Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–8, 2015

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2015.12.002

● *Technical Note*

RELIABILITY OF ABDOMINAL MUSCLE STIFFNESS MEASURED USING ELASTOGRAPHY DURING TRUNK REHABILITATION EXERCISES

David MacDonald,* Alan Wan,* Megan McPhee,* Kylie Tucker,† and François Hug*‡
*School of Health and Rehabilitation Sciences, University of Queensland, Brisbane, QLD, Australia; †School of Biomedical Sciences, University of Queensland, Brisbane, QLD, Australia; and ‡Laboratory “Movement, Interactions, Performance” (EA 4334), UFR STAPS, University of Nantes, Nantes, France

(*Received* 12 *September* 2015; *revised* 29 *October* 2015; *in final form* 7 *December* 2015)

Abstract—The aim of this study was to assess the intra-session and inter-rater reliability of shear modulus measured in abdominal muscles during two commonly used trunk stability exercises. Thirty healthy volunteers performed a series of abdominal hollow and abdominal brace tasks. Supersonic shear imaging was used to measure the shear modulus (considered an index of muscle tension) of the four anterior trunk muscles: obliquus externus abdominis, obliquus internus abdominis, transversus abdominis and rectus abdominis. Because of measurement artifacts, internus abdominis and transversus abdominis data were not analyzed for 36.7% and 26.7% of the participants, respectively. These participants exhibited thicker superficial fat layers than the others. For the remaining participants, fair to excellent intra-session and inter-rater reliability was observed with moderate to high intra-class coefficients (0.45–0.97) and low to moderate standard error of measurement values (0.38–3.53 kPa). Reliability values were consistently greater for superficial than for deeper muscles. (E-mail: francois.hug@univ-nantes.fr) © 2015 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Physiotherapy, Shear wave elastography, Shear modulus, Ultrasound, Electromyography.**

INTRODUCTION

Rehabilitation strategies that include trunk stability exercises are associated with improved outcomes in individuals with low back pain (LBP) (Macedo et al. 2009). To this end, a variety of tasks that differentially target trunk muscle activation are commonly used. The abdominal hollowing technique is commonly thought to preferentially recruit the transversus abdominis (TA). This may be important, as the TA contributes to the control of spinal motion (Hodges et al. 2003; Kaigle et al. 1995), and differences in the behavior of this muscle have been observed in people with a history of LBP (Hodges 1999; Hodges and Richardson 1996). Alternative approaches to muscle retraining forego the intention to independently contract specific trunk muscles, with the intention to increase torso stiffness through trunk flexor and extensor muscle co-contraction (Hodges et al. 2013; McGill 2007) or abdominal bracing (Grenier and McGill 2007). Each rehabilitation protocol is thought to address a specific aspect of spinal control during its performance (Hodges et al. 2013).

As both techniques involve the development or refinement of a fine motor skill, the efficacy of the rehabilitation protocol may depend on the ability of the patient to accurately perform the task. To this end, a real-time, non-invasive measure to quantify individual muscle tension may benefit clinical practice. For both research and clinical practice, techniques such as electromyography (EMG) and B-mode ultrasound may be used to indirectly provide this information. However, there are several limitations to these techniques that require consideration. First, fine-wire EMG is invasive and, therefore, not applicable in clinical routine. Second, non-invasive surface EMG recordings are affected by cross-talk and cannot be used to isolate the activity of small or deep muscles (Farina et al. 2006). Third, the amplitude of EMG is influenced by many non-physiologic factors such as placement of electrodes in relation to muscle fiber direction and electrical noise from the environment (Farina et al. 2006). Finally, the relationship between muscle architecture (thickness or length) measured with ultrasound and force is not linear (Brown and McGill 2010), which makes it difficult to

Address correspondence to: François Hug, UFR STAPS, University of Nantes, Nantes, F-44000, France. E-mail: francois.hug@univ-nantes.fr

D. MacDonald and A. Wan contributed equally to this work.

accurately infer a change in muscle tension from a change in muscle architecture.

A real-time ultrasound shear wave elastography technique, called supersonic shear imaging (SSI), can be used to accurately measure shear modulus (*i.e.*, stiffness) of a localized muscle region (Lacourpaille et al. 2012). Previous studies have reported that the muscle shear modulus measured using SSI is linearly related to both active (Ates et al. 2015; Bouillard et al. 2011) and passive (Hug et al. 2015; Maisetti et al. 2012) muscle force. As a result, measurements of changes in muscle shear modulus during isometric contractions can be used to estimate changes in individual muscle force (or tension) (Hug et al. 2015; Sasaki et al. 2014). Elastography presents a unique method of assessing spinal stability exercises by providing a real-time index of individual muscle tension. However, before this technique is used in clinical practice, it is important to quantify the reliability of shear modulus measurements in abdominal muscles. Unlike work completed in superficial limb muscles (Lacourpaille et al. 2012), factors such as the depth of the trunk muscles, subcutaneous fat layer and respiratory movements are likely to affect the quality of the measurements.

The aim of the present study was to assess the intra-session and inter-rater reliability of shear modulus measured in the abdominal muscles during two commonly used trunk stability exercises, the abdominal hollow and abdominal brace tasks. Muscle shear modulus was measured using SSI.

METHODS

Participants

Thirty healthy volunteers participated in the study (16 males, 14 females; age 20 ± 3 y, height 170 ± 9 cm, weight 62 ± 12 kg, body mass index [BMI] 21.2 ± 2.8 kg/m^2). Participants were informed in detail of the purpose of the study and the methods used, and provided informed written consent. Participants with a history of low back pain that had required musculoskeletal rehabilitation by a physiotherapist, current musculoskeletal pain on lying or abdominal surgery in the prior 24 mo were excluded from the study. None of the participants had experience with either of the two stability trunk exercises. Only one participant did not complete both trunk stability exercises (29 participants completed the abdominal hollowing and 30 completed the abdominal bracing). This study received ethical approval from the University of Queensland Human Ethics Unit.

Examiners

Two physiotherapy students (A.W. and M.M.) who had not previously used SSI served as the examiners for this reliability study. Before testing, both examiners underwent 20 h of practical training with co-investigator F.H., who has extensive experience with the SSI technique.

Instrumentation

Electromyography. Surface electromyographic activity was recorded by electrodes placed over the right obliquus externus abdominis (EO) and the right obliquus internus abdominis (IO). Two pairs of self-adhesive Ag/AgCl electrodes (Blue Sensor N, Ambu, Copenhagen, Denmark) were placed over the right EO, inferior and medial to the 12th rib, and the right IO, medial to the anterior superior iliac spine (Fig. 1). A reference electrode was placed over the 10th thoracic vertebra. Skin was prepared using abrasive gel (Nuprep, D. O. Weaver, Aurora, CO, USA) and alcohol. EMG signals were pre-amplified 1000 times, bandpass filtered (20–500 Hz), notch filtered (50 Hz) and sampled at 1 kHz using a Power1401 Data Acquisition System with Spike2 software (Version 7.09a, Cambridge Electronic Design, Cambridge, UK). Electromyographic amplitude (displayed on a feedback screen as a percentage of the participant's maximal voluntary contraction [MVC]) was monitored by the examiner during the training period and was used to direct verbal instructions to the participants regarding level of abdominal muscle activation.

Elastography. An Aixplorer ultrasound scanner (Version 8.1.1, Supersonic Imagine, Aix en Provence, France), coupled with a linear transducer array (2–10 MHz; SuperLinear 10-2, Vermon, Tours, France) was used in the shear wave elastography mode (general preset) to measure shear modulus (Bercoff et al. 2004) of the four anterior trunk muscles: EO, IO, TA and rectus abdominis (RA). The ultrasound transducer was

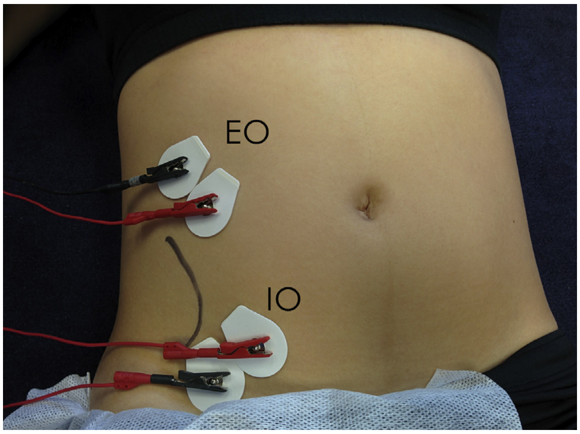

Fig. 1. Surface electromyography electrode placement for obliquus externus abdominis (EO) (top) and obliquus internus abdominis (IO) (bottom).