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Original Article

Ultrasound Evaluation of Muscle Thickness Changes in the External Oblique, Internal Oblique, and Transversus Abdominis Muscles Considering the Influence of Posture and Muscle Contraction

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Abstract. [Purpose] The aim of this study was to investigate muscle thickness changes in the external oblique (EO), internal oblique (IO), and transversus abdominis (TrA) muscles between the neutral position and trunk rotation, under a state of rest without voluntary contractions, and isometric contractions to both sides with resistance of 50% of the maximum trunk rotation strength. [Subjects] The subjects of this study were 21 healthy young men. [Methods] Muscle thickness changes in the EO, IO, and TrA in each position and state were evaluated by ultrasound. The range of motion at maximum trunk rotation and the maximum strength of trunk rotation were measured using a hand-held dynamometer. [Results] In the neutral position and at 50% trunk rotation to the right side, the thicknesses of the IO and TrA significantly increased with resistance. In both states, the thicknesses of the IO and TrA significantly increased at 50% trunk rotation to the right side. [Conclusion] The muscular contractions of the IO and TrA were stronger during ipsilateral rotation than in the neutral position and with resistance than at rest. Moreover, the muscular contraction was strongest in the resistive state during ipsilateral rotation.
Key words: Trunk rotation, Low back pain, Functional evaluation

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INTRODUCTION

Among the trunk muscles, the transversus abdominis (TrA) reportedly acts as a feed-forward control element prior to movement[1)], and it is also involved in the stabilization of the lumbar and pelvic regions. In healthy subjects and those with low back pain, the activity and strength of the trunk muscles reportedly differ[2, 3)]. However, the response time and activity of the TrA have been shown to change[4)].

In recent years, some authors have reported that the change in muscle thickness of the TrA measured by ultrasound is a useful index for functional evaluation[5–7)]. Functional evaluations of the TrA during various movements have been performed, but the operative mechanism of the TrA during trunk rotation is not well understood[8)]. Trunk rotation is involved in various movements, from walking to sports. Trunk rotation is a key factor in 60% or more of low back pain[9)]. Therefore, to clarify the anatomical and kinesiological characteristics of trunk rotation is important for preventing and ameliorating low back pain. Surface electromyography and needle electromyography are the techniques used to evaluate the function of the abdominal muscles during trunk rotation. Ultrasound is gaining attention as a new evaluation technique.

Studies concerning the relation between muscle activities of the external oblique (EO), internal oblique (IO), and TrA using needle electromyography have reported that during trunk rotation, the EO acts contralaterally whereas the IO and TrA act ipsilaterally[10)]. Few studies of the thickness of the abdominal muscles with trunk rotation have been performed using ultrasound, and there are no studies in the literature which have investigated the thickness of abdominal muscles horizontal trunk rotation. We previously examined the reliability of measuring the muscle thicknesses of the EO, IO, and TrA by ultrasound in the neutral position and at 50% trunk rotation, and reported that the mean value of three measurements showed a high coefficient of reliability[11)]. To clarify the characteristics of the abdominal muscles during trunk rotation using ultrasound is important for functional evaluation of the abdominal muscles and various movements.

Thus, the aim of this study was to evaluate by ultrasound the characteristics of muscle thickness changes in the EO, IO, and TrA in the neutral position and during trunk rotation.

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SUBJECTS AND METHODS

The study subjects were 21 healthy young men with no history of orthopedic or neurological disorders and no lumbar symptoms. In conformity with the principles of the Declaration of Helsinki, each subject was informed about the study, privacy protection, and the absolute right to withdraw at any time, and their consent to participation was obtained before the start of the study.

Before measuring abdominal muscle thicknesses using ultrasound, the range of motion (ROM) at maximum trunk rotation and the maximum strength of trunk rotation were measured using a hand-held dynamometer (HHD; the Commander Powertrack Dynamometer; J-Tech Medical, Salt Lake City, UT, USA). The ROM at maximum trunk rotation was measured once as the angle at the intersection of the basic axis line linking the posterior superior iliac spines of both sides and the movement axis line linking the acromions of both sides. Maximum strength of trunk rotation was measured with resistance applied to the greater tuberosity of the humerus from the front. The maximum strength in the neutral position was measured three times and the mean value was calculated.

The subjects adopted a seated position with their feet flat on the ground and their arms crossed on their chests. The hip and knee joints were flexed at 90°, and the thighs were fixed with a belt. For all measurements, the pelvic position of the subjects was corrected to the neutral position in the sagittal plane and the subjects were instructed to maintain the neutral position. Measurements were recorded with the trunk in the neutral position and at 50% of the maximum trunk rotation (50% trunk rotation). Measurements were also recorded with the subjects at rest without voluntary contractions (the resting state) and with resistance applied to isometric contractions to both sides of 50% of the maximum rotation strength as measured by the HHD (the resistive state). Each of the two positions and states was measured three times. Moreover, one examiner operated the ultrasound equipment and the other operated the HHD.

The muscle thicknesses were measured on longitudinal images obtained using real-time B-mode ultrasound equipment (My Lab25; Hitachi Medical Corporation, Japan) with a 7.5 MHz linear-array probe. The probe was first placed onto the right side of the abdomen in line with the upper end of the umbilicus, after which it was fixed by hand when the muscle thicknesses of EO, IO, and TrA were clearly observed on the ultrasound image. The muscle thicknesses of the EO, IO, and TrA were recorded on video (5 s). A still image was extracted of a position in which the three muscles were distinct, and the muscle thicknesses were measured using imageJ image analysis software (National Institutes of Health, Bethesda, MD, USA). Muscle thicknesses were measured at 15 mm from the muscle tendon junction of the TrA towards the muscle belly (Fig. 1).

For statistical analysis, one-way analysis of variance of the muscle thicknesses (EO, IO, and TrA) for all conditions was performed. Then, Tukey's multiple comparison method was performed to examine the significance of changes in muscle thickness with and without muscular contraction.

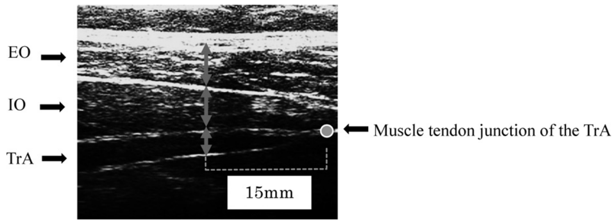

Fig. 1. Position at which muscle thickness was measured for external oblique (EO), internal oblique (IO), and transversus abdominis (TrA) on ultrasound images

The muscle thicknesses of the EO, IO, and TrA in the resting state and the resistive state for each position were compared. In addition, the t-test was performed to examine the significance of the changes in muscle thickness at the different angles of trunk rotation. The results of the muscle thickness measurements in the neutral position and at 50% trunk rotation of both states were compared.

All data are reported as the mean (standard deviation [SD]). We used SPSS, version 17.0 for Windows (SPSS Inc., Chicago, IL, USA) for the statistical analyses, and a significance level of 5%.

RESULTS

The subjects had a mean age of 23.8 (3.0) years, a mean height of 171.5 (7.0) cm, and a mean weight of 64.1 (7.9) kg. The ROM at maximum trunk rotation was 48.3 (7.8)° in right rotation and 49.3 (8.5)° in left rotation. The maximum strength of right rotation was 147.4 (25.8) N, and 138.9 (22.7) N in left rotation. The rotation angle at 50% trunk rotation to the right side was 24.2 (3.9)°, and that at 50% trunk rotation to the left side was 24.6 (4.2)°.

In the neutral position, the thickness of the EO was significantly reduced by left rotation with resistance, and the thicknesses of the IO and TrA were significantly increased by right rotation with resistance. At 50% trunk rotation to the right side, the thicknesses of the IO and TrA were significantly increased. At 50% trunk rotation to the left side, the thicknesses of the EO and IO were significantly reduced. In the resting state and at 50% trunk rotation to the right side, the thicknesses of the IO and TrA were significantly increased. At 50% trunk rotation to the left side, there were no significant differences in the thickness of the three muscles. In the resistive state and at 50% trunk rotation to the right side, the thicknesses of the IO and TrA were significantly increased. At 50% trunk rotation to the left side, the thicknesses of the IO and TrA were significantly reduced (Table 1).

DISCUSSION

In the neutral position, the thickness of the EO significantly reduced by left rotation with resistance. In addition, the thicknesses of the IO and TrA significantly increased by right rotation with resistance. There are two important points to note here. First, the muscle activity of the EO in-

Table 1. Descriptive statistics for the muscle thicknesses of the external oblique, internal oblique, and transversus abdominis with and without resistance and 50% trunk rotation (n=21)

	EO		IO		TrA	
	Resting	Resistive	Resting	Resistive	Resting	Resistive
Right						
neutral (mm)	7.4 (1.1)	7.4 (1.9)	7.2 (1.9)	9.6 (2.9)*1	3.6 (0.7)	5.6 (1.8)*1
50% (mm)	7.0 (1.2)	7.7 (2.4)	9.4 (2.7)*2	12.0 (3.9)*1,*2	4.5 (0.9)*2	6.6 (2.0)*1,*2
Left						
neutral (mm)	7.6 (1.1)	6.6 (1.2)*1	7.1 (1.9)	6.7 (1.8)	3.7 (0.8)	4.2 (1.5)
50% (mm)	8.0 (1.4)	6.7 (1.3)*1	6.9 (1.9)	6.2 (2.3)*1,*2	3.6 (0.8)	4.0 (1.6)*2

Mean (SD), *Significant difference (p<0.01)
neutral, neutral position; 50%, 50% trunk rotation; resting, resting state; resistive, resistive state; EO, external oblique; IO, internal oblique; TrA, transversus abdominis, *1 resting state versus resistive state, *2 neutral position versus 50% trunk rotation

creased at trunk rotation angles of 20° or more[12], and second, the activity of the EO was greater during trunk rotation with flexion in a horizontal rotation exercise in the neutral position. In addition, the IO and TrA fixed the trunk by raising abdominal pressure to resist. At 50% trunk rotation to the right side, the thicknesses of the IO and TrA were significantly increased, because these muscles raised the abdominal pressure to resist ipsilateral trunk rotation. At 50% trunk rotation to the left side, the thicknesses of the EO and IO were significantly reduced, because these muscles are stretched by thoracic rotation and horizontal trunk rotation. Furthermore, from an anatomical point of view, the significant changes in the thickness of these muscles were caused by muscular stretch. There were two reasons for this muscular stretch: the lowest fiber of the EO extends almost vertically from the eighth lowest rib to the anterior of the iliac crest; and the backward ilium fiber of the IO extends from the upper side of the inferior border to the lowest 3–4 ribs[13].

With regard to the kinematic function of the abdominal muscles during trunk rotation, the IO and TrA have been shown to have a functional role in ipsilateral trunk rotation, whereas the EO has a role in contralateral trunk rotation[10]. The thicknesses of the IO and TrA significantly increased in the resting state at 50% trunk rotation to the right side, and there were no significant differences in the thicknesses of the three muscles at 50% trunk rotation to the left side. The results indicate that the function of these muscles is to maintain a specific position rather than to initiate joint movement. In the resistive state at 50% trunk rotation to the right side, the IO and TrA showed the greatest thicknesses of all the conditions. At 50% trunk rotation to the left side, the thicknesses of the IO and TrA were significantly reduced, because the contralateral IO and TrA were extended to a greater degree through the rectus sheath by strong contraction of the ipsilateral IO and TrA. However, with regard to the EO, there was no significant difference in the resistive state during contralateral trunk rotation, because the muscle fiber extends from the ribs to below the iliac crest and is stretched by trunk rotation. Hence, the significant change in the EO thickness was not caused by muscle contraction.

In the present study, there was no significant difference in the EO in the resistive state during contralateral trunk rotation. However, three factors need to be considered. First, from an anatomical point of view, the muscle is easily extended from this position by trunk rotation. Second, the movement in this study was horizontal trunk rotation, and differed from the trunk rotation with flexion that increased the muscle activity of EO and IO. Third, the direction of resistance was from the anterior position. In left rotation, resistance applied to the right shoulder strengthened the connection to the left abdomen and weakened the activity of the right EO. However, it is difficult to measure the muscle thickness of both sides at the same time using ultrasound, meaning this point could not be clarified. It is important that the timing of the muscular contractions of the abdominal muscles coincides with the activity and that the timing of the muscular contractions coincides with that of the back muscles in trunk rotation. Hence, future analysis is needed to evaluate trunk function during trunk rotation using surface electromyography and three-dimensional motion analysis, and to examine the activity of the abdominal and back muscles and their association with trunk rotation angles. In addition, it is possible to measure muscle thickness and quantitatively evaluate trunk function with various movements simply, easily, and spontaneously by clarifying the association between muscle activity and muscle thickness changes with different trunk rotation angles using ultrasound.

In conclusion, the thicknesses of the IO and TrA during ipsilateral trunk rotation were greater in the resistive state than in the resting state, and greater in the neutral position than in trunk rotation. In addition, the thicknesses of the IO and TrA were greatest in the resistive state during ipsilateral rotation. Both the IO and TrA have important functions in maintaining a specific position and initiating joint movement, and these functions play a role in the mobility of the thoracolumbar region and pelvic stability.

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