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Technical and measurement report

Test-retest reliability of measurements of abdominal and multifidus muscles using ultrasound imaging in adults aged 50–79 years

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A B S T R A C T

Test-retest reliability of the combined process of ultrasound imaging (USI) and image measurement of thickness of abdominal and upper lumbar multifidus (MF) muscles and MF cross sectional area (CSA) of older adults has not been established. Imaging muscles of older adults can be challenging due to age-related changes in the spine and skeletal muscle so establishing test-retest reliability in this population is important. This study aimed to evaluate test-retest reliability of USI of abdominal and MF muscle thickness and MF CSA for adults aged 50–79 years. One operator took single sets of ultrasound images of abdominal and MF muscles of 23 adults aged 50–79 years participating in a clinical trial of vitamin D supplementation for knee osteoarthritis, on two occasions, one week apart. Images were subsequently measured by a single examiner. Test-retest reliability for abdominal muscle thickness and MF CSA was substantial (intraclass correlation coefficients (ICC) > 0.81) and for MF thickness ranged from fair to substantial (ICC 0.55–0.86). The standard error of measurement (SEM) was low (0.02–0.21) in every case. ICCs were low and SEM values were high for percentage thickness change. The substantial test-retest reliability of abdominal and MF (L4-L5) muscle thickness and of MF CSA supports the use of USI as a clinical and research tool to assess abdominal and MF muscle thickness and MF CSA of older adults.
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1. Introduction

The muscles of the lumbopelvic region have a role in stability and function of the spine, locomotion and maintenance of posture and balance (Bergmark, 1989; Granacher et al., 2013). However, research on abdominal and lumbar multifidus (MF) muscles in older adults is limited (Cuellar et al., 2016).

Ultrasound imaging (USI) is used clinically and in research to assess muscle morphology. Its reliability in older adults is not yet fully ascertained. There are two key aspects of reliability, namely reliability of repeatedly measuring the same image and test-retest reliability, where the entire imaging process is repeated by the same person days or weeks apart and measurements made on the resulting sets of images (Rousson et al., 2002). Test-retest reliability is critical to clinical practice and longitudinal research where imaging is repeated to monitor patients' progress. This has greater potential for measurement error than just remeasuring the same image due to additional sources of variation, for example, from repositioning the participant and transducer and identification of landmarks (Hides et al., 2007).

The inter and intra-rater reliability of repeatedly measuring ultrasound images of abdominal and multifidus muscles has recently been reported as substantial in adults aged 65–89 years (Wilson et al., 2016), consistent with that in lateral abdominals in adults of mean age 72 years (Stetts et al., 2009). However, despite the critical importance of test-retest reliability to clinical and research practice, in older adults this has only been reported for MF thickness at the L4-L5 spinal level (Sions et al., 2014a,b) (Cuellar

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et al., 2016) and not for MF cross-sectional area (CSA) or abdominal muscle thickness. Test-retest reliability of MF thickness beyond L4-5 is important as MF morphology varies by spinal level (Hides et al., 1995) and clinical conditions such as low back pain (LBP) affect MF at levels additional to L4-5. Therefore, this study aimed to evaluate the test-retest reliability of USI for assessing abdominal and MF muscle thickness and MF CSA at the L2–L5 vertebral levels.

2. Methods

2.1. Participants

Participants were drawn from an USI sub-study on trunk muscles (n = 186) of the "Vitamin D Effect on Knee Osteoarthritis" (VIDEO) clinical trial in Tasmania (n = 261) (Jin et al., 2016). In brief, VIDEO participants aged 50–79 years, with symptomatic knee osteoarthritis for at least six months, and serum 25-(OH)D levels between 12.5 and 60 nmol/L, were recruited from the community. Twenty-three participants from the USI sub-study took part in the reliability study. The USI sub-study was approved by The Tasmania Health and Human Ethics Committee. All participants gave written informed consent. We measured each participant's height by stadiometer, weight by calibrated scales, calculated body mass index (BMI) (weight (kg)/height (m^2)) and ascertained LBP status by questionnaire asking "Do you currently have any pain in your lower back?".

2.2. Image capture and measurement

USI was performed twice, one week apart, using a Phillips HDI 5000 diagnostic ultrasound (Bothwell, WA, USA) in brightness (B) mode, with a hand held 4–7 MHz curved array transducer. All USI was conducted by a physiotherapist who undertook 36 h of practical training in USI from JAH. Single sets of images were obtained to reduce time to accommodate the USI sub-study within the clinical trial.

Transverse images of transversus abdominis (TrA), internal oblique (IO) and external oblique (EO) were obtained at rest and contracted with participants directed to "take a relaxed breath in and out, hold your breath out, and then draw in your lower abdomen without moving your spine" (Hides et al., 2007). Images were obtained along a line halfway between the lower angle of the rib cage and the iliac crest for right, then left, sides. The transducer was oriented transversely such that full vision of all muscle bellies was possible and the fascial insertion of TrA was close to the medial edge of the image with the muscle relaxed. In younger adults, the medial fascial insertion of TrA would be positioned 2 cm from the medial edge of the screen image (Hides et al., 2007), but this was not possible in these older adults due to body habitus. Transverse images of rectus abdominis (RA) were obtained at rest, for right, then left sides, with the transducer oriented transversely and placed lateral to the umbilicus until RA was centred on the screen (Rankin et al., 2006).

For MF thickness, parasagittal images were obtained on the right side at rest and on isometric contraction at L2-L3 to L5-S1 vertebral levels. For the latter, participants were instructed to take a relaxed breath in and out, hold their breath out and try to slowly "swell" and contract the muscle without moving the spine (Hides et al., 2008b). Participants lay prone with one pillow under the abdomen to reduce lumbar lordosis. L2 to L5 spinous processes were palpated, marked with a pen and then confirmed using USI (Wallwork et al., 2009). Bilateral CSA images of MF were obtained in the transverse plane at vertebral levels L2 to L5 with the muscles relaxed.

Images were stored and later measured offline by a single examiner using ImageJ software 1.36b (http://imagej.nih.gov/ij). Abdominal muscle thickness was measured as the perpendicular distance between the superior and inferior muscle fascias at approximately the middle of the image identified using the software's Cartesian coordinates (Fig. 1A and B) (Hides et al., 2007). MF CSA was measured by tracing the inner edge of the fascial boundaries (Fig. 1C) (Hides et al., 2008a) and thickness measured from the tip of the zygapophyseal joint to the inferior fascial edge of the superior border of the muscle (Fig. 1D) (Wallwork et al., 2007).

3. Statistical analysis

Percentage thickness change was calculated as 100*(thickness of muscle contracted - thickness relaxed)/thickness relaxed. Bland and Altman plots were inspected to identify any systematic patterns in the differences associated with muscle size (Bland and Altman, 1986). Intraclass correlation coefficients were calculated (ICC 3,1) (Shrout and Fleiss, 1979) and classified according to the recommendations of Shrout (Shrout, 1998) (≤0.10 = virtually none, 0.11–0.40 = slight, 0.41–0.60 = fair, 0.61–0.80 = moderate, and 0.81–1.0 = substantial). Standard error of measurement (SEM) (de Vet et al., 2006) and minimal detectable change (MDC) were also calculated. STATA 12 was used for data analysis.

4. Results

Table 1 summarises the characteristics of the reliability study participants and of the other participants in the USI sub-study of the VIDEO trial. The reliability study group included relatively more males, and women who were shorter and lighter than the other women in the USI sub-study.

Other than for the right IO when contracted (ICC 0.75), ICC values for abdominal muscles were substantial (0.87–0.98) (Tables 2 and 3). Other than for IO when contracted (difference 6.5%), the differences between measurements were relatively small (≤3.2%) and considerably smaller than their corresponding MDC values. ICCs were lower, and SEM values higher, for percentage thickness change. Reliability of measurements of right MF thickness (at rest and contracted) was fair to moderate at the L2-L3 and L3-L4 spinal levels (ICC 0.55–0.74) (Table 4) and moderate to substantial at other levels. On average, the test-retest differences were small (≤3%) and considerably smaller than the corresponding MDC. Percentage change thickness was not reliably measured. Reliability of MF CSA measures was substantial (ICC 0.84–0.91) (Table 5), with small test-retest differences that were much smaller than the MDC.

Bland and Altman plots of all muscle measurements revealed no systematic pattern of variability across the range of measurement (data not shown).

5. Discussion

This study reports test-retest reliability of USI and measurement of thickness of abdominal and MF muscles, and MF CSA (L2-L5) in adults aged 50–79 years. Importantly, we assessed test-retest reliability for muscles for which this has not previously been reported in older adults (Cuellar et al., 2016). Reliability was substantial for all measures other than thickness of IO and of MF at L2-L3 and L3-L4 spinal levels, supporting the use of USI as a reliable tool for the assessment of abdominal and MF muscle thickness and MF CSA of older adults for clinical and research purposes.

Age related changes in skeletal muscle such as increased water and fat content and fibrous tissue can increase ultrasound image echogenicity, and could reduce the reliability of muscle measurements in older adults (Stokes et al., 2005, Teyhen et al., 2007).

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