Title:

Investigation of the contraction ratio of transversus abdominis and internal oblique muscles during lumbopelvic stability test

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Abstract:

Background: The clinicians administer lumbopelvic stability to test core stability of lumbar spine and TrA muscle function. While the reduced thickness and contraction ratio of the TrA is well documented among people with nonspecific low back pain (NSLBP), the direct morphological changes of TrA during the lumbopelvic test has not been reported so far.

Purpose: To determine and compare the contraction ratio of deep abdominal muscles (TrA and IO) during the 7 progressive stages of the lumbopelvic stability test (LPST) in healthy individuals.

Methods: Thirty healthy volunteers (15 males and 15 females) aged 21.83 ± 0.46 years participated in an experimental study. The TrA and IO thickness was assessed by ultrasound imaging (USI) TOSHIBA, Famio8, SSA-530A) at the right side in mid axillary line between 12^{th} rib and iliac crease. Images were taken for 2 trials during each level of LPST (7 levels) as measured by the pressure biofeedback unit (PBU). The thickness of the TrA and IO muscles were measured by Image J program (Image J®, NIH, USA) and the contraction ratio was calculated. A one way repeated measure ANOVA with post hoc analysis using the Bonferroni test at $p<0.05$ was used to analyse the data.

Results: The contraction ratio of TrA showed a decreasing trend as the LPST was progressed to the 7 levels. Post hoc analysis showed a significant reduction in the contraction ratio of the TrA muscle in the 7^{th} level of the LPST ($F=14.53$, $p=0.001$). However, the contraction ratio of IO remains unchanged during all the 7 levels of LPST.

Conclusion: The TrA muscle responds to the lumbopelvic stability testing by reduced contraction ratio across the 7 levels of the test procedure as measured by the PBU and USI. Further studies are warranted to compare the adaptation of the TrA muscle across 7 levels of the testing among patients with NSLBP.

Title page - Original article

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Conclusion: The TrA muscle responded by reduced contraction ratio across the 7 levels of the LPST as measured by the PBU and USI. Further studies are warranted to compare the adaptation of the TrA muscle across 7 levels of the LPST among patients with NSLBP.

Level of Evidence – 2b

Key words: low back pain, musculoskeletal, physiotherapy, rehabilitation, transversus abdominis, ultrasound imaging

INTRODUCTION:

Approximately 90% of the pain originating from the lumbar spine are classified as non-specific low back pain (NSLBP) (1). The mechanical overuse and dysfunction of the spine and the surrounding structures such as core muscles were proposed as one of the contributing factors for NSLBP (1). An impaired function of the deep core muscles such as transversus abdominis (TrA) and internal oblique (IO) was reported to affect stability, robustness and movement control of the lumbar spine leading to recurrent low back pain (2). TrA and IO as deep abdominal muscles particularly had received greater attention due to their close proximities resulting in pre-activation prior to the limb movement and thus contributing to the core stability of the lumbopelvic region (3). For example, 20.9% of reduced thickness and the delayed anticipatory onset of TrA muscle during limb loading had been reported among patients with NSLBP (4,5). Recently, the measure of TrA morphometry had been suggested to be a treatment effect modifier for NSLBP patients (6). On the other hand, the thickness of TrA had been studied in terms of gender difference, between rest and contraction, hand dominance and side to side differences among healthy participants to understand the normative function of TrA muscle (7,8). Therefore, many clinicians might consider the assessment and treatment of the core muscles as one of the factors towards the management of NSLBP (9). Although several pieces of evidence were available on TrA muscle anatomy and function, the changes in TrA muscle during the different levels of the LPST through an abdominal draw-in maneuver had never been studied before.

The function of the TrA was evaluated by clinicians through an abdominal drawing-in manoeuvre using a pressure biofeedback unit (PBU) (10,11). In theory, the PBU was placed under the lumbar spine in crook lying position and the patients were instructed to tuck in the abdomen. Any pressure fluctuations greater than 4 mmHg during a standard test using 40mmHg was considered as poor stability of the lumbar spine. If no fluctuations, the participants performed a unilateral leg lift in the sagittal plane followed by the seven progressive levels of LPST (12). An ability to maintain the registered pressure at 40 mmHg during the testing movement was marked as a successful performance. When the participants were not able to hold 40±4 mmHg in the PBU, the progression of the LPST would be stopped. Although testing the TrA muscle using the PBU was reported to have good reliability of the TrA function (11), the concurrent validity was reported to be poor against the electromyography (13). A recent systematic review concluded that the ability of the test to directly assess the function of TrA had not been answered (14). Perhaps, this was due to the fact that the test did not measure directly the changes in the TrA, instead, it measured the changes in the pressure of the PBU as an indirect evaluation of the TrA muscle contractility. Till now, no studies had investigated the changes in the TrA function during different levels of the LPST as indicated by the different upper and lower limb movements. Furthermore, an absence of any normative understanding of the TrA muscle function among healthy individuals remains a challenge for clinicians to interpret its outcome among low back pain patients. Therefore, the main aim of the study is to investigate the changes in the contraction ratio of the TrA muscle during different levels of the LPST among healthy participants. The study hypothesizes that the contraction ratio of TrA and IO differs significantly during different levels of the LPST. The current study is the first study to report on the contraction ratio of the TrA and IO during the different levels of the LPST. It is important to establish normative data in the healthy population as it becomes a benchmark for any conditions such as NSLBP.

Study design

A cross-sectional study with an experimental design was conducted to investigate the differences in TrA and IO during different levels of the LPST. The details of the study were advertised through posters around a community setting. The participants for the study were recruited through pre-defined study criteria from a community population. The study was carried out in the pain and neuromusculoskeletal research laboratory in a university setting. The study was conducted according to the international ethical standards recommended in the clinical and field science research (15). A university institutional ethics board approved the ethics of the study according to the Declaration of Helsinki.

Participant characteristics

A total of among a total of 30 healthy individuals (15 males and 15 females) participated in the study. Any participants who did not have body aches or pain over the last 3 months were invited to participate in the study. The participants were excluded if they had referred pain or neurological involvement in lower limbs, had any history of past surgery and had any history of injury in the last 3 months. The purpose of the study and the study procedure were explained to all the participants and written informed consent was obtained prior to their participation in the study.

Procedure

Lumbopelvic stability testing

A pressure biofeedback stabilizer unit (PBU) (Stabilizer Pressure Biofeedback-Chattanooga Group, USA) was used during the test. PBU was reported to be a reliable device to test the lumbopelvic stability. (16). The LPST was performed in supine crook lying position with the participant hip and knee flexed to 70° and 90° respectively through an established protocol (12).

Before the test, the PBU was calibrated and pre-tested through an established protocol by loading the unit for 24 hours with 4 kg of weight (17). The PBU unit was considered for use only if the device lost no more than 0.4 mm Hg during the testing period and the same unit was used throughout the study period. After calibration, the PBU was placed beneath the lumbar spine between the levels of the second lumbar spine and the first sacral spine. Theparticipants were instructed to tuck in their naval by drawing in the abdomen. The pressure in the pressure gauge was maintained at 40 mm Hg and the participants were instructed not to exceed more than 4 mm Hg during the abdominal drawing-in manoeuvre. Once the participants were able to maintain the pressure, the tests were progressed into 7 levels in the following order (12); core with alternate hip abduction, core with alternate knee raise, core with both arms adduction, core with both arms extension, core with alternate arm lift, and core with alternate leg lift and finally core with alternate leg and arm lift. The test was stopped when the participants exceeded the pressure more than 40±4 mm Hg and the level of the test was noted as completed.

Real-time ultrasound measurement of TrA

The real-time ultrasound imaging (USI) measurement of the TrA muscle was carried using a B-mode real-time ultrasound imaging unit (TOSHIBA, Famio8, SSA-530A) through an established protocol (18). The ultrasound measurement was carried out simultaneously when the participants performed the different levels of the LPST. The participants were positioned in crook lying with their head and knee supported by pillows. Ultrasonic gel was applied to a 5-MHz curvilinear transducer and the transducer was placed in the transverse plane over the midaxillary line at a midpoint between the lower rib and the iliac crest. An experienced physiotherapist who was trained to conduct USI measurement carried out all the measurements. A surface marking was made on the skin using a surface marker to ensure the transducer was placed over the same location for every measurement during the seven levels of the test.

The images of TrA thickness were captured and measured using NIH (Bethesda, MD) Image J Software (Version 1.8). The total resting muscle thickness was defined as the distance between the superior border and the inferior border of TrA muscle. Then, the patients were instructed to draw in their abdomen and TrA muscle thickness during contraction was measured during the 7 levels of the test. **Figure 1** shows the USI measurement of the muscle thickness during the LPST. All the measurements were taken at the end of the expiration. The mean thickness of the three measurements on each side was calculated for analysis. The contraction ratio of the TrA muscle was calculated for all the 7 levels of the test using an established formula (19).

$$\text{Contraction ratio} = \frac{\text{Muscle thickness during contraction}}{\text{resting muscle thickness}}$$

Statistical analysis

The sample size for the study was calculated using the G*Power software program by selecting 2-tails comparison between groups with an effect size of 0.71 for the primary outcome TrA with a power of 95%, alpha error probability of 0.05 which suggested a sample size of at least 15 per gender. The statistical software package for social sciences (SPSs windows version 22.0) was used for data analysis (20). The measured values were normally distributed according to the Kolmogorov-Smirnov test. The differences in the contraction ratio of TrA and IO muscles between the 7 levels of testing were analysed using One-way Repeated measures ANOVA. The level of significance was set as 0.05. In terms of any significant differences, a Post hoc was analysed using Bonferroni at $p< 0.05$.

RESULTS:

A total of 30 healthy individuals (15 males and 15 females) with a mean age of 21.3 years participated and completed the study. The descriptive characteristics of the study participants were given in **Table I**. The mean (SD) value of the resting thickness and the thickness during contraction of TrA and IO for all the 7 levels of the LPST were shown in **Table II**. The result showed that the values of the contraction ratio of the TrA and IO decreased as the tests were progressed into the different 7 levels of the testing. The results of the post hoc analysis showed that the contraction ratio of TrA significantly reduced in the 7th levels of the testing ($F=14.53$, $p=0.001$). However, the contraction ratio of IO remains unchanged in all the 7 levels of LPST.

DISCUSSION:

This was the first study that investigated the changes in the contraction ratio of TrA and IO muscles during the 7 different progressive stages of the LPST. The findings of the study suggested that TrA muscle possibly were showing signs of fatigue as the muscle was repeatedly made to contract during the 7 progressive levels of the LPST. In clinical practice, one might argue that this was the characteristic pattern of the LPST which might explain that the difficulty levels of the 7 progressive stages of the test might demand an increasing workload on TrA muscle. It was worth noting that a past study challenged the notion that the PBU could clinically assess TrA contraction during the abdominal drawing-in manoeuvre (10). However, the findings on TrA muscle were proposed based on a population of NSLBP and the TrA muscle was not tested in different levels of LPST. In contrast, the current study might suggest that the abdominal drawing-in task through PBU had engaged TrA and the TrA muscle responded with decreasing values of contraction thickness across the 7 levels of the LPST. While the past studies used PBU to measure the lumbopelvic stability as an indirect measurement of TrA muscle function (10,11) none of the past studies directly measured how the TrA muscle adapts and functions to the 7 progressive stages of the LPST. Therefore, the current study findings might provide a direct measurement of the TrA with the normative value which could provide clinicians an understanding of how TrA muscle responds to the LPST on healthy individuals. An understanding of the normative values and function of TrA muscle might help clinicians to interpret the test results among NSLBP.

The average values of the contraction ratio of TrA muscle in the current study were similar to other established evidence. For instance, the range of TrA contraction ratio measured in our study ranged between 1.5 mm Hg and 1.8 mm Hg which fell within the range of 1.5 mm Hg up to 2.2 mm Hg (21,22). It could be suggested that the norms of measurements were acceptable within the practice standards. The contraction ratio of IO had been reported to be the thinnest during rest and thickest during the abdominal drawing-in manoeuvre (23). Also, irrespective of the measurements of the cross-section of TrA and IO either at rest or during the testing procedure, it was reported that IO and TrA muscles remained the thickest and the thinnest, respectively (23). However, the cross-section ratio of TrA was the thickest ranging from 1.5-1.8 mm Hg, while the cross-section ratio of the IO was the thinnest ranging from 1.1-1.3 mm Hg. Perhaps, the difference could be because the previous study tested the contraction ratio of TrA and IO during the abdominal drawing-in task, while the current study used a tougher testing procedure of testing the muscles across 7 levels of the LPST. Also, the past study reported values from the low back pain population, while the findings of the current study were from healthy individuals. Furthermore, the current findings were in line with a recently reported evidence among healthy participants that the activation levels of the TrA were between 1.5-2.0 mm Hg (24,25). Therefore, it could be possible that the cross-section ratio of TrA and IO muscles might adapt and respond differently between healthy individuals and NSLBP population. Therefore, further studies were warranted to test the adaptation of the cross-section ratio of TrA and IO muscles across the 7 levels of LPST between healthy individuals and NSLBP.

Clinical Implication

The current study might have some practice implications. Reference values of the clinical tests among healthy individuals are necessary, as these results may contribute to clinical practice and for setting up training targets (26). For instance, an understanding of certain baseline normative data on the contraction ratio of TrA and IO among the healthy individuals during the LPST might provide clinicians a reference point and comparison standard for NSLBP. A past study raised a clinical question about the measurement property of PBU to engage TrA (15). Also, the engagement of TrA with PBU was questioned due to poor correlation with electromyography (27). In the above context, the current study findings supported that TrA and IO were engaged and activated using a PBU and USI supporting the notion that the contraction ratio of TrA muscle could be evaluated using the 7 levels of the LPST. The small sample size is one of the limitation for the study. Although a sample size of 15 participants were identified as sufficient for a gender in the study, one might suggest that the study consisted of a small number of research participants and hence, the findings might be more prone to variability. Also, another limitation of this study might be mixing the results of men and women, as the thickness of the muscles might be associated with gender.

Conclusion:

A significant reduction in the contraction ratio of TrA was observed in the 7th level of the LPST as measured by the PBU and USI. However, the contraction ratio of IO remains unchanged during all the 7 levels of LPST. As the levels of the LPST increased, the contraction ratio of deep stabilizing muscles were insufficient to stabilize the lumbopelvic region. Further studies are warranted to compare the adaptation of TrA and IO muscles across 7 levels of the testing among patients with NSLBP.

Conflict of Interest – The authors declare that they have no conflict of interests (15).

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Figure I: Ultrasound imaging of the internal oblique and transversus abdominis

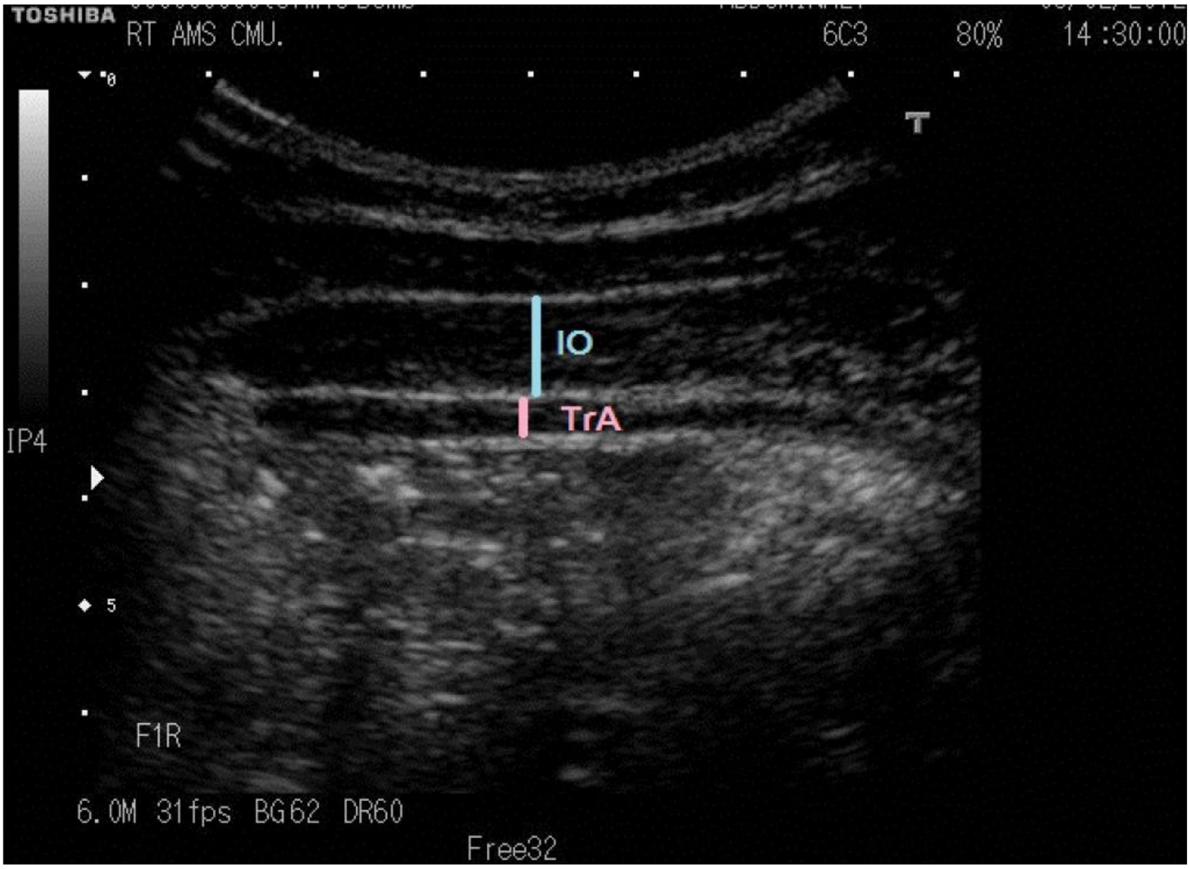

Table I. Characteristics of the study participants

Variables	Mean±SD	Min	Max
age (years)	21.83±0,46	20.00	22.00
weight(kg)	55.48±11.6	41.00	100.00
height(cm)	163.87±8.14	150.00	181.00
BMI (Kg/m²)	20.541±3.28	16.61	35.43

Table II. Transversus abdominis and internal oblique muscles thickness and contraction ratio during 7 levels of lumbopelvic stability test (LPST)

Variables	Muscle	LPST level							
		resting	1st	2nd	3rd	4th	5th	6th	7th
Muscle Thickness (mm)	TrA	2.23 ± 0.5	4.07 ± 0.9	4.21 ± 0.9	4.10 ± 1.1	3.76 ± 1.1	3.85 ± 1.2	3.67 ± 1.2	3.17 ± 1.2
	IO	5.38 ± 1.9	6.11 ± 2.7	6.10 ± 2.4	6.41 ± 2.6	7.09 ± 5.4	6.21 ± 2.3	6.24 ± 2.5	6.22 ± 2.2
Contraction Ratio	TrA	-	1.89±0.4	1.95±0.4	1.88±0.4	1.73±0.4	1.76±0.5	1.70±0.5	1.46±0.5*
	IO	-	1.13±0.3	1.14±0.2	1.20±0.3	1.28±0.6	1.17±0.2	1.17±0.2	1.18±0.2

*significantly difference at $p < 0.001$ when compared to 1st level of LPST