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Changes in Transversus Abdominis Muscle Thickness after Lumbo-Pelvic Core Stabilization Training among Chronic Low Back Pain Individuals

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Abstract

Objective. Lumbo-pelvic core stabilization training (LPST) is one of the therapeutic exercises common in practice for rehabilitation of patients with chronic low back pain. This study was carried out to examine the therapeutic effects of LPST on the muscle thickness of transversus abdominis (TrA) at rest and during contraction among patients with chronic non-specific low back pain.

Materials and Methods. A total of 25 participants (7 males and 18 females) with chronic non-specific low back pain participated in a within-subject, repeated measures, double-blinded, placebo-controlled comparisons trial. The participants received three different types of experimental therapeutic training conditions which includes the lumbo-pelvic core stabilization training (LPST), the placebo treatment with passive cycling (PC) and a controlled intervention with rest (CI). The interventions were carried out by randomization with 48 hours between the sessions. The effectiveness of interventions was studied by measuring the changes in muscle thickness of TrA at rest and during contraction using a real time ultrasonography.

Results. Repeated measures ANOVA demonstrated that the LPST provided significant therapeutic benefits as measured by an increase in the muscle thickness of the TrA at rest ($p<0.05$) and during contraction ($p<0.01$). The percentage change of the muscle thickness observed during LPST was significantly higher ($p<0.01$) when compared to the other two experimental training conditions.

Conclusion. The findings indicated that the LPST might provide therapeutic benefits by increasing the muscle thickness and function of TrA. Therefore, it is suggested that LPST technique should be considered as part of management program for treatment of low back pain.
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Key words: *back pain, core stabilization, lumbo-pelvic exercise, transversus abdominis, rehabilitation*

Introduction

Chronic low back pain is a common problem among athletes. Many groups of athletes such as foot ball players, elite cricket players, weight lifters suffer from low back pain during their professional career (1-3). Altered motor control of the core muscles of lumbar spine is one of the predominant reasons for occurrence of low back pain in athletes (1). Athletes who suffer with chronic low back pain were found to have difficulty to draw in abdominal wall than those without low back pain (4). Evidence suggests that co-contraction of transversus abdominis (TrA) serves as the biomechanical basis for enhancing the lumbopelvic stability with reported feed forward contraction during various athletic functional activities (5). On the other hand, motor control changes such as dysfunction of TrA is associated with higher long term incidence of low back pain (6). Furthermore, adequate activation of deep muscles of lumbar spine such as TrA did not resume even after remission of pain among low back pain patients (7).

The deep abdominal muscle TrA receives particular attention with regard to its role on core stability of the lumbar spine. The functional mechanism through which the contraction of TrA provides lumbo-pelvic stability involves either by tensioning of the thoracolumbar fascia, generation of intra abdominal pressure or by the combination of both these factors (8). When contracting, the horizontal orientation of TrA fibers results in reduction of abdominal circumference inducing increase in intra abdominal pressure and reducing displacement of abdominal contents (8). Thus, a good quality of TrA contraction is suggested to contribute to lumbo-pelvic stability by producing stiffness of lumbosacral spine through its attachment with pelvis and thoracolumbar fascia (9). An efficient bilateral symmetrical contraction of TrA transforms the muscle to act like a natural corset encircling the lumbo-pelvic region, protecting and stiffening the various spinal segments (10). In lieu, if the contraction of TrA is either delayed or reduced during athletic movements of extremities, the stability of the lumbo-pelvic region is challenged (10, 11). Hence, exercise programs to condition the TrA muscle contraction plays an important aspect in back pain management. In clinical practice, therapists and athletes work together in lumbo-pelvic stabilization training (LPST) towards gaining effective TrA contraction to minimize back pain and to enhance the physical athletic performances.

The LPST of the lumbar spine has been highlighted as crucial to provide spinal stability and to prevent injury to the lumbo-pelvic region (12). The goals of the LPST

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are to train motor pattern of local muscles such as TrA, to increase spinal stability, to restrain aberrant movements at lumbar segments and to reduce associated pain (13). In the therapeutic protocol of LPST program, the patients are trained to perform isolated contractions of the TrA through abdominal hallowing maneuvers (14). The effectiveness of the lumbo-pelvic stabilization exercise practice is judged by evaluating the relative increase in the thickness of the TrA muscle (13). While the LPST receives particular attention in clinical practice, a clinically relevant question arises with regard to the clinical outcome of a non-specific exercise training methods such as passive automated cycling exercises among patients with low back pain.

A recent systematic review concludes that there are no significant changes in treatment benefits obtained between the core-stabilization exercises and other active exercise methods (15). Such reports query the therapeutic efficacy and justification for prescribing LPST in every day practice. Nonetheless, the reported evidence has not weighed the benefits of LPST passive automated cycling exercises and the rested state of the core muscle without any exercises. Therefore, the main purpose of the study is to determine the therapeutic effects of LPST on the muscle thickness of TrA among patients with low back pain. In addition, the therapeutic benefits of the LPST is compared with the passive-automated cycling exercise training and as well as the resting effects without any training for TrA. The clinical evidence from the study may add further insight on the benefits of lumbo-pelvic core stabilization program in the management of low back pain.

Materials and Methods

Design

This is a within-subject, repeated measure with double-blinded, placebo-controlled comparison trial conducted in an outpatient physiotherapy department from a university teaching hospital. This study design is selected to compare the effects of LPST exercise on TrA thickness against the other two modes of exercise intervention (placebo exercise condition and controlled rest condition) without any bias that may arise between the subject characteristics.

Subjects

A total of 25 participants (7 males, 18 females; age 33.33 ± 14.37 years) with chronic non-specific low back pain voluntarily participated in the study. All the participants were recruited from the community and university area using a pre-defined inclusion and exclusion criteria. The inclusion criteria were participants aged 20-35 years old with mild to moderate back pain (Visual Analog Scale Pain Score of 2-7/10) of greater than 3 months with location of pain in the area between the lowest rib 12th to gluteal folds. The subjects had no referred pain or neurological involvement in lower limbs, had no history of past surgery, and had no history of injury in the last 3 months before participating in this study. The subjects were also requested not to take stimulants, medications, alcohol or instructed not to participate in heavy physical activities at least 8 hours prior to the test. The study was approved by the institutional ethics committee and a written informed consent was obtained from each individual prior to their participating in the study.

Experimental exercise training conditions

All of the study participants received 15 minutes of three different experimental exercise conditions; the LPST, the placebo (automated passive cycling training), and the control (rest) intervention. All the exercise interventions were administered by randomization with 48 hours between sessions. All experimental sessions were conducted in the controlled environmental room (i.e., temperature of 24.5 ± 0.5°C, relative humidity of 60 ± 5%).

Lumbo-pelvic core stability training condition

The LPST was conducted as per an established protocol (16). The participants were in supine crook position (i.e., hip flexion and knee flexion in 70° and 90°, respectively) on the Pilates power gym transformer (Thane Fitness®, UK) to perform the lumbo-pelvic core stabilizing exercise (16). Air pressure biofeedback unit was also placed beneath the lumbar spine from L2 to S1 and inflated to 40 mmHg. Core muscle contraction (i.e., abdominal hollowing and co-contraction of trunk muscles) in conjunction with leg and arm movements were performed to facilitate motor control of the core stabilizers in various positions (e.g., 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, core with alternate leg lift, core with alternate leg and arm lift). Each exercise position was repeated for 10 times and consequently progressed to the harder step of exercise positions until the subject could not maintain the registered air pressure at 40 ± 10 mmHg.

Placebo (automated passive cycling) condition

The participants were relaxed on the Pilates power gym transformer in the same supine crook position similar to that of the core stability training condition. The feet of the participants were attached to the pedals of the automatic bicycle (Reck Motomed Viva®, RECK Technik, Germany). Passive alternate legs movement was induced by the automatic bicycle with the speed of 30 revolutions per minute (rpm) (17).

Control (rest) condition

The participants were relaxed and set in the supine crook position on the Pilates power gym transformer. This position is selected to resemble the training position similar to that of the core stabilizing exercise and the placebo conditions. Both knees were supported by pillow in hip flexion of 70° and knee flexion of 90°.

Outcome measure

Ultrasound image assessment: The muscle thickness of the TrA was measured using real time ultrasonography

(Toshiba, Famio 8, SSA-530A®) in B-mode with a 12-MHz linear transducer. The measurement procedure for TrA was adopted from our previously established protocols (18, 19). The participants were positioned in crook lying position on a plinth with a pillow under their head and the knees. The ultrasound transducer is placed in a transverse plane just superior to the right iliac crest along the auxiliary line. The localization of the transducer was standardized by maintaining the hyper echoic interface between the transverses abdominis and thoracolumbar fascia at the far left of the image. Hypoechoic pixel before the fascial layers was used to define the boundaries of the muscle and the angle of the transducer was adjusted accordingly for clear capture of the image. The angle of the transducer was adjusted to optimize the visualization of the muscle boundaries. After the initial placement of the transducers, surface markings on the skin was made using markers in order to standardize the same location of the transducer for further capturing of the data. Subjects were given one practice session on abdominal drawing in maneuver before the image acquisition. Images of TrA thickness at rest and during contraction were taken at the end of exhalation when the subjects were relaxed. Images were stored for offline analysis. All images were measured using Image J program (version 1.36b, http://rsb.info.nih.gov/ij/). Measurements were conducted perpendicular to muscle fascias. The measurement was carried out 3 times and averaged for each image. The thickness of the TrA at rest (absolute thickness) was as the distance between the superior and inferior hyperechoic muscle fascias at the middle of the image. The thickness of TrA during contraction (contraction ratio -CR) was calculated by the thickness during contraction divided by the resting thickness. All the measurements were taken by a single independent musculoskeletal physiotherapist who is experienced in ultrasound imaging techniques of core stabilization muscles.

Statistical analysis

The data were analyzed using statistical software package (SPSS®) for Windows version 20.0.The sample size for this study was calculated using the G*power program for a significant alpha level of $p \leq 0.05$ and power analysis of 0.80 with an estimate effect size of 0.54. Examination of the normality of data using Shapiro-Wilk test showed normal distribution of the variables. The changes in the muscle thickness of TrA within each group and between the groups were analyzed using repeated measures analysis of variance (ANOVA). The percentage change in the TrA muscle thickness were measured by estimating the difference between pre and post muscle thickness changes divided by hundred.

Table 1. Subjects' characteristics represented as mean ± standard deviation (SD)

Gender (n = 25)	M (7), F (18)
Age (yr)	33.33 ± 14.37
Weight (kg)	58.42 ± 9.66
Height (cm)	162.40 ± 10.66
Duration of onset (mo)	40.36 ± 35.55
Pain intensity (10-cm pain VAS)	4.29 ± 1.81

Results

The characteristics of the study subjects were reported in Table 1.

The results on the TrA thickness at rest and during contraction from the three experimental training programs were shown in Table 2.

The results showed that the lumbo-pelvic core stabilization exercise was able to increase muscle thickness of TrA for both resting ($p<0.05$) and during contraction conditions ($p<0.01$). No significant changes in muscle thickness of TrA were observed under the placebo (automated passive cycling) and control (rest) conditions. Furthermore, the percentage changes in muscle thickness of TrA during contraction and lumbo-pelvic stability outcomes were significantly greater than that of the placebo and control conditions ($p<0.01$). Figure 1 shows the observed trend of changes in the TrA muscle thickness across the three different experimental exercise conditions at rest and during contraction.

Table 2. Comparison of transversus abdominis (TrA) thickness between conditions

	Conditions								
Outcomes	Core Exercise			Placebo			Control		
	Pre-	Post-	%Ch	Pre-	Post-	%Ch	Pre-	Post-	%Ch
TrA thickness (mm)									
Resting muscle thickness	2.46 (0.52)	2.64* (0.51)	8.75% [b] (14.41)	2.50 (0.55)	2.57 (0.63)	3.20% (10.78)	2.56 (0.67)	2.43* (0.54)	-3.80% (10.10)
Contraction muscle thickness	3.70 (1.19)	4.33*** (1.16)	19.51% [a,b] (17.87)	3.89 (1.16)	3.96 (1.27)	2.04% (13.29)	3.81 (1.31)	3.77 (1.16)	-1.13% (11.87)

No significant differences of the baseline data among three conditions ($p \geq 0.10$)
[a]Significant differences between placebo ($p<0.05$)
[b]Significant differences between control ($p<0.05$)
Note: Significant differences between pre-post (* $p<0.05$; ** $p<0.01$; *** $p<0.001$)

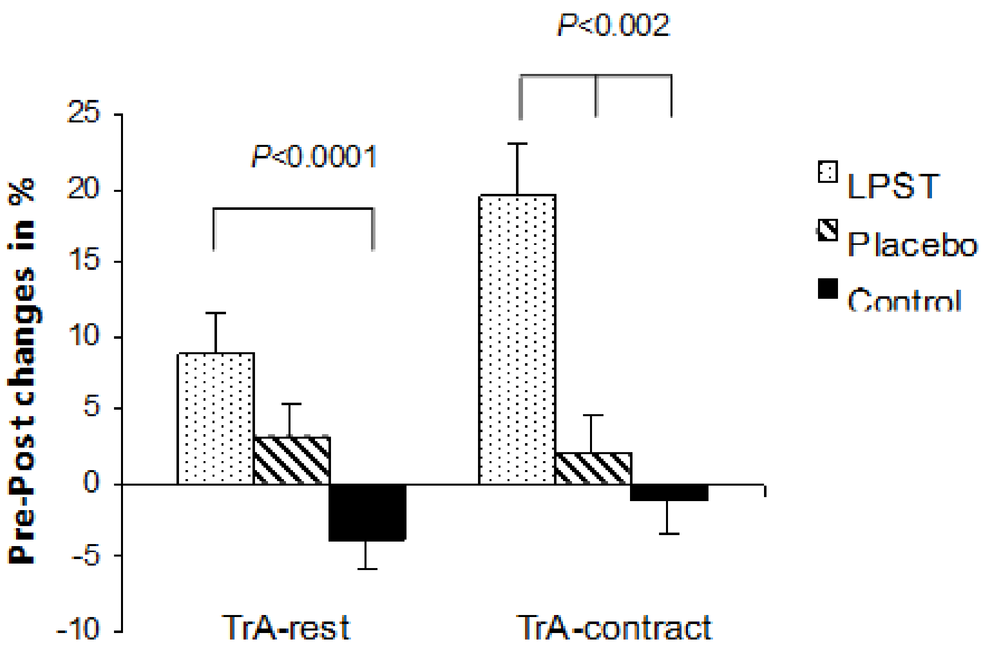

Fig. 1. Trend of percentage changes in the TrA thickness at rest and during contraction across three types of exercise interventions.

Discussion

The main aim of the study was to determine the therapeutic effects of LPST on the muscle thickness of TrA at rest and during contraction in comparison with a placebo intervention (passive automated cycling) and controlled (rest) intervention. The findings of the study supported that the participants were able to recruit TrA muscle contraction with significant efficiency after the LPST. The better contraction of the TrA in the LPST was supported by a significant increase in the TrA thickness and a significant increase in the percentage change of TrA thickness before and after the training. The results supported that the participants were not only able to recruit muscle tone as seen in resting muscle size, but also showed active muscle contraction function of TrA as seen in the increase of the size of the muscle during contraction. Interestingly, such findings in the thickness of TrA muscle thickness did not happen in the other two modes of experimental interventions (passive automated cycling conditions and controlled resting conditions).

Lumbo-pelvic core stabilization exercise is commonly used in the physiotherapy practice for the rehabilitation of back pain. Despite its common use, a recent systematic review concluded that the stabilization exercises were not more than effective than any other form of exercises (20). However, the results of the current study did not agree with the above finding as there was a significant difference in TrA muscle thickness observed in LPST when compared to other forms of exercises. There are multiple systematic reviews regarding the effectiveness of lumbar stabilization exercises for people with chronic low back pain. As more systematic reviews are published, the more it is recognized that the weak methodological quality of the studies included in these reviews affects the validity and conclusion drawn from the pooled data (21). Inclusion of different sub-types of low back pain participants, heterogeneity of methodologies, mixed interventions, diversified outcome measures, different treatment frequencies, and exercise dosages make it hard to standardize the clinical efficacy of the lumbo-pelvic stabilization exercises in the systematic reviews (22). Therefore, trainers and practitioners should consider the above mentioned facts and make a careful interpretation in practice when applying lumbo-pelvic core stabilization exercises to athletes and people with low back pain.

Several other evidences reported positive benefits of core stabilization exercises in chronic low back pain (23, 24). The findings of the current study supports the positive benefits and provides rationale that core stabilization exercises may improve the muscle function of TrA as witnessed by increased thickness of the muscle in resting and contracting state. A past study reported an absolute increase of 7.8% in recruitment of TrA followed by motor control training (25). In current study, the increase in thickness of TrA was observed much higher up to 8.7% at rest and 19.5% during contraction respectively after LPST. Interestingly, such increase in the percentage thickness of TrA was not observed in the placebo and control group. On the contrary, the percentage thickness change in TrA reduced than the normal in the control group supporting the Pain Adaptation Model Theory (26).

The reduction in muscle size might implies that without an effective exercises for TrA, the muscle become relaxed and reduced in muscle tone, when the participants were rested in crook lying with pillow supported under the knee for 15 minutes. In day to day practice, after the LBP patients having a rest or sleeping for a long time, before wake-up or getting to the up- right position, they need to exercise their core muscle first to recruit muscle tone for core muscle and prepare for contracting function of the core muscle to protect the stability of the spine.

Lack of long term follow up of the participants was one of the limitations of the study. Hence, the long term benefits of the LPST are not known among the participants. Also, the therapeutic benefits of the training were purely assessed based on the muscle thickness changes of TrA alone. Future studies should consider the effects of LPST on the lumbo-pelvic stability, pain perception and tissue healing, in order to understand the overall benefits of TrA training effects. Such information is necessary for holistic rehabilitation of the athletes and participants with chronic low back pain.

In conclusion, LPST may significantly increases the muscle thickness of TrA at rest and during contraction when compared to the placebo (passive automated cycling) an control (rest) intervention. Hence, lumbo-pelvic core stabilization can be useful in the rehabilitation of chronic low back pain.

Conflict of interest: None

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