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Original Article

Differences in the transversus abdominis thickness during various motor tasks in the supine position

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Abstract. [Purpose] The aim of this study was to evaluate simple and efficient transversus abdominis exercises performed in the supine position using ultrasonography. [Participants and Methods] Sixteen healthy males performed six motor tasks including left shoulder flexion, draw-in, left straight leg raise, and the vocalization of vowel sounds (55–60 dB, 65–70 dB, and 75–80 dB), in a random order while in the supine position. The thicknesses of the transversus abdominis, internal oblique, and external oblique were measured using ultrasonography. [Results] There was a significant increase in the transversus abdominis thickness during the draw-in and vocalization tasks than during other tasks. With respect to draw-in and the three vowel sound volumes, there was a significant difference between draw-in and the 65–70 dB sound. However, there was no significant difference in the transversus abdominis thickness between draw-in and the three vocalization tasks. [Conclusion] These results suggest that the vocalization of vowel sounds is an effective and easy way to exercise the transversus abdominis for patients experiencing difficulty in performing draw-in exercises.

Key words: Transversus abdominis training, Vocalize vowel sounds, Ultrasonography

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INTRODUCTION

Abdominal trunk muscles are categorized as global muscles in shallow layers and local muscles in deep layers. While global muscles do not attach directly to the vertebra, they are segmentally articulated in response to the large loads placed on the lumbar pelvic region. This function improves the stability of the entire spine. Alternatively, local muscles are involved in the segmental stability of the spine and their relationship to lower back pain has been reported in clinical practice. One group of local muscles, the transversus abdominis, adheres to the thoracolumbar fascia and is involved in the increase of intra-abdominal pressure along the diaphragm and pelvic floor muscle, and is able to maintain the stability of the spine with a corset in the abdomen and lumbar region. Although palpation of the transversus abdominis is very difficult as they are located deeper than the internal oblique muscles, it is still necessary to judge their low-level voluntary contractions during exercise.

Therefore, in recent years, research on the functional evaluation and training of the abdominal trunk muscles using ultrasonography has been increasing. This simple, non-invasive technique can evaluate soft tissues such as skeletal muscles, ligaments, and tendons in real-time. These advantages significantly increase the usefulness of ultrasonography in clinical practice. High reliability for functional assessments of the transversus abdominis has been reported[1)].

Draw-in is a typical transversus abdominis exercise. Draw-in is supposed to allow for selective contraction of the transversus abdominis and is considered important because it can prevent lower back pain. Springer et al.[2)] measured the trans-

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versus abdominis thickness using ultrasonography in a healthy group of individuals, and reported that the muscle thickness significantly increased during draw-in as compared to that at rest. The usefulness of draw-in has also clearly been indicated in previous research[3, 4]. In addition, Fuse et al.[5] reported a significant increase in transversus abdominis thickness during the vocalization of "u" and "o" sounds compared to the end of resting exhalation, suggesting the usefulness of vocalizing vowel sounds.

In addition to the difficulty in palpating the transversus abdominis, evaluating elderly patients with dementia in clinical practice is difficult since they typically have difficulty understanding the draw-in instructions. Teaching vocalization is easier and highly useful in clinical practice if there is no significant difference in transversus abdominis thickness during draw-in and vowel sound vocalization. In addition, there are many cases where patients are forced to be in the supine position for long periods of time, such as with vertebral fractures. These special cases require an efficient exercise that can be performed while in the supine position to prevent loss of core muscle strength.

Therefore, the purpose of this study was to use ultrasonography to evaluate simple and efficient exercise methods used to contract the transversus abdominis that could be performed in the supine position. And, it is considered that it helps the exercise therapy by comparing with the various motor tasks that can be easily performed in clinical.

PARTICIPANTS AND METHODS

Sixteen healthy men with a median (25 percentile, 75 percentile): age, 21 years (19, 22); height, 170.8 cm (167.5, 174.0); weight, 62.4 kg (57.4, 70.0); Body Mass Index (BMI), 21.3 kg/m^2, (19.9, 24.0); percent body fat, 15.1% (12.6, 17.6); muscle mass, 50.3 kg (46.4, 54.9); percent trunk body fat, 14.5% (9.9, 19.2); and trunk muscle mass 27.4 kg (25.8, 29.4), participated in this study. Participants were excluded if they had neurological and orthopedic diseases in the lumbar or pelvic girdle or a history of surgery.

In this study, the thickness of the abdominal trunk muscles during various motor tasks was examined while the participants were in the supine position. Thicknesses of the transversus abdominis, internal oblique, and external oblique muscles were determined using an ultrasonography imaging method (SonoSite, SonoSite180PLUS). A digital sound-level meter (Japan 3B Scientific Co., #U11801) was used as a barometer for the loudness of the vocalized vowel sounds.

All measurements were performed with the participants in the supine position with both hip and knee joint flexion at 0°. Based on previous research[6], the measurement site was the right anterior axillary line between the middle part of the rib cage and the iliac crest, and the probe was placed such that it was orthogonal to the right anterior axillary line. The measurement site was marked so that the fixed position of the probe could be replicated. During the vowel sound vocalization task, a clip was used to position the digital sound-level meter 30 cm away from the participant's mouth, similar to a previous study[5].

Measurements of motor tasks included the following: 1) resting expiration (control group), 2) left shoulder flexion, 3) draw-in, 4) left straight leg raise (SLR), and 5) the vocalization of vowel sounds (55–60 dB, 65–70 dB, and 75–80 dB). The resting expiration task instruction was "Please breathe normally," and the level was measured during the third resting exhalation. The left shoulder flexion task involved grasping a 1 kg dumbbell and raising it approximately by 150°. The study participants were asked to raise their left leg by approximately 30° for the left SLR task. Measurements were taken in these raised positions. In the shoulder flexion task, a unified weight of 1 kg was used, rather than setting the dumbbell load according to a muscle mass ratio with the left upper limb, so that even the older participants could easily raise the weight. The left shoulder flexion task and the left SLR task are easy exercises that are often used in clinical, and they were imposed for comparison with draw-in. The instruction for the draw-in task was "After you inhale, please slowly exhale while drawing your navel to your spine". Measurements were then taken while the participant vocalized a vowel sound. The vowel sound was an "o" sound, which is a rounded vowel, and corresponded to three human voice conditions, a small ordinary voice (55–60 dB), a large ordinary voice (65–70 dB), and a large voice (75–80 dB). Each motor task was practiced before starting the measurements. All measurements were started after the participants had been resting in the supine position for approximately 2 minutes. In addition, participants were allowed to rest between each motor task while the participants' level of fatigue was assessed.

Resting expiration was performed first followed by the remaining 6 conditions in random order. Each test condition was performed twice, and the average value was taken as the representative value. Resting expiration and draw-in were recorded at the end of exhalation, and ultrasound images were recorded at the end of the vocalization tasks.

In the statistical analysis, we performed the Shapiro-Wilk test, but because the data were not normally distributed, we conducted a Friedman test to compare motor tasks and muscle thicknesses. Comparisons among groups were conducted using a Wilcoxon signed rank test. The significance level was set at 0.05 and there were 21 conditions (0.05/21=0.0023; $p<0.0023$). To examine the correlation of each muscle thickness in each motor task, we performed the Shapiro-Wilk test, but the data were not normally distributed so correlation analysis was conducted using the Spearman's rank method. The significance level was set at 0.05. IBM SPSS Statistics Version 25 (Armonk, NY, USA) was used for all analyses.

The study was conducted according to the World Medical Association Declaration of Helsinki. The purpose and details of this study were explained to all participants. Measurements were made after consent was obtained from the participants. The protocol was previously approved by the Ethics Committee of International University of Health and Welfare (reference number: 17-IO-190). There is no conflict of interest in this research.

RESULTS

A comparison of the motor task and each abdominal trunk muscle thickness is shown in Table 1. The transversus abdominis thickness was significantly increased during draw-in, and 55–60 dB, 65–70 dB, and 75–80 dB vocalizations compared to resting expiration. There was a significant difference only between draw-in and the 65–70 dB vocalization among the others. There were no significant differences among the three vowel sound conditions (55–60 dB, 65–70 dB, and 75–80 dB). The internal oblique thickness was significantly increased during draw-in, and 65–70 dB, and 75–80 dB vocalizations compared to resting expiration.

Next, the correlation of the transversus abdominis thickness with each motor task is shown in Table 2. A strong positive correlation was found between resting expiration and left shoulder flexion ($p<0.01$), and a positive correlation was found among resting expiration and draw-in, 55–60 dB, 65–70 dB, and 75–80 dB ($p<0.05$). In addition, a strong positive correlation was found among draw-in and 55–60 dB, 65–70 dB, and 75–80 dB ($p<0.01$). Among the three vowel sound conditions, a strong positive correlation was found among each task ($p<0.01$).

The correlation of the internal oblique thickness with each motor task is shown in Table 3. A strong positive correlation

Table 1. Comparison between the motor task and each muscle thickness

	TrA (mm)	IO (mm)	EO (mm)
RE	3.10 (2.40, 3.84)	7.57 (6.64, 9.20)	6.14 (5.10, 6.54)
LSF	3.31 (2.54, 4.16)	7.14 (5.99, 9.57)	4.83 (4.51, 6.04)*
Draw-in	6.30 (5.15, 7.37)*†	9.33 (6.92, 12.57)*	4.36 (4.00, 4.76)*
LSLR	3.14 (2.51, 4.24)‡	8.00 (7.09, 10.10)	8.01 (6.40, 8.69)*†‡
55–60 dB	5.62 (4.70, 6.71)*†§	7.82 (7.48, 10.51)	4.60 (4.22, 5.32)*§
65–70 dB	5.71 (4.60, 6.88)*†‡§	8.42 (7.05, 10.97)*	4.22 (3.59, 4.97)*†§
75–80 dB	6.18 (4.61, 7.21)*†§	8.65 (7.20, 11.43)*†	4.02 (3.79, 4.83)*†§**

$p<0.0023$ *: vs. RE; †: vs. LSF; ‡: vs. draw-in; §: vs. LSLR; **: vs. 55–60 dB.
TrA: transverse abdominal muscle; IO: internal oblique muscle; EO: external oblique muscle; RE: resting expiration; LSF: left shoulder flexion; LSLR: left straight leg raise.

Table 2. Correlation of the transversus abdominis thickness with each motor task

	RE	LSF	Draw-in	LSLR	55–60 dB	65–70 dB	75–80 dB
RE	—	0.76**	0.57*	0.41	0.59*	0.58*	0.54*
LSF		—	0.60*	0.59*	0.58*	0.50*	0.48
Draw-in			—	0.36	0.80**	0.88**	0.63**
LSLR				—	0.24	0.22	0.29
55–60 dB					—	0.80**	0.76**
65–70 dB						—	0.82**
75–80 dB							—

*$p<0.05$, **$p<0.01$.
RE: resting expiration; LSF: left shoulder flexion; LSLR: left straight leg raise.

Table 3. Correlation of the internal oblique thickness with each motor task

	RE	LSF	Draw-in	LSLR	55–60 dB	65–70 dB	75–80 dB
RE	—	0.65**	0.53*	0.42	0.64**	0.60*	0.75**
LSF		—	0.53*	0.37	0.62*	0.33	0.51*
Draw-in			—	0.25	0.52*	0.55*	0.57*
LSLR				—	0.22	0.24	0.30
55–60 dB					—	0.55*	0.71**
65–70 dB						—	0.83**
75–80 dB							—

*$p<0.05$, **$p<0.01$.
RE: resting expiration; LSF: left shoulder flexion; LSLR: left straight leg raise.

was found among resting expiration and left shoulder flexion, 55–60 dB, and 75–80 dB ($p<0.01$), and a positive correlation was found among resting expiration and draw-in and 65–70 dB ($p<0.05$). In addition, a positive correlation was found among draw-in and 55–60 dB, 65–70 dB, and 75–80 dB ($p<0.05$). A strong positive correlation was found between 55–60 dB and 75–80 dB, and between 65–70 dB and 75–80 dB ($p<0.01$).

DISCUSSION

In this study, it was possible to obtain the same muscle contractions during draw-in and in vowel sound vocalizations, suggesting the effectiveness of either as a transversus abdominis exercise. Compared to the other tasks, there was a significant increase in transversus abdominis thickness during draw-in and the vocalization of vowel sounds. And there was a significant increase in internal oblique thickness during draw-in, and 65–70 dB, and 75–80 dB vocalizations compared to resting expiration. In a previous study, many references found a relationship between draw-in and transversus abdominis thickness. And there are some references that draw-in significantly increases the thickness of the transversus abdominis and the internal oblique, which is consistent with the results of this study. In addition, they reported that there was a significant increase in transversus abdominis thickness during “u” and “o” vocalization compared to the end of exhalation[5]. However, there has been no study comparing draw-in and the vocalization of vowel sounds. In this study, there was a significant difference only in the 65–70 dB range when compared to draw-in, but there was no pronounced difference in the muscle thickness between draw-in and the 3 vowel sound vocalizations. Since vowel sound vocalization is easy to teach and effective as a transversus abdominis exercise, it is ideal for participants who find it difficult to complete complex exercise tasks such as elderly patients with dementia.

Subsequently, no significant differences were found among the 3 vowel sound vocalization conditions, suggesting that volume does not affect the thickness of the transversus abdominis. Therefore, regardless of the volume of the voice, it is possible to obtain transversus abdominis muscle contractions with a simple teaching phrase such as “Please continue vocalizing for as long as possible”. The results of this study reveal that the vowel sounds to sustain by transversus abdominis exercises are important, and vital capacity and respiratory muscle strength during the end of voicing out are needed. Draw-in and the vocalization of vowel sounds show similar contraction patterns (Tables 2 and 3).

Because voice production is necessary to adjust the expiratory and intra-abdominal pressure, and because it has a low load, like draw-in, it is an efficient exercise of the transversus abdominis.

Finally, in this study, it was suggested that the left shoulder flexion and the left SLR are less useful as a transversus abdominis exercise.

Conflict of interest

There is no conflict of interests in this research.

REFERENCES

1) Kaneko H, Sato H, Maruyama H: Reliability of lateral abdominal muscles thickness measurement using ultrasonography. Rigakuryoho Kagaku, 2005, 20: 197–201 (in Japanese). [CrossRef]
2) Springer BA, Mielcarek BJ, Nesfield TK, et al.: Relationships among lateral abdominal muscles, gender, body mass index, and hand dominance. J Orthop Sports Phys Ther, 2006, 36: 289–297. [Medline] [CrossRef]
3) Urquhart DM, Hodges PW, Allen TJ, et al.: Abdominal muscle recruitment during a range of voluntary exercises. Man Ther, 2005, 10: 144–153. [Medline] [CrossRef]
4) Larivière C, Gagnon D, De Oliveira E Jr, et al.: Reliability of ultrasound measures of the transversus abdominis: effect of task and transducer position. PM R, 2013, 5: 104–113. [Medline] [CrossRef]
5) Fuse Y, Yazaki T, Fukui T: Relationship between vowel utterance and the transversus abdominis muscle function. PT J, 2015, 49: 1055–1057 (in Japanese).
6) Urquhart DM, Barker PJ, Hodges PW, et al.: Regional morphology of the transversus abdominis and obliquus internus and externus abdominis muscles. Clin Biomech (Bristol, Avon), 2005, 20: 233–241. [Medline] [CrossRef]