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Original Article

Tape measure-based real-time feedback during the abdominal draw-in maneuver facilitates isolated transverse abdominal contraction

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Abstract. [Purpose] Although the abdominal draw-in maneuver improves delayed onset of transverse abdomen in patients with low back pain, it is difficult to perform. We investigated whether the maneuver with tape measure-based feedback was more effective in facilitating isolated transverse abdominal muscle contractions than that without feedback in healthy participants. [Participants and Methods] Twenty healthy males performed the maneuver without feedback (control condition) and then with feedback using a tape measure (tape measure condition) in the crook lying, sitting, and standing positions. A B-mode ultrasonography imaging system was used to determine lateral abdominal muscle thicknesses, the percent changes from before the maneuver were calculated for each condition, and the main effects and interactions for each tested muscle were determined. [Results] The percent change in the thickness of the transverse abdominal muscle was significantly greater under the tape measure condition than under the control condition. The percent change in internal oblique thickness during the maneuver was significantly greater in the standing position than in the crook lying or sitting positions. Significant condition-by-position interactions were not observed for any of the examined muscles. [Conclusion] The abdominal draw-in maneuver with tape measure-based feedback may be more effective at facilitating isolated transverse abdominal contractions in all the positions than that without feedback.

Key words: Abdominal draw-in maneuver, Feedback method, Muscle thickness

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INTRODUCTION

Low back pain (LBP) is a prevalent musculoskeletal condition, with a lifetime prevalence of 70–85%, and is associated with decreasing quality of life and activities of daily living[1)]. Among individuals with acute LBP, reports suggest that 8% will develop chronic LBP and 50% will develop recurrent LBP[2)].

Previous studies have reported that individuals with LBP display delayed activity of the local muscles, such as the transverse abdominal (TrA) and multifidus muscles, contributing to segmental spinal instability and over-activity of global muscles, such as the internal oblique (IO) and external oblique (EO) and lumbar erector spinae muscles[3–6)]. Altered activity patterns of the trunk muscles have been reported to be responsible for chronic and recurrent LBP[7)] and are associated with reorganization of the motor cortex network[8, 9)].

The abdominal draw-in maneuver (ADIM) has been reported to improve TrA delayed activity in individuals with LBP[10, 11)]. Therefore, the ADIM is a treatment regimen used for patients with LBP. The maneuver has been suggested to

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improve isolated TrA activity and to elevate the intra-abdominal pressure, contributing to the segmental stability of lumbo-pelvic region[12]. Because accurate performance of ADIM is difficult in individuals with LBP[13], feedback methods are used, including real time ultrasonographic imaging (RUSI) and pressure biofeedback units. However, RUSI is difficult to use with home-based ADIM exercises because of its expense. Additionally, the pressure biofeedback unit is difficult to use in the sitting and standing positions. Therefore, the development of an inexpensive feedback method is important for accurately implementing home ADIM exercises that may be used in any position.

Because the TrA acts to draw in the abdominal wall and narrow the waist, we hypothesized that wrapping a tape measure (TM) around the waist while drawing the lower abdomen towards the spine might be an effective feedback method for helping participants feel TrA contractions. Thus, the primary aim of the present study was to investigate the effect of TM-based feedback on lateral abdominal muscle thicknesses during ADIM. The secondary objective was an investigation of the effect of posture on lateral abdominal muscle thicknesses during ADIM.

PARTICIPANTS AND METHODS

Twenty healthy male volunteers (age, 24.2 ± 6.6 years; height, 169.8 ± 5.2 cm; weight, 65.3 ± 5.1 kg) participated in this study. Volunteers were excluded if they had histories of neurological, musculoskeletal, psychological, or cardiopulmonary disease. This study was approved by the Kawasaki University of Medical Welfare Research Ethics Committee (approval number: 17–063). Before data collection, the entire procedure was explained to the participants, and each signed an informed consent form.

A previous study reported that ultrasound imaging was a valid measure of TrA and IO muscle activity[14–17]. Therefore, A B-mode ultrasound imaging system, with a 10-MHz linear array transducer (SSD-3500SX, Aloka, Tokyo, Japan), was used to determine lateral abdominal muscle thicknesses. A gel was poured on the probe, prior to it being placed on the skin at the midpoint between the right iliac crest and the last rib, 2.5-cm anterior to the right mid-axillary line; no pressure was applied to the probe.

Each participant performed the ADIM, without feedback (control condition) and with TM-based feedback (TM condition) in the crook lying, sitting, and standing positions. In the crook lying position, the participant was asked to lay in a supine position with his knees flexed to 90°. In the sitting position, each participant was asked to sit, unsupported in a neutral lumbopelvic position, on an adjustable chair with his feet positioned shoulder width apart and his knees and hips flexed to 90°. In the standing position, each participant was asked to stand with his feet positioned shoulder width apart. During the control condition, each participant was asked to breathe normally, maintain his spine and pelvic positions while slowly lifting his pelvic floor, and slowly drawing his lower abdomen towards the spine. During the TM exercise, a TM was wrapped around the participant's waist at the iliac crest level, and each participant was also asked to maintain his spine and pelvic positions while slowly lifting his pelvic floor and drawing his lower abdomen towards his spine. During the exercise, each participant was asked to feel the narrowing of his waist to gain feedback regarding TrA contractions (Fig. 1). Ultrasound measurements taken, at rest, in the crook lying position were stored as baseline measures for calculating lateral abdominal muscle thickness changes. The sitting during rest and standing during rest were also used to investigate the influence of position. Before data collection, the participants practiced the ADIM to familiarize themselves with the testing procedure. Images were collected during each type of ADIM (with and without feedback), in each position; each maneuver was performed twice and all images were stored at the end of a relaxed expiration. The measurement order was randomly assigned. Percent changes from baseline muscle thicknesses were calculated for each condition as [(ADIM-baseline muscle thickness)/baseline muscle thickness ×100] (%)[18].

Statistical analyses were performed using SPSS version 21 (IBM, Tokyo, Japan). One-way repeated measure analysis of variance (ANOVA) was used to detect differences in lateral abdominal muscle thicknesses between positions (crook lying, sitting, and standing) during rest. Two-way repeated measure ANOVA, with 2 within-participant factors (condition: ADIM with and without TM-based biofeedback; position: crook lying, sitting, standing), was used to determine the main effects and the interaction for each tested muscle. The Bonferroni method was used as a post hoc test. A $p<0.05$ level was chosen as an indicator of statistical significance.

RESULTS

Muscle thicknesses in each position, during rest, are shown in Table 1. One-way repeated measure ANOVA showed that the TrA thickness, during rest, was significantly different among the three positions ($p<0.01$). The thicknesses of the IO and EO muscles during rest did not differ significantly in the different positions ($p>0.05$). In the post hoc analysis, the TrA thickness, during rest, was greater in the standing and sitting positions than in the crook lying position ($p<0.05$).

The percent changes in muscle thicknesses, during each ADIM condition, are shown in Table 2. Two-way repeated measure ANOVA showed a significant main effect for the condition on the TrA ($p<0.001$). The percent changes in the thicknesses of the IO and EO muscles were not significantly affected by the condition ($p>0.05$). In the post hoc analysis, the percent change in TrA thickness was significantly greater in the TM condition than in the control condition ($p<0.001$). There were also significant positional main effects for the IO muscle ($p<0.001$). The percent changes in TrA and EO thicknesses were

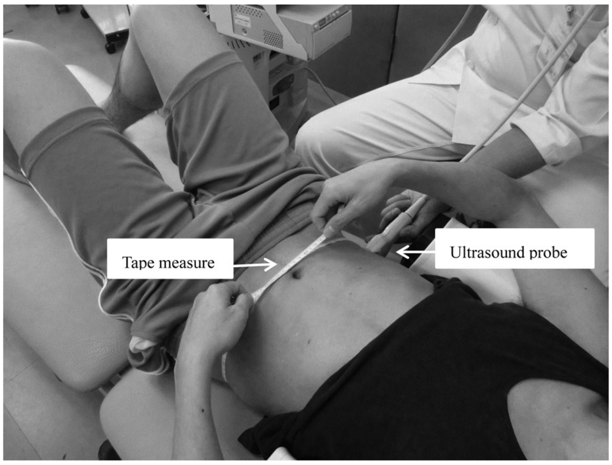

Fig. 1. The abdominal drawing-in maneuver using the tape-measure-based feedback method in the crook lying position. Each participant wrapped a tape measure around his waist at the iliac crest level. While maintaining the spinal and pelvic positions, the participant slowly lifted his pelvic floor and drew his lower abdomen towards his spine. At the same time, he measured and felt the narrowing of his waist.

Table 1. Muscle thickness in each position at rest (mm)

	Crook lying	Sitting	Standing
Transverse abdominal	3.5 ± 0.7	4.1 ± 1.4*	4.6 ± 1.6*
Internal oblique	11.3 ± 2.5	11.8 ± 3.0	12.0 ± 2.5
External oblique	8.3 ± 1.9	8.4 ± 2.3	8.4 ± 2.2

Values shown as means ± standard deviation.
*Significantly different compared with crook lying ($p<0.05$).

Table 2. Percent changes in muscle thickness during the abdominal drawing-in maneuver, with and without tape measure-based feedback

Parameters	Control condition	TM condition
Percent change in thickness (%)		
Transverse abdominal *		
Crook lying	74.1 ± 43.3	92.5 ± 43.9
Sitting	71.3 ± 48.0	94.4 ± 52.1
Standing	89.6 ± 57.2	105.0 ± 59.1
Internal oblique		
Crook lying	19.1 ± 15.4	11.7 ± 15.7
Sitting	23.0 ± 31.0	21.9 ± 24.0
Standing †	35.3 ± 31.0	35.6 ± 29.3
External oblique		
Crook lying	2.7 ± 13.6	−0.2 ± 23.8
Sitting	−1.4 ± 26.9	1.9 ± 26.2
Standing	5.0 ± 19.7	12.0 ± 28.0

Values are shown as means ± standard deviation.
*In the post hoc analysis, the percent change in TrA thickness was significantly greater in the TM condition than in the control condition ($p<0.001$).
†In the post hoc analysis, the percent change in IO thickness during ADIM was greater in the standing position than in the crook lying and sitting positions ($p<0.05$) .

not significantly affected by position ($p>0.05$). In the post hoc analysis, the percent change in IO thickness during ADIM was greater in the standing position than in the crook lying ($p<0.001$) and sitting ($p<0.05$) positions. There were no significant condition-by-position interactions for any of the examined muscles (p>0.05).

DISCUSSION

The primary aim of the present study was to investigate the effect of tape measure-based feedback on lateral abdominal muscle thickness during ADIM. Our findings indicate that the percent change in TrA thickness was greater in the TM condition than in the control condition. In this regard, unlike the IO and EO, the TrA muscle fibers are reported to pass transversely and medially to the midline and during bilateral TrA contraction, the muscle produces a drawing-in of the abdominal wall and narrowing of the waist[19]. Participants were able to narrow the waist more easily by obtaining feed-back of the decrease in abdominal girth in real time. Therefore, we believe that in the TM condition, muscle thickness of the TrA was increased by a greater narrowing of the abdominal girth. The percent changes in IO and EO thicknesses were not significantly affected by the TM condition in this study. Richardson reported that because the IO and EO run obliquely from the pelvis to the rib cage, they cannot narrow the waist[13, 19]. Therefore, because the participants used the extent of waist narrowing as feedback, the percent changes in thickness of IO and EO were not significantly different between the conditions.

In this study, the TrA thickness during rest was greater in the standing and sitting positions than in the crook lying position. This is consistent with results from previous studies that investigated trunk muscle thickness in the supine and standing positions[20]. The standing and sitting positions are more unstable than the crook lying position because the base of support is narrower and the center of gravity is higher in the former positions. Additionally, the shearing force applied to the sacroiliac joint increases more in the standing and sitting positions than the in supine position. The TrA has been hypothesized to contribute to lumbopelvic stability by increasing the intra-abdominal pressure and compressing the sacroiliac joints[12, 21]. Therefore, because of the instability associated with the standing and sitting positions, more TrA activity is required to maintain posture in these positions.

The percent change in IO thickness during ADIM was greater in the standing position than in the crook lying and sitting positions. This result can be explained by the greater gravitational pull upon the abdomen when standing. This increased gravitational pull leads to increased feedback from the IO stretch receptors, increasing the excitability of the IO's motor-neuron pool and increasing IO activity[22, 23]. The percent change in TrA thickness during ADIM was greatest in the standing position, followed by in the sitting and crook lying positions. However, no differences in the magnitudes of TrA thickness changes were noted during ADIM among the three positions. In this regard, instructing participants to perform pelvic floor contractions during ADIM has been reported to facilitate TrA thickness increases[24]. Because our participants performed pelvic floor contractions during ADIM, we believe that the TrA activity during ADIM was greater than the TrA activity required by position changes. Therefore, the percent change in TrA thickness during ADIM was not significantly affected by the participant's position.

The feedforward activity of the TrA has been demonstrated to be delayed in individuals with LBP[4, 6], and isolated TrA exercises have been reported to correct delayed TrA activity[10, 11]. In this study, the percent change in TrA thickness was greater in the TM condition than in the control condition, while the percent changes in IO and EO thicknesses were unaffected. In addition, the percent changes in TrA thickness during ADIM were not significantly affected by the participant's position. Therefore, ADIMs performed with TM-based feedback may be more effective at facilitating isolated TrA contractions, regardless of position, than ADIMs without feedback.

This study has some limitations. Although an ultrasound imaging system was used to determine lateral abdominal muscle thicknesses, previous studies showed that electromyographic changes in EO activity were not correlated with changes in EO thickness[15, 17, 25]. Thus, additional work is needed to properly assess EO activity on electromyography during ADIM with TM-based feedback. In addition, this study is limited by the small number of participants and by the inclusion of only healthy, young males. Thus, the study results cannot be generalized to other populations. Therefore, the benefits of the TM-based feedback during ADIM should be evaluated, in future investigations, in a larger sample of individuals with LBP.

In conclusion, all of these findings suggest that the ADIM with TM-based feedback is more effective at facilitating isolated TrA contractions in all positions than is the same maneuver without feedback.

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Conflict of interest

There are none.

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