The Relationship of Abdominal Muscles Balance and Body Balance

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Abstract. [Purpose] This study aimed to identify what impact the thickness differences between the leftside and rightside transversus abdominis (TrA), internal obliquus (IO) and external obliquus (EO) have on balance ability in the abdominal drawing-in maneuver (ADIM) and resting postures. [Subjects and Methods] In this study, 41 young adults were asked to adopt a resting posture and to perform ADIM. The thicknesses of the abdominal muscles (TrA, IO, EO) were measured using ultrasound imaging. Then balance ability was measured, so that a comparative analysis could be carried out. [Results] According to the results, the thicknesses of TrA and IO very significantly increased when ADIM was performed. The changes in thickness of the muscles on the left and right sides showed no significant correlations with balance ability. [Conclusion] According to the study results, the difference in thickness between the left and right side muscles in a normal person is small (symmetric), and the differences in the thickness of TrA and IO on the left and right side reduced when the ADIM, which is a re-education method for abdominal muscles was performed. Therefore, we consider that the ADIM should be used in future clinical trials to induce symmetric contraction of the abdominal muscles. Also, the correlation results of muscle balance and body balance can be used as empirical data.

Key words: Ultrasound, Abdominal muscle, Imbalance

(This article was submitted Jan. 31, 2013, and was accepted Feb. 22, 2013)

INTRODUCTION

The spinal column and balance are closely related with each other, in order for the adjustment of body posture to meet the stability and mobility requirements of the body joints at the same time¹⁾. The muscles of the abdomen play an important role in stabilization of lumbar vertebra. Especially, the abdominal muscles, such as the transversus abdominis (TrA) and the internus obliquus (IO), enable functional movements by providing stability to each segment of the lumbo-pelvic region when supporting the body's weight^{2, 3)}. In short, the inner abdominal muscles, such as TrA, have impacts on balance by reacting to changes in body posture⁴⁾.

In the case of stroke patients, imbalance of trunk muscles, including abdominal muscles, causes asymmetric posture. The imbalance also it causes a disorder in posture adjustment by reducing the ability to maintain the center of gravity of the trunk on the weight-bearing surface and the reaction required to maintain a symmetric posture⁵⁾.

The muscle activity pattern of the spinal column affects balance ability and stability⁶⁾. Compared to normal per-

sons, back pain patients have a difference in mobilization of motor units in the lumbar region, namely asymmetric muscle activity, which works as a factor increasing damage to spinal structures^{7, 8)}. Changes caused by damage to spinal structures cause changes in lumbar movement in back pain patients, reducing their balance ability¹⁾.

Previous studies have investigated the reduction in balance ability caused by asymmetric movement of trunk muscles, including the abdominal muscles, in stroke and back pain patients. However, most of them were carried out by using electromyography, and there are few studies which have been carried out using ultrasound imaging. Also, the previous ultrasound imaging studies of normal persons have focused on measurements of muscles⁹⁾, but few studies have focused on correlations between the balance (symmetry) of muscles and body balance. Accordingly, in this study, thickness changes in the left and right side inner abdominal muscles, TrA, IO and the externus obliquus (EO), were analyzed using ultrasound imaging. We aimed to identify the impact the thickness differences (symmetry) between the left and right abdominal muscles have on balance ability.

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SUBJECTS AND METHODS

The study subjects were 41 healthy men and women in their 20s. According to the selection criteria, the selected participants had no neurologic diseases or orthopedic problems, no pains or dysfunction in their lumbar region in the last 6 months, and no disease that could have affected the balance test used in this study.

For the ultrasound measurement, images were captured using the B-mode of an ultrasound diagnostic device (Logiq sonography system, $\alpha\alpha$ -200, Samsung-GE Medical Systems Inc., Seongnam, Korea). The thickness changes in abdominal muscles (TrA, IO, EO) on both on the left and right sides were measured using a 7.5-MHz linear transducer, with subjects at rest and performing the abdominal drawing in maneuver (ADIM). The average value of three measurements of each posture was used in the analysis. A one-minute break was taken between measurements of the postures. The measurements of abdominal muscle thicknesses in each posture followed the general method used in previous studies^{10, 11}.

For the measurement of balance, the evaluation of static and dynamic balance was carried out. A Tetrax Portable Multiple system (Tetrax Ltd, 56 Miryam Ramat Gan, Sunlight, Israel) was used for the static balance evaluation. The force platforms of Tetrax were positioned for both feet, and the postural sway was evaluated by the changes in weight on the 4 points (2 for each forefoot, and 2 for each heel). The stability test index (STI) was calculated for the static balance over 30 seconds in the standing posture. A one-minute break was taken between each measurement¹². The test was carried out with the subjects' eyes closed. A higher STI value, the score for static balance, means greater postural sway. A lower STI value means less postural sway¹³.

In order to measure the dynamic balance, the functional reach test (FRT) was carried out. For the FRT, a tape measure parallel to the floor was attached to a wall at the height of each subject's acromion. After putting their feet parallel to each other, subjects rotated both arms to 90 degrees to the horizontal position, and performed forward bending from a position next to the starting point of tape measure with the wrists maintained in the neutral position. The maximum forward reach distance was measured¹⁴. The average value of three measurements was used in the analysis.

The SPSS 15.0 for Windows was used for the statistical analysis. Pearson's correlation coefficients were calculated

to analyze the impact of the thickness difference between the leftside and rightside abdominal muscles on balance ability in the ADIM and resting postures. The paired t-test was carried out to compare the thicknesses of TrA, IO and EO on the left and right side when adopting taking each posture. The level of the statistical significance was chosen as 0.05.

RESULTS

The general characteristics of the participants were age of 20.8 ± 1.0 years, height of 165.0 ± 6.2 cm, weight of 57.4 ± 7.5 kg, and a body mass index (BMI) of 21.0 ± 2.0 kg/m². The 41 participants comprised 9 men and 32 women.

According to the analysis of thickness changes between the resting and ADIM postures, the muscle thicknesses of both left and right side TrA and IO increased significantly ($p < 0.01$) (Table 1), when adopting the ADIM posture, compared to those of the resting posture.

In contrast, in the case of EO, the muscle thickness was significantly greater in the resting posture than in the ADIM posture ($p < 0.01$) (Table 1).

According to the correlation analysis of the balance (Tetrax, FRT) and thickness difference between the left and right muscles of each posture, there were no significant correlations (Table 2). In the case of TrA and IO the thickness difference reduced in the ADIM posture (Table 2).

DISCUSSION

As in previous studies in which asymmetry of the inner abdominal muscles was measured on using ultrasound

Table 1. Comparison of thickness changes in TrA, IO, EO muscles on the left and right

		Rest	ADIM
TrA (mm)	Rt. side	31.6 ± 10.5	$44.4 \pm 12.5^*$
	Lt. side	32.5 ± 12.7	$45.1 \pm 14.0^*$
IO (mm)	Rt. side	74.4 ± 18.2	$93.2 \pm 23.4^*$
	Lt. side	72.1 ± 17.5	$93.4 \pm 22.5^*$
EO (mm)	Rt. side	50.3 ± 14.4	$43.1 \pm 13.0^*$
	Lt. side	47.5 ± 13.6	$39.3 \pm 12.4^*$

ADIM, Abdominal drawing-in maneuver. TrA, transversus abdominis. IO, internal obliquus. EO, external obliquus. * = $p < 0.01$

Table 2. Correlation analysis of balance and the thickness difference between the left and right muscles

		Mean $\pm$ SD	STI EO (r)	STI EC (r)	FRT (r)
TrA (mm)	rest	0.9 ± 10.8	0.2	-0.2	0.0
	ADIM	0.8 ± 10.3	-0.0	-0.2	0.1
IO (mm)	rest	2.3 ± 17.1	-0.2	-0.2	-0.0
	ADIM	0.2 ± 18.8	0.2	0.1	0.3
EO (mm)	rest	2.8 ± 13.0	-0.2	-0.3	-0.0
	ADIM	3.8 ± 8.6	0.1	0.2	-0.1

STI EO, stability test index eyes open. STI EC, stability test index eyes closed. FRT, Functional reach test. ADIM, Abdominal drawing-in maneuver. TrA, transversus abdominis. IO, internal obliquus. EO, external obliquus. * = $p < 0.05$

images, we demonstrated that the thickness difference between the left and right side abdominal muscles in the ADIM posture reduced, though asymmetry between the left and right side muscles was not detected in this study. This implies that the ADIM posture induces symmetric contraction of the abdominal muscles. The reaction of the inner abdominal muscles, TrA and IO, demonstrated in this study, may support those studies which have suggested that these muscles provide the lumbar pelvis region with stability for functional movement, and TrA and IO are closely related to the movement and balance of the spinal column^{1–3}). In other studies, it has been suggested that back pain patients show asymmetric muscle activities of the trunk muscles, unlike healthy persons, which causes pain and affects balance^{7, 8}). However, as seen in this study, healthy persons showed symmetry of the abdominal both muscles, and they also showed symmetric contraction, so we consider that thickness of the abdominal muscles does not have a significant correlation with balance.

Though many studies have been carried out on the inner abdominal muscles, such as TrA and IO, it is not easy to find studies about left-right imbalance of abdominal muscles.

Most studies have focused on the imbalance of trunk muscles in stroke patients and back pain patients, and we could find no study which focused on correlation between muscle imbalance and body balance. Therefore, the results of this study of healthy persons may be used as empirical data.

According to the study of Reeves and others, the thoracic region of back pain patients and the asymmetric muscle activity of left and right lumbar erector spinae are closely related to pathological factors¹⁵). Renkawitz and others have demonstrated a correlation between the neuromuscular imbalance of the erector spinae and back pain¹⁶). In general, symmetric co-contraction between erector spinae and inner abdominal muscles enhances the trunk stability, and motor control is used as a treatment method utilizing this symmetry¹⁷). Namely, the symmetry of the inner abdominal muscles, as well as that of the erector spinae is closely related to trunk stability, and consequently, asymmetry of inner abdominal muscles may reduce balance ability. It will be necessary to carry out studies in the future, recognizing the importance of the inner abdominal muscles.

The limitations of this study are as follows. As the number of participants was small, it is difficult to generalize the data, and all the participants were young adults, so generalization across ages is impossible. Also, all the participants were healthy, so it will be necessary to carry out comparative research with stroke patients and back pain patients in the future.

In conclusion, in this study, symmetric contraction of the abdominal muscles was induced by ADIM, which is a

re-education method focusing on inner abdominal muscles. This method should be aggressively used to treat patients with central nervous system disorders, including stroke patients who have asymmetric contraction, and patients with musculoskeletal diseases such as back pain patients. Also, the correlation analysis results of balances and the inner abdominal muscles can be used empirical data.

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