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Cross-Sectional study

Automatic activity of deep and superficial abdominal muscles during stable and unstable sitting positions in individuals with chronic low back pain

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Objective: The purpose of this study was to assess muscle thickness changes in the deep and superficial abdominal muscles, during sitting on stable and unstable surfaces in subjects with and without chronic low back pain (CLBP).
Method: A cross-sectional study was conducted involving 40 participants (20 CLBP and 20 healthy). Ultrasound imaging was used to assess changes in the thickness of the Transversus abdominis (TrA), Internal Oblique (IO), Rectus abdominis (RA) and External oblique (EO) muscles. Muscle thickness under two different sitting postures; (sitting on a chair and sitting on a Swiss ball), was normalized to actual muscle thickness at rest in the supine lying position and was expressed as a percentage of thickness change of muscles.
Result: The results showed significantly greater thickness changes in RA muscle in the CLBP patients compared to the healthy subjects, during both stable and unstable sitting positions. Also, significantly lower thickness changes in TrA muscle was observed in subjects with CLBP compared to those without CLBP, during unstable sitting position.
Conclusion: There was an imbalance between the automatic activity of TrA and RA muscles in the subjects with CLBP, compared to the pain-free controls, during an unstable sitting position. Therefore, it is necessary to pay attention, to the altered automatic activity of the abdominal muscles while utilizing a Swiss ball, for rehabilitation of subjects with CLBP.

1. Introduction

Low back pain (LBP) is an extremely common health problem. The lifetime prevalence rate for an adult suffering a LBP episode has been reported to be as high as 80% (Rubin, 2007). It is believed that decreased lumbar stability due to altered motor control might be a possible cause of LBP (Panjabi, 1992). Therefore, spinal stability exercises are prescribed for LBP patients. This exercise approach is based upon the theory of spinal stabilization proposed by Bergmark (1989) (Bergmark, 1989). The abdominal muscles are generally considered as a group of muscles that contribute to the stability of the lumbar spine (Bergmark, 1989; Hodges and Richardson, 1999). Bergmark 1989 described the presence of two muscle systems involved in spinal stability, The first one is the "global muscle system" consisting of large, superficial muscles around the abdominal and lumbar region that produce a larger torque on the spine without directly attaching to it (Bergmark, 1989) and are unable to control inter segmental motion. The second system is the "local muscle system" consisting of deep, intrinsic muscles that directly attach to the lumbar vertebra and control inter-vertebral motion to provide inter-segmental stability. Transverse Abdominis (TrA) and

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Internal Oblique (IO) are deep abdominal muscles classified as local muscles (Akuthota and Nadler, 2004). In contrast, Rectus Abdominis (RA) and External Oblique (EO) are superficial muscles, classified as global muscle system (Akuthota and Nadler, 2004).

Researchers have suggested that motor control training of the abdominals for subjects with LBP is well achieved with exercises that minimize activation of the superficial muscles and target local abdominal muscles (Jull et al., 1993; O'Sullivan et al., 1997). Accordingly, unstable postures have been found to increase the activity of deep abdominal muscles in subjects with CLBP (Imai et al., 2010; Rasouli et al., 2011). However, the activity of superficial muscles is unknown during unstable sitting positions in subjects with CLBP. Understanding the activity of muscles during different positions would guide therapists to designing optimal training protocols for CLBP patient.

Swiss ball is a commonly used rehabilitation tool to induce unstable surface and facilitate deep abdominal muscle activity (Marshall and Murphy, 2005). However, there is little scientific evidence to support its use (Standaert and Herring, 2007). Researchers have found the increased thickness of TrA and IO muscles during sitting on Swiss ball compared to sitting on a chair in healthy subjects (Ainscough-Potts et al., 2006) and subjects with CLBP (Rasouli et al., 2011). However, previous studies have assessed only the deep abdominal muscles while superficial muscles (RA or EO) have not been measured.

Since Swiss ball exercises are widely used for subjects with CLBP, it is necessary to assess automatic activities of the deep and superficial abdominal muscles during stable and unstable sitting positions in patients with CLBP. Therefore, the purpose of this study was to assess the changes in the thickness of the all abdominal muscles during sitting in a stable position (sitting on a chair with both feet on the ground) and unstable sitting position (sitting on a Swiss ball with both feet on the ground) in subjects with and without CLBP.

2. Materials and method

2.1. Subject

The participants of this study were 40 men (20 with non-specific CLBP and 20 with no LBP) aged between 20 and 40 years. Participants with CLBP were selected among the individuals seen in an orthopaedic and physiotherapy departments. Subjects without LBP, matched in age, were selected from the same clinical settings as the control group. All participants signed a consent form approved by the Human Subject's Ethics Committee at the University of Social Welfare and Rehabilitation Sciences before participating in the study. Patients were included if they had a history of LBP for more than twelve weeks before the study or had on-and-off back pain and had experienced at least three episodes of LBP, each lasting more than one week, during the year before the study. Patients were excluded if they had neurological signs, specific spinal pathology (e.g. malignancy, inflammatory joint or bone disease). In the testing day, the pain intensity (in the past 7 days) should have been lower than 3 on a 10-cm visual analogue scale (VAS). Participants in the control group were included if they had no complaint of any pain or dysfunction in their low back, pelvis, thoracic and lower extremities. Participants were excluded if they had a history of neuromuscular or musculoskeletal pain elsewhere in the spine or lower limbs and cardiopulmonary diseases.

2.2. Experimental procedure

2.2.1. Ultrasound measurement of the abdominal muscle thickness

A diagnostic ultrasound-imaging unit set in B-mode (Ultrasonix- ES500, Canada) with a 7.5 MHz linear head transducer was used to measure the thickness of the TrA, IO, EO and RA in three different positions. The testing positions used for the ultrasound measurements were as follow: 1. Supine lying (hook-lying position) for normalizing the thickness changes in other positions. 2. Stable postural control test condition: sitting comfortably on a chair with a seat height 43 cm supported against a backrest, (with no arm-rests) with arms folded; hands gently resting on the opposite shoulders and both feet on the ground. 3. Unstable postural control test condition: sitting comfortably with a straight back on a 65 cm diameter Swiss ball, with arms folded and resting on the opposite shoulders (Ainscough-Potts et al., 2006; Rasouli et al., 2011). To compare the sitting positions, the height of the chair was not adjustable similar to the Swiss ball. When a 70-kg person sat on the Swiss ball, it reduced the ball height to 43 cm.

Erect sitting was defined as a position in which the subject had a neutral pelvic tilt, neutral lumbar lordosis, and neutral thoracic kyphosis. Using standardized instructions, the participants were positioned by the same investigator for all the trials (O'Sullivan et al., 2002). Each position was held enough for the examiner to have a clear picture of the muscle thickness at the end of expiration. The testing positions were randomly selected. All testing procedures were performed in the biomechanics laboratory of the Department of Physical Therapy at the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.

All measurements were carried out on the right side of the abdominal wall. For antero-lateral abdominal wall muscles (TrA, IO and EO), the ultrasound transducer was transversely located across the abdominal wall over the anterior axillary line, midway between the12th rib and the iliac crest, to obtain a clear image of the tested muscles. For the RA muscle, the ultrasound transducer was transversely located about 2 cm above the umbilicus and shifted 2 cm to the right side from the midline (Norasteh et al., 2007). The image was frozen and a vertical straight line through the centre of the ultrasound image was used to ensure standardized placement of the measurement line. The cursor points carefully measured the muscle thickness between the inside edge of fascial bands in millimetres (mm). The ultrasound transducer was not displaced during the testing procedure. The thickness of each abdominal muscle was normalized to the muscle thickness at the hook-lying position. Next the percentage of thickness change was expressed for both sitting positions. Three receptions were executed for each condition and the mean normalized data were used for the analysis. The examiner was blinded to the group allocation.

The reliability of US thickness measurements has been assessed previously during the automatic activity of the abdominal muscles in subjects with and without CLBP. High intra-tester reliability (ICC: 0.85–0.95) has been reported for the US measurement of the thickness of the abdominal muscles in sitting positions (Arab et al., 2013).

2.3. Data analysis

SPSS statistical package was used for statistical analysis. Kolmogorov-Smirnov test was used to assess the normality of distribution for tested variables. Normal distribution was observed for variables in both groups. Repeated measure analysis of variance (ANOVA) with two within-subjects factor (two sitting stability level and four muscles) and one between-subjects factor group (CLBP patients and controls) were used to test the main effects of position difficulty, group, muscle and their interactions on the thickness change of tested muscles. Significant main effects and interactions were further analysed using the Bonferroni test. Statistical significance was set at $P = 0.05$. Partial eta squared ($\eta 2$) were calculated for repeated measure ANOVA to indicate effect sizes and reported