Comparison of Abdominal Muscle Activity in Relation to Knee Angles during Abdominal Drawing-in Exercises Using Pressure Biofeedback

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Abstract. [Purpose] The leg angles that are the most effective for abdominal muscle activation were investigated by performing abdominal drawing-in exercises at different leg angles with a biofeedback pressure unit. [Methods] Subjects were asked to adopt a supine position, and the tip of the biofeedback pressure unit was placed under the posterior superior iliac spine. Then, the pressure was adjusted to 40 mmHg while referring to the pressure gauge connected to the biofeedback pressure unit. Subjects were instructed to increase the pressure by 10 mmHg using the drawing-in technique upon the oral instruction, “Start,” and to maintain the drawn-in state. The time during which the pressure was maintained within an error range of ±1–2 mmHg was measured in seconds. [Result] During the abdominal drawing-in exercises, the activity of the rectus abdominis, the internal and external obliques, and the transverse abdominis increased as the knee joint flexion angle increased from 45° to 120°. [Conclusion] When trunk stabilization exercises are performed at the same pressure to reduce damage after the acute phase of low back pain, trunk muscle strength can be efficiently increased by increasing the knee joint angle gradually, while performing abdominal drawing-in exercises with a biofeedback pressure unit.

Key words: Trunk muscles activity, Drawing-in, Biofeedback

INTRODUCTION

Trunk stabilization involves the simultaneous activation of the abdominal muscles and the spinal muscles1, 2). These muscles are postural and tonic muscles that play important roles in trunk stability and postural control3). The spinal muscles that are important for central stability can be categorized as local and global muscles. The local muscles include the interspinalis, the internal oblique, the transverse spinalis, and the multifidus. They maintain the anterior, posterior, and lateral stability of the spine and support the spinal curvature. The global muscles used to maintain balance against gravity and external loads include the rectus abdominis, the external oblique, and the paravertebral muscles3-4). Richardson et al.3 reported that abdominal exercises were appropriate as trunk stabilization exercises that correct neutral spinal postures in response to body rotations caused by external force, since these exercises reduce the contraction of the rectus abdominis and cause the co-contraction of the external oblique, internal oblique and the transverseus abdominis muscles. Methods of trunk stabilization include increasing the resistance and the number of the exercises, increasing the instability of the bearing surface using form-rollers, balance boards, or therapy-balls, and increasing the intensity of exercises5). Among the stabilization exercises, bridging exercises increase lumbar stability and improve control of the pelvis3). Richardson and Jull6 reported that during bridging exercises, deep muscles should be contracted together with superficial muscles, and that if these two groups were not co-contracted, lumbar lordosis would be increased due to compensation. Abdominal drawing-in exercises are used to increase intra-abdominal pressure by contracting the abdomen, thereby contracting the internal oblique and the transverse abdominis. These exercises are an efficient method of inducing lumbar stabilization, thereby reducing excessive pelvic anterior tilt or lumbar lordosis3).

Jull et al.7 stated that pressure biofeedback units are clinically necessary to evaluate the effects of lumbar stabilization and are suitable for use with lumbar stabilization exercises. Pressure biofeedback units are inelastic units that are inflated when intra-pressure increases. These units are connected to pressure gauges to facilitate training and enable the indirect identification of the abdominal walls’ movements through changing pressure10). These units can be beneficial when training patients in selective muscle contraction10). When pressure biofeedback units are used to perform abdominal drawing-in during bridging exercises, lumbar compensation has been shown to be reduced; thus,
the exercise is more effective at improving the strength of the hamstring muscle than the gluteus maximus\(^{12}\). Kim et al.\(^{13}\) reported that during bridging exercises, abdominal muscles showed maximum activity when the knee joint flexion angle increased, whereas the erector spinae muscle showed minimum activity when knee joint flexion angle increased.

In the present study, the leg angles that are the most effective for abdominal muscle activation were investigated by performing abdominal drawing-in exercises at different leg angles with a pressure biofeedback unit.

**SUBJECTS AND METHODS**

The subjects of this study were 20 healthy adults in their 20s, who understood the experimental procedure participation. They had the muscular strength, range of motion, and ability to balance that would enable them to perform the required exercises. Subjects with nervous or cardiovascular system problems, or orthopedic musculoskeletal issues related to the trunk or lower extremities were excluded. The subjects’ average age was 21.40±1.39 years, their average weight was 56.90±4.38 kg, and their average height was 163.75±4.38 cm. Subjects were asked to adopt a supine position, and the tip of a biofeedback pressure unit was placed under the posterior superior iliac spine (PSIS)\(^9\). Then, the pressure was adjusted to 40 mmHg while referring to the pressure gauge connected to the pressure biofeedback unit. Subjects were instructed to increase the pressure by 10 mmHg using the drawing-in technique upon the oral instruction, “Start,” and maintain the drawn-in state\(^9\). The time during which the pressure was maintained within an error range of ±1–2mmHg was measured in seconds\(^9\).

A comparative analysis of the activities of the rectus abdominis, the external oblique, the internal oblique, and transverse abdominis was performed. One-way analysis of variance was used to examine differences in the muscle activities during the abdominal drawing-in exercises performed at different leg angles. As a post hoc test, the least significant difference was used. For the data analysis, SPSS version 18.0 was used. The significance level chosen as 0.05.

**RESULTS**

During the abdominal drawing-in exercises, the activities of the rectus abdominis, the internal and external obliques, and the transverse abdominis increased as the knee joint flexion angle increased from 45° to 120° (Table 1).

| Leg Angle | RA* | EO* | IO* | TrA* |
|-----------|-----|-----|-----|------|
| 45°       | 0.0062±0.003 | 0.0051±0.003 | 0.0052±0.003 | 0.0054±0.003 |
| 60°       | 0.0065±0.003 | 0.0075±0.008 | 0.0060±0.003 | 0.0058±0.002 |
| 90°       | 0.0283±0.014€EE | 0.0257±0.015€EE | 0.0222±0.014€EE | 0.0235±0.024€EE |
| 120°      | 0.0406±0.028¥‡ | 0.0364±0.028¥‡ | 0.0307±0.025¥‡ | 0.0261±0.021¥‡ |

\(\ast p<0.05, \text{Mean±SD} \)

RA: Rectus abdominis, EO: external oblique, IO: internal oblique, TrA: Transversus abdominis

\(\ast\) significant difference between 120° and 60° (p<0.05), \(\ast\) significant difference between 120° and 45° (p<0.05), \(\ast\) significant difference between 90° and 60° (p<0.05), \(\ast\) significant difference between 90° and 45° (p<0.05)

**DISCUSSION**

The purpose of trunk stabilization exercises is to maximize the mobility and stability of spinal segments by repeatedly and continuously stretching and reinforcing trunk muscles\(^{14}\). Trunk stabilization exercises can also correct postural alignment and increase body balance\(^{15}\). In addition, trunk stabilization exercises improve the bilateral symmetry of pelvic alignment to promote normal motor patterns and reduce muscle hypertonicity\(^9\). Among the trunk stabilization exercises, bridging exercises are lumbosacral region stabilization exercises that activate local and global muscles in appropriate ratios to reeducate muscles’ synergistic action patterns\(^{16}\). Abdominal drawing-in using a pressure biofeedback unit during bridging exercises increases intra-abdominal pressure to enable effective performance of lumbar stabilization training\(^9\).

Mannion et al.\(^{17}\) reported that abdominal hollowing and spinal stabilization exercises that teach patients to perform a separated contraction of the transversus abdominis are popular in physical therapy for treating low back pain. They also found that muscle thicknesses increased during abdominal muscle hollowing in both an experimental group and a control group, and that this exercise was related to muscle thicknesses. In a study of muscle load and spinal stability in which healthy adults performed lumbar stabilization exercises, it was reported that bridging exercises were highly related to abdominal muscle activity\(^8\).

Kim et al.\(^{13}\) reported that during bridging exercises performed while maintaining abdominal drawing-in, the rectus abdominis, the internal oblique, and the external oblique muscles’ activities increased, because other abdominal muscles contracted simultaneously. Controlling the contraction of the external oblique while performing abdominal hollowing has been reported to be quite difficult\(^9\).

In the present study, the activities of the abdominal muscles were measured at different angles (45°, 60°, 90°, and 120°) in a supine position using a biofeedback pressure unit to maintain the same pressure. The rectus abdominis, the external oblique, the internal oblique, and the transversus abdominis on the right side had significantly higher electromyogram values at leg angles of 90° and 120° than at 45° and 60°; and the rectus abdominis, the external oblique, the...
internal oblique, and the transversus abdominis on the left side showed significantly higher electromyogram values at leg angles of 120° than at other angle. As the knee joint angles increased, the activities of the rectus abdominis, the internal oblique, the external oblique, and the transversus abdominis increased. As the knee joint flexion angles increased, the weight arm of the abdominal muscle lever increased, thereby also increasing the loads on the abdominal muscles leading to increases in the activities of the trunk muscles. We suggest that when trunk stabilization exercises are to be performed at the same pressure to reduce damage after the acute phase of low back pain, trunk muscle strength can be efficiently increased by increasing knee joint angles gradually while performing abdominal drawing-in exercises using a biofeedback pressure unit.

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