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The effects of the angles of the knee and heel-off on the muscle activity during a bridge exercise

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Received: July 27, 2015 / Revised: August 3, 2015 / Accepted: August 17, 2015

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| Abstract |

PURPOSE: The purpose of this study is to investigate the effects of the angles of the knee and heel-off on the muscle activity during a bridge exercise.

METHODS: 15 healthy adult men and women with the balance ability and joint working range required for performing a bridge exercise participated in this study, in which 120°, 90° and 60° angles of the knee-flexion and heel-off were applied during the bridge exercise.

RESULTS: Our data showed that there were significant differences in muscle activities of elector spinae and rectus abdominis when 120° and 60° angles of the knee were applied, of internal oblique when 120° and 60° were applied, and external oblique when 90° and 60° were applied. When heel-off was applied, there were significant differences in muscle activities of elector spinae and rectus abdominis when 120° and 60° were applied, of internal oblique when 120° and 60° were applied, and external oblique when 90° and 60° were applied.

CONCLUSION: In this study on an application of heel-off to the bridge exercise, we showed that the effect of

the angles of the knee on the muscle activities of elector spinae, rectus abdominis, internal oblique and external oblique were all similar to the regular bridge exercise, but overall muscle activities were increased with heel-off when compared with the regular bridge exercise.

Key Words: Bridging exercise, Heel off, Knee angle, Muscle activity

I. Introduction

The bridge exercise is a trunk stabilization exercise that prevents the damages that result from the repetitive stimulations of various muscles, ligament tissues, and joints around the spine during daily life (Jeon, 2010). Stevens et al (2007) argue that the bridge exercise is a posture that makes patients with back pain comfortable, reducing their pain. It also allows patients to retrain large local muscles to coordinate at the proper ratio. Furthermore, this exercise is frequently performed in clinical settings and prescribed to patients because it is easy for therapists to teach.

An investigation into the effect the bridge exercise has on muscular activation in normal people revealed that performing this exercise on an unstable surface increased the activation of the trunk muscles. Furthermore, starting

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Table 1. muscle attachment sit

Muscle	Attachment sites
Internal oblique	Umbilicus and ASIS in middle region
External oblique	15cm outside from the umbilicus
Rectus abdominis	3cm upperfrom theumbilicus
Erector spine	2cm later from L3 spinal proces

this exercise on a stable floor and changing to an unstable floor improved stability and balance in the lumbar muscles in patients with back pain (Park, 2012). Hong et al (2010) find that setting different support surface stability levels during the bridge exercise contributes to greater muscular activation and endurance. Bjerkerfors et al(2010) report that deep muscle activity may increase when deep abdominal muscle training is applied to the bridge exercise.

The multifidus and transverse abdominis contract earlier than the other muscles involved in stabilization during every body movement to maintain the body's balance (Hodges and Gandevia, 2000). Furthermore, the internal oblique, external oblique, and quadratus lumborum muscles perform both stabilization and motility functions (Lee et al, 2013).

In this study, the bridge exercise was altered. The heel was raised and the knee angle was changed during the bridge exercise to provide gradual resistance using body weight while simultaneously applying the optimum knee angle at which trunk muscle stabilization increased. Raising the heel and changing the knee angle may be an efficient exercise method. Therefore, the change in muscular activation after the heel was raised and the knee angle was changed during the bridge exercise was examined.

II. Method

1. Subjects

The study included 15 healthy male and female adults with the ability to balance and the range of joint motion required to complete the bridge exercise. The participants

also understood the details of study and chose to participate.

The selection criteria were as follows.

- Individuals who had not experienced back pain during the previous six months
- Individuals who had no problem walking independently and had not experienced any muscle strength weakening in their lower limbs and trunk
- Individuals who had no complaints about pain during the motion and no contracture of the hip joints that limited the necessary motion
- Individuals who had no surgical or neurological history related to the musculoskeletal system of the body and lower limbs; and
- Individuals who agreed to participate in the study.

2. Electromyogram and Data Processing

1) Electromyogram (EMG)

In this study, EMG electrodes were attached to the internal oblique, external oblique, rectus abdominis, and erector spine muscles to measure their activation during the bridge exercise. The ground electrode was attached to the dominant anterior superior iliac spine (ASIS) (Arokoski et al, 2001; Cram et al, 1998). To prepare for the EMG measurement, adhesive Ag/AgCl surface electrodes were attached after alcohol disinfection to minimize potential skin resistance at the sites to which the electrodes were attached (Table 1).

2) EMG Data Processing

The EMG was measured using a surface electromyograph

Table 2. General characteristics of subjects

(N=15)

Variables	Mean±SD	Range
Age (yrs)	22.84±2.19	20~28
Height (cm)	164.15±8.30	150~178
Weight (kg)	57.84±11.80	42~80

(Biopac Student Lab MP 36, Biopac Systems, Inc., USA) with a band pass filter that removed the noises from the surrounding environment. Furthermore, the root mean square data of each muscle was measured for five seconds in the anatomical position. The muscle activation was measured three times for five seconds in each posture, and the %RVC value was calculated after the exclusion of one second before and after this measurement. This calculation standardized the data from each participant so it could be comparatively analyzed.

3. Experimental Procedure

1) Bridge Exercise

In this study, based on the bridge exercise that is generally used in clinical settings, the subjects lied down in the supine position with their feet parallel to each other, their soles in full contact with the floor, and both knees bent at 60°. They kept both hands comfortably spread on the floor with their palms facing downward. In this position, the subjects raised their pelvis based on the rater's signal and aligned their trunk with their pelvis. They maintained this posture for five seconds (Jeon, 2010; Stevens et al, 2006). Before this experiment, each subject practiced the bridging position with their spine and pelvis maintained in the neutral position for 10 minutes and both their arms were positioned at specific angles so their lower limbs stayed parallel and at an appropriate angle. The subjects received continuous feedback to adjust their specified posture.

2) Heel Raising using the Ankle Joint During the Bridge Exercise

The participants' knees were bent at 120°, 90°, and 60°, and then, their heels were raised during the bridge exercise. When their heels were raised, the participants were instructed to maintain an angle of maximum contraction for five seconds. The order in which the participants were asked to position their knees in the three knee angles was determined randomly. A five-minute resting period was given after each exercise to avoid muscle fatigue, which can significantly affect the EMG measurements.

4. Statistical Processing

The collected data were analyzed using SPSS 18.0 for Windows. The activation of each muscle measured during the bridge exercise was analyzed using one-way ANOVA. Each significant difference was tested post-hoc using Bonferroni's correction. The statistical significance level was set to $\alpha=0.05$.

III. Results

1. General Characteristics of the Subjects

The study consisted of 15 normal male and female adult participants. Their ages ranged from 20 to 28, with a mean age of 22.84±2.19 years. Their mean height was 164.15±8.30 cm, and their mean weight was 57.84±11.80 kg (Table 2).

Table 3. Comparison of trunk muscle activation among the various bridging exercise position (unit: %RVC)

Muscle	120	90	60	F	P
ES*	1171.5±82.54	1374.11±105.64	1614.81±154.28 [‡]	3.53	.038
EO*	185.51±15.65	202.01±18.88	254.38±18.96 ^{‡‡}	4.03	.025
RA*	170.07±11.59	184.32±12.30	220.00±15.48 [‡]	3.77	.031
IO*	250.33±33.78	287.01±34.09	392.61±40.01 ^{‡‡}	4.19	.022

Mean±SE, *p<.05

ES: elector spinae, EO: external oblique, RA: rectus abdominis, IO: internal oblique

[‡]significant difference between 120° and 60° (P<0.05).

^{‡‡}significant difference between 90° and 60° (P<0.05).

Table 4. Comparison of trunk muscle activation among the various bridging exercise position with heel off

Muscle	120°	90°	60°	F	P
ES*	1299.68±122.44	1612.82±182.91	2091.12±217.82 [‡]	4.97	.012
EO*	239.23±25.78	290.14±25.86	400.21±30.33 ^{‡‡}	9.01	.001
RA*	210.86±26.96	247.03±26.28	310.43±29.35 [‡]	3.34	.045
IO*	342.95±44.49	473.14±57.78	761.21±102.48 ^{‡‡}	8.68	.001

Mean±SE, *p<.05

ES: elector spinae, EO: external oblique, RA: rectus abdominis, IO: internal oblique

[‡]significant difference between 120° and 60° (P<0.05).

^{‡‡}significant difference between 90° and 60° (P<0.05).

2. Comparison of Trunk Muscle Activation Based on the Bending Angle of the Knee Joint

Significant differences in the erector spine and rectus abdominis muscle activations were found between 120° and 60° knee angles (p<0.05), but no significant differences were found between 120° and 90° knee angles and between 90° and 60° knee angles. For the internal oblique and external oblique muscles, significant differences were found between 120° and 60° knee angles and between 90° and 60° knee angles (p<0.05), but no significant difference was found between 120° and 90° knee angles (Table 3).

3. Comparison of Trunk Muscle Activation Based on Knee Joint Angle and Heel Raising

With regard to heel raising, significant differences in the erector spine and rectus abdominis muscle activations were found between 120° and 60° knee angles (p<0.05), but no significant differences were found between 120° and

90° knee angles and between 90° and 60° knee angles. For the internal oblique and external oblique muscles, significant differences were found between 120° and 60° knee angles and between 90° and 60° knee angles (p<0.05), but no significant differences were found between 120° and 90° knee angles (Table 4).

IV. Discussion

Functional stability training requires the appropriate activation of local muscles and the interaction between local and large muscles (Hodges and Moseley, 2003). Akuthota and Nadler (2004) claim that core strengthening of the lumbar muscles is critical for functional stability. This core strengthening starts with core stability. Hodges (1999) assumes that the activation of both the deep and local abdominal muscles plays a key role in stabilization. The bridge exercise is a trunk stabilization and muscle strength

training intervention used in almost every rehabilitation environment, including the treatment of orthopedic diseases (Kim et al, 2010).

This study was conducted to investigate the effects knee angle and heel raising during the bridge exercise have on trunk muscle activation. The erector spine, rectus abdominis, external oblique, and internal oblique muscle activations were measured at different knee angles (120°, 90°, 60°) without heel raising during a general bridge exercise. Then, these muscle activations were measured with heel raising at each of the knee angle changes (120°, 90°, 60°) during the same bridge exercise. The erector spine and rectus abdominis muscles showed significant differences between 120° and 60° knee angles, but they showed no significant differences between 120° and 90° knee angles and between 90° and 60° knee angles. These results suggest that as the knee angle reduced in size and the legs moved farther from the trunk and the distance of the lever arm increased; the lever arm stabilized the trunk and increased the erector spine and rectus abdominal muscle activations to raise the trunk. This result supported the findings of Lee et al (2012) who research the effects the bridge exercise knee angle had on the stabilization muscles of the trunk.

However, no significant differences were found between 120° and 90° knee angles and between 90° and 60° knee angles, which suggests that the knee angle changes between 120° and 90° and between 90° and 60° did not require an increase in muscle activation to perform the exercise. For the internal oblique and external oblique muscles, significant differences were found between 120° and 60° knee angles and 90° and 60° knee angles, but no significant differences were found between 120° and 90° knee angles. This result suggests that between 120° and 90°, the activation of the internal oblique and external oblique muscles did not increase because the activation of the erector spine and rectus abdominis muscles provided sufficient stability. However, between 120° and 60° knee

angles and between 90° and 60° knee angles, the activation of the internal oblique and external oblique muscles increased because increased abdominal pressure required core stabilization and an increase in the length of the legs. This result also supported the findings of Lee et al (2013).

The heel was raised during the bridge exercise had the same muscle activation differences as those measured during the knee angle changes for the erector spine, rectus abdominis, internal oblique, and external oblique muscles, but heel raising generally increased muscle activation when compared to the general bridge exercise. This result suggests that trunk stabilization in the general bridge exercise can be performed at progressive levels of resistance that result from the knee angle. When patients get better and a greater resistance is needed, knee angle and heel raising can be adjusted to provide a progressive amount of resistance using the weight of patients rather than performing additional resistance exercises using other tools. Therefore, the maximum effect can be obtained by simply changing the bridge exercise method.

V. Conclusion

In this study on an application of heel-off to the bridge exercise, we showed that the effect of the angles of the knee on the muscle activities of erector spinae, rectus abdominis, internal oblique and external oblique were all similar to the regular bridge exercise, but overall muscle activities were increased with heel-off when compared with the regular bridge exercise.

Acknowledgements

This work was supported by Dong-Eui University Re-search Grant No. 2015AA093.

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