



Original Article

The effect of bridge exercise method on the strength of rectus abdominis muscle and the muscle activity of paraspinal muscles while doing treadmill walking with high heels

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Abstract. [Purpose] The purpose of this research is to investigate the effect of the method of bridge exercise on the change of rectus abdominis muscle and the muscle activity of paraspinal muscles while doing treadmill walking with high heels. [Subjects and Methods] The subjects of this research are healthy female students consisting of 10 persons performing bridge exercises in a supine group, 10 persons performing bridge exercises in a prone group, and 10 persons in a control group while in S university in Busan. Bridge exercise in supine position is performed in hook lying position. Bridge exercise in prone position is plank exercise in prostrate position. To measure the strength of rectus abdominis muscle, maintaining times of the posture was used. To measure the muscle activity of paraspinal muscles, EMG (4D-MT & EMD-11, Relive, Korea) was used. [Results] The strength of rectus abdominis muscle of both bridge exercises in the supine group and bridge exercises in the prone group increases significantly after exercise. The muscle activity of paraspinal muscle such as thoracic parts and lumbar parts in bridge exercises in the prone group decreases statistically while walking on a treadmill with high heels. Muscle activity of thoracic parts paraspinal muscle and bridge exercises in the supine group decreased significantly. [Conclusion] According to this study, we noticed that bridge exercise in a prone position is desirable for women who prefer wearing high heels as a back pain prevention exercise method.

Key words: Bridge exercise, Rectus abdominis muscle, Paraspinal muscle

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INTRODUCTION

High heels are recognized as a part of fashion and have been developed into various designs¹⁾ and have become very popular among women. Women under 30 years of age prefer higher heels even though they wear them for extended periods²⁾. High heels are preferred by women for esthetic reasons, but if they are worn for a long time, they cause back pain by fatiguing the lumbar muscles³⁾. Nevertheless, according to research, women in their 20's, prefer to wear 7 cm heels⁴⁾. In general, high heels over 6 cm increase lumbar muscle fatigue resulting in high back pain³⁾. The muscle activity of the erector muscle of the spine while wearing high heels increased muscle activity^{5, 6)}. This research has demonstrated that patients with back pain have higher muscle activity than people without back pain⁷⁾. This indicates a higher risk of back pain when people wear high heels for extended periods.

The cost of treating back pain in our modern society is expensive, and it is quite common⁸⁾. According to recent research, over 80% of the population experiences back pain⁹⁾. In addition, people with back pain tend to avoid physical activities in order to minimize pain, which causes extensor muscular atrophy and deterioration, resulting in increased pain over time¹⁰⁾.

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The above research results indicate that deterring the weakening of extensor muscles and improving muscular strength can prevent or reduce back pain. Therefore, recent studies regarding the effects of strength exercise for muscles around the waist have been performed, and in particular, studies on the effect of lumbar stabilization exercises have been performed as therapeutic approach for deep muscles of the waist with the goal of reducing or preventing back pain. Brill and Couzens¹¹⁾ mentioned that lumbar stabilization exercise is effective for balancing posture and strengthening of paraspinal muscles. Among muscles involved in lumbar stabilization, multifidus and transversus abdominis contract earlier than other muscles in all the movements of the human body, and secure stabilization of the spine and provide the proper body balance¹²⁾. Thus, lumbar stabilization exercise not only increases stabilization of the spine and pelvis by strengthening the deep muscles of the trunk¹³⁾. It also improves functional movements and balance ability¹⁴⁾.

Lumbar stabilization exercise includes pelvic tilting, abdominal drawing, bridge exercise and four-point kneeling¹⁵⁾. Bridge exercise can retrain fine motor and gross motor coordination in the proper ratio. This results in stabilization of the trunk and increase of muscular strength of the lower limbs and hips. Therefore, bridge exercise is frequently used in clinics¹⁶⁾. Bridge exercise is performed in supine and prone positions¹⁷⁾. Kong¹⁸⁾ claimed that while the bridge exercise in prone position increases abdominal muscle activity in the standing posture more than bridge exercise in supine or bridge exercise on the therapeutic ball, it decreases muscle activity of the erector muscle of the spine.

On the other hand, there are not enough studies on whether lumbar stabilization exercise has a direct effect on actual daily life movement. Insufficient studies have been performed on the effect of paraspinal muscles on muscular strength while lumbar stabilization exercises are performed. Because the purpose of exercise is to perform daily life activities functionally by improving muscular strength, it is very important to understand the functional change of paraspinal muscles during functional activities after lumbar stabilization exercises are performed. Therefore, the purpose of this study is to find out the effects of bridge exercises which are regarded as effective as lumbar stabilization exercises on paraspinal muscles during functional activities. In particular, this study was intended to demonstrate how paraspinal muscles are affected in women who do a significant amount of walking in high heels.

SUBJECTS AND METHODS

The subjects of this study were 30 female students who go to S University located in Busan. The subjects understood the purpose and intention of this subject and signed written consent forms. Women were chosen who had not previously experienced back pain, nervous system diseases, pain or hypofunction on upper and lower limbs, or undergone surgical treatment in the previous 6 months. The subjects were randomly categorized into groups of 10 in bridge exercise in supine position, 10 in bridge exercise in prone position, and 10 in control group. The average age of subjects in the bridge exercise in supine group was 21.8, the average height was 159.8 cm, and the weight was 56.4 kg. The average age of subjects in the bridge exercise in prone group was 21.5, the average height was 164.9 cm, and the weight was 57.8 kg. The average age of subjects in the control group was 22.2, the average height was 161.5 cm, and the weight was 55.3 kg. There was no difference in general characteristics among the groups (Table 1).

In this study, surface electromyogram (4D-MT & EMD-11, Relive, Korea) was used for measurement of muscle activity. To measure muscle activity of paraspinal muscles, we revealed the body parts for electrode pad placement, and then removed hair and wiped the skin to reduce skin resistance against surface electromyography signals. Electrode MT100 was used. This electrode is disposable, soft gel type, 30 mm in external diameter, 22 mm electrode size, round in shape and with a conductivity of Ag/AgCl. The attachment part of the surface electrode was the paraspinal muscle, which is 2 cm apart to the left and the right from spinous process of C7, T7, and L5¹⁹⁾. The electrode was attached on both sides parallel with muscular fiber. The sampling rate of the electromyogram signal was set at 1,000 Hz, 60 Hz analog notch filter, and 20–500 Hz digital band pass filters were used to extract the electromyogram signal. After sampling electromyogram signal with 1,000 samples/sec, we digitized it by using integrated analysis program. The average value of RMS (root mean square) was used for the paraspinal muscle activity. After linear filtering data value for 5 seconds, RMS average value for 3 seconds excluding the first and last seconds was calculated. The high heels used in this study were set back heels with 7 cm height according to the standard suggested by³⁾. We researched the effect of bridge exercise by measuring muscle activity of paraspinal muscles while the subjects walked in high heels before and after bridge exercises.

For measuring the strength of abdominal muscles, all subjects were asked to lie down, to bend their knees at 90° and to put their feet on the ground. Next, they stretched their arms forward and lifted their upper trunk until their fingertips barely

Table 1. The general characteristic of subjects

| Variables | BES (N=10) | BEP (N=10) | Control (N=10) |
|-------------|-------------------------|-------------|----------------|
| Age (years) | 21.8 ± 0.8 ^a | 21.5 ± 1.0 | 22.2 ± 1.0 |
| Height (cm) | 159.8 ± 4.2 | 164.9 ± 6.6 | 161.5 ± 6.0 |
| Weight (kg) | 56.4 ± 5.9 | 57.8 ± 10.8 | 55.3 ± 9.6 |

^aMean ± SD. BES: Bridge Exercise in supine; BEP: Bridge Exercise in prone

touched their knees, and maintained the position. We measured how many seconds transpired until they couldn't stay the motion, and the value was recorded and compared.

The posture of the bridge exercise in supine position with the abdominal muscle drawing-in method applied started when the subjects lay straight, bent their knee joints at 90°, spread both feet and knees at shoulder width, put their soles parallel on the ground, and put both hands comfortably parallel on the ground. They maintained the neck and head straight without tilting and stared straight ahead. When the tester said "Raise your hips", the subjects raised their pelvis. When they heard "Stay", they maintained that position for 30 seconds. When the instruction "Put your hips down" was given, they put their pelvis down and rested for 30 seconds. The tester instructed the subjects to exhale while lowering their abdomen toward the ground during the exercises. Five repetitions of this process were considered as 1 set, and a total of 3 sets were performed. A 5-minute break was taken after each set¹⁸). The posture of the bridge exercise in prone position began with the subjects lying face down with their elbows bent at 90°. They supported their body weight by using forearm and toes, their neck was drawn slightly, and they stared straight ahead. When the measuring person said "Start", the exercising subjects lifted their body. When they heard "Stay", they maintained their position for 30 seconds. When they heard "Put down", they put their body back down and had a 30 second break. To reduce errors of posture during exercise, they stayed in the neutral posture to prevent bending the lumbar area. Five repetitions of this process were considered as 1 set, and a total 3 sets were performed. A 5-minute break was given per set¹⁸).

Data analysis was performed using one-way ANOVA to demonstrate the different general characteristics among the groups and the difference of muscle strength and paraspinal muscle activity. Subsequently paired comparison t-test was performed to find out whether the bridge exercise had an effect on muscle strength of the straight muscles of the abdomen and on paraspinal muscle activity. To demonstrate the difference of change amount among the groups, analysis of covariance (ANCOVA) was performed. The statistical program that was used was SPSSWIN (ver. 23.0), and statistical significance level was $\alpha=0.05$.

RESULTS

The muscle strength of rectus abdominis muscle before bridge exercises the in supine group was 26.6 seconds, the prone group was 31.7 seconds, and the control group was 36.5 seconds. Although a difference was demonstrated, the difference was not significant. The paraspinal muscle activity of cervical spine, the bridge exercise in supine group was 91.1mV, the bridge exercise in prone group was 84.6mV, and the control group was 81.2mV. There was no significant difference in paraspinal muscle activity of cervical spine among the groups. The paraspinal muscle activity of thoracic parts, the bridge exercise in supine group was 119.8mV, the bridge exercise in prone group was 124.1mV, and the control group was 126.3mV. There was no statistically significant difference in paraspinal muscle activity of thoracic parts among the groups. The paraspinal muscle activity of lumbar parts, the bridge exercise in supine group was 86.9mV, the bridge exercise in prone group was 79.6mV, and the control group was 94.9mV. There was no statistically significant difference in paraspinal muscle activity of lumbar parts among the groups (Table 2).

The change of muscle strength of rectus abdominis muscle after exercise, the bridge exercise in supine group increased muscle strength from 26.6 seconds before exercise to 34.4 seconds after exercise, which showed a significant increase ($p<0.05$). The bridge exercise in prone group significantly increased muscle strength from 31.7 seconds before exercise to 42.5 seconds after exercise, which showed a significant increase ($p<0.05$). The bridge exercise in the control group slightly decreased from 36.5 seconds to 34.9 seconds after exercise, but no statistically significant difference was demonstrated. The comparison of aspect of change among the three groups showed that while the bridge exercise in supine group and the bridge exercise in prone group increased, the control group decreased ($p<0.05$) (Table 3). Regarding the paraspinal muscle activity of cervical spine while the subjects were walking on the treadmill with high heels, the bridge exercise in the supine group decreased from 91.1mV before exercise to 89.6mV after exercise; the bridge exercise in the prone group also decreased from 84.6mV before exercise to 84.2mV after exercise with no significant statistical difference; and the control group decreased from 81.2mV before exercise to 80.1mV after exercise, with no significant statistical difference as well. The comparison of aspect of change among the three groups in the paraspinal muscle activity of cervical spine showed no statistical difference among the groups. Regarding the paraspinal muscle activity of thoracic parts, the bridge exercise in supine group significantly decreased from 119.8mV before exercise to 89.5mV after exercise ($p<0.05$), and the bridge exercise in the prone group

Table 2. The difference of muscle strength and muscle activity among the groups

| Variables | BES | BEP | Control |
|------------------------|--------------------------|--------------|--------------|
| Strength (sec) | 26.6 ± 16.8 ^a | 31.7 ± 22.4 | 36.5 ± 24.7 |
| Cervical | 91.1 ± 31.9 | 84.6 ± 30.3 | 81.2 ± 26.2 |
| Activity (mV) Thoracic | 119.8 ± 31.1 | 124.1 ± 36.4 | 126.3 ± 29.5 |
| Lumbar | 86.9 ± 33.0 | 79.6 ± 25.4 | 94.9 ± 36.3 |

^aMean ± SD. BES: Bridge Exercise in supine; BEP: Bridge Exercise in prone

also significantly decreased from 124.1mV before exercise to 93.7mV after exercise ($p<0.05$). However, the control group decreased from 126.3mV before exercise to 112.6mV after exercise, but there was no statistical difference. The comparison of aspect of change among the three groups in the paraspinal muscle activity of thoracic parts all showed a decreasing tendency, but there was no statistical difference among the groups. Regarding the paraspinal muscle activity of lumbar parts, the bridge exercise in supine group decreased from 86.9mV before exercise to 83.0mV after exercise, and the control group decreased from 94.9mV before exercise to 94.5mV after exercise, but both groups showed no statistical difference. However, the bridge exercise in prone group significantly decreased from 79.6mV before exercise to 54.7mV after exercise ($p<0.05$). The comparison of aspect of change among the three groups in the paraspinal muscle activity of lumbar parts showed that the bridge exercise in the prone group decreased more than the control group ($p<0.05$) (Table 4).

DISCUSSION

High heels have become popular for their aesthetic aspect, but wearing them for a long time can pose a risk for fatigue and pain in the lower back muscles³). The height of the heels can affect changes in the position of the body joints and center of gravity, which requires a large amount of kinetic and mechanical compensation on other body structures, such as the spine²⁰). A large amount of compensation from the structures around the spine can cause lower back pain, and as the lower back pain becomes more severe, cross-sectional decrease and atrophy may occur in muscles around the spine²¹). Various approaches to treatment are being proposed today since pain and reduced muscle mass can cause limitations in physical activity that causes difficulties in activities of daily life²²). With respect to this, Brill and Couzens¹¹) reported that maintaining a well-balanced posture and strengthening lower back muscles through lumbar stabilization exercises can be effective in treating lower back pain. Most of the previous studies focused on finding effective exercise routines by comparing the level of trunk muscle activities achieved through lumbar stabilization. However, studies on the effects of these exercise routines on actual functional activities are still lacking. Accordingly, the present study measured the level of abdominal muscle activities from applying different types of bridge exercise, which is effective for lumbar stabilization, and the study aimed to use the findings in examining the changes in the level of activity in the muscles near the spine during the functional activity of walking on a treadmill while wearing high heels. As a result, this study revealed that, as compared to the control group, both the BES and BEP groups showed significant increase in the muscle strength of rectus abdominis muscles after bridge exercise. Lumbar stabilization requires coordinated contractions of anterior, posterior, and lateral muscles of the spine^{23, 24}). In addition, weakening of the abdominal muscles can cause lower back pain by increasing anterior pelvic tilt and lumbar lordosis²⁵). Bridge exercises require motor control and balance, and because spinal stabilization requires enough strength to prevent anterior pelvic tilt and lumbar lordosis, muscle activity in the rectus abdominis muscle may have increased. Studies by Kavcic et al.²⁶) and Kim et al.²⁷) reported that rectus abdominis muscle activity was highly correlated with bridge exercise, which was consistent with the findings in this study that found a significant increase in rectus abdominis muscle activity during bridge exercise.

In order to identify the functional role of bridge exercise, the present study measured the differences between the groups in activities of muscles near the spine from walking on a treadmill wearing high heels, before and after bridge exercise. Both the BES and BEP groups showed no significant differences in muscles near the cervical vertebrae. However, both groups showed significant decrease in the muscles near the thoracic vertebrae. Also, the BEP group showed a significant decrease in the activities of muscles near the lumbar vertebrae, but the BES group showed no significant change.

A study by Stevens et al.²⁸) reported that bridge exercise resulted in a significant decrease in the activities of the thoracic

Table 3. The changes of rectus abdominis muscle strength after bridge exercise (Unit: sec)

| Group | Pre-exercise | Post-exercise |
|---------|--------------------------|---------------|
| BES*† | 26.6 ± 16.8 ^a | 34.4 ± 19.0 |
| BEP* | 31.7 ± 22.4 | 42.5 ± 24.6 |
| Control | 36.5 ± 24.7 | 34.9 ± 22.9 |

^aMean ± SD. BES: Bridge Exercise in supine; BEP: Bridge Exercise in prone

†BES=BEP>Control by ANCOVA test

* $p<0.05$

Table 4. The changes of spinal muscle activity after bridge exercise (Unit: mV)

| Area | Group | Pre-exercise | Post-exercise |
|----------|---------|--------------------------|---------------|
| Cervical | BES | 91.1 ± 31.9 ^a | 89.6 ± 31.9 |
| | BEP | 84.6 ± 30.3 | 84.2 ± 22.3 |
| | Control | 81.2 ± 26.2 | 80.1 ± 27.4 |
| Thoracic | BES* | 119.8 ± 31.1 | 89.5 ± 21.1 |
| | BEP* | 124.1 ± 36.4 | 93.7 ± 35.2 |
| | Control | 126.3 ± 29.5 | 112.6 ± 34.8 |
| Lumbar‡ | BES | 86.9 ± 33.0 | 83.0 ± 30.2 |
| | BEP* | 79.6 ± 25.4 | 54.7 ± 14.5 |
| | Control | 94.9 ± 36.3 | 94.5 ± 35.7 |

^aMean ± SD. BES: Bridge Exercise in supine; BEP: Bridge Exercise in prone

‡BEP>Control by ANCOVA test

* $p<0.05$

vertebrae muscles, which was consistent with the present study that found significant decrease in the activities of the muscles near the lumbar vertebrae following bridge exercise. Moreover, it is believed that decrease in the activities of muscles near the lumbar vertebrae may be attributed to prevention of anterior pelvic tilt by strengthening the abdominal muscles through bridge exercises, and minimizing hyperextension of the trunk by reducing lumbar lordosis that resulted in reduced tension.

In summarizing the findings in this study, it is believed that as the supporting surface area decreased, somatosensory information that is input proportionately to the cross-sectional area that the body touches during bridge exercise also decreased, which caused the muscles to become more tense, which resulted in significant changes in the muscle strength of abdominal muscles. Many women wear high heels for long hours for aesthetic reasons and due to work requirements. For these women, abdominal muscle strengthening through bridge exercise can help prevent anterior pelvic tilt and decrease lumbar lordosis, which could play a role in reducing tension in the muscles around the spine. By doing so, the frequency of lower back pain can be reduced by relieving excessive muscle tension and limiting unnecessary muscle use during functional movement.

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