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Original article

Ultrasound measurement of deep and superficial abdominal muscles thickness during standing postural tasks in participants with and without chronic low back pain

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ABSTRACT

Background: Activity of deep abdominal muscles increases the lumbar stability. Majority of previous studies indicated abdominal muscle activity dysfunction during static activity in patients with low back pain (LBP). However, the number of studies that evaluated deep abdominal muscle activity in dynamic standing activities in patients is limited, while this assessment provides better understanding of pain behavior during these activities.
Objective: Investigation of superficial and deep abdominal muscles activity in participants with chronic LBP as compared to healthy individuals during standing tasks.
Design: Case control study.
Methods: Ultrasound imaging was used to measure the thickness of transverse abdominis (TrA), internal oblique (IO) and external oblique (EO) muscles in female participants with ($N = 45$) and without chronic LBP (CLBP) ($N = 45$) during tests. The Biodex Balance System was used to provide standing tasks. The thickness of each muscle in a standing task was normalized to actual thickness at rest in the supine lying position to estimate its activity.
Results: The results indicate increases in thickness of all muscles in both groups during dynamic as compared to static standing tasks ($P < 0.05$, $ES > 0.5$). Lower percentages of thickness change for TrA muscle and higher for EO muscle were found in the patients as compared to healthy individuals during all tests ($P < 0.05$, $ES > 1.28$).
Conclusions: Higher activity of superficial than deep abdominal muscles in patients as compared to healthy individuals during standing tasks indicates motor control dysfunction in patients with CLBP. Standing tasks can discriminate the individuals with and without LBP and can be progressively used in training.

1. Introduction

Low back pain (LBP) is one of the most common musculoskeletal disorders (Gourmelen et al., 2007; Bandpei et al., 2014) that occurs at least once in lifetime of 70–80% of individuals (Ehrlich, 2003). Changes in motor control function of local segmental muscles such as transversus abdominis (TrA) have been frequently found in patients with LBP (Hodges and Richardson, 1996, 1998). Most of the previous studies reported voluntary activity dysfunction of TrA muscle in patients with LBP as compared to healthy individuals (Critchley and Coutts, 2002; Teyhen et al., 2005; Mew, 2009). Some studies have also indicated that automatic activity of the TrA muscle was decreased during internal perturbations in patients with LBP that could affect the anticipatory protective mechanisms of the lumbar segmental control (Hodges et al., 2003; Ferreira et al., 2004; Hides et al., 2009; Teyhen et al., 2009). However, the number of studies that investigated automatic activity of the TrA muscle in dynamic tasks condition is limited (Rasouli et al., 2011). Dynamic tasks are common conditions in daily activities such as standing on stable or unstable support surfaces, walking, running and stairs

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climbing that may have a pain-provoking effect on patients with LBP (van Deursen et al., 2002). Therefore, measurement and monitoring of automatic activity of TrA muscle during dynamic functional activities is necessary to provide better understanding of pain behavior in clinical environments, planning for more effective training to control pain during daily standing activities for patients with LBP.

Standing on unstable support surfaces is a common postural challenge occurring in a large numbers of functional activities such as walking, running and stair climbing (van Deursen et al., 2002). In order to increase neuromuscular demand in the condition of external perturbation, it appears that activity of deep trunk muscles increases to maintain sufficient control of spine (Mew, 2009; Desai and Marshall, 2010; Debuse et al., 2013). Accordingly, some investigators have advocated training on unstable surface to train deep abdominal muscles in the patients with LBP (Imai et al., 2010; Saliba et al., 2010; Kang et al., 2012; Ehsani et al., 2015). In this regard, some studies have shown progressive improvement in activation of deep trunk muscles by long-term training on gym ball in patients with LBP (Marshall and Murphy, 2006, 2008). On the other hand, a few studies reported significant decrease in deep trunk muscles activation during sitting on unstable surfaces in the patients with LBP as compared to healthy participants (Willigenburg et al., 2013). Findings of some studies also indicated over-activation of superficial trunk muscles during standing on unstable surface in patients with LBP as compared to healthy participants (Newcomer et al., 2002; Boudreau et al., 2011; Jacobs et al., 2011; Jones et al., 2012a,b). Accordingly, efficiency of dynamic postural task on function of deep trunk muscles is not clear in patients with LBP. Thus, the purpose of the current study was to compare superficial and deep abdominal muscles activity of patients with LBP and healthy individuals during dynamic standing tasks. We hypothesized that:

- During standing on unstable surfaces, the activity of abdominal muscles in patients with chronic LBP (CLBP) will be more decreased as compared to healthy individuals.
- Unstable surfaces enhance activity of deep abdominal muscles more than stable surfaces in patients with LBP.

2. Materials and methods

2.1. Participants

This case control study was a two-factor mixed design to compare the lateral abdominal muscles activity in different testing conditions and between groups with and without chronic LBP. Forty eight healthy female participants and 50 female participants with LBP were selected during a simple non-probability sampling method and matching grouping. This sample size presented 85% power to detect the effect of standing postural task dynamicity on objective outcomes in two groups with 95% confidence interval (CI). Finally based on inclusion and exclusion criteria, 45 healthy controls and 45 patients with CLBP were investigated. Fig. 1 represents the flowchart of eligibility assessment throughout the study.

Patients with a history of LBP for more than six weeks, recurrent LBP with at least three episodes lasted more than one week during the last year and a pain score between 30 and 70 mm on a visual analog scale (VAS) on the testing day were included (Nourbakhsh and Arab, 2002). Patients with severe spinal pathologies, deformity of spine such as scoliosis, kyphosis, or lordosis, previous history of surgery in abdominal and spinal regions, nerve root pain, sciatalgia or radicular pain were excluded from the study (Airaksinen et al., 2006; Koes et al., 2006; Chou et al., 2007). Participants in control group were recruited from University students and staff and included if they had no history of back pain. The participants in both groups were excluded if they had vision, vestibular, auditory or cognitive impairment, respiratory disorder, diabetes, recent lower limb pathology, pregnancy, or history of recent use of any medication or substance which may influence their balance during 48 h prior the testing. A specialist physical therapist screened the participants of two groups (A.AM). The participants of control group were matched with LBP patients group in age, weight, height and body mass index (BMI).

2.2. Ultrasound measurement of the abdominal muscle thickness

A Diagnostic Ultrasound (US) Imaging Unit (HS-2100V, Japan) set in B-mode with a 7.5 MHz linear head transducer was applied to measure the thickness of the TrA, internal oblique (IO) and external oblique (EO). Real-time US imaging is a reliable and valid technique for assessing muscle structure, function and activity (McMeeken et al., 2004; Teyhen et al., 2007; Costa et al., 2009). Changes in the thickness of muscle measured with US imaging during a dynamic task in relation to the thickness of resting position, could indicate *the activity of muscles* (Ferreira et al., 2004; Teyhen et al., 2007; Hebert et al., 2009). Post graduated physical therapy (E.F, PhD. level) who was trained with an experienced specialist (A.AM) during 3 months, conducted the US assessment. The examiner was blind to participants grouping.

A Biodex Balance System (BBS) (950-302, SD, New York) was also used to create standing static or dynamic support surfaces for standing postural tasks. The BBS assess the ability to maintain balance, while standing on a static or movable support surface with varying degrees of instability in different directions (levels 1 and 12 of movable support surface showing the greatest and lowest instability, respectively) (Hinman, 2000). During pilot study, participants with CLBP were not able to complete dynamic tests of stability level 3 or lower, without losing their balance or aggravation of their symptoms. Accordingly, the static level and movable levels of 6 and 3 were used for test conditions in the study. The study was conducted from November 2014 to April 2015. The study has adhered to STROBE checklist criteria.

Measurement of muscles thickness was implemented on the right side of the abdomen in three testing conditions with a 5-min inter trial interval. All tests were carried out in a single session (see Fig. 2). For measurement of antero-lateral abdominal wall muscles thickness, the participants were asked to lie down in supine position. The US transducer was transversely located across the right side of the abdominal wall over the anterior axillary line, midway between the 12th rib and the anterior superior iliac crest, where a clear image of all three lateral abdominal muscles (TrA, internal oblique (IO), external oblique (EO)) was obtained (McMeeken et al., 2004). The location showing a clear image of the muscles was marked to be used for placement of transducer in standing test conditions.

Participants were instructed to stand on the platform of BBS level during the tests without holding on to the handrails of the BBS by hands, while they were barefooted with arms crossed behind their back (see Fig. 3A). Prior to the test, the instrument panel was covered and participants were asked to look at a paper on a wall (2 m away) in front of their eyes for a period of 30 s. The motion of US transducer during dynamic test conditions has been suggested to be as a potential source of error by distorting the images (Klimstra et al., 2007). Therefore, a transducer fixator (TF) was used in order to improve the reliability of US through minimizing motion artifacts (Bunce et al., 2004) (see Fig. 3A). The TF was made from a