Investigation of transabdominal real-time ultrasound to visualise the muscles of the pelvic floor

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Margaret Sherburn
University of Melbourne

Trevor J Allen
Monash University (Australia)

Mary Galea
University of Melbourne

Investigation of transabdominal real-time ultrasound to visualise the muscles of the pelvic floor

Margaret Sherburn[1], Claire A Murphy[1], Sara Carroll[2], Trevor J Allen[3] and Mary P Galea[1]

[1]Rehabilitation Sciences Research Centre, The University of Melbourne [2]Curtin University of Technology [3]Department of Physiology, Monash University

Clinical measurement of pelvic floor muscle activity commonly involves techniques that are both physically and psychologically invasive. This study investigated transabdominal application of ultrasound to measure pelvic floor muscle action. The specific aims were to establish the face validity of ultrasound measures of displacement of the posterior bladder wall as a reflection of pelvic floor muscle contraction, and the reliability of measurement between raters and between testing occasions. Non-pregnant adult female subjects aged 24 to 57 years were tested in lying with a 3.5 MHz 35 mm curved array ultrasound transducer over the lower abdomen. Posterior bladder wall displacement was observed in both sagittal and transverse planes. Digital vaginal palpation and transabdominal ultrasound were undertaken simultaneously during pelvic floor muscle contractions to confirm that pelvic floor contractions were performed correctly and to grade pelvic floor muscle strength. Displacement (mm) was measured using electronic calipers on the ultrasound monitor screen. In all subjects, a correct pelvic floor muscle contraction was confirmed on digital palpation, and consistent anterior and cephalic movement was observed on screen. Digital strength grading did not correlate with ultrasound measures in either transverse or sagittal planes (r = 0.21 and -0.13). Average intra-class correlation coefficients for within session inter-rater reliability ranged between 0.86 and 0.88 (95% CI 0.68 to 0.97), and for inter session intra-rater reliability between 0.81 and 0.89 (95% CI 0.51 to 0.96). Transabdominal application of diagnostic ultrasound is a personally non-invasive method for imaging and assessing pelvic floor muscle activity and is both valid and reliable. **[Sherburn M, Murphy CA, Carroll S, Allen TJ and Galea MP (2005): Investigation of transabdominal real-time ultrasound to visualise the muscles of the pelvic floor. *Australian Journal of Physiotherapy* 51: 167–170]**

Key words: Real-time ultrasound, Transabdominal ultrasound, Pelvic floor muscles, Reliability, Validity

Introduction

Physiotherapists currently use a variety of measurement tools to assess and treat pelvic floor muscle function. Digital muscle palpation performed vaginally or per rectum, is considered the ‘gold standard’ (Peschers et al 1998). Generally, it is used in combination with a muscle strength grading scale (Laycock 1994), although evidence does not support it as a reliable tool particularly between testers (Bø and Talseth 1996). A consistent problem with perineometry is the potential of false-positive measurements as a result of trick manoeuvres (Bump et al 1996, Peschers et al 1998, Morkved and Bø 1997).

The application of diagnostic ultrasound for imaging the pelvic organs and structures is not new, however a transabdominal approach has not yet been evaluated in relation to pelvic floor muscle function. Dietz et al (1998) used ultrasound to visualise pelvic floor muscle activation via trans-perineal application. However, to our knowledge no study has investigated the personally non-invasive (i.e. neither internal nor perineal) application of ultrasound to examine or measure the activity of pelvic floor muscles.

The specific aim of this study was to establish the validity and reliability of transabdominal ultrasound image-derived measures of bladder wall displacement as a reflection of pelvic floor muscle action in sagittal and transverse plane imaging.

Method

Subjects Thirty non-pregnant females, 10 for the validity study (age 26 to 54, mean 41.8, SD 11.0), and 20 for the reliability study (age 24 to 57, mean 39.3 SD 10.4), were recruited via newsletter advertising. No exclusions were made on the basis of any medical or surgical history. Parity was similar for both groups (6 of 10 and 11 of 20) and all nulliparous women were pre-menopausal. Continence physiotherapists were recruited as subjects for the validity study due to the invasive nature of the digital palpation used to assess and grade correct pelvic floor muscle contractions. The University of Melbourne Human Research Ethics Committee (HREC) granted approval for the project.

Procedure An Acoustic Imaging Performa[a] ultrasound unit with a 3.5 MHz 35 mm curved array transducer was used for these studies. The transducer frequency was selected to achieve sufficient depth of the ultrasound signal to reach the pelvic fascia while still obtaining good image resolution. A bladder filling protocol was implemented to ensure subjects had sufficient fluid in their bladders to allow clear imaging of the pelvic floor fascia. This protocol, modified from World Health Organisation Guidelines (Palmer 1995), involved subjects consuming 600–750 ml of water in a one-hour period, completed half an hour prior to testing, without voiding during this period.

Subjects were tested in supine lying with hips flexed

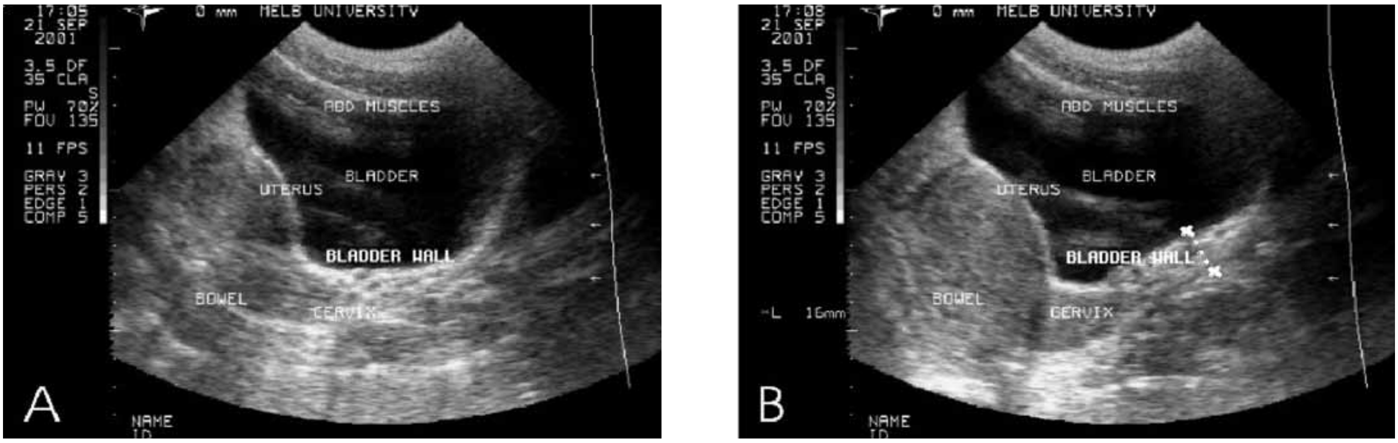

Figure 1. Ultrasound images of pelvic floor at rest (A) and at maximum contraction (B).

comfortably and head supported with pillows, observing the ultrasound screen if they chose. The ultrasound transducer was applied to the lower abdomen in the mid-line. Subjects performed a series of pelvic floor muscle contractions prior to recording to ensure correct technique and for appropriate placement and angulation of the ultrasound transducer. The clearest bladder wall displacement during a pelvic floor muscle contraction was observed when the angle from the vertical in a cephalic direction was between 15 and 30 degrees.

After this initial practice, subjects performed three maximal pelvic floor muscle contractions so that displacement of the posterior bladder wall, as a result of a pelvic floor muscle contraction, could be measured. A clearly defined edge, at the point of greatest observed displacement clearly visible throughout the movement, was selected for measurement. The position of this point at rest was marked electronically with an ‘X’. The subject then performed a maximum voluntary pelvic floor muscle contraction and the image was captured at the moment of maximum displacement. At this time the subject relaxed the pelvic floor muscles. The investigator then measured the displacement to its current position in the stilled image (Fig. 1) and was blinded to the measurement value until after the calliper had been fixed at the end point. The ultrasound transducer was not moved during the procedure to ensure the field of vision remained constant between rest and maximal contraction. The mean of three measurements in each plane by a single investigator was used for statistical analysis for each study.

Validation study A digital vaginal examination, the standard Australian clinical practice, was considered the most appropriate outcome measure for validation of pelvic floor muscle contraction using transabdominal ultrasound. An experienced investigator performed the digital examination, noted any fascial or relevant anatomical pathology, and confirmed whether correct muscle activation occurred when the subject performed three pelvic floor muscle contractions. Simultaneously, the second investigator observed the displacement occurring on ultrasound during the muscle contractions.

In addition, the first investigator also graded pelvic floor muscle strength according to the modified Oxford method (Laycock 1994). Ultrasound displacement of pelvic floor muscle contraction was measured in separate trials immediately following the digital strength grading, as distortion of the tissues occurred during digital examination. The two investigators remained blind to each other’s assessment of pelvic floor muscle activation during the testing process.

Reliability study Subjects were tested on two occasions up to five days apart. The investigators and planes of imaging were both randomised to avoid order effects. Subjects performed a series of three maximum voluntary pelvic floor muscle contractions for both sagittal and transverse plane measurements with each tester.

Immediately after testing, subjects voided into a collection unit fitted under the toilet seat, and measured the voided bladder volume to the nearest 25 ml. Another ultrasound scan was used to test for residual bladder volume.

Data management Reliability was analysed using the intraclass correlation coefficient (ICC, model 1,3 for intra-rater reliability and model 2,3 for inter-rater reliability) and 95% confidence intervals (CI). In addition, consistency of repeated responses over time was measured and expressed as the standard error of measurement (SEM).

Results

Validity study In all ten subjects, a correct pelvic floor muscle contraction was confirmed on digital palpation, and the movement observed on ultrasound imaging was consistent between subjects. In the sagittal plane view, a correctly performed pelvic floor muscle contraction resulted in posterior bladder wall displacement in an anterocephalic direction, incorporating a vertical and horizontal component on the monitor. Horizontal displacement reflected movement in a cephalic direction (the ‘lift’ component of pelvic floor muscle contraction). Vertical displacement was indicative of the anterior draw of the pelvic floor muscles, toward the pubic symphysis. The direction of displacement was in agreement with the direction of movement palpated by the first investigator.

In the transverse plane, a correct pelvic floor muscle contraction confirmed by digital palpation was characterised

Table 1. Intra-rater and inter-rater ICC values and SEM (n = 20).

Intra-rater reliability	Sagittal plane		Transverse plane	
	Session 1	Session 2	Session 1	Session 2 (n = 19)
Mean displacement (mm)	9.31	8.96	8.43	7.51
SEM (mm)	0.22	0.57	0.28	0.44
SEM as % of mean	2.34	6.38	3.20	5.79
ICC (95% CI)	0.89 (0.72 to 0.96)	0.84 (0.61 to 0.94)	0.85 (0.62 to 0.94)	0.81 (0.51 to 0.93)

Inter-rater reliability	Sagittal plane		Transverse plane	
	Rater 1	Rater 2	Rater 1	Rater 2 (n = 19)
Mean displacement (mm)	9.89	10.33	8.53	8.70
SEM (mm)	0.22	0.46	0.10	0.42
SEM as % of mean	2.18	4.42	1.14	4.78
ICC (95% CI)	0.88 (0.73 to 0.95)	0.86 (0.81 to 0.97)	0.87 (0.69 to 0.95)	0.86 (0.68 to 0.95)

by displacement in a vertical direction on the monitor, representing predominantly a cephalic direction of pelvic floor muscle movement. The anterior draw was not evident in this plane as the displacement was more perpendicular to the direction of the ultrasound waves.

For further confirmation, subjects were also requested to perform the manoeuvre of bearing down. Caudal fascial displacement was observed in both planes of view, clearly distinguishable from images obtained during a pelvic floor muscle contraction. Contraction of the gluteal muscles resulted in a displacement image similar to that of a correct pelvic floor muscle contraction; however the movement associated with this contraction and any other hip muscle recruitment was immediately obvious to the investigator.

A Pearson correlation coefficient, calculated to investigate the relationship between displacement measures taken in the sagittal and transverse planes, was 0.38, indicating a weak relationship. Spearman correlation coefficients indicate that there is no relationship between displacement in the sagittal ($r = -0.13$) or the transverse planes ($r = 0.21$) and manually graded muscle strength.

Reliability study Average measure ICC values with 95% CI and the standard error of the measurement were calculated within investigator and between investigators in both planes (Table 1).

These ICCs indicate good agreement for a single investigator between measurement occasions and good agreement between investigators during the same measurement occasion. The standard errors of measurement are low and represent a small percentage of total displacement.

Bladder volumes ranged between 100 ml and 800 ml at each testing occasion, mean volume at Test 1 being 499 ml, and at Test 2, 505 ml. No subject recorded any residual volume after voiding.

Discussion

Validity of transabdominal ultrasound We have shown that displacement of the bladder wall observed using ultrasound imaging, reflects pelvic floor muscle action. Real-time ultrasound can immediately confirm whether the correct muscle action has been performed. Corroboration via digital palpation may therefore not be necessary in determining correct pelvic floor muscle action. Peschers et al (1998) and Bø and Finckenhagen (2001) stated that digital palpation was the only way to ensure a correct pelvic floor muscle contraction was being performed and remained the gold standard. Digital examination is important for palpating components of pelvic floor dysfunction, such as muscle defects, tone, or pain, but it is not the only method to assess pelvic floor muscle action.

This study clearly demonstrated that the displacement observed with a correct pelvic floor muscle contraction was easily identifiable and distinguishable from incorrect technique. The direction of displacement of the bladder wall as a result of a pelvic floor muscle contraction is corroborated by the findings of Dietz et al (1998), Dietz et al (2002), Reddy et al (2001) and Thompson et al (2003), although the different applications of ultrasound (perineal versus transabdominal) result in a different direction of displacement when viewed on the monitor.

There was, however, poor agreement between displacement measures in the sagittal and transverse planes. This suggests that displacement measures in the two planes reflect different vector components of a pelvic floor muscle contraction. The poor agreement between displacement values (in either plane) and manually graded muscle strength suggest that these measures, too, reflect different aspects of pelvic floor muscle action. This interpretation is in agreement with the findings of Dietz et al (2002) who compared perineal ultrasound-derived measures, strength grading and perineometry (vaginal squeeze pressure) and found moderate correlation values between all three measures. The ultrasound-derived bladder wall displacement measured in this study and that of Dietz et al (2002) is a reflection of the lift and anterior draw action of the pelvic floor muscles, but does not measure the occlusive/squeeze component of their function. However, there is neither published nor clinical evidence to suggest that there is a single tool available to fully assess the function of the pelvic floor muscles.

Reliability of transabdominal ultrasound The ICC values indicate that the between-session intra-rater reliability and within-session inter-rater reliability were very similar. Reliability was generally better in the sagittal than in the transverse plane. However, the standard error of measurement indicated that there was as much variability due to the operator as the plane of measurement. Errors in the transverse plane of imaging may be due to the variation in angulation of the transducer due to different abdominal contours. The sagittal plane was prone to variation if the transducer was not directly in the midline, correctable by aligning the transducer with the navel and pubic symphysis.

Subjects were tested at about the same time of day, following the same filling protocol, yet could have quite different bladder volumes on the two test occasions, indicating that bladder volume itself did not influence the displacement measures. Hence a strict bladder filling protocol may not be necessary.

Limitation of transabdominal ultrasound Ultrasound imaging to measure displacement of the bladder neck (Dietz et al 1998, Reddy et al 2001) uses a fixed starting point for measurement, the pubic symphysis. However, using transabdominal ultrasound there is no bony landmark within view, meaning that pelvic floor displacement can only be expressed relative to a potentially mobile starting point. This may be a problem in establishing normative displacement values.

Conclusion

Transabdominal application of diagnostic ultrasound to assess pelvic floor muscle function is valid and reliable, and personally non-invasive. An objective assessment of pelvic floor muscle activity where an invasive procedure is inappropriate has not been possible previously.

Footnotes [a]Dornier Medtech, USA

Correspondence Margaret Sherburn, School of Physiotherapy, The University of Melbourne. Email: m.sherburn@unimelb.edu.au

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