Comparison of Trunk Muscle Activation Ratios with Different Knee Angles during a Bridge Exercise with/without an Abdominal Drawing-in Maneuver

IL-HUN BAEK, MS, PT), BONG-OH GOO, PhD, PT), SUNG-HAK CHO, MS, PT), KANG HOON KIM, MS, PT)

1) Department of Physical Therapy, College of Health Sciences, Catholic University of Pusan: 9 Bugok 3-dong, Geumjung-gu, Busan 609-757, Republic of Korea. TEL: +82 51-510-0574, FAX: +82 51-510-0578, E-mail: b101h@naver.com

Abstract. [Purpose] The purpose of the present study was to investigate changes in activation ratios of the transversus abdominis (TrA), internal abdominal oblique (IO), and external abdominal oblique (EO) at knee angles of 60, 90, and 120 degrees when an abdominal drawing-in maneuver (ADIM) was introduced to a bridge exercise. [Subjects] A total of 44 healthy people agreed to participate in the study, and based on age, height, and weight, these subjects were matched and randomly assigned to either the bridge exercise group (n=22) or the bridge exercise with ADIM group (n=22). [Methods] The thickness of the abdominal muscles was measured using a SonoAce X4 (Samsung Medison Co., Ltd., Seoul, South Korea). The main outcome variables were the ratios of the TrA, IO, and EO thickness during the exercise versus in the relaxed position (TrA, IO, and EO activation ratios). [Results] Differences were found in the TrA and IO activation ratios at knee angles of 90 and 120 degrees between the groups. The TrA and IO activation ratios increased at angles of 90 and 120 degrees compared with 60 degrees, within the bridge exercise with ADIM group. [Conclusion] In conclusion, a knee angle of 90 degrees might be a more effective angle during the hooklying bridge exercise with an ADIM when spinal stabilization exercises are performed or when studies are prepared in this area.

Key words: Bridging exercise, Knee angle, Abdominal drawing-in maneuver

INTRODUCTION

The bridge exercise is generally employed for therapeutic exercises for lumbopevic stabilization. The supine position with the knees and hips bent is a pain-free posture for patients with low back pain1). The bridge exercise was first adopted in clinical practice to strengthen the leg extensor muscles. As demand for stabilization exercise programs for patients with low back pain grew, the bridge exercise was modified to include various postures based on its hook-lying position to increase its effects on low back pain. Lehman et al2) reported an increase in trunk muscle activation when modified common bridge exercises were performed. Another study identified different activation levels among selected muscles in the bridge position under various conditions. This study demonstrated that it is possible to strengthen a specific abdominal muscle easily3). Muscles being stimulated during the bridge exercise are divided into local and global muscles based on their different roles in stabilizing the trunk4). Hodge et al. emphasized the role of local muscle, particularly the TrA, in firing5). The abdominal drawing-in maneuver (ADIM) or hollowing exercise is based on this finding. The ultimate purpose of the ADIM is to accelerate the contraction of local stabilizing muscles first and then cause global torque that results in the muscles contracting properly. Thus, the anticipatory activity of the TrA is a key element to achieve the co-contraction of local and global muscles. However, the anticipatory activity of the TrA occurs more slowly (or not at all) in patients with low back pain compared with control groups. Either case leads to spinal instability, which increases the risk of low back pain6). It is therefore emphasized that the ability to activate the TrA is essential for performance of a series of tasks. In the same way, an ADIM is described as a basic exercise for patients with low back pain6). ADIMs, accompanied by the bridge exercise, are combined with various postures and have been widely explored in studies to prove their effects on trunk muscle activation and stability.

Many studies have investigated stability of ground state, leg lift movement, and stabilizing abdominal muscles as variables associated with the effects of an ADIM accompanied by the bridge exercise. However, few studies have looked into the effects of this therapeutic technique at varying knee angles. One study allowed subjects to perform the bridge exercise at a knee angle of 60 degrees, while another study allowed a knee angle of 90 degrees7). Other
researchers have often described varied knee angles as study limitations. This study investigated changes in the activation ratios of the TrA, IO, and EO at knee angles of 60, 90, and 120 degrees during the bridge exercise with and without an ADIM.

SUBJECTS AND METHODS

A total of 44 healthy people were informed of the study’s purpose and agreed to participate. Based on age, height, and weight, these subjects were matched and randomly assigned to one of two groups: the bridge exercise group (n=22) or the bridge exercise with ADIM group (n=22). Some subjects were excluded because of low back pain over the last six months, low back surgery, leg injury, leg surgery, cardiovascular problem, respiratory problem, nerve damage, and problems with body movements. Before the study began, subjects were trained for two days to master an ADIM and the bridge exercise at knee angles of 60, 90, and 120 degrees. During the ADIM training, rehabilitative ultrasound imaging (RUSI) was used as a feedback tool.

Subjects took the hook-lying position to begin the bridge exercise while placing their feet on a rubber ground cover. Their knee angles were measured during the bridge exercise under the following conditions: the stationary arm was placed pointing toward the greater trochanter of the femur, moving arm was placed pointing toward the fibula head, and axis was placed over the lateral epicondyle of the fibula. After the three sets of knee angles (60, 90, and 120 degrees) were tested, the subjects were instructed to return to the resting position slowly. After one minute of resting, the subjects began the bridge exercise by placing their hands on the ground. The bridge exercise with ADIM group performed an ADIM and was instructed to lift the hips from the ground until the hip point was parallel with their knee joint and to stay in that position for five seconds.

The bridge exercise group followed the same instructions without performing an ADIM. In addition, exercises were performed in random sequence based on a random number table. The subjects rested for one minute to avoid post-exercise fatigue.

The thickness of the abdominal muscles was identified using a SonoAce X4 (Samsung Medison Co., Ltd., Seoul, South Korea) and measured with a 7.5 MHz linear transducer in B-mode. The transducer was transversely placed midway between the bottom of the rib cage and the top of the iliac crest. To reduce the influence of respiration on muscle thickness, the images were captured at the end of expiration, which was determined by visual inspection of the ultrasound image. The thicknesses of all three muscles were measured by means of establishing a vertical reference line that was positioned 2.5 cm from the left edge (the muscle–fascia junction) of the TrA. Measurements were taken three times for each position to obtain the mean value. The main outcome variables were the ratios of the TrA, IO, and EO thickness during the exercise versus in the relaxed position (TrA, IO, and EO activation ratios).

The activation ratios of the abdominal muscles were compared at three different knee angles and between the groups using a two-way ANOVA. A post hoc analysis was performed with Tukey’s multiple comparison. The criterion for statistical significance was set at 0.05, and SPSS 18.0 Win was employed for the statistical analysis of the collected data.

RESULTS

As shown in Table 1, the general participant characteristics did differ between the groups. Significant differences were found in the total TrA and IO activation ratios for the different knee angles (p=0.07, p=0.03) as well as with the ADIM (p=0.00, p=0.00), and there was also a tendency for interaction between the group and the change in knee angles (p=0.01, p=0.03). The activation of these muscles particularly showed correlations with knee angle in the bridge exercise with ADIM group (p=0.03, p=0.02). However, the changes in muscle activations were not statistically significant for comparisons between angles of 90 and 120 degrees (p=0.923, p=0.783). The ratios of TrA, IO, and EO thickness did not reveal significant differences for any of the target angles in the bridge exercise group. The EO activations also did not show significant differences between and within the groups (Table 2).

DISCUSSION

The present study aimed to determine the activation ratios of the TrA, IO, and EO at three different knee angles 60, 90, and 120 degrees, during the bridge exercise after an ADIM was complete for lumbar stabilization. In addition, these activation ratios were compared with those of the group that performed only the bridge exercise. Significant differences were found in the TrA and IO activation ratios between the groups. These activations show a significant increase at angles of 90 and 120 degrees compared with 60 degrees in the bridge exercise with ADIM group. The bridge exercise is seen as one of the spinal stabilizing programs designed to improve muscle co-activation patterns and motor control. Richardson and Jull stressed the adverse effects of the bridge exercise when global muscle contraction was induced first instead of contraction of local stabilizing muscles. They claimed excessive increases in lumbar lordosis and subsequent low back pain as possible adverse effects. In this study as well, the activation of the hip flexors was not directly prevented in the bridge exercise group, although the hip was parallel to the knees in the bridge position for a neutral spine. However, it was shown that the bridge exercise performed for trunk stability is more effective when accompanied by an ADIM or hallowing exercise. These combined exercises increase intra-abdominal pressure and effectively train muscles to induce the co-activation of trunk muscles, which reduces the anterior tilt of the hip bone. Thus, they are highly effective in improving spinal stability. The findings of the present study are consistent with those of earlier studies.

In the present study using RUSI, the activation of the TrA and IO or local stabilizers increased progressively with increasing knee angles, while activation of the EO, one
of the global stabilizers, did not change significantly. The activation of local stabilizing muscles was more significant in the group that performed an ADIM. These findings explain why a small joint angle of the hip induced by a small knee joint angle relaxes the hip flexor, making posterior pelvic tilt more effective when the hip is lifted in the bridge position. That is, the activation of the abdominal muscles associated with the pelvic movement decreases progressively with decreases in knee angle. At high knee angles, the increased length of the lever arm accelerates the contraction of deep stabilizing abdominal muscles by causing relative instability.

Since Hodges and Richardson’s study, activation of the local stabilizing system, with the global stabilizing system being relaxed, has been highly recommended as the most effective approach to spinal stabilization exercises. Based on this recommendation, an ADIM was performed in the hook-lying position as a means of boosting the TrA activation in this study. The measured TrA activation ratios in the present study were 1.34 and 1.61 at knee angles of 60 and 90 degrees, respectively (smaller than the activation ratio of 1.75 found in the study by Teyhen et al., in which healthy adults performed an ADIM and the bridge exercise). However, they are similar to the activation ratio of 1.57 found at a knee joint angle of 90 degrees in the study by Nathaniel Gorbet et al., which also employed combined exercises. The varied TrA activation ratios are likely due to the different activity levels of the subjects: Subjects had variable activity levels in the study by Teyhen et al. and the present study, while the subjects were military recruits with higher activity levels in the study by Teyhen et al. The TrA activation ratio was higher, 1.64, at an angle of 120 degrees, and it was significantly higher than that at an angle of 90 degrees. It is therefore likely that TrA activation is not greatly affected at knee angles of over 90 degrees.

In this study, the changes in the thickness of the TrA and IO at an angle of 90 degrees were similar to the results of the study by Axler et al. and the study by Teyhen et al. In both studies, abdominal crunches were performed to help strengthen the TrA and IO muscles. Still, significant changes in the thickness of the abdominal muscles were also identified during Pilates exercises performed in conjunction with the imprint action (a kind of ADIM). The reason for the co-activation of the TrA and IO was explained in the study by Beith et al. They attributed the co-activation to the anatomical structure of the abdominal muscles in which aponeuroses and their reflex connections are combined, making it difficult for the TrA and IO to function independently. The findings of the present study support their view. While the activity of the TrA and IO increased significantly at angles of 90 and 120 degrees, some participants reported pain in the hamstring and soleus regions at an angle of 120 degrees.

The changes in the EO muscle were not significant in every exercise. The EO muscle is a global core muscle producing torque. The bridge exercise performed with a ball increases EO activity to prevent the trunk from rolling off the ball. However, the exercises were performed on the ground in this study, so rotation torque did not appear to occur, and eventually the EO activity remained almost unchanged.

This study suffers many limitations, as it failed to investigate lower-limb extensor power despite the fact that it is closely affected by the bridge exercise and knee angle. Further study is necessary to compare the activation of the abdominal muscles with lower-limb extensor power for better study results.

In conclusion, the TrA and IO activation increased significantly at angles of 90 and 120 degrees during the bridge exercise with an ADIM. The thickness of the TrA and IO did not show significant increases during activation when compared with the thicknesses at rest in the bridge without ADIM group. This study therefore proposes that consideration be given to desired knee angles when spinal stabilization exercises are performed or when studies are prepared in this area.

Table 1. General characteristics of subjects (n=44)

<table>
<thead>
<tr>
<th></th>
<th>BE (n=22)</th>
<th>BE with ADIM (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21.4 ± 0.5</td>
<td>21.7 ± 0.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.4 ± 1.8</td>
<td>168.0 ± 2.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.3 ± 2.8</td>
<td>59.3 ± 3.1</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.6 ± 0.7</td>
<td>21.0 ± 1.0</td>
</tr>
</tbody>
</table>

Mean ± SD; BMI, body mass index. BE, bridging exercise; ADIM, abdominal drawing-in maneuver

Table 2. Comparison of activation ratios with the different knee angles during the bridging exercise with/without an ADIM (n=44)

<table>
<thead>
<tr>
<th></th>
<th>TrA</th>
<th>IO</th>
<th>EO</th>
</tr>
</thead>
<tbody>
<tr>
<td>B60</td>
<td>1.26 ± 0.31</td>
<td>1.10 ± 0.25</td>
<td>0.87 ± 0.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B90</td>
<td>1.19 ± 0.30</td>
<td>1.06 ± 0.22</td>
<td>0.84 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B120</td>
<td>1.23 ± 0.25</td>
<td>1.18 ± 0.25</td>
<td>0.90 ± 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>AB60</td>
<td>1.34 ± 0.32</td>
<td>1.22 ± 0.22</td>
<td>0.90 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>AB90</td>
<td>1.61 ± 0.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.47 ± 0.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.86 ± 0.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>AB120</td>
<td>1.64 ± 0.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.53 ± 0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.85 ± 0.17&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

B, bridging exercise; AB, bridging exercise with an abdominal drawing-in maneuver. The numbers in the group names represent the knee angles (60, 90, and 120 degrees). Different superscripts within the same columns indicate significant differences (p<0.05).

REFERENCES

2) Lehman GJ, Hoda W, Oliver S: Trunk muscle activity during bridging exercises on and off a Swiss ball. Chiropr Osteopat, 2005, 13: 14. [Medline] [CrossRef]


7) Mew R: Comparison of changes in abdominal muscle thickness between standing and crook lying during active abdominal hollowing using ultrasound imaging. Man Ther, 2009, 14: 690–695. [Medline] [CrossRef]


