



Original Article

Changes in the activity of trunk and hip extensor muscles during bridge exercises with variations in unilateral knee joint angle

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Abstract. [Purpose] This study compared abdominal and hip extensor muscle activity during a bridge exercise with various knee joint angles. [Subjects and Methods] Twenty-two healthy male subjects performed a bridge exercise in which the knee joint angle was altered. While subjects performed the bridge exercise, external oblique, internal oblique, gluteus maximus, and semitendinosus muscle activity was measured using electromyography. [Results] The bilateral external and internal oblique muscle activity was significantly higher at 0° knee flexion compared to 120°, 90°, and 60°. The bilateral gluteus maximus muscle activity was significantly different at 0° of knee flexion compared to 120°, 90°, and 60°. The ipsilateral semitendinosus muscle activity was significantly increased at 90° and 60° of knee flexion compared to 120°, and significantly decreased at 0° knee flexion compared with 120°, 90°, and 60°. The contralateral semitendinosus muscle activity was significantly higher at 60° of knee flexion than at 120°, and significantly higher at 0° of knee flexion than at 120°, 90°, and 60°. [Conclusion] Bridge exercises performed with knee flexion less than 90° may be used to train the ipsilateral semitendinosus. Furthermore, bridge exercise performed with one leg may be used to train abdominal and hip extensor muscles.

Key words: Bridge exercise, Electromyography, Muscle activation

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INTRODUCTION

The primary muscles for trunk stabilization are the abdominal muscles, gluteal muscles, diaphragm, and pelvic floor muscles. These muscles serve as a muscular corset that works as a unit to stabilize the trunk, and therefore affects limb movement and functional activities¹⁾. The muscles required for trunk stabilization include global muscles, which directly control thoracic and pelvic movement, and local muscles, which stabilize the lumbar region. Trunk stabilization exercises that employ harmonious movement of global and local muscles improve balance and functional movements²⁾. In doing so, these compound movements reduce low back pain (LBP) by increasing spinal stability through improvements in the motor control and strength of the trunk muscles³⁾. In addition, stabilization exercises reduce pain, disability, and kinesiophobia in patients with menstrual LBP⁴⁾.

Common exercises for trunk stabilization include the pelvic tilt, the quadruped position, abdominal hollowing, and bridge exercises with hip extension in a supine crook-lying position⁵⁾. Bridge exercises make patients feel more comfortable by reducing pain and retraining the global and local muscles to ensure they are coordinated in an appropriate manner⁶⁾. These are useful for increasing hip extensor strength and motor control of the pelvis and lumbar region⁷⁾.

According to previous studies, the angle of the knee joint during bridge exercise affects the activity of the hip extensor muscle⁸⁾. Furthermore, bridge exercises have been associated with increased gluteus maximus activity and decreased pelvic

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anterior tilt as the knee abduction angle is increased⁹). Prior research has indicated that the knee joint angle affects trunk muscle activity during bridge exercises. Kim et al. reported that abdominal muscle activity decreased with reductions in the knee joint flexion angle¹⁰); however, Kim et al. reported that abdominal muscle activity increased with a corresponding decrease in the knee joint flexion angle¹¹). Similar studies have indicated that changes in knee and hip joint angles affect abdominal and hip muscle activity. In most of these studies, unilateral muscle activity was investigated, and the knee angle was the same on both sides. Thus, the investigated changes in the activity of abdominal and hip extensor muscles on both sides during bridging exercises when just one knee joint angle is varied were investigated.

SUBJECTS AND METHODS

The subjects were 22 healthy males in their 20s and 30s, who had sufficient muscle strength, range of motion, and balance to perform the bridge exercise. Their average age, height, and weight were 30.07 ± 4.18 years, 174.13 ± 1.27 cm, and 73.13 ± 7.32 kg, respectively. Prior to participation, all subjects were required to provide written informed consent, in accordance with the ethical principles of the Declaration of Helsinki. The protocol for this study was approved by the local ethics committee of the Catholic University of Pusan (CUPIRB-2016-001). Those with disorders of the nervous system, cardiopulmonary system, or musculoskeletal system of the trunk and the lower extremities were excluded from the study.

The position of the bridge exercise was as follows: The subjects were asked to cross their arms and place them on their chest and to place their feet shoulder-width distance apart. The bridging exercise in this study included 4 variations; in each case, the non-dominant knee was at 90° flexion, and the dominant knee varied among 120°, 90°, 60°, and 0° flexion when the participants lifted their hips from the table. Next, the trunk and lower extremities were elevated to form a straight line, with hip flexion at 0°. Using a universal manual goniometer, the investigator measured the hip and knee joint angles to place the subjects in the bridge position. At a dominant knee joint flexion angle of 0°, participants were instructed to lift the dominant leg until the bilateral thighs were parallel. To control for the angle of the pelvis in every exercise, a bar was set at a fixed height above the anterior superior iliac spine bilaterally. To prevent excessive lumbar hyperlordosis during the bridge exercise, the exercise was practiced after maintaining a lumbar neutral position following a pelvic tilt. All trials were repeated 3 times, and the trial order was randomized using a table of random sampling numbers. Each exercise was performed for 7 seconds. Excluding 2 seconds at the start and end, the muscle activity data for 3 seconds in the middle of the exercise were used for analysis.

A surface electromyography system (Telemyo 2400T-G2 Dynamic EMG, Noraxon, Inc., USA) was used to measure activity in the external oblique (EO), internal oblique (IO), gluteus maximus (GM), and semitendinosus (ST) muscles bilaterally. The sampling rate was set to 1,024 Hz. A band-pass filter between 10 and 350 Hz was used. The EMG data were processed into the root mean square (RMS) value, which was calculated from 150-ms data windows. The experimental results were analyzed using SPSS Version 21.0 (IBM Corp., Armonk, NY, USA) for Windows. If a statistically significant difference was found, a Bonferroni correction was employed, setting a significance level of 0.0083 (0.05/6).

RESULTS

Bilateral EO and IO muscle activity was significantly higher with knee flexion at 0° than at 120°, 90°, and 60°. Bilateral GM muscle activity was significantly different for 0° compared with that at 120°, 90°, and 60° knee flexion. Ipsilateral ST muscle activity was significantly increased at 90° and 60° knee flexion compared with 120°, and significantly decreased at 0° of knee flexion compared with 120°, 90°, and 60°. Contralateral ST muscle activity was significantly higher at 60° of knee flexion than at 120° and significantly higher at 0° of knee flexion than at 120°, 90°, and 60° (Table 1).

DISCUSSION

Bridge exercises have an important relationship with functional movements, such as movements in bed, use of the toilet, removal of pressure from the lower back, dressing, using the lower extremities, and gait-related pelvic movements. Furthermore, bridge exercises also increase postural control when moving from a sitting to a standing position, and strengthen the extensor muscles of the lower spine and hip joints in preparation for the stance phase of gait⁷). According to previous studies, changes in bilateral knee joint angles during bridge exercises affect muscle activity; however, only trunk muscles were examined. In addition, few studies have examined the effect of bridge exercises on hip extensor activity^{6, 12, 13}). There is limited evidence for the use of one-sided muscular training for hemiplegic patients or patients with one-sided musculoskeletal disorders. Therefore, an attempt was made to identify the effects of asymmetric knee flexion on the activation of the abdominal (EO, IO) and hip extensor (GM, ST) muscles.

Bilateral EO and IO muscle activity was significantly higher at 0° knee flexion than at 120°, 90°, and 60°. The significant difference during unilateral exercise could be explained by the requirement to counteract the force of gravity to maintain the trunk and pelvis in a bridged position. Furthermore, the unilateral conditions may have induced rotational forces around the trunk's longitudinal axis due to loss of support, which requires bilateral co-contracted abdominal muscle activity¹⁴).

Kim et al. argued that the activation of the IO and EO muscles is significantly higher at 60° than at 120° of knee flexion

Table 1. Comparison of muscle activation according to the various bridge exercise positions (μV)

Muscle	Side	120°	90°	60°	0°
EO	Ipsilateral	4.21 \pm 1.53	4.45 \pm 1.15	5.22 \pm 1.72	15.20 \pm 5.79 ^{£¢§}
	Contralateral	5.30 \pm 2.10	5.20 \pm 1.60	5.77 \pm 1.96	12.71 \pm 6.10 ^{£¢§}
IO	Ipsilateral	4.27 \pm 2.42	4.77 \pm 3.30	5.38 \pm 3.90	14.68 \pm 7.39 ^{£¢§}
	Contralateral	4.17 \pm 1.24	4.04 \pm 0.93	5.01 \pm 1.69	11.09 \pm 5.53 ^{£¢§}
GM	Ipsilateral	19.16 \pm 10.17	18.95 \pm 10.70	16.62 \pm 11.86	5.85 \pm 1.87 ^{£¢§}
	Contralateral	17.64 \pm 10.03	18.71 \pm 9.04	21.68 \pm 11.12	59.22 \pm 28.45 ^{£¢§}
ST	Ipsilateral	18.55 \pm 11.64	56.97 \pm 31.29 [†]	79.31 \pm 32.13 [‡]	4.03 \pm 1.66 ^{£¢§}
	Contralateral	30.25 \pm 20.03	53.15 \pm 33.66	64.09 \pm 28.10 [‡]	123.20 \pm 47.39 ^{£¢§}

Mean \pm SD, EO: external oblique; IO: internal oblique; GM: gluteus maximus; ST: semitendinosus.

120°: 120° of knee flexion; 90°: 90° of knee flexion; 60°: 60° of knee flexion; 0°: 0° of knee flexion.

[†] Significant difference between 120° and 90° ($p < 0.05$).

[‡] Significant difference between 120° and 60° ($p < 0.05$).

[£] Significant difference between 120° and 0° ($p < 0.05$).

[¢] Significant difference between 90° and 0° ($p < 0.05$).

[§] Significant difference between 60° and 0° ($P < 0.05$).

because of the increased abdominal pressure required for core stabilization and the increase in the distance of the feet from the trunk¹¹). However, this study showed no significant difference because only the flexion angle of the dominant knee was changed, while the non-dominant knee was held constant at 90° flexion.

At 90° and 60° knee flexion, ipsilateral ST activity was significantly higher compared with that at 120° because of muscle length-tension relationships during isometric contraction. ST activity was significantly decreased when the ST length was shortened and knee flexion angles increased¹⁵).

Although contralateral ST activity was not associated with a change in length under all conditions, it was significantly higher at 60° ipsilateral knee flexion than at 120°. At 60° knee flexion, intrinsic muscle activity of the foot may be decreased because the ipsilateral forefoot sometimes did not contact the floor. Thus, contralateral ST activity was increased to maintain the bridge posture¹⁶). Ipsilateral ST was differently activated according to knee joint angle (120°, 90°, 60°); conversely, ipsilateral GM activity was not significantly affected when the knee joint angle was varied (120°, 90°, 60°), as the GM did not change its length at different angles because it only crosses one joint¹⁷).

There was a significantly greater difference bilaterally in the abdominal muscles and in the contralateral ST and GM with the unilateral bridge exercise (0°) compared with bridge exercises performed at 120°, 90°, or 60° knee flexion. This increased activation was due, in part, to participants' having to balance against gravity when using one foot for a unilateral bridge exercise¹⁸).

There are some limitations to this study. First, the results of the present study cannot be generalized to other populations because all of the study subjects were healthy males 20–40 years old. Second, the rectus abdominis and erector spinae muscles maintain a neutral position during pelvic tilt and lifting of the pelvis; however, their activities were not measured in this study.

In conclusion, both EO and IO activity were significantly higher when the unilateral bridge exercise was performed at 0° knee flexion than at 120°, 90°, and 60° flexion of the dominant knee. Contralateral GM activity was significantly higher at 0° of knee flexion than at 120°, 90°, and 60°. The ST, a muscle that crosses 2 joints, had higher activity with knee flexion angles less than 90°. Thus, bridge exercises with unilateral knee flexion angles of less than 90° are recommended to train the ipsilateral ST. The unilateral bridge exercise with one foot on the floor is recommended for training both the EO and IO abdominal muscles, and the contralateral hip extensor muscles.

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