Original article

A Comparison of Automatic and Voluntary Contractions in subjects with and without Low Back Pain

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Background: The comparison between voluntary and automatic contraction of deep abdominal muscles in patients with Nonspecific Low Back Pain (nLBP) may the best treat for them. The aim of this case-controlled study was to compare changes in the thickness of the Transverses Abdomin is (TrA) and Internal Oblique (IO) muscles during the Abdominal Drawing-In Maneuver (ADIM) and the Active Straight-Leg Raise (ASLR) test.
Methods: This study involved 30 women including 20 women with and 10 women without non-specific low back pain. The abdominal muscle thickness in the supine crook-lying, ASLR, and ADIM exercises were measured. Two-way repeated-measures ANOVA was used to compare the thickness ratio results between the two groups.
Results: There were significant differences between the TrA ($p < 0.05$) and IO ($p < 0.05$) muscle thickness ratios during the ADIM compared to the ASLR in the neutral lumbar posture in supine lying in the healthy group; However, in the subjects with nLBP, only the TrA ($p < 0.005$) muscle thickness ratio was significantly higher in the ADIM rather than in the ASLR.
Conclusion: These findings suggest that in both groups the deep abdominal muscles (the TrA and the IO) responded differently according to the variable type of activities such as voluntary or automatic, therefore, in training programs, in addition to a voluntary workout, automatic type of exercises should also be taught.

Keywords: Nonspecific Low Back Pain, Ultra sonography, Abdominal Draw-In Maneuver (ADIM), Active Straight Leg Raise (ASLR)

Introduction

Among the deep abdominal muscles, the Transverses Abdomin (TrA) one of the dynamic stabilizers, and the middle fibers of the TrA are the only muscle fibers that consistently attach to the thoraco-lumbar fascia. Through this union, bilateral activation of the TrA transmits tension to the lumbar spine (Tesh, Dunn, & Evans, 1987). The function of the TrA and its feed-forward activity is different in people with and without Nonspecific Low Back Pain (nLBP) (Hodges, 2001). Changes in the deep abdominal muscles, such as changes in stability, muscle strength, and motor control, and changes in the morphology and behavior of these muscles have been associated with low Back Pain (LBP) (Cholewicki et al., 2002 & Hall et al., 2009).

Various clinical strategies are used by physical therapists to activate and retrain the deep abdominal muscles (Pinto et al., 2011). The Abdominal Drawing-In Maneuver (ADIM) is commonly prescribed to target the TrA during rehabilitation (Gorbet et al., 2010). Ultrasound imaging (RUSI) studies showed that during the ADIM, subjects without LBP had greater changes in muscle thickness than those with LBP, and common trunk-strengthening exercises improved the deep abdominal muscle thickness (Teyhen et al., 2005).

The ADIM is a fundamental procedure in volitional activation of the TrA. Thus, during daily activities such as sitting, standing, walking, bending, and load lifting, activation of this muscle is not voluntary; but automatically. Accordingly, studies have revealed that

during functional activities such as arm movement (Kiesel, et al., 2008) and the Active Straight-Leg Raise (ASLR) test automatic feed forward activation of the TrA occurs before (Kiesel, et al., 2008 & Koppenhaver, et al., 2009). In these tasks, the individual is required to flex his or her upper or lower extremity without focusing on contracting the abdominal muscles. Thus, automatic activation of abdominal muscles is necessary in functional activities and has a significant role in lumbar stability and prevention of LBP (Lee, S. H., Kim, T. H., Lee, B. H., 2014). However, limited information exists regarding a comparison of automatic and volitional behavior of the deep abdominal muscles in subjects with and without chronic low back pain.

Therefore, the aim of this study was to compare changes in the thickness of the TrA and IO muscles during ASLR (as an automatic abdominal muscle contraction) and the ADIM (as a voluntary abdominal muscle contraction) in female subjects with and without nLBP. This is important knowledge for understanding motor control strategy for activating abdominal muscles to provide the best control training programs in nLBP for the TrA and IO muscles.

Methods
Participants

In this case-controlled study, 20 women with recurrent non-specific episodes of LBP with no specific etiology and who were pain free during the test or whose maximum pain score was ≤ 2 on the Visual Analogue Scale (VAS) participated in case group. Ten female subjects as a control group without a history of back pain for 1 year or longer or back pain that lasted less than 3 months total throughout their lives were matched with women in case group according to sex, age, and Body Mass Index (BMI). The demographics for both groups are shown in Table 1. There were no differences between the groups (P < 0.05).

Table 1. Comparing demographic data and rest thickness of abdominal muscles in participants with and without tnLBP.

Description	without nLBP (mean ± SD) (n = 10)	with nLBP (mean ± SD) (n = 20)	*P*value
Age (years)	30.8 ± 8.53	31.50 ± 6.34	0.8
Height (m)	1.72 ± 0.07	1.61 ± 0.06	0.5
Weight (kg)	60.90 ± 6.98	62 ± 7.78	0.85
BMI (kg/cm²)	23.93 ± 3.21	25.34 ± 3.58	0.29
VAS (0-10 cm)		1.53 ± 0.53	
Rest thickness TrA (mm)	2.22 ± 0.74	2.91 ± 1.18	0.7
Rest thickness IO (mm)	3.38 ± 0.97	4.45 ± 1.21	0.1

nLBP: Nonspecific Low Back Pain, BMI: Body Mass Index, VAS: Visual Analog Scale, TrA: Trans versus Abdominis, IO: Internal Oblique.

Exclusion criteria for all subjects included having dysfunction and surgery of the upper and lower extremity and trunk; presence of spinal abnormalities; neurologic and systemic disorders, heart diseases, current and previous pregnancy; training with involving the back and abdominal muscles within three previous months; performing professional sports activities; and currently taking any prescribed medications. Subjects were asked to sign written informed consent for the test procedures. The Institutional Ethics Committee of Medical Research of Tarbiat Modares University approved the study, and all procedures conformed to the Declaration of Helsinki.

A rehabilitation ultrasound imaging unit set in B-mode (SHIMADZU–SDU-450, Japan) with a frequency range of 7-12 MHz linear probe and central frequency of 10 MHz was used to measure the thickness of the TrA and IO muscles in three positions: (1) resting position, (2) ASLR, and (3) ADIM. According existed evidence (Teyhen, et al., 2009), while muscle measuring, the tests were done on the left side of the body. Three images were recorded in each position. The average of the three measurements in each state was used in the statistical analysis. The changes in the thickness of each abdominal muscle in the different positions were normalized to the actual muscle thickness at the resting position in the supine crook-lying position and expressed as a ratio of the thickness change.

The ultrasound transducer was transversely located across the abdominal wall over the anterior axillaries line, midway between the 12th rib and the iliac crest, to obtain a clear image of the deep abdominal layers. To standardize the placement of the transducer among the subjects, the hyper echoic interface between the TrA and the thoraco-lumbar fascia was the right-most structure of the ultrasound image. The angle of the transducer was altered to ensure that the best image was captured and the facial layers of the abdominal muscles were parallel on the screen (Teyhen et al., 2007 & Gorbet et al., 2006). The ultrasound transducer was not displaced during the testing procedure, and the examiner's hand was fixed on the subjects' torso without any inward pressure applied to the transducer as in previous studies (Whittaker, 2008; Ishida, & Watanabe, 2012). The image was frozen at the end of the expiration; however, we were careful to avoid a forced expiration (Ishida & Watanabe, 2012). All measurements were performed after the experiment was completed. The cursor points carefully measured the muscle thickness in millimeters as the distance between the superior and inferior muscle fascia band at

approximately the middle of the image (Hides et al., 2007).

To doing the tests, initially, the subjects were instructed to lie down on a standard plinth on which a rigid, straight mat was placed, and then the abdominal muscles underwent imaging in 3 positions. At first, resting thickness values were obtained at the end of a normal expiration, with participants in the supine position and knees bent to 90 degrees, Secondly, the ASLR test was performed with the subject lying supine and lower extremities extended on the plinth, hands resting on the chest, the elbows on the chest, and the feet positioned 20 cm apart. The subjects were asked to raise the lower extremity 5cm off the table with the knees extended. The automatic muscle contraction was maintained, and no attention was given to the subjects about abdominal region. After the thickness values were recorded, the subjects were asked to lower the extremity. All subjects were required to raise their right lower extremity, although there is a symmetric response in the deep abdominal muscles regardless of which lower extremity is lifted during the ASLR test as described by others (Teyhen et al., 2009; Gill, Mason & Gerber, 2012). As the third task, changes in muscle thickness during the ADIM test were assessed. While the subjects were in the supine position with muscles at rest, the subjects were required to perform an abdominal drawing-in maneuver, and imaging continued while the contraction of the TrA was controlled by the Pressure Biofeedback (PBF) device. Before the subjects we asked to perform the ADIM, the correct form of the muscle contraction was taught to each subject separately with PBF. The subjects were instructed to "take a breath in and after exhale, pull their belly button in and back towards their lumbar spine" (Gorbet et al., 2010 & Teyhen et al., 2008). To establish intra rater reliability, the ultrasound measurements in all positions were repeated twice within a session in 10 volunteers. All testing procedures were performed by one expert examiner (one of the authors), in the biomechanics laboratory of the department of physical therapy at the university.

Statistical analyses of the data were performed by using a statistics software, SPSS version 16.The Interclass Correlation Coefficient (ICC) and two-way mixed effect model were used to assess the intra rater reliability of the measurements of the muscle thickness on two occasions. The muscle (TrA, IO) activation ratio was determined by dividing the contracted muscle thickness by the relaxed muscle thickness as previously described (Gorbet et al., 2010; Teyhen et al., 2008). TrA or IO contraction ratio calculated as (TrA or IO thickness contracted)/(TrA or IO thickness at rest). Descriptive statistics of the data are presented as means ± SD. For the comparison of different abdominal contraction and groups, the data were examined using one-way analysis of variance (ANOVA), that were performed to examine the main effects of group and exercise interaction. The Bonferroni test was conducted as post-hoc tests to evaluate the pair wise comparison. The measured data were statistically processed using SPSS ver. 16.0 and a significance level of $\alpha = 0.05$ was considered. Assumptions of homogeneity and sphericity in the data were checked, and, where appropriate, adjustments in the degrees of freedom for the ANOVA were made.

Results

Table 1 shows the demographic characteristics of the studied women. There is no significant diffidence's between two groups ($p > 0.05$). The ICC results were between 0.89 and 0.97for each ultrasound measurement for the TrA and IO muscles during all tested positions. There were no significant differences in the rest thickness of the abdominal muscles in TrA ($p = 0.92$) and IO ($p = 0. 33$) between the case and control groups (Table 2).
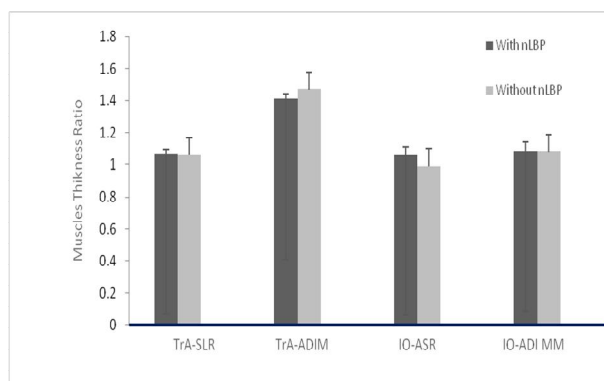
Table 2. Comparing subjects with and without nLBP regarding the rest thickness of abdominal muscles.

Variables	Without nLBP (n = 10) (mean ± SD)	With nLBP (n = 20) (mean ± SD)	P value
Rest thickness TrA (mm)	2.22± 0.74	2.91± 1.18	0.7
Rest thickness IO (mm)	3.38± 0.97	4.45± 1.21	0.1

nLBP: Nonspecific Low Back Pain, TrA: Transverses Abdominals, IO: Internal Oblique.

The main effects of group on the activation ratio TrA ($p = 0.63$) and IO ($p = 0.36$) were not significant. Based on the findings shown in Figure 1, there were no differences in the TrA and IO thickness ratio between subjects with and without nLBP in terms of ASLR and ADIM, but the main effects of exercise was significant ($P < 0.001$), so that the subjects without nLBP, had a high activation ratio of IO in ADIM than ASLR ($P < 0. 001$, figure 2) while in the LBP subjects there was a significant difference only in the muscle activation ratio between the ASLR and the ADIM for the TrA ($P < 0. 001$, Figure 3) but no

difference in the IO muscle (P = 0. 055).Indeed, in subjects with nLBP, IO has contracted in the same way in ADIM and ASLR exercises.

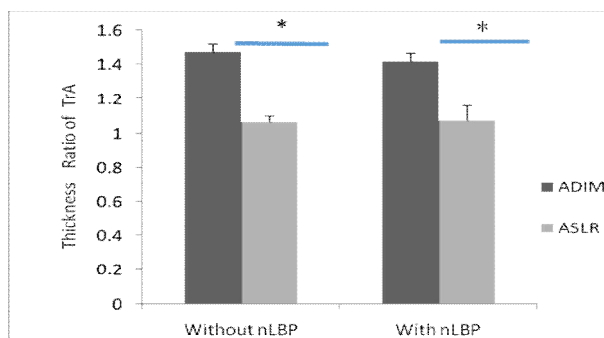SLR: Straight Leg Raising; ADIM:Abdominal Drawing-In Maneuver.

Figure 1. Comparing of activation ratios of the TrA and IO, between ASLR and ADIM in subjects with and without nLBP
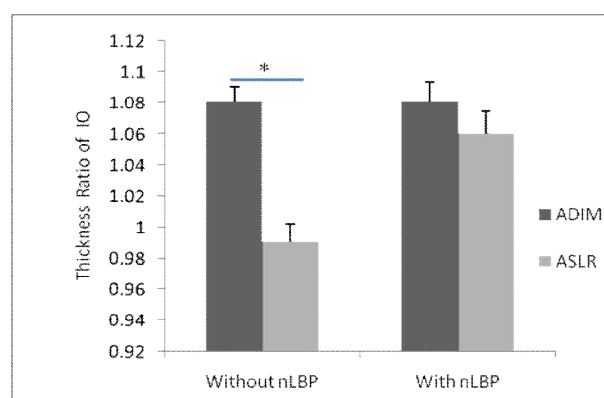
*P value < 0.05
SLR: straight leg raising; ADIM: abdominal drawing-in maneuver.

Figure 2. Activation ratios of IO thickness, comparison, between ASLR and ADIM in subjects with and without nLBP.

*p value < 0.05.
SLR: straight leg raising; ADIM: abdominal drawing-in maneuver.

Figure 3. Activation ratios of TrA thickness, comparison between ASL and ADIM in subjects with and without nLBP

Discussion

Measuring the thickness of abdominal muscles showed a significant difference in the TrA activation ratios between the ASLR and the ADIM in subjects with and without nLBP, demonstrating that the function of the TrA and how it is activated during automatic contraction and voluntary contraction are different.

Pinto et al. believed that many control training programs include voluntary leg tasks as a challenge to the control of the spine and pelvis muscles. During the ASLR, the hip flexors may have stimulated contraction of the TrA and the IO.This increase in muscle thickness change may be required to counterbalance the destabilizing force generated in the lumbar spine and pelvis by the leg task (Gorbet et al., 2010) that may be more useful in people with nLBP due to pain reduction. In agreement with others (Gorbet et al., 2010 & Hides, et al., 2007).This study found no difference in the automatic TrA thickness change between people with and without LBP in the neutral lumbar posture in the supine lying position, although the IO thickness in nLBP was a little higher in ASLR than in subjects without nLBP. Future studies on more subjects and load tasks are needed to shed light on whether impaired motor control and altered patterns of abdominal muscle activation in patients would affect this muscle in this maneuver.

These results seem to challenge a previous study (Ferreira, et al., 2004 & Teyhen et al., 2009 & Hides, et al., 2007).Probably the low load task SLR or unloaded leg was not an appropriate task to demonstrate differences in the automatic TrA thickness ratio between the two groups. This is agreement with Hides' (Hides, et al., 2009)and Pinto (Pinto et al., 2011) studies. Hides found the group difference when SLR was leg loaded, and in the study of Pinto et al., the lumbar flexed posture created a group difference rather than the neutral lumbar posture in the TrA. Lee, S. H., Kim, T. H., Lee, B.H., found the ASLR with bracing in sitting can improve spinal stability via activation of the TrA and the IO (Lee, S. H., Kim, T. H., Lee, B. H., 2011). Thus, when stability is not at risk for subjects with impaired motor control, the increasing thickness of deep abdominal muscles TrA and IO is similar to asymptomatic subjects.

There were no significant differences in the ADIM exercise between the two groups for the two muscles TrA and IO. The subjects with and without nLBP contracted both muscles during the ADIM exercise, which was indicated by an activation ratio greater than 1 concomitant with other studies. (Teyhen et al., 2009)

showed the lower value of muscle thickness in symptomatic subjects for the TrA and IO muscles than asymptomatic control subjects. In line with this study, previous researches (Gorbet et al., 2010) found no significant differences between subjects with and without nLBP for activating the TrA during the ADIM exercise. The ability of the exercise to activate the TrA is consistent with the previous study. However, in this study, in addition to activation of the TrA, activation of the IO was evaluated in two groups with RUSI. The lack of a difference between TrA and IO activation between the subjects with and without nLBP also indicates that verbal instruction and feedback from a therapist may be enough to teach a person to perform the exercise correctly and implies that the ADIM exercise can be learned if verbal cueing is used. Contracting the TrA and IO muscles in rehabilitation programs is important for clinicians. As other studies (Jacobs, Henry & Nagle, 2009; Hedayati et al., 2014) the big difference between subjects with and without nLBP is related to delayed activation and not correct contraction of the TrA, that it could support the lumbar spine in a position of misalignment.

The expected findings of the study (Figure 1) showed that ADIM or voluntary exercise did a better job at contracting the TrA than the SLR or automation exercise in both groups. In spite of more activation ratio (7%) of the IO in ASLR exercise in the LBP group but it was not significant between two groups. Inversely in previous evidence (Teyhen et al., 2009) Study a subgroup of people with unilateral lumbo-pelvic pain demonstrated a diminished change in muscle thickness of both the TrA and IO muscle compared with asymptomatic subjects. in a study on trunk muscle activation during induced pain with injected 5% hypertonic saline into the longissimus muscle adjacent to the lumbar multi fid us at theL4 level have indicated that induced pain attenuates a thickness change in the TrA during a voluntary recruitment task (Kiesel et al., 2008). Therefore, the results of our study would probably change if our participants in the LBP group had unilateral pain during the measurement procedure. The activation ratios of the TrA and the IO in this study were lower than those reported by others (Teyhen et al., 2009; Teyhen et al., 2008). Since the purpose of our study was to compare muscular automatic activation with voluntary activation, for maintaining the automatic nature of the ASLR, no training was provided before the ASLR was performed, no verbal feedback was given to the participants about the abdominal region while they performed the ASLR, and the participants were required to lift their lower extremity without

focusing on the abdominal region. Similarly, to perform the ADIM, training was done at the ultrasound imaging session following the ASLR test, and no previous training period was used because neuromuscular learning may affect the muscle activation ratio. Therefore, we may have seen lower activation ratios due to the lack of neuromuscular learning.

As a limitation, all participants in our study subjects were female. In this regard, previous studies observed that the absolute values of muscle thickness in the lateral abdominal wall were greater in men compared to women (Manshadi et al., 2011).Therefore, the same could be true in our study, so smaller activation ratios were observed.

Conclusion

These findings suggest that in both groups the deep abdominal muscles (the TrA and the IO) respond differently according to the variable type of activities such as voluntary or automatic. Therefore, in training programs, in addition to a voluntary workout, automatic type of exercises should also be taught.

Conflict of Interest

There is no conflict of interest for this study.
Author contributions.

Author contribution

FM; Study implementation, Data collection and analysis, writing the first draft of Paper.

SK, FM, MMD; Study design and data analysis, editing and confirming the final draft of the paper.

SK, FM, MMD; Study design, confirming the final draft of the paper .

References

Tesh, K. M., Dunn, J. S. & Evans, J. H. (1987) The abdominal muscles and vertebral stability. *Spine*. 12 (5), 501-508.

Hodges, P. W. (2001) Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. *Experimental Brain Research*. 141 (2), 261-266.

Cholewicki, J., Greene, H. S., Polzhofer, G. K., Galloway, M. T., Shah, R. A. & Radebold, A. (2002) Neuromuscular function in athletes following recovery from a recent acute low back injury. *Journal of Orthopaedic& Sports Physical Therapy*. 32 (11), 568-575.

Hall, L., Tsao, H., MacDonald, D., Coppieters, M. & Hodges, P. W. (2009) Immediate effects of co-contraction training on motor control of the trunk muscles in people with recurrent low back pain. *Journal of Electromyography and Kinesiology*. 19 (5), 763-773.

Pinto, R. Z., Ferreira, P. H., Franco, M. R., Ferreira, M. C., Ferreira, M. L., Teixeira-Salmela, L. F., et al. (2011) The effect of lumbar posture on abdominal muscle thickness during an isometric leg task in people with and without non-specific low back pain. *Manual therapy*. 16 (6), 578-584.

Gorbet, N., Selkow, N. M., Hart, J. M. & Saliba, S. (2010) No difference in transverse abdominis activation ratio between healthy and asymptomatic low back pain patients during therapeutic exercise. *Rehabilitation Research and Practice*, 210.

Teyhen, D. S., Miltenberger, C. E., Deiters, H. M., Del Toro, Y. M., Pulliam, J. N., Childs, J. D., et al. (2005) The use of ultrasound imaging of the abdominal drawing-in maneuver in subjects with low back pain. *Journal of Orthopedic & Sports Physical Therapy*. 35 (6), 346-355.

Kiesel, K. B., Uhl, T., Underwood, F. B. & Nitz, A. J. (2008) Rehabilitative ultrasound measurement of select trunk muscle activation during induced pain. *Manual Therapy*. 13 (2), 132-138.

Koppenhaver, S. L., Hebert, J. J., Fritz, J. M., Parent, E. C., Teyhen, D. S. & Magel, J. S. (2009) Reliability of rehabilitative ultrasound imaging of the transversusabdominis and lumbar multifidus muscles. *Archives of Physical Medicine and Rehabilitation*. 90 (1), 87-94.

Lee, S. H., Kim, T. H. & Lee, B. H. (2014) The effect of abdominal bracing in combination with low extremity movements on changes in thickness of abdominal muscles and lumbar strength for low back pain. *Journal of Physical Therapy Science*. 26 (1), 157-160.

Teyhen, D. S., Bluemle, L. N., Dolbeer, J. A., Baker, S. E., Molloy, J. M., Whittaker, J. et al (2009) Changes in lateral abdominal muscle thickness during the abdominal drawing-in maneuver in those with lumbopelvic pain. *Journal of Orthopedic & Sports Physical Therapy*. 39 (11), 791-798.

Teyhen, D. S., Gill, N. W., Whittaker, J. L., Henry, S. M., Hides, J. A. & Hodges, P. (2007) Rehabilitative ultrasound imaging of the abdominal muscles. *Journal of Orthopedic & Sports Physical Therapy*. 37 (8), 450-466.

Whittaker, J. L. (2008) Ultrasound imaging of the lateral abdominal wall muscles in individuals with lumbopelvic pain and signs of concurrent hypocapnia. *Manual Therapy*. 13 (5), 404-410.

Ishida, H. & Watanabe, S. (2012) Influence of inward pressure of the transducer on lateral abdominal muscle thickness during ultrasound imaging. *Journal of Orthopedic & Sports Physical Therapy*. 42 (9), 815-818.

Ishida, H., Hirose, R. & Watanabe, S.(2012) Comparison of changes in the contraction of the lateral abdominal muscles between the abdominal drawing-in maneuver and breathe held at the maximum expiratory level. *Manual Therapy*. 17(5), 427-431.

Hides, J. A., Wong, I., Wilson, S. J., Belavý, D. L. & Richardson, C. A. (2007) Assessment of abdominal muscle function during a simulated unilateral weight-bearing task using ultrasound imaging. *Journal of Orthopedic & Sports Physical Therapy*. 37 (8), 467-471.

Teyhen, D. S., Williamson, J. N., Carlson, N. H., Suttles, S. T., O'Laughlin, S. J., Whittaker, J. L., et al. (2009) Ultrasound characteristics of the deep abdominal muscles during the active straight leg raise test. *Archives of Physical Medicine and Rehabilitation*. 90 (5), 761-767.

Gill, N. W., Mason, B. E. & Gerber, J. P. (2012) Lateral abdominal muscle symmetry in collegiate single-sided rowers. *International Journal of Sports Physical Therapy*. 7 (1), 13-19.

Teyhen, D. S., Rieger, J. L., Westrick, R. B., Miller, A. C., Molloy, J. M. & Childs, J. D. (2008) Changes in deep abdominal muscle thickness during common trunk-strengthening exercises using ultrasound imaging. *Journal of Orthopedic & Sports Physical Therapy*. 38 (10), 596-605.

Ferreira, P. H., Ferreira, M. L. & Hodges, P. W., (2004) Changes in recruitment of the abdominal muscles in people with low back pain: ultrasound measurement of muscle activity. *Spine*. 29(22),. 2560-2566.

Hides, J. A., Belavý, D. L., Cassar, L., Williams, M., Wilson, S. J. & Richardson, C. A. (2009) Altered response of the anterolateral abdominal muscles to simulated weight-bearing in subjects with low back pain. *European Spine Journal*. 18 (3), 410-418.

Hedayati, R., Kahrizi, S., Parnianpour, M., Bahrami, F., Kazemnejad, A. & Mobini, B. (2014) The study of the variability of anticipatory postural adjustments in patients with recurrent non-specific low back pain. *Journal of Back and Musculoskeletal Rehabilitation*. 27 (1), 33-40.

Jacobs, J. V., Henry, S. M. & Nagle, K. J. (2009) People with chronic low back pain exhibit decreased variability in the timing of their anticipatory postural adjustments. *Behavioral Neuroscience*.123 (2), 455.

Manshadi, F. D., Parnianpour, M., Sarrafzadeh, J., rezaAzghani, M. & Kazemnejad, A. (2011) Abdominal hollowing and lateral abdominal wall muscles' activity in both healthy men & women: An ultrasonic assessment in supine and standing positions. *Journal of Bodywork and Movement Therapies*. 15 (1), 108-113.