

Changes of Thickness in Abdominal Muscles between Crook Lying and Wall Support Standing during Abdominal Hollowing in Healthy Men



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Purpose: This study investigated changes in the thickness of the transversus abdominis (TrA), internal abdominal oblique (IO), and external abdominal oblique (EO) muscles between crook lying and wall support standing positions during abdominal hollowing (AH), using ultrasound imaging.

Methods: Experiments were conducted on 20 healthy male adults (mean age=22.45±4.08 years) who voluntarily agreed to participate in the experiments. The changes in the thickness of the subjects' abdominal muscles were measured during AH in crook lying and wall support standing positions.

Results: The difference in the thickness of TrA between the two positions during AH was statistically significant, but the differences in the thicknesses of IO and EO were not significant.

Conclusion: Activity of the TrA, which is a deep muscle, was stimulated in the standing position, which is, therefore, more functional than the crook position, but the activities of IO and EO muscles did not decrease. Therefore, various methods to induce the activity of TrA while decreasing the activities of IO and EO, in the functional standing position that can stimulate deep muscles, need to be designed.

Keywords: Abdominal hollowing, Ultrasound, Abdominal muscles, Thickness changes

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1. Introduction

Training of the transversus abdominis (TrA) and multifidus (MF) muscles is believed to be a critical element in the rehabilitation of patients with low back pain (LBP).^{1,2} The belief comes from the fact that TrA and MF play key roles in spinal stability.^{2,3} TrA consists of three types of fascicles and plays many different roles. The upper fascicles of TrA, arising from the costal cartilages, stabilize the rib cage, the middle fascicles, attaching to the thoracolumbar fascia (TLF), control the lumbar spine, and the lower fascicles, arising from the iliac crest, support the abdominal contents and generate forces that compress the sacroiliac joints.² Furthermore, TrA muscles move before the movement of limbs, regardless of the direction of movement.⁴ MF muscles provides segmental stiffness to the spine,⁵ control of the neutral zone of spinal segments,⁶ and stabilization of the spine when its stability is challenged.⁷ Changes in the deep

abdominal muscles, such as delayed onset⁴ and changes in muscle thickness and slide^{8,9} have been associated with LBP. In most cases, these changes lead to dysfunction or pain related to motor control.

Patients with LBP do stabilization exercises to solve the dysfunction of deep muscles such as TrA and MF. The initial stabilization exercise that clinicians often teach patients with LBP is an abdominal “drawing-in” maneuver that has become known as abdominal hollowing (AH). This exercise was designed to stimulate the coactivation of TrA and MF to stabilize the trunk before the movement of limbs. In particular, this exercise can selectively contract the TrA muscles more than the superficial abdominal muscles.¹⁰ Clinicians have also recommended crook lying, prone lying, four point kneeling and wall support standing as positions for AH. Mew¹¹ reported, however, that the deep abdominal muscles were more effectively activated during AH in more functional positions, such as standing. Another study¹² also

found that the deep abdominal muscles were more activated in functional positions. Still, research data are insufficient for comparing the effects of different positions on the selective stimulation of TrA.

Various tools have been used for accurate evaluation of the activity of TrA. Among them, ultrasound imaging is a noninvasive, safe, and cost-effective tool. Furthermore, it has been used not only for the direct evaluation of atrophy or hypertrophy of other muscles,¹³ but also for the evaluation of the effects of rehabilitation programs by measuring the size and thickness of deep muscles.^{11,14}

In the prior study examined thicknesses of abdominal muscles between crook lying and standing during abdominal hollowing by Mew¹¹ using ultrasound, several questions were shown. There have been the several questions that have related identify of subjects, exercise positions, exercise method and measurement method. To supplement the several questions that showed in the prior study, this study measured the changes in the thickness of abdominal muscles during traditional AH by Richardson and Jull¹⁵ in crook lying and wall support standing positions using ultrasound imaging. In addition, this study is intended to compare the differences in the activities of abdominal muscles between the two positions and to provide the data required for selecting more effective positions.

II. Methods

1. Subjects

The subjects of this study were 20 healthy male adults who voluntarily agreed to participate in the experiments after listening to the purpose and method of study. Those who had pain or dysfunction in upper limbs or lower limbs during exercise, who had not experienced AH exercise, who experienced LBP during the last 6 months, who had undergone a surgical treatment or, who had a nervous system disease were excluded from the study.

2. Experiment method

1) Measuring instruments

Sonoace X4 from Medison, Korean was used to measure the thickness of TrA, IO and EO muscles during AH. The data were collected using a 7.5 MHz linear transducer.

2) Exercise method

Before the experiment, the subjects were educated on the exercise method. All subjects were asked to slowly pull their navel inward and upward while not moving their spine, ribs, and pelvis.¹⁵ Once their navel moved closer to their spine, they had to maintain abdominal contraction for 10 seconds while they breathed normally. In order to prevent muscle fatigue, they had a rest of 2 minutes after abdominal hollowing. They repeated this three times for each position.¹⁶ Depending on the level of understanding of the subjects, the education time ranged from 15 to 20 min.

The two positions were as follows: crook lying¹⁷ with the knee flexion of 90 degrees and wall support standing¹⁸ while maintaining a distance of 15 cm between the wall and heel. To measure the contraction of the abdominal muscles in each position, the thicknesses of TrA, IO, and EO were measured first in the resting state, and then the thicknesses of these muscles were measured during AH. The averages of three measurements were calculated and compared.

3) Ultrasound recordings

The transducer was placed transversely halfway between the 11th costal cartilage and the iliac crest.¹⁹ Furthermore, to standardize the location of the catheter, it was set in such a way that the space where TrA and TLF meet would appear at the right end of the ultrasound image (Figure 1).¹⁰ To control the effects of

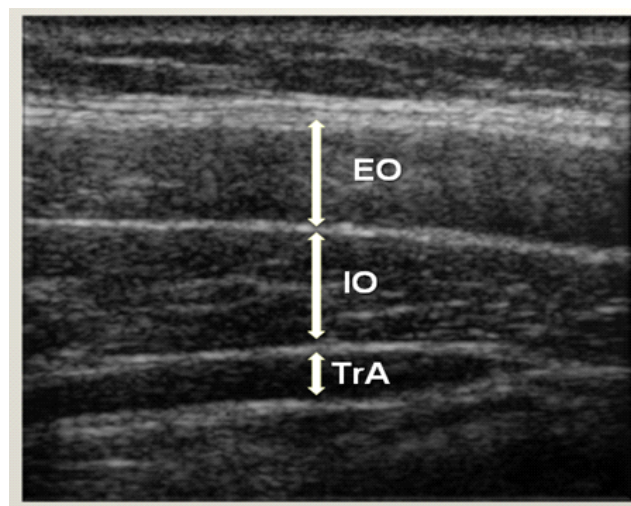


Figure 1. A transverse view of an ultrasound image of a subject's anterolateral abdominal wall. TrA: Transversus abdominis, IO: Internal abdominal oblique, EO: External abdominal oblique

respiration,²⁰ the subjects were educated to perform AH during exhalation. Ultrasound images were captured at the end of the exhalation. The examiner who conducted measurements was located at the right-hand side of the subject. The education and measurement of the subjects were carried out by the same researchers.

3. Data analysis

An independent t-test was conducted to compare the differences in the thickness of muscles between the two positions during AH. For statistical significance, the level of significance was set $\alpha=0.05$ and the collected data were analyzed using the SPSS 12.0 for Windows.

4. Reliability testing

Inter-rater reliability was examined using interclass correlation coefficients (ICC). ICC was demonstrated for 3 repeat measurements of each muscle, whilst resting and AH state, and in both positions in 9 sets of data. ICC of TrA, IO and EO were shown 0.99, 0.98 and 0.98.

III. Results

1. Characteristics of the subjects

The mean age, mean height, mean weight, and BMI of the subjects were 22.45 ± 4.08 years, 176.3 ± 5.8 cm, 68.1 ± 10.08 kg, and 21.84 ± 2.4 kg/m², respectively.

2. Changes in the thickness of muscles in each position

The thickness of TrA, IO, and EO during resting state in the crook lying position were 3.92 ± 1.11 , 8.35 ± 1.62 , and 6.38 ± 1.33 mm, respectively. In the same position, the thicknesses of TrA, IO, and EO during AH exercise were 4.74 ± 1.32 , 9.40 ± 1.94 ,

and 6.88 ± 1.30 mm, respectively. The differences in the thicknesses of TrA, IO, and EO between resting and AH exercise in the crook lying position were 0.81 ± 0.50 , 1.03 ± 0.82 , and 0.49 ± 0.44 mm, respectively. While resting in the wall support standing position, the thicknesses of TrA, IO, and EO were 4.92 ± 1.15 , 9.06 ± 2.22 , and 5.49 ± 0.95 mm, respectively. In the same position, the thicknesses of TrA, IO, and EO during AH exercise were 6.11 ± 1.50 , 10.43 ± 2.78 , and 6.12 ± 0.97 mm, respectively. The differences in the thicknesses of TrA, IO, and EO between resting and AH exercise in the wall support standing position were 1.20 ± 0.57 , 1.37 ± 1.18 , and 0.64 ± 0.29 , respectively. The differences in the thicknesses of the muscles between the two positions during AH exercise are shown in Table 1. Only the differences in the thickness of TrA between the two positions were statistically significant. The changes in the thicknesses of all abdominal muscles were greater in wall support standing position than in crook lying position.

IV. Discussion

Many studies have examined the activities of trunk muscles according to different positions and exercises with patients with LBP using electromyograms,²¹⁻²³ but studies using ultrasound are insufficient. Accordingly, this study investigated the differences in the thickness of abdominal muscles in two positions during abdominal hollowing, which is a spinal stabilization exercise. The difference in the thickness of TrA between resting and AH in the wall support standing position was statistically significant and greater than in the crook lying position. The results of the study by Mew¹¹ using ultrasound imaging and the study by Park and Lee²⁴ using electromyograms also showed higher activity of the TrA muscle in standing than in crook lying, similar to the findings of this study. The reason for this appears to be that the

Table 1. Change in muscle thicknesses between crook lying and wall support standing during AH (N=20)

	Muscle thickness (mm)		Difference	p value
	Crook lying	Wall support standing		
TrA	0.81 ± 0.50	1.20 ± 0.57	+0.39	0.03*
IO	1.03 ± 0.82	1.37 ± 1.18	+0.34	0.31
EO	0.49 ± 0.44	0.64 ± 0.29	+0.15	0.23

*Significant difference ($p<0.05$)

AH: Abdominal hollowing

TrA: Transversus abdominis, IO: Internal abdominal oblique, EO: External abdominal oblique

recruitment of TrA increases in the wall support standing position which is more functional than crook lying as it requires more force when you have to pull up the navel against gravity, and the large feedback from the stretch receptors of TrA increases the motor-neuron pool excitation of TrA. In Mew's study¹¹, TrA showed greater increases in the thickness on abdominal hollowing compared to this study in two positions. In this study, all the subjects were trained regarding the method of exercise by Richardson and Jull.¹⁵ However, in the study of Mew, all the subjects were trained abdominal hollowing by Richardson and Jull,¹⁵ and asking subjects to lift up their pelvic floor muscle. This could be the cause of the result, because two studies were shown difference of exercise method.

During the resting state, too, the change in the thickness of TrA was greater in wall support standing than in crook lying, which agreed with the results of a prior study.¹¹ The changes in resting muscle thickness between the two positions can occur primarily by the change in 'involuntary postural tone'. The greater change in the thickness of TrA in wall support standing seems to be due to the increased postural tone of TrA when more stability is required.²⁵ Furthermore, based on the study by Hodges et al²⁶ the thickness of TrA in the wall support standing position seems to increase more because small movements of the extremities were allowed during the position. These results support the findings from prior studies^{12,27} that the activities of deep abdominal muscles could be more effectively stimulated in more functional positions.

The difference in the thickness of IO was greater in the wall support standing position than in crook lying, but the difference was not statistically significant. In another study,¹¹ the change in the thickness of IO was greater in crook lying than in standing, contrary to the results of this study. It appears that, as the inferior fiber of IO runs together with TrA below the anterior superior iliac spine,²⁸ the activity of TrA in the wall support standing position increased more than in crook lying, which in turn increased the activity of IO. In fact, due to such running direction and linkage between TrA and IO, some studies^{16,24,28} using superficial electromyograms write TrA and IO as TrA/IO and measure and report findings together as one.

Even though the difference in the thickness of EO was greater in the wall support standing position than in the crook lying position, the difference was not statistically significant. This implies that it is difficult to induce the separate contraction

of TrA by minimizing the activity of EO in wall support standing. In fact, the subjects who showed separate contraction of TrA while maintaining the difference in the thickness of EO in crook lying between resting and AH at 0.3 mm or lower were 30% (6/30) of the total, and only 15% (3/20) of the total subjects could induce selective contraction of TrA by minimizing the contraction of EO. This supports the result of a prior study²⁹ which induced the selective contraction of TrA while minimizing the activity of EO in the crook lying position during AH. Another prior study¹¹ actively recommended the standing position which could increase the activity of TrA while decreasing the activity of EO. Although subjects and exercise methods in this study differ from Mew's study, this study was consistent with the result reported by Mew that the changes of thicknesses in TrA were shown higher in standing than crook lying. This is due to the advantage of a functional position. Based on the result of two studies, performing AH could be effective in standing position. However, the activity of EO was also higher and the separate contraction of TrA was difficult in this study. As a method to induce the separate contraction of TrA while reducing the activity of EO in the wall support standing position, real-time ultrasound feedback is being used. Henry and Westervelt³⁰ trained healthy people for AH using real-time ultrasound feedback and reported that the number of training sessions required for accurate AH decreased. Therefore, because reduction of the activity of IO and EO muscles can effectively induce the activity of TrA, a deep abdominal muscle, further research on methods to achieve this in the functional standing position using real-time ultrasound feedback is needed. And although ultrasound is good tool for evaluation of the activity of abdominal muscles, it is possible that errors of measurements have been existed by examiners. In the country, physical therapists are still insufficient skills of ultrasound because very few use ultrasound in clinical field. To improve the use skills of ultrasound, more training and efforts will be necessary for physical therapists in the country.

V. Conclusion

This study investigated the changes in the thickness of abdominal muscles in crook lying and standing positions during AH, using ultrasound imaging. The activity of TrA was

stimulated in the standing position, which is more functional than the crook lying position, but the activities of IO and EO did not decrease. Therefore, various methods to induce the activity of TrA, by decreasing the activities of IO and EO in the functional standing position, need to be designed.

Author Contributions

Research design: Park DJ

Acquisition of data: Park DJ

Analysis and interpretation of data: Park DJ

Drafting of the manuscript: Park DJ

Research supervision: Park DJ

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