research interests

Sports physical therapy, musculoskeletal physical therapy

**E-mail:** jghur7@empas.com

#### ✉ Jingang Her

Hallym Polytechnic University, 48, Janghakgil, Dong-Myeon, Chuncheon-si, Gangwon-do, Republic of Korea