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Comparison of Changes in the Transversus Abdominis and Neighboring Fascia in Subjects With and Without a History of Low Back Pain Using Ultrasound Imaging

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Abstract. [Purpose] This study attempted to clarify the relationship between low back pain and changes in the abdominal and thoracolumbar fascias that are caused by contraction of the transversus abdominis. [Subjects] The subjects were 51 men with a mean age of 22.9 ± 4.0 years. [Methods] A medical history was obtained from all subjects through interviews and each person was assigned to one of 3 groups in relation to experience of low back pain. Subjects' abdominal girth at the umbilical level was measured from the anterior, antero-lateral and posterior parts and recorded using an ultrasound US diagnostic device during rest and contraction of the transversus abdominis. [Results] Contraction of the transversus abdominis was confirmed by observing the US image, while the subjects were urged to make a conscious effort to contract the muscle. In the group of those who had been treated for low back pain, the distance covered by the movement of the abdominal fascia and that of the tip of the transversus abdominis (musculotendinous junction) was reduced in spite of contraction occurring at a uniform level. [Conclusion] The results indicate that there is a correlation between the mobility of the abdominal and thoracolumbar fascias and a history of low back pain. This suggests that analysis of the movement of each fascia, measuring the distance covered by the movements of the abdominal fascia and the tip of transversus abdominis(TA) instead of measuring the muscle thickness of TA alone, would be effective for providing an understanding of the etiology of low back pain and the segmental stability of the spine.
Key words: Low back pain, Transversus abdominis and neighboring fascia, Ultrasound imaging

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INTRODUCTION

Lately, studies on training the trunk muscles to stabilize the trunk-pelvic system and to elucidate the related mechanisms have been attracting attention in the field of athletics and in medical practice. Among the trunk muscles, the transversus abdominis is attached to the abdominal fascia at its anterior and the thoracolumbar fascia at its posterior. It runs transversely as if to surround the abdominal region. Therefore, together with the diaphragm and pelvic floor muscle group, it is involved in changes in intra-abdominal pressure[1]. When the transversus abdominis contracts bilaterally, the anterior abdominal wall is pulled back in the posterior direction (toward the visceral side). Consequently, the intra-abdominal pressure rises[1] and the tension of the thoracolumbar fascia increases[2]. Furthermore, the generation of the laterally directed tension (an increase in tonus) of the thoracolumbar fascia caused by the transversus abdominis[3] has the effect of controlling the inter-segmental movement of the spine, bringing the adjacent vertebra closer[4].

It has been reported that persons with low back pain lack preliminary activity of the transversus abdominis associated with spinal oscillation in limb exercise[5]. Teyhen et al.[7] reported that in individuals with unilateral low back pain, the increase in muscle thickness of the transversus abdominis associated with an abdominal drawing-in maneuver is minimal.

As described above, reports have been presented on the relationship between activities of the transversus abdominis and low back pain. Because these muscles and fascias are deep-seated, it is not easy to measure their activities by surface electromyography or similar methods. Using a non-invasive ultrasound diagnostic device, however, the fascias

can be clearly delineated. Based on such measurements, studies have measured the muscle thickness of the transversus abdominis[8,9]. Muscle thickness has been measured, but few studies have compared increases in the muscle thickness due to contraction of the transversus abdominis (a mechanism for segmental stability of the spine), changes in the abdominal and thoracolumbar fascias on a single image, or the relationship between such phenomena and low back pain.

In this study, we attempted to elucidate the correlation between changes in the abdominal and thoracolumbar fascias caused by contraction of the transversus abdominis and a history of low back pain through measurements made by ultrasound imaging.

SUBJECTS AND METHODS

Subjects

A consent form was prepared and the purpose of the study was explained to 51 men (mean age; 22.9 ± 4.0 years, mean height; 172.0 ± 6.7 cm, mean weight; 66.0 ± 9.3 kg) who gave their consent in writing to participate in the study. The study was conducted with the approval of the Committee of Juntendo University on Research Ethics, Graduate School, Department of Studies on Sports Health Sciences (Approval Number, In-21-64).

Methods

Interviews were conducted and questionnaires were distributed with the aid of a low back pain evaluation table. Subjects were stratified according to the presence of low back pain: those who had sought medical care for low back pain (Group A), those who suffered from occasional back pain but had never been treated (Group B), and those who had never experienced low back pain (Group C).

For the measurement with the ultrasound diagnostic device, the level of the umbilicus was chosen as the sole site of measurement. Markings were made around the abdominal region and with confirmation from images, the final probe (7.5 MHz, a linear form PLM-703AT by Toshiba) was set at a fixed position. Furthermore, the final marking was performed at this position. For the measurement we used a NEMIO SSA-550A (Toshiba) digital ultrasound diagnostic device in the B mode.

The subjects were told to "contract the anus and slowly draw in the lower abdominal region" to contract transversus abdominis while getting visual feedback from the ultrasound image. The thickness of the transverse abdominal muscle was confirmed in ultrasound images and then an ultrasound image indicating selective contraction of the transverse abdominal muscle alone (i.e., increase in the thickness of muscle) was adopted. During the measurement, the subjects were instructed to maintain a normal breathing pattern.

For the measurement from the anterior, the subjects assumed a supine position and imaging was conducted by focusing on the anterior portion of the abdominal fascia and transversus abdominis. The distance between the skin and the anterior abdominal fascia was measured during rest and in contraction of the transversus abdominis (arrow, Fig. 1-a). For the measurement from the antereo-lateral side, the subjects also assumed a supine position. During rest, the tip of the transversus abdominis was adjusted to the right edge of the image, for imaging the muscle and the anterior portion of the abdominal fascia. The distances between the left edge of the image and the edge of the muscle were measured at rest and in contraction (arrow, Fig. 1-b). For the measurement from the posterior, the subjects were instructed to lie in a prone position. During rest, the tip of the transversus abdominis was adjusted to the right side of the image to capture the muscle and the thoracolumbar fascia on a single image. The distance between the left side of the image and the edge of the transversus abdominis(TA) was measured during rest and in contraction of TA (arrow, Fig. 1-c). The thickness of the muscle was determined by measuring the distance of a perpendicular from the upper fascia to the lower one at a central region where both fascias were parallel. All measurements were made on the left and right sides and the sequence of imaging was decided at random drawing. The measurement was always performed by the same investigator and the position of the probe during measurement was monitored by one of the other 2 investigators, with the other confirming the position of the skin, when motion was unclear on the image, i.e., the measurement was performed by the team of 3 investigators.

The ultrasound images of each section were recorded on a DVR(Pioneer) at rest and while the transversus abdominis was contracted. Employing image editing software (Win DVD Corel Corp.), a stationary image in which the muscle thickness was at the minimum was extracted. Furthermore, using Image J by the National Institutes of Health of the United States, each site of determination was measured and the amount of change each site at rest and during contraction of the transversus abdominis was computed. The muscle thickness and distance of shift at each site of measurement were compared among the groups using one-way analysis of variance and a multiple comparison test with the Bonferroni correction. SPSS Version 10.0J for Windows (by SPSS, Inc.) was used for statistical analysis and values of $p<0.05$ were considered significant.

RESULTS

According to the results of the interviews on the subject of low back pain, 20 subjects were stratified as Group A, 17 as Group B, 14 as Group C (Table 1).

The muscle thickness of the transversus abdominis measured from the anterior part and changes in the distance between the skin and the anterior abdominal fascia are shown in Table 2. On both the left and right sides, no significant changes were found in the amount of change in the muscle thickness. On the other hand, the changes in the distance between the skin and the anterior abdominal fascia changed significantly on both sides. The changes in Group A were significantly reduced compared to the other groups (Table 2-a).

The changes in the muscle thickness of the transversus

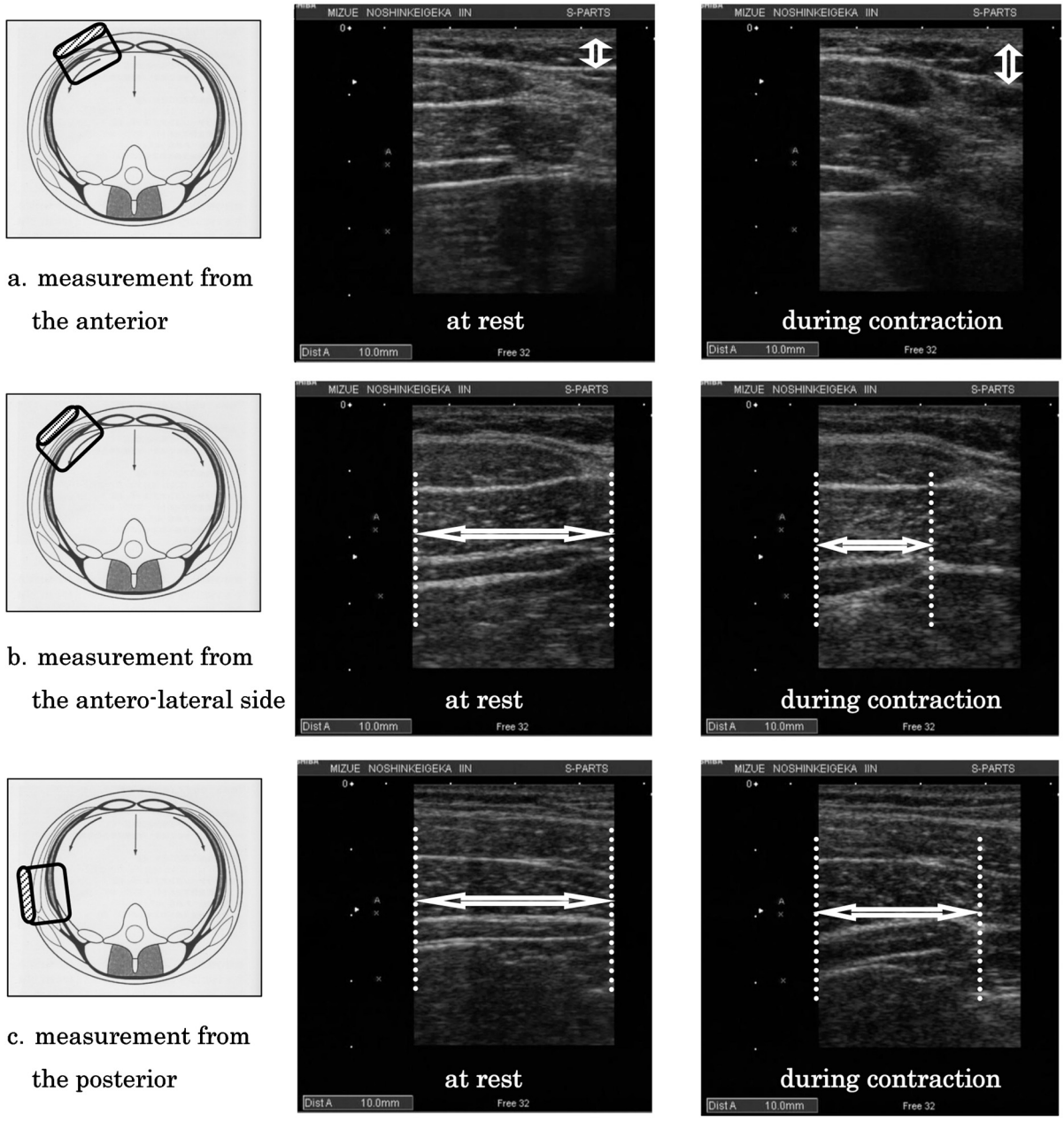

Fig. 1. Ultrasound images of each site of measurement (at rest and during contraction).

abdominis and the distance moved by its tip (measured from the antero-lateral part) are shown in Table 2. On both the left and right sides, no significant changes were found in the amount of change in the muscle thickness. On the other hand, significant differences were noted for the changes in the distance moved by the end of the transversus abdominis on both sides, with Group A showing the least change (Table 2-b).

The changes in the thickness of the transversus abdominis and the distance moved by its tip (measured from the posterior part) are shown in Table 2. On both the left and right sides, no significant changes were found in the amount of change in the muscle thickness. On the other hand, significant differences were noted for the changes in the distance moved by the end of the transversus abdominis on both sides, with Group A showing the least change (Table 2-c).

Table 1. Basic attributes of the subjects in each group

	number of subjects	age (years)	height (cm)	weight (kg)
Group A	20	22. 6 ± 3. 4	171. 9 ± 6. 7	67. 5 ± 8. 0
Group B	17	23. 1 ± 4. 3	172. 0 ± 5. 9	65. 4 ± 11. 7
Group C	14	23. 1 ± 4. 8	172. 2 ± 8. 0	64. 8 ± 7. 6

(n=51)
The numbers are given as a mean ± standard deviation.
Significant difference among the groups: N.S.
Group A: those who had been treated for low back pain.
Group B: those who had experienced occasional low back pain but had not been treated.
Group C: those who had not experienced low back pain

Table 2. Results of the measurement of the transversus abdominis and fascias in Groups A–C

a: measurement from the anterior	A	B	C
[left side]			
muscle thickness of the transversus abdominis	1.3 ± 0.6	1.3 ± 0.6	1.8 ± 0.4
distance between the skin ←→ anterior abdominal fascia (mm)	0.4 ± 0.5*	1.0 ± 0.8	1.4 ± 0.7
[right side]			
muscle thickness of the transversus abdominis	1.1 ± 0.4	1.6 ± 0.7	1.5 ± 0.5
distance between the skin ←→ anterior abdominal fascia (mm)	0.4 ± 0.6*	1.2 ± 0.7	1.4 ± 0.9

(n=51)

b: measurement from the antero-lateral side	A	B	C
[left side]			
muscle thickness of the transversus abdominis	1.2 ± 0.5	1.5 ± 0.6	1.6 ± 0.6
image of the tip of the transversus abdominis distance from the left (mm)	6.9 ± 3.0*	10.1 ± 2.7	9.4 ± 2.3
[right side]			
muscle thickness of the transversus abdominis	1.2 ± 0.7	1.5 ± 0.7	1.7 ± 0.7
image of the tip of the transversus abdominis distance from the left (mm)	7.4 ± 2.2*	10.4 ± 2.0	9.2 ± 2.3

(n=51)

c: measurement from the posterior	A	B	C
[left side]			
muscle thickness of the transversus abdominis	1.7 ± 0.8	1.8 ± 0.7	2.2 ± 0.5
image of the tip of the transversus abdominis distance from the left (mm)	2.0 ± 1.6 *	5.1 ± 2.3	5.1 ± 1.7
[right side]			
muscle thickness of the transversus abdominis	2.0 ± 0.8	2.0 ± 0.7	2.2 ± 0.9
image of the tip of the transversus abdominis distance from the left (mm)	2.5 ± 2.3*	5.2 ± 2.2	6.0 ± 1.9

(n=51)
The figures indicate the changes (mean ± standard deviation) of each measurement. *: $p<0.05$.

DISCUSSION

To establish the relationship between the abdominal and thoracolumbar fascias, that are altered by contraction of the transversus abdominis and low back pain, the changes in these fascias were examined in this study with ultrasound images captured during rest and contraction of TA. Because these fascias and the muscle are deep-seated, it is necessary to employ an ultrasound diagnostic device to take their measurements. It has been reported that the fascias are readily captured by ultrasound diagnostic device and these 3 muscular structures of the antero-lateral abdominal wall can be clearly differentiated[10]. In this study, the fascias were clearly depicted in the images, enabling definitive identification of the muscle and fascias. McMeeken et al.[11] investigated the correlation between the changes in the muscle thickness of the transversus abdominis and electromyograms and reported that muscle acitivities expressed by the electromyograms increased relative to the increase in muscle thickness, which was depicted on an ultrasound diagnostic device, with a high level of correlation (r=0.87).

The transversus abdominis was observed in this study. It is classified as part of the local muscle system that is located deep in the trunk region (at the center) and serves to stabilize the spinal segments[12]. It was reported that each belly muscle terminates at the thoracolumbar fascia in the posterior and at the abdominal fascia in the anterior, conferring stability to the lumbar vertebrae and pelvic through the fascial system[1]. The transversus abdominis is associated

with an extensive attachment system, exerts significant influence on the tension of the thoracolumbar fascia, and adds tension to the middle lamina and the lamina posterior of the same fascia at its middle and lower regions[13].

In a prior study on the relationship between low back pain and the transversus abdominis, it was found that in patients with this condition, in comparison with normal individuals, the activities of the transversus abdominis was delayed and compromised when the subjects were in motion[5]. It was also reported that dysfunctions of the local system involving the deep-seated muscle (e.g., delays and reductions in its activity) most readily develop in association with low back pain[10]. Ferreira, et al.[14], using ultrasound imaging and needle electromyography, examined automatic contraction of the transversus abdominis during isometric contraction of the legs and reported that patients with low back pain exhibited a limited increase in muscle thickness and unilateral activity of the TA.

In this study, the relationship between the muscle thickness of the transversus abdominis and low back pain was examined. We also captured images of this muscle and the abdominal fascia in the anterior or the thoracolumbar fascia in the posterior (the area around muscle/fascia junction) on a single image to investigate the relationship further. Cresswell et al.[1], reported that bilateral contraction of the transversus abdominis results in a reduction in the abdominal circumference, planarization of the belly wall, an increase in abdominal pressure and additional tension in the anterior fascia. They further stated that the contraction and shortening of the transversus abdominis results in lateral drawing of the anterior fascia attachment and pulling of the anterior portion of the abdominal wall toward the posterior direction[6]. According to the images obtained in this study, contraction of the transversus abdominis (i.e., an increase in TA muscle thickness) result in pulling the anterior abdominal wall toward the posterior direction (arrow a, Fig. 2) and lateral pulling of the anterior abdominal fascia (arrow b, Fig. 2). The distance covered by these movements was least in Group A. Individuals in Group A did not show any difference in muscle thickness when compared with Group B or Group C. Lateral drawing of the abdominal fascia, which is involved in the segmental stability of the spine and a rise in abdominal pressure, and posterior drawing of the anterior abdominal wall, create tension in the anterior abdominal fascia, pointing to the involvement of the mobility of these fascias. Specifically, individuals belonging to Group A showed reduced mobility of the anterior portion of the abdominal fascia in spite of contraction of the transversus abdominis. In other words, these individuals were unable to achieve sufficient segmental stability of the spine or increase in abdominal pressure through pulling back of the fascia. This may constitute a cause for low back pain. In subjects with a history of low back pain, the transverse abdominal muscle contracted, however, the flexibility of the anterior fascia decreased. Consequently, the spinal segments were not fully stable and the intraperitoneal pressure did not increase sufficiently because of the lack of posterior traction of the fascia, which can be one of the causes of low back pain.

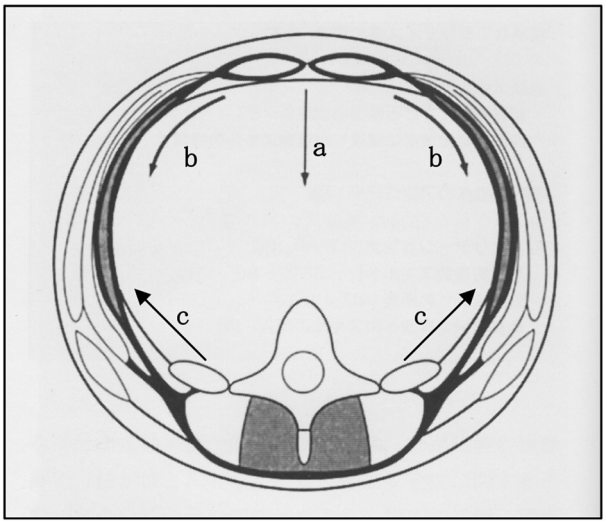

Fig. 2. Changes in each fascia at contraction of the transversus abdominis.
a: the anterior part of the abdominal (abdominal wall) drawn in the posterior direction.
b: the anterior abdominal fascia drawn in the lateral direction.
c: the posterior thoracolumbar fascia drawn toward the lateral direction.

When such reduction in the flexibility of the fascia was observed and the fascia did not slide, the abdominal fascia did not move toward the organ side; although the thickness of the transverse abdominal muscle increased. The change in the distance between the skin and abdominal fascia was an indicator as to whether or not the flexibility of the fascia decreased. When the change in the distance was less, the flexibility of the fascia was lower.

It has been reported that when the transversus abdominis contracts and is shortened, the fascia attachment section is drawn in the lateral direction to the back and the resultant development of tension causes the thoracolumbar fascia to tighten[10]. According to the images obtained in this study, contraction of the transversus abdominis (i.e., an increase in muscle thickness) resulted in lateral drawing of the posterior thoracolumbar fascia (arrow c, Fig. 2). The distance covered by this move was least in Group A. When Groups A, B and C were compared, no difference in muscle thickness were seen. Therefore, we believe that the mobility of the fascias is involved in the lateral drawing of the thoracolumbar fascia that is involved in the segmental stability of the spine and increase in abdominal pressure. In the group of subjects who had experienced low back pain, the transversus abdominis contracted but the mobility of the thoracolumbar fascia was reduced; thus, these individuals were unable to limit the vertebral rotation/translation movements that control the changes in the length of the fascia or its tension (fascial tension). Furthermore, the lack of tension in the lateral direction of the mid-layer fibers of the thoracolumbar fascia, which converge at the transverse process of the lumbar vertebrae and travel in a diagonal direction, interferes with the narrowing of the gap between the adjacent vertebrae. If segmental stability of the spine and the rise in the intra-

abdominal pressure that are achieved by lateral drawing of the fascia become insufficient, it may in turn become a cause of low back pain.

In this study, the subjects were urged to make a conscious effort to contract the transversus abdominis at a single level while the result was confirmed on an US image. Group A exhibited reductions in the distance of the shifts of the abdominal fascia and the tip of the transversus abdominis. The objective of this study was to confirm the motion of the fascia and the subjects were required to consciously contract the transverse abdominal muscle by visual feedback. Consequently, the difference in thickness of the fascia was rather less. A relationship between low back pain and the transversus abdominis was indicated in prior studies. However, the muscle thickness of the transversus abdominis alone may not be sufficient to determine the relationship. The relationship with low back pain may need to be substantiated through an analysis of the abdominal fascias and thoracolumbar fascias that are involved in the mechanism of spinal stability. The measurement was performed twice, and the position of a measurement probe was always confirmed. The interclass correlation coefficient (ρ) (1, 1) of the distance of fascia motion (during contraction) was between 0.90 and 0.91 in the anterior part, 0.90 and 0.92 in the ventrolateral part and 0.88 and 0.90 in the posterior part, respectively, showing good reliability. On the other hand, it was difficult to create real-time images of the beginning and end points of the fascia and transverse abdominal muscle using ultrasonography due to the size of the probe. In contrast, the tip of the transverse abdominal muscle was clearly shown in ultrasound images and the spine and transverse process, the beginning point, varied less, therefore, the movement of the spine and transverse process was considered to be representative of the flexibility of the fascia. Our results indicate that studies including measurement of the distance through which the abdominal fascia and the tip of the transversus abdominis move, instead of measurement of TA thickness alone, will be productive in the investigation of factors affecting low back pain and segmental stability of the spine.

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