The Effects of Different Support Surfaces on Trunk and Lower Extremity Muscle Activity in a Back Bridging Exercise

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Abstract. [Purpose] The purpose of the present study was to investigate the effects of different support surfaces on muscle activity when healthy adults performed the back bridging exercise. [Subjects] Twenty healthy adults participated in the present study. [Methods] The subjects performed a back bridging exercise on different support surfaces (mat, balance pad, air cushion, and Swiss ball). Surface electrodes were used to record the electromyographic signal amplitudes of trunk muscles (erector spinae, obliquus externus abdominis, obliquus internus abdominis, and rectus abdominis) and lower extremity muscles (gluteus maximus, vastus medialis, semitendinosus, and soleus). The EMG data were normalized as a percentage of the maximum voluntary contraction, and were analyzed using 1 × 4 repeated measures analysis of variance. [Results] We found that the activities of the vastus medialis, semitendinosus, and soleus increased significantly when the exercise was performed on a Swiss ball, compared to their values during performance on a mat or a balance pad. No such difference was found for the gluteus maximus. [Conclusion] When the back bridging exercise was performed for stabilization, the changes in support surface did not affect the activity of the trunk muscles.

Key words: Bridging exercise, EMG activity, Muscles

INTRODUCTION

The definition of spinal stability is not definitive but many researchers have defined it as coactivation of local and global muscles1, 2). Spinal stabilization through the coactivation of trunk muscles is crucial for the prevention and rehabilitation of damage caused by lumbar instability3). Local muscles such as the transverse abdominis, multifidus, and obliquus internus abdominis are located deep within the body to increase segmental stability of the vertebrae4), whereas global muscles are located near the surface and produce power and torque5). Spinal stabilization can be achieved through specific training exercises designed to enhance the coactivation of both local and global muscles. Among such exercises, the back bridging exercise is most frequently used6, 7).

The preparation posture for the back bridging exercise, bending the knee and hip joints in a supine position, is the preferred posture for back pain patients as it reduces pain. As the exercise involves lifting the pelvis from the preparation posture, the movement can strengthen paraspinal muscles and hip extensors through weight bearing. It can also facilitate pelvic motion in a standing posture and in preparation for the stance phase of gait8). An unstable support surface causes body perturbation, leading to an increase in activity by the trunk muscles in an effort to maintain postural stability9). Therefore, if an unstable surface is used during the back bridging exercise, the coactivation of trunk muscles be enhanced to reduce body perturbation. When a back bridging exercise was performed on an unstable supporting surface using a balance pad or an air cushion, the trunk muscle activity ratio increased6), and the transverse abdominis activity ratio increased during a sling-based back bridging exercise when the exercise was performed with abduction of the hip10). Although Imai et al. 3) used various stabilization exercises and unstable support surfaces, the changes of muscle activities in the back bridging exercise could not be isolated in their study, and there are conflicting opinions on whether using unstable surfaces such as a Swiss ball is effective at increasing the level of difficulty9, 11).

Numerous studies of stabilization exercises that strengthen spinal stability have been conducted, and conflicting results have been presented concerning unstable support surfaces. This research aims to determine the effects of using unstable support surfaces on trunk and lower extremity muscle activity in the back bridging exercise.

SUBJECTS AND METHODS

Before the experiment, the researcher explained the study protocol to the participants, and their informed consent was obtained. The participants were twenty healthy adults...
who had no orthopedic or neurologic problems in the last 6 months. The mean ± standard deviation of age, height, and weight of the participants were 23.00 ± 1.92 years, 168.15 ± 10.02 cm, and 58.10 ± 10.74 kg, respectively.

To prepare participants for the lifting of the hip in the abdominal draw-in maneuver during the back bridging exercise, contraction training for the transverse abdominis and pelvic floor muscles was performed for 30 minutes before the experiment. The back bridging exercise started from the supine position. The participants were asked to spread their feet to shoulder width, their legs raise their hips so that were perpendicular to the ground, and place their palms on the ground with a 30° abduction of the shoulder joints. During the exercises, the chin was pointed towards the ground, and the eyes were directed towards the ceiling (Fig. 1). The supporting surfaces tested were a mat, a balance pad, an air cushion, and a Swiss ball. The heights of the support surfaces were adjusted such that all 4 conditions were of the same level in order to reduce differences in joint angles between the conditions. The order of each condition was decided by randomly choosing cards numbered 1–4. For each condition, the exercise was repeated 3 times for 5 seconds for each trial, and a 1-minute rest was given between trials. When the supporting surface was changed, a 2-minute rest was given.

Disposable 1-cm Ag/AgCl surface electrodes (T246H; Bioprotech, Korea) with an interelectrode distances of 2 cm were used for surface electromyography (Myosystem 1400A; Noraxon Inc., USA) recording of muscle activity. MyoResearch XP (Noraxon Inc., USA) master edition 1.06 was used to store and process the signals of the raw EMG. In order to reduce skin impedance to below 5 kΩ, the skin was cleansed with alcohol swabs and skin abrasives. The electrodes were attached perpendicular to the muscle fibers, and the common reference electrode was attached to the right anterior superior iliac spine.

The EMG data were sampled at 1000 Hz and band-pass filtered between 20 and 500 Hz. EMG data were full-wave rectified and smoothed by computing root mean square (RMS) values with a window of 50 ms\(^2\). EMG signal amplitudes for each muscle were calculated for the 3 seconds in the middle of 5 seconds of activity and were normalized as %maximal voluntary isometric contraction (%MVIC). The highest RMS of the 3 MVIC trials for each muscle was used as the basis for EMG signal normalization of the data.

Statistical analyses were performed using SPSS 12.0 software package (SPSS Inc., Chicago, IL) for Windows. Repeated measures analysis of variance (ANOVA) was used to evaluate muscle activity of the trunk and lower extremity muscles during the back bridging exercise and the Bonferroni correction was used for post hoc analysis. The alpha level was chosen as 0.05.

**RESULTS**

Activity of the trunk and lower extremity muscles during the exercise ranged from low to medium (4.9%–55.6%). There were no significant differences in muscle activities of the trunk muscles when the support surfaces were changed. However, among the lower extremity muscles, significant differences in the activities of the vastus medialis, semitendinosus, and soleus (Table 1). In order to reduce skin impedance to below 5 kΩ, the skin was cleansed with alcohol swabs and skin abrasives. The electrodes were attached perpendicular to the muscle fibers, and the common reference electrode was attached to the right anterior superior iliac spine.

**Fig. 1.** Bridging exercise: a) mat, b) balance pad, c) air cushion, d) Swiss ball

- Activity of the trunk and lower extremity muscles during the exercise ranged from low to medium (4.9%–55.6%).
- There were no significant differences in muscle activities of the trunk muscles when the support surfaces were changed. However, among the lower extremity muscles, significant differences in the activities of the vastus medialis, semitendinosus, and soleus were found when the conditions were changed (p<0.05). The muscle activities of the vastus medialis and semitendinosus significantly increased during exercise using the Swiss ball during exercise compared to the mat, balance pad, and air cushion (p<0.05). Muscle
activity in the soleus increased using the Swiss ball or air cushion, compared to the mat or balance pad (p<0.05). The results are displayed in Table 2.

**DISCUSSION**

Cooperation between local and global muscles is important for maintaining spinal stability. The back bridging exercise is frequently used to enhance motor control and muscle coactivation for spinal stabilization. The present study explored the effects of using different support surfaces for back bridging exercise on the activities of the trunk and lower extremity muscles. In the present study, muscle activity differed according to support surface, and muscle activity increased as the level of difficulty of the training increased. We found that the activities of the trunk muscles did not differ with the support surface. However, among the lower extremity muscles, the activities of the vastus medialis, semitendinosus, and soleus significantly increased when the exercise was performed on a Swiss ball. The results of the present study suggest that performing the back bridging exercise on a Swiss ball led to significant increases in the muscle activities of the vastus medialis, semitendinosus, and soleus.

Stevens et al. found that, when performing the back bridging exercise with a Swiss ball, muscle activity of the obliquus externus abdominis increased more than that of the obliquus internus abdominis, suggesting that trunk stability was affected more by global muscles than by local muscles. They also found that in the back bridging exercise with a stable support surface, the muscle activities of the obliquus internus abdominis and obliquus externus abdominis were similar, but in the unilateral back bridging exercise, the muscle activity in the obliquus internus abdominis was higher. In the present study, contrary to the findings of Stevens et al., we did not find any differences in trunk muscle activities when the support surface was changed. This may be because our subjects performed the abdominal hollowing maneuver to lift up the pelvis, thus maintaining tension in the abdominal muscles. However, we found that performing the back bridging exercise on a Swiss ball led to significant increases in the muscle activities of the vastus medialis, semitendinosus, and soleus.

The results of the present study suggest that performing the back bridging exercise on a Swiss ball increases postural instability, and the body compensates by intensifying activity in the lower extremity muscles instead of the trunk muscles. The absence of a significant difference in activity in the gluteus maximus may be because our subjects lifted the pelvis during the bridging exercise, which was done to prevent excessive lumbar lordosis.

**Table 1.** Electrode placement

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominis</td>
<td>2 cm lateral to the umbilicus</td>
</tr>
<tr>
<td>Externus Abdominis</td>
<td>Intersection of a line lateral to the umbilicus and superior to the anterior superior iliac spine (ASIS)</td>
</tr>
<tr>
<td>Internus Abdominis</td>
<td>2 cm inferior and medial to ASIS</td>
</tr>
<tr>
<td>Erector Spinae</td>
<td>3 cm lateral to the spinous process</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>Half the distance between the trochanter and the sacral vertebrae</td>
</tr>
<tr>
<td>Vastus Medialis</td>
<td>2 cm medial to the superior rim of the patella</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>3 cm medial to the lateral border of the thigh</td>
</tr>
<tr>
<td>Soleus</td>
<td>Inferior and lateral aspects of the leg, below the belly of the gastrocnemius</td>
</tr>
</tbody>
</table>

**Table 2.** Normalized surface EMG amplitudes (%MVIC) of each muscle during the back bridging exercise

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Mat</th>
<th>Balance pad,</th>
<th>Air cushion</th>
<th>Therapeutic ball</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominis</td>
<td>27.23 ± 59.49</td>
<td>30.70 ± 58.59</td>
<td>26.87 ± 42.22</td>
<td>30.18 ± 51.20</td>
</tr>
<tr>
<td>Externus Abdominis</td>
<td>39.17 ± 67.14</td>
<td>33.33 ± 44.63</td>
<td>27.19 ± 26.90</td>
<td>33.88 ± 29.78</td>
</tr>
<tr>
<td>Internus Abdominis</td>
<td>26.20 ± 28.81</td>
<td>26.11 ± 29.55</td>
<td>25.02 ± 27.33</td>
<td>27.67 ± 30.36</td>
</tr>
<tr>
<td>Erector Spinae</td>
<td>55.21 ± 57.37</td>
<td>51.35 ± 33.03</td>
<td>53.61 ± 38.11</td>
<td>55.65 ± 29.60</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>22.06 ± 23.17</td>
<td>19.48 ± 21.21</td>
<td>22.26 ± 24.22</td>
<td>23.03 ± 24.47</td>
</tr>
<tr>
<td>Vastus Medialis</td>
<td>5.14 ± 2.93</td>
<td>5.23 ± 3.30</td>
<td>5.30 ± 3.46</td>
<td>6.39 ± 4.01†</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>25.79 ± 10.86</td>
<td>31.05 ± 14.22</td>
<td>33.10 ± 19.89</td>
<td>45.20 ± 18.38*</td>
</tr>
<tr>
<td>Soleus</td>
<td>7.67 ± 3.84</td>
<td>10.65 ± 6.47</td>
<td>19.30 ± 21.41†</td>
<td>19.77 ± 14.24†</td>
</tr>
</tbody>
</table>

(N=20) NOTE. Values are mean ± SD. *Statistically significant difference compared to mat, balance pad, and air cushion (p<0.05). †Statistically significant difference compared to mat, balance pad (p<0.05)
Imai et al.\textsuperscript{3)} found that the rectus abdominis, obliquus externus abdominis, transverse abdominis, erector spinae, and multifidus were highly activated during an elbow-toe exercise on unstable support surfaces. However, they did not find any change in the activities of trunk muscles during the back bridging exercise. In addition, in another study, no significant differences in the activities of trunk muscles were observed during four other stabilization exercises with a Swiss ball\textsuperscript{9)}. In the present study, similar to the findings of Imai et al.\textsuperscript{3)}, we found that the use of unstable support surfaces resulted in higher muscle activity than stable supporting surfaces. However, we only found significant differences in the activities of lower extremity muscles. This finding corresponds with those of some previous studies\textsuperscript{3, 9)}.

The present study investigated the effect of various support surfaces on trunk and lower extremity muscles using the back bridging exercise. We found that although the use unstable support surfaces disturbed balance and increased the activity of the lower extremity muscles, they had no discernible effect on trunk muscles. Therefore, it is unnecessary to use unstable support surfaces in an attempt to increase trunk muscle activity in the back bridging exercise. This knowledge is useful when considering stabilization exercises for patients with lower back pain.

Imai et al.\textsuperscript{3)} and Stevens et al.\textsuperscript{7)} compared muscle activities on stable and unstable support surfaces without taking into account the differences in surface height. These differences may have led to disparities that may have affected muscle activity. This possibility was reduced in the present study, because the heights of the support surfaces were adjusted to minimize differences in joint angles.

Although young and healthy participants were studied in our experiment, the level of fitness or individual differences in exercise experience may have affected the performance of the participants. Future studies focusing on elderly people or patients with back pain should be conducted to confirm our findings.

REFERENCES