Manual Therapy 18 (2013) 481–486

Contents lists available at SciVerse ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

Inter-session reliability of the measurement of the deep and superficial layer of lumbar multifidus in young asymptomatic people and patients with low back pain using ultrasonography

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ARTICLE INFO

Article history:
Received 17 May 2012
Received in revised form
25 April 2013
Accepted 30 April 2013

Keywords:
Lumbar multifidus
Low back pain
Ultrasonography

ABSTRACT

Study design: Reliability study.
Objective: To investigate the inter-session reliability of measuring the thickness of deep (dMF) and superficial layer of lumbar multifidus (sMF) using ultrasonography for participants with and without low back pain (LBP).
Background: The lumbar multifidus is an important muscle in maintaining spinal stability. The dMF is considered important in maintaining tonic contraction and joint stability. Motor control impairment is also discovered in patients with LBP. However, no study to date has investigated the method of observing both the sMF and dMF through ultrasound imaging (USI).
Methods: Twenty subjects aged 18–35 years old with LBP ($N = 10$) and without LBP ($N = 10$) were recruited. Every subject extended the upper trunk in prone lying with maximal isometric contraction. Simultaneously, the examiner measured the thickness of the dMF and the sMF using ultrasonography after ensuring the muscle belly was located. The participants performed three trials of isometric trunk extension in each session, with 30 min between each session. The reliability of measuring the change of thickness is represented by the intra-class correlation coefficient (ICC).
Results: Through averaging three trials of measurement, the reliability of measuring the thickness of the dMF or the sMF in static or in the contracted condition, and the change of the thickness during contraction, is reliable (ICC = 0.84–1.00).
Conclusions: The intra-rater inter-session reliability of measurement of the dMF and the sMF with USI has been established. This method could be applied to the qualification of the activation level of the dMF and the sMF with specific tasks.

1. Introduction

Depending on the anatomic attachment, lumbar multifidus (MF) can be divided, morphologically and functionally, into two layers: the superficial (sMF) and the deep MF (dMF) (Macintosh et al., 1986; Lonnemann et al., 2008; Rosatelli et al., 2008). The dMF is thought to provide a segmental compressive force and to serve as a postural muscle, which is different to the function of the sMF (Moseley et al., 2002, 2003, 2004; Hodges et al., 2003a; Hides et al., 2004; MacDonald et al., 2006, 2009, 2010; Dickx et al., 2010a). The dMF may provide compressive force or proprioception, because of the short muscle bundles (Rosatelli et al., 2008), whereas sMF generates an extension force. The tendency toward a higher percentage of type I muscle in the dMF, compared to the muscle fiber in the sMF or the erector spinae, suggests that the dMF may be used for tonic contraction or the maintenance of posture (Sirca and Kostevc, 1985; Dickx et al., 2010a). EMG results show that the dMF is activated to stabilize the spine, regardless of the direction of perturbation. In contrast, the sMF are activated in accordance with the direction of the external load (Moseley et al., 2002).

Studies have quantified the Electromyographic (EMG) activity of sMF in healthy subjects, during various forms of exercise. They are used for core stabilization processes, including the Abdominal Draw-In Maneuver (ADIM) (Danneels et al., 2001b), arm/lower extremity lift in the prone position (Danneels et al., 2001a, 2002;

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1356-689X/$ – see front matter
http://dx.doi.org/10.1016/j.math.2013.04.006

Ekstrom et al., 2007, 2008) and in resisting lumbar extension at the end range (Ekstrom et al., 2008). During ADIM, only about 5% of maximal voluntary isometric contraction (MVIC) is generated. Furthermore, during the arm/lower extremity lift exercise in either prone or quadruped positions, moderate activity (less than 50% of MVIC) of the back muscle is generated (Danneels et al., 2002; Ekstrom et al., 2007, 2008). During resisted lumbar extension at the end range, the MF is highly activated (over 75% of MVIC) (Ekstrom et al., 2008). Therefore, tasks that involve different amounts of muscle contraction can be used to improve the strength or endurance of the sMF (Danneels et al., 2002; Ekstrom et al., 2007, 2008).

Physiological and morphological changes have been observed in dMF and sMF, in patients with recurrent/chronic low back pain, which may result in less than optimal spinal stabilization in relation to recurrent/chronic symptoms. The changes in the control of lumbar MF include decreased activation of the sMF in patients with chronic (Flicker et al., 1993; Danneels et al., 2002; Wallwork et al., 2009) or experimental (Dickx et al., 2010b) lower back pain (LBP), even after the remission of symptoms (MacDonald et al., 2010). A lack of anticipatory contraction of the dMF is also found in patients with experimental (Moseley et al., 2004) and chronic LBP (Leinonen et al., 2001) and during the remission of symptoms (MacDonald et al., 2009, 2010). Patients with LBP have shown changes in the composition of muscle fibers (Rantanen et al., 1993; Mengiardi et al., 2006) and rapid atrophy of the total Cross-Sectional Area (CSA) of MF (Hides et al., 1994, 1996, 2008; Hodges et al., 2006; Kamaz et al., 2007; Kulig et al., 2009), which corresponds to decreased change of activation. Regaining the ability to control the trunk stabilizer in the initial period of treatment has also become more common in treatment, in recent years (Richardson and Jull, 1995; Hides et al., 1996; O'Sullivan et al., 1998; Tsao and Hodges, 2008).

The non-invasive, dynamic and real-time information provided by ultrasonography imaging (USI) (Zagzebski, 1996) is a feasible and reliable way to evaluate the activation of different layers of MF. The morphological changes of the muscles under USI, such as the muscle thickness or the pennation angle, correlate highly with EMG firing, during low load activity (Hodges et al., 2003b; Kiesel et al., 2007). USI of the MF can be obtained from cross-sectional or parasagittal scanning. The parasagittal view allows scanning along the orientation of the muscle fascicle, the thoracolumbar fascia and multi-segment facet joints, which renders the observation of muscle contraction easier and more precise than the use of the cross-sectional view (Hides et al., 1992, 1998; Wallwork et al., 2007). The reliability of measurement of the CSA (Hides et al., 1992, 1995; Stokes et al., 2005; Pressler et al., 2006) or the thickness (Van et al., 2006; Kiesel et al., 2007; Wallwork et al., 2007) of the sMF is good, when the measurements are obtained on the same day (Hides et al., 1992; Van et al., 2006; Kiesel et al., 2007; Wallwork et al., 2007) or on different days (Hides et al., 1992, 1995; Stokes et al., 2005; Pressler et al., 2006). In previous studies, the muscle examined has been mainly composed of sMF.

The quantitative pattern of the superficial and deep layers of MF in asymptomatic participants, during a specific task, serves as a reference for later comparison of the change in motor control in patients with low back pain. This is the first study to observe the sMF and dMF separately, using USI. The purpose of this study is to test the reliability of this method of measuring the thickness of multifidus between asymptomatic participants and patients with low back pain.

2. Method

2.1. Subjects

Ten participants, aged 18–35 years old, without current discomfort or discomfort lasting for more than one day during the past 3 months, were recruited as the asymptomatic group. Another ten participants, who had experienced discomfort for more than one day during the past 3 months, were recruited as the LBP group. The exclusion criteria were pregnancy, neoplasm or systemic inflammation disease, previous surgery on the lumbar spine or lower extremity, neurological signs, previous instruction in trunk stability exercises, and a history of crush injuries, sport injuries, or car accidents.

2.2. Procedure

All participants signed a written consent form, prior to participation in the experiment. The study was approved by the local Institutional Human Study and Ethics Review Board. In order to eliminate factors that interfere with reliability, the posture of the subjects was restricted to the prone position during isometric contraction. A standard technique to define the MF by tracing the origin and insertion of the muscles was also established.

Before measuring the thickness of the sMF and the dMF, the examiner traced the origin and insertion of the muscle, to ensure the muscle bundle. This technique was developed in previous studies by the authors, in order to examine the cervical muscle, using USI (Lee et al., 2007; Lin et al., 2009). During measurement of the image of the MF, the transducer was placed initially at a longitudinal orientation and identified the spinal processes for L3, L4 and L5, using USI and these were marked on the skin, using a water-soluble crayon. The transducer was placed transversely over the spinous process of L4 and moved laterally, in order to determine the facet point of L4/L5. The examiner medially rotated the transducer through 90 degrees, to a longitudinal orientation, parallel with the sMF, in order to obtain a clear image of the fibers (Fig. 1).

The identification of specific vertebral landmarks with ultrasound was demonstrated in a previous pilot work by the authors, using ultrasound imaging to scan the porcine spines, before and after dissection of the muscle layers about the bony landmarks (Liu et al., 2010). After careful dissection of the multifidus in the porcine spines, it was possible to identify the bony landmark in the ultrasound sound imaging by removing the overlying muscles to visualize the bony landmark, including the facet processes. The overlying muscles were then replaced in their original position and the image was scanned again, to confirm that the structure identified in ultrasound was the visualized bony structure. After identifying the facet process, it is possible to identify the anatomical structure around the facet process. In order to identify the dMF (Fig. 1), the L4 spinal process and L4/5 facet joint was first located. The transducer was aligned in the direction from the L4/5 facet to the L3 spinal process, in order to produce a clear muscle fascia line from L4/5, passing over the L3/4 facet, in the direction of L3 spinal process. The transducer was then adjusted slightly to obtain a clear image of the bony landmark, the lamina of L4, which is located beneath the muscle fascia line of the dMF. The transducer was moved superiorly, to trace the muscle fascia of the dMF to its attachment to the base of the spinal process, in order to confirm the attachment of the dMF muscle fascia. It was necessary to tilt the transducer medially and laterally, so that the border of the dMF could be clearly observed. Finally, the transducer was inclined in the anterior and posterior directions, so that the thoracolumbar fascia in the USI was in a horizontal position. This procedure was used to confirm the location and orientation of the transducer in three-dimensional space, so that the transducer could consistently be aligned with the bony and internal landmarks of the body, such as L4/5, the L3/4 facet joints, the L4 lamina, and the thoracolumbar fascia. Therefore, the plane of view of USI could be maintained in a similar orientation during repeated measurements.