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Original article

Effects of posture and anatomical location on inter-recti distance measured using ultrasound imaging in parous women

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ABSTRACT

Study design: Cross-sectional repeated measures.
Objectives: To quantify the effects of posture and measurement site on the inter-recti distance (IRD) and investigate the reliability of IRD measurement using ultrasound imaging in different postures.
Background: The linea alba connects the rectus abdominis muscles anteriorly and the width is known as the IRD. The IRD is usually measured in crook-lying and is the primary outcome measure to assess for a divarication of recti abdominis (DRA). The effects of posture and measurement site on the IRD have not been investigated.
Methods: Ultrasound imaging was used to measure IRD in 41 women ≥8 weeks postpartum. The IRD was measured at three sites (superior-umbilicus, umbilicus and inferior-umbilicus), in three postures (crook-lying, sitting and standing), and repeated one-week later. The effects of posture and site were investigated using one-way ANOVAs. Reliability was analysed using Intraclass correlation coefficients (ICCs), Bland Altman analyses, standard error of measurement and minimal detectable change.
Results: The IRD was wider when standing vs. lying at both the superior-umbilicus and umbilicus by 0.30 cm (95% CI 0.21 to 0.39) and 0.20 cm (0.11–0.30) respectively ($p < 0.001$). Measurements at the inferior-umbilicus were, on average, 1.6 and 2.1 cm narrower than superior-umbilicus and umbilicus sites, respectively ($p < 0.001$). There was high intra-rater reliability within-session ($ICC_{3,3}$) and between-session ($ICC_{3,1}$) at all sites measured.
Conclusion: The IRD can be measured reliably at all sites and postures. The IRD is wider at superior-umbilicus and umbilicus when upright compared with lying. There is a difference in IRD between all sites measured.

1. Introduction

An increase in the width of the linea alba, known as inter-recti distance (IRD) during pregnancy is common (Boissonnault and Blaschak, 1988; Gilleard and Brown, 1996; Rett et al., 2009) and leads to divarication of the rectus abdominis muscles (DRA) and thinning of the linea alba (Axer et al., 2001). Hormonal elastic changes within the connective tissue, prolonged stretch from the growing uterus and displacement of the abdominal organs in the third trimester (Mantle et al., 2004), causes this widening of IRD and appears to be a natural consequence of pregnancy (Boissonnault and Blaschak, 1988; Mantle et al., 2004; Noble, 1985; Rett et al., 2009, 2012) There is a partial natural reduction in the IRD in the eight-weeks post-delivery for some women (Boissonnault and Blaschak, 1988; Boxer and Jones, 1997; Bursch, 1987; Coldron et al., 2008) and for 60% of women by six months postpartum, the IRD naturally reduces towards normal values (Coldron et al., 2008; Gilleard and Brown, 1996; Liaw et al., 2011; Mota et al., 2015). However, for up to 40% of parous women the IRD is still wider than normal one year post-delivery (Candido et al., 2005; Coldron et al., 2008; Liaw et al., 2011; Mota et al., 2015) and years later (Spitznagle et al., 2007). A DRA can affect the integrity of the myofascial system (Liaw et al., 2011), lead to poor posture (Boissonnault and Blaschak, 1988), abdominal muscle dysfunction (Chiarello et al., 2016), reduced lumbopelvic stability (Lee and Hodges, 2016; Sperstad et al., 2016), reduced pelvic floor support (Benjamin et al., 2014; Spitznagle et al., 2007) and a less cosmetic appearance of the abdomen (Lee and Hodges, 2016; Mota et al., 2015; Pascol et al., 2014). Rehabilitation using abdominal muscle exercises may reduce these effects in women with a DRA (Benjamin et al., 2014).

The linea alba is the central tendon of the combined aponeurosis of the lateral abdominal muscles and the sheath of the rectus abdominis (Axer et al., 2001; Standing, 2008). It runs from the xyphoid process to the pubic symphysis and its length is dependent on height and torso length. Cadaver studies report mean linea alba lengths of 26.2 cm^2 to

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29.1 cm (Rath et al., 1996) with the umbilicus positioned just over half-way down. A DRA is diagnosed when the IRD is wider than normal. (Axer et al., 2001; Rath et al., 1996), While there is no firm agreement on what is the normal IRD (Benjamin et al., 2014; Mota et al., 2015), it is commonly cited to be within normal range when the IRD is up to 15 mm at xyphoid, 22 mm at 3 cm above and 16 mm at 2 cm below umbilicus (Beer et al., 2009).

Measurement of the IRD is used to assess and monitor the DRA (Benjamin et al., 2014; Lee and Hodges, 2016; Van de Water and Benjamin, 2016). Traditionally the IRD is measured in crook-lying during a head lift, while the therapist palpates the medial borders of the rectus muscles and measures in finger-widths the distance between them at different points along the linea alba (Van de Water and Benjamin, 2016). Crook-lying enables the IRD to be measured at rest and during a head-lift. The head lift shortens rectus abdominis and approximates the medial rectus borders which reduces the IRD (Mota et al., 2015). Research suggests the reliability of palpation to measure the IRD in this position is poor-to-moderate (Bursch, 1987; Mota et al., 2013).

Abdominal muscle exercises to correct a DRA use the direction and attachment of the abdominal muscle fibres to draw the rectus muscles together and thereby reduce the linea alba width (Benjamin et al., 2014; Chiarello et al., 2016; Mota et al., 2015). There is, however, no evidence that the linea alba width itself can be reduced and current research suggests a head-lift may actually slacken or bulge the linea alba rather than shorten it (Lee and Hodges, 2016). Therefore the relevance of measuring the IRD in the non-functional position of crook-lying is questionable. Instead the measurement of the IRD in upright postures such as sitting and standing could more closely reflect the IRD in functional positions and give a more accurate picture of the changes to the IRD during dynamic abdominal muscle exercises.

The width and formation of the linea alba varies down its length from the xyphoid to pubis insertion (Axer et al., 2001; Beer et al., 2009; Rath et al., 1996). There is no consensus within the literature as to where to measure the IRD (Mota et al., 2015). Studies commonly use the umbilicus as the reference point and measure at set distances above and below (Benjamin et al., 2014; Mota et al., 2015; Noble, 1985). To date there has been no study into the selection of the measurement site on the linea alba, accounting for anatomical differences and individual torso measurements.

The aim of this study was to determine the effect of posture and anatomical measurement site on the IRD using ultrasound imaging and to investigate the reliability of measuring the IRD using ultrasound imaging in different postures.

2. Method

2.1. Participants

This cross-sectional study recruited a convenience sample from a university and a private physiotherapy practice of parous women, ≥8 weeks post-delivery who had a vaginal birth. All provided written informed consent. The sample size was based on a test of ICC; with a type I error rate of 5%, 80% power and 2 repeated measurements, and with a null hypothesis of ICC 0.7 (minimum level of acceptable reliability) and alternative hypothesis of ICC 0.85 (desired level of reliability) (Walter et al., 1998). Women were excluded if they had previous abdominal surgery including a caesarean section, current pregnancy, back or pelvic pain in the last 6-months, or an allergy to hypoallergenic gel or face paint crayon. The study was approved by the School of Health & Social Care Research Governance and Ethics committee at Teesside University (reference: 005/14).

2.2. Ultrasound imaging

Rehabilitative ultrasound imaging is used in musculoskeletal rehabilitation for the assessment of muscle morphology and architectural changes in muscles and associated structures (Costa et al., 2009; Whittaker et al., 2007, 2013). Ultrasound imaging is a reliable, valid, repeatable, non-invasive tool to measure IRD (Barbosa et al., 2013; Chiarello and Mcauley, 2013; Liaw et al., 2011; Mendes et al., 2007; Mota et al., 2012, 2013; Barbosa et al., 2013).

2.3. Instrumentation and examiner

A digital ultrasonic diagnostic imaging unit (Mindray DP50) was used, with a working frequency of 5 MHZ, and a 53-mm (75L53 EA) linear transducer. Ultrasound images of the recti abdominis were obtained in B-mode, producing two-dimensional cross-sectional grey-scale images. The lead author (SG), a women's health physiotherapist with 22 years' experience, > 12 months scanning experience, and specialist training on a British Medical Ultrasound Society endorsed program, performed all scans.

2.4. Procedures

The site of the transducer was standardised and each measurement location was marked on the skin with face crayon, with the participant in crook-lying. The transducer was placed transversely across the abdomen, along the midline at a perpendicular angle to the muscle length. Care was taken to minimise pressure through the probe so as not to distort the image. The medial borders of the rectus abdominis muscle were identified and the linea alba visualised. Still images were obtained at the end of normal expiration, to control for the influence of respiration and provide consistency (Whittaker et al., 2007). Two images were taken at three specified sites and in three postural positions.

2.4.1. Postural positions

Each of the three postural positions was standardised. In crook-lying, a pillow was placed under the head, legs were hip width apart and knees flexed at 90° (measured with a manual goniometer), with feet facing forward. Mid-pelvic alignment was established by teaching the participant to pelvic tilt. In sitting the participant sat over the edge of the plinth with feet flat on the floor, arms resting on their thighs and mid-pelvic alignment (as above). In standing the participant stood facing forwards with legs hip width apart, arms by their sides and in mid-pelvic alignment (as above). To avoid order effects there was random assignment of the postural positions using Latin squares.

2.4.2. IRD measurement sites

The measurement sites were located by; palpating the xyphoid and superior pubis bony landmark in line with the umbilicus and then measuring the distance from the umbilicus to the bony landmarks using a flexible measuring tape. An 8 cm horizontal line was made with a ridged ruler, to enable alignment of the transducer. The three sites were: a) superior-umbilicus located a third of the distance between the xyphoid and umbilicus; b) just superior to the umbilicus; and c) inferior-umbilicus half-way between the umbilicus and the pubis. All sites were scanned in the three postures detailed above. All scans were repeated twice within-session and repeated on a separate day at the same time of day, to try to minimise differences in activities of daily living and food intake on the separate days.

2.4.3. Data processing

The ultrasound images were downloaded, converted into JPEG files and measured offline by SG, using bespoke Matlab image-processing software (version 7.1) following a similar procedure to that of Mota et al. (2012). The inner borders of the left then right rectus abdominis muscles were traced (Whittaker and Stokes, 2011), a 4th order polynomial regression fit through the traced points was then used to determine the muscle border (Fig. 1). The IRD was defined as the transverse linear distance between the most medial points of the borders of