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Comparison of the Effects of Hollowing and Bracing Exercises on Cross-sectional Areas of Abdominal Muscles in Middle-aged Women

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Abstract. [Purpose] The purpose of this study was to examine the effects of hollowing and bracing exercises on cross-sectional areas of abdominal muscles. [Subjects] Thirty healthy female adults participated in this study. The exclusion criteria were orthopedic or neurologic diseases. [Methods] The subjects of this study were assigned randomly to one of two groups, each with 15 people. Each group performed a 60-minute exercise program, one performed a bracing exercise, and the other performed a hollowing exercise, with both groups performing the exercise three times a week for six weeks. [Results] The changes in cross-sectional areas after the bracing exercise showed statistically significant differences in the left rectus abdominis and both internal and external obliques. The changes in cross-sectional areas after the hollowing exercise showed statistically significant differences in the left and right transversus abdominis and left rectus abdominis. [Conclusion] Performing bracing exercises rather than hollowing exercises is more effective for activating the abdominal muscles.
Key words: Hollowing exercise, Bracing exercise, Cross-sectional area

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INTRODUCTION

Low back pain can be felt around the waist from the 2nd lumbar vertebra to the sacroiliac joints where the spinal nerve ending[1)]. The causes of low back pain can be classified into structural, psychological, and biomechanical factors of the dynamical musculoskeletal system[2)]. The core is comprised of passive and active structures and a neural control unit[3)]. The core local muscles include the transverse abdominis, multifidus, internal obliques, transversospinalis, and pelvic floor muscles; the core global muscles include the erector spinae, external obliques, rectus abdominis, and quadratus lumborum[4)]. One's sensorimotor ability is essential for stability and lumbar spine functioning[5)]. Patients with low back pain experience spinal instability due to the weakness of these core muscles.

In one study, patients with acute low back pain performed spinal stabilization exercises as a form of exercise therapy to strengthen weakened core muscles. The results indicated that co-contraction of the transversus abdominis and multifidus was found in the experimental group, and recurrence of low back pain was infrequent[6)]. Koumantakis et al.[7)] reported that once a stabilization exercise was applied to patients with low back pain, the experimental group was more effective in resolving lumbar segmental instability, and stabilization exercise improved the motor control of the abdominal and trunk muscles[8)]. Stabilization training involves isolated local muscle contraction and integration of the local and global muscle systems during particular movement patterns[9)]. Hollowing exercises, which concentrate on the contraction of local muscles, draw the belly button toward the lumbar spine. On the other hand, bracing exercises, which contract the local and global muscles at the same time, are performed by pushing the abdomen out externally[10)].

With regard to these two types of exercise, once Kavcic et al.[11)] discovered that a single trunk muscle alone cannot contribute to stabilization, they recommended a mobility program, by which a patient's entire mobility pattern, rather than a few specific muscles, can be strengthened. On the other hand, Hodges and Richardson[12)] focused on the functional importance of the transversus abdominis and multifidus in lumbar instability. With regard to the two exercises, there have been many studies comparing different muscle activities through EMG of superficial muscles (external obliques, rectus abdominis) and deep muscles (transverse abdominis, internal obliques), but not many have compared the cross-sectional changes in the superficial muscles with those in the deep muscles. Therefore, this study attempted to determine which exercise is more efficient by comparing cross-sectional areas of abdominal muscles such as the transverse abdominis, internal obliques, external obliques, and rectus abdominis through CT image analysis after applying the hollowing and bracing exercises.

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SUBJECTS AND METHODS

Subjects

The subjects of this study were 30 healthy female adults in their 30s to 40s. None of the subjects had a prior history of psychiatric disorders or neurological and orthopedic diseases. They were given sufficient explanation regarding the purpose and experimental method of this study before participating and gave voluntary consent. This protocol was approved by the Institutional Review Board of Daegu University and was conducted in accordance with the ethical standards of the Declaration of Helsinki. The experiment was performed for the six weeks from July 23rd to September 1st of 2012 (Table 1).

Methods

The study subjects were divided into two groups, a hollowing exercise group (15 participants) and a bracing exercise group (15 participants), and performed three 60-minute sessions of the exercise per week for six weeks. As a pretest, cross-sectional areas of superficial and deep muscles such as the transverse abdominis, internal obliques, external obliques, and rectus abdominis were subjected to computed tomography (CT). As a posttest, the same examination and methods were performed with respect to the two exercise groups after six weeks of performing the exercise.

The exercise in this study consisted of exercise programs that promote spinal stability, focusing on sensorimotor control[13, 14]. The exercise programs, consisting of hollowing and bracing exercises, were aimed at evaluating and rehabilitating the abdominal muscles[15–17]. The participants were made fully aware of the exercises by showing them videos of the exercises in advance, and both exercises were taught by a physiotherapist who was experienced in teaching these exercises. No results were recorded until he was satisfied that the correct actions were being performed. Both exercises were checked and confirmed as satisfactory by two qualified physiotherapists experienced in teaching these exercises.

Sixty-minute sessions were performed three times a week. After a light warm-up exercise was performed for 10 minutes, the main exercise was performed for 40 minutes. Each item in the exercise was performed 20 times, each taking 15 seconds. This was repeated two times. As a cool-down exercise after the main exercise, 10 minutes of stretching was done, thereby making each session 60 minutes in length. Tables 2 and 3 present the bracing and hollowing exercise programs.

CT equipment (SOMATOM Definition AS+128 channel MDCT, SIEMENS AG, Munich, Germany) was used to measure the cross-sectional areas of the abdominal muscles (transverse abdominis, internal obliques, external obliques, rectus abdominis), and each study subject's lumbosacral spine was scanned with the knee joints flexed 25 degrees while in a supine posture, thereby obtaining a reference cross-sectional image traversing the upper end-plate surface of the fourth and fifth (L4 and L5) lumbar vertebrae. Along the boundary between the transverse abdominis on the left and right sides and the internal obliques, external obliques, and rectus abdominis, a cross-sectional area of muscle was obtained by selecting cross-sectional measurement function of the CT equipment (Fig. 1).

Table 1. General characteristics of subjects (M±SD)

	Bracing group (n=15)	Hollowing group (n=15)
Age (yrs)	39.0±5.4	37.5±3.4
Height (cm)	160.6±3.1	160.6±3.7
Weight (kg)	54.1±6.1	52.6±5.2
Body mass index (kg/m^2)	21.0±2.4	20.4±2.0

M±SD: Mean ± standard deviation

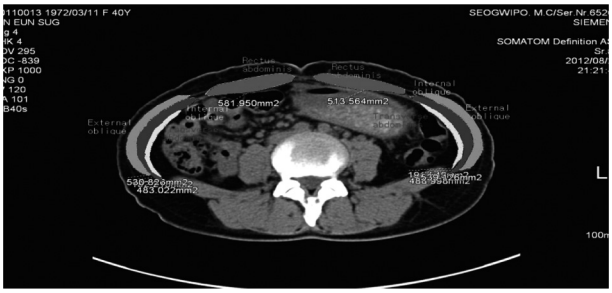

Fig. 1. Cross-sectional areas of abdominal muscles (unit: mm^2)

The data in this study were processed statistically using SPSS 20.0 for Windows, and the average and standard deviation per group were calculated for all the variables as descriptive statistics. In addition, changes in muscle activity and muscle cross-sectional area before and after the exercise within each group were calculated using a paired t-test, and differences between the experimental and control groups were measured using a independent t-test. Values of $p < 0.05$ were considered statistically significant.

RESULTS

The within-group and between-group changes in the cross-sectional abdominal muscle areas are shown in Tables 4 and 5. The bracing group showed a statistically significant difference in the left rectus abdominis, both internal obliques, and both external obliques before and after the exercise ($p < 0.05$). The hollowing group showed a statistically significant difference in the cross-sectional areas of the left and right transversus abdominis and left rectus abdominis ($p < 0.05$). Between the two groups, there was no statistically significant difference before the exercise ($p > 0.05$). However, after six weeks of exercise, there was a statistically significant difference between the groups in the cross-sectional muscle area in the right transversus abdominis, left internal oblique, and both external obliques ($p < 0.05$).

DISCUSSION

Stabilization exercises, which aim to protect the spinal joints from microtrauma and degenerative changes, can

Table 2. Bracing exercise program

Contents	Description
Abdominal bracing (1)	Breathe in and out. Gently and slowly push out your waist without drawing your abdomen inward or moving your back or pelvis.
Abdominal bracing (2)	In a supine position with the knees bent at 90°, gently and slowly push out your waist while performing a heel slide without drawing your abdomen inward or moving your back or pelvis, with one leg facing forward.
Plank exercise	This exercise involved subjects making a prone bridge on their elbows and toes, with only the toes and forearms touching the floor.
Side plank exercise	This exercise is performed by supporting the body with one elbow and foot.

Table 3. Hollowing exercise program

Contents	Description
Abdominal draw-in maneuvers (1) (in hook-lying position)	Breathe in and out. Gently and slowly draw in your lower abdomen below your navel without moving your upper stomach, back and pelvis.
Abdominal draw-in maneuvers (2) (in standing position)	Breathe in and out. Gently and slowly draw in your lower abdomen below your navel without moving your upper stomach, back and pelvis.
Abdominal draw-in maneuvers (3) (in sitting position)	Breathe in and out. Gently and slowly draw in your lower abdomen below your navel without moving your upper stomach, back and pelvis.
Abdominal draw-in maneuvers (4) (in 4-point kneeling position)	Breathe in and out. Gently and slowly draw in your lower abdomenbelow your navel without moving your upper stomach, back and pelvis.

Table 4. Comparison of abdominal muscles between the pretest and posttest in each group (unit: mm^2)

	Abdominal muscles	Pretest	Posttest
Bracing group (n=15)	Right transversus abdominis	148.1±14.3	154.5±20.1
	Left transversus abdominis	156.3±33.8	163.4±31.6
	Right rectus abdominis	408.6±98.4	423.0±105.7
	Left rectus abdominis*	416.3±92.5	440.3±104.3
	Right internal oblique*	519.2±88.4	549.9±91.9
	Left internal oblique*	484.2±55.4	601.6±78.5
	Right external oblique*	503.8±44.2	642.5±116.2
	Left external oblique*	557.1±100.9	649.4±101.5
Hollowing group (n=15)	Right transversus abdominis*	150.5±15.1	175.4±15.2
	Left transversus abdominis*	152.2±23.4	173.9±27.6
	Right rectus abdominis	399.0±80.7	404.3±90.9
	Left rectus abdominis*	413.3±92.5	428.7±96.9
	Right internal oblique	520.1±70.1	528.3±75.4
	Left internal oblique	493.3±58.7	504.2±118.6
	Right external oblique	514.7±39.4	530.2±120.1
	Left external oblique	555.1±78.3	561.6±73.6

M±SD: Mean ± standard deviation
* $p < 0.05$

normalize functional and morphological trunk changes[8, 18]. Stabilization exercises consisting of hollowing and bracing exercises, which are the opposite of each other, have shown different results in previous studies on exercise. For instance, Grenier and McGill[19] claimed that a bracing exercise showed better results than a hollowing exercise, whereas Richardson et al.[16] claimed that a hollowing exercise supported better stability. Therefore, this study attempted to compare and analyze the effects of hollowing and bracing exercises on the cross-sectional areas of abdominis muscles.

Allison et al.[15] found a significant difference in transverse abdominis muscle activity between hollowing and bracing groups. In their study of muscle activity in the abdomen, Bjerkefors et al.[20] showed that stabilization exercises including a hollowing exercise resulted in higher EMG activity in the transverse abdominis. In their study on transverse abdominis activity, Urquhart et al.[21] also

Table 5. Comparison of abdominal muscles between each group (unit: mm^2)

Abdominal muscles	Bracing group	Hollowing group
Right transversus abdominis*	−6.4±9.3	−24.9±14.7
Left transversus abdominis	−7.1±15.0	−21.7±27.3
Right rectus abdominis	−14.4±27.3	−5.3±15.7
Left rectus abdominis	−24.0±23.3	−15.4±20.4
Right internal oblique	−30.7±18.6	−8.2±35.4
Left internal oblique*	−117.4±103.8	−10.9±146.1
Right external oblique*	−138.6±94.1	−15.6±106.0
Left external oblique*	−92.3±32.5	−6.5±23.8

M±SD: Mean ± standard deviation
* $p < 0.05$

reported that hollowing exercises resulted in more significant improvements than bracing exercises. That is, during a hollowing exercise, abdominis muscles such as the rectus abdominis, internal obliques, and external obliques showed no difference in muscle activity, but the transverse abdominis showed significant improvements in activation independently. The present study also showed that after applying the two exercises, the cross-sectional muscle area of the right transverse abdominis showed a significant difference between the two groups, and significant changes in the left and right transverse abdominis were shown within the group after the hollowing exercise. This finding proves that hollowing exercises can selectively and independently contract the transverse abdominis, which is a deep abdominal muscle.

With regard to rectus abdominis activity, Allison et al.[15] found no difference between the two groups. In their study on abdominal muscle activity, Bjerkefors et al.[20] also reported that a hollowing exercise caused single contractions of the transverse abdominis because it did not act on the rectus abdominis. Urquhart et al.[21] also showed no between-group difference in rectus abdominis activity, which is similar to previous studies. However, the cross-sectional area of the left rectus abdominis showed a significant within-group difference in both groups, indicating that the hollowing exercise was also related to contraction of the rectus abdominis, and the bracing exercise (a plank exercise) caused co-contraction of the entire trunk muscle.

In their study on muscle activity, Urquhart et al.[21] showed no significant difference in internal oblique activity between subjects performing bracing versus hollowing exercises, but the bracing group had higher muscle activity than the hollowing group in the external oblique, showing a significant difference. In the present study, the cross-sectional muscle area of the left internal oblique and both external obliques showed significant improvement in both groups. Also, with regard to changes in cross-sectional muscle area within groups, the bracing group only showed significant improvement in both internal obliques and both external obliques. Thus, the plank exercise involved co-contraction of the entire abdominal muscles, and the side bridge exercise acted on the internal and external obliques, thereby increasing the cross-sectional muscle area.

Summarizing the above results, performing bracing exercises, which can contract both deep and superficial muscles entirely, rather than performing hollowing exercises, which only contract deep muscles independently, is more effective for activating the abdominal muscles. One limitation of this study, however, is that we were not able to control subjects' physical activities outside of the exercise programs. Moreover, the multifidus and erector spinae were not compared in the comparison of cross-sectional areas, and these and other muscles will be addressed in a future study.

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