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Test-Retest and Intrarater Reliability of 2-Dimensional Ultrasound Measurements of Distance Between Rectus Abdominis in Women

Diastasis recti abdominis (DRA) has been defined as an impairment characterized by a midline separation of the 2 rectus abdominis (RA) muscles along the linea alba (LA).[22,27] This increased interrectus distance (IRD) has its onset during pregnancy, immediately after birth, or in the first weeks following childbirth.[5,13]

As the fetus grows, the 2 muscle bellies of the RA, connected by the LA, elongate and curve as the abdominal wall expands, and separation of the 2 muscle bellies with protrusion of the umbilicus may occur.[5,14,15] Studies have found that DRA may affect between 30% and 70% of pregnant women[5] and may remain separated in the immediate postpartum period in 34.9%[9] to 60% of women.[5-7] However, the condition has also been found in 38.7% of older, parous women undergoing abdominal hysterectomy[25] and in 52% of urogynecological menopausal patients.[27]

Reported prevalence of DRA or increased IRD may be inaccurate due to unreliable methods of measuring the condition, with the most common assessment method being palpation[5,7,20,22] and calipers.[6,17] Ultrasound imaging has recently been suggested as a useful method to assess muscular geometry and as an indirect measure of muscle activation via changes in muscle thickness.[24] Coldron et al[10] used ultrasound to characterize RA changes during the first year postpartum, and de Almeida Mendes et al[12] claimed ultrasonography to be an accurate method to measure DRA above and at the umbilicus when compared with surgical compass during abdominoplasty. However, a search of the literature did not reveal studies address-

STUDY DESIGN: Single-group test-retest reliability study.

OBJECTIVES: To evaluate the test-retest intraobserver reliability of 2-dimensional ultrasound measurement of the distance between the rectus abdominis muscles, the interrectus distance (IRD).

BACKGROUND: Diastasis recti is defined as the separation of the 2 rectus abdominis muscles, with a reported prevalence of between 30% and 70% in women during pregnancy and in the postpartum period. The condition is difficult to measure, and ultrasound imaging has been suggested as a useful method to quantify the diastasis. However, to date, no studies have investigated intratester or intertester reliability of ultrasound to measure the distance between the rectus abdominis muscles during rest and contraction.

METHODS: Ultrasound images from the rectus abdominis were recorded in 24 healthy female volunteers at rest and under 2 conditions of abdominal contraction: abdominal crunch and drawing-in exercises. The probe was positioned at 2 locations: below and above the umbilicus. A blinded investigator measured the IRD offline from 2 different ultrasound images collected on 2 different days (test-retest). Additionally, reanalyses of the same ultrasound images were done on 2 separate occasions (intra-image).

RESULTS: Test-retest measurements of IRD demonstrated good to very good reliability, with intraclass correlation coefficient values between 0.74 and 0.90. The only exception was for IRD measured 2 cm below the umbilicus during the abdominal crunch exercise, which had an intraclass correlation coefficient of 0.50. For intratester reliability of the same images, the intraclass correlation coefficient values were all above 0.90.

CONCLUSION: Ultrasound imaging is a reliable method for measuring the IRD at rest and during abdominal crunch and drawing-in exercises.
J Orthop Sports Phys Ther 2012;42(11):940-946, Epub 18 July 2012. doi:10.2519/jospt.2012.4115

KEY WORDS: *diastasis, postpartum, reliability, ultrasonography*

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This study is part of the research project "Effects of Biomechanical Loading on the Musculoskeletal System in Women During Pregnancy and the Postpartum Period" (PTDC/DES/102058/2008), supported by the Portuguese Foundation for Science and Technology. This study was also supported by the International Society of Biomechanics Dissertation Grant. This study was approved by the Review Board of the Technical University of Lisbon, Faculty of Human Kinetics, Lisbon, Portugal.
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TABLE 1 Background Variables*

Variables	All Subjects (n = 24)	Postpartum (n = 12)	Different Parity (n = 12)
Age, y	30.54 (16-55)	31.17 (26-36)	29.92 (16-55)
Body mass index, kg/m^2	22.71 (18.90-28.51)	23.96 (20.76-28.51	21.46 (18.90-24.61)
Parity (births), n	0.75 (0-2)	1.0 (0-2)	0.5 (0-2)
Length of time since last pregnancy		10.91 wk (9-13)	11.5 y (1-24)
College/university education, n	20	12	8

Values are mean (range), except for college/university education.

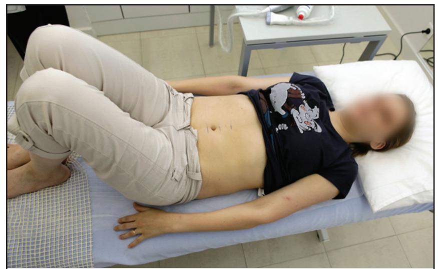

FIGURE 1. Rest position, start position, and end position of drawing-in exercise.

FIGURE 2. Abdominal crunch exercise.

ing the intratester or intertester reliability of the ultrasound measurement of the IRD at rest or during abdominal muscle contraction. Across-day reliability may be of interest to physiotherapists who perform repeated assessments of abdominal muscle function over time,[16] and factors such as relocation of the original imaging site and reproduction of the same transducer pressure and orientation, as well as maintenance of these factors during muscle contraction, could adversely affect reliability.[16]

The aims of the present study were to evaluate test-retest and intrarater reliability of 2-dimensional ultrasound imaging of the IRD at rest and during abdominal crunch and drawing-in exercises, and to verify the differences in IRD related to the postpartum condition.

METHODS

Design

This was a test-retest study evaluating the intrarater reliability of IRD measurements. For the test-retest analysis, 2 test sessions were performed. In addition, the images collected during session 1 were analyzed a second time by the same investigator.

Participants

Twenty-four healthy female volunteers participated in this study. Twelve of the women were in the postpartum period and were recruited from a private physiotherapy clinic, and the others were among colleagues, friends, and family. Demographic data with respect to age, body mass index, and parity are presented in **TABLE 1**. The participants were eligible for the study if they agreed to participate in 2 testing sessions and were able to perform 2 different abdominal exercises. To ensure external validity, 12 women in the postpartum period (less than 6 months) and 12 women with different parity (range, 0-2 births) were included in the study. Pregnant women were excluded from the present study.

The study was approved by the Review Board of the Technical University of Lisbon, Faculty of Human Kinetics. Signed informed consent was obtained before participation in this study, and the rights of the participants were provided in verbal and written form.

Instrumentation and Procedures

An ultrasound scanner (LOGIQ e; GE Healthcare, Waukesha, WI) with a 4- to 12-MHz, 39-mm linear transducer was used to collect images in brightness mode (B-mode) by the same examiner. The investigator was a physiotherapist with specific training in image capturing and measuring IRD. Before starting the study, the ultrasound protocol and analysis were discussed and practiced with an experienced radiologist.

The transducer was placed transversely along the midline of the abdomen in 2 locations, 2 cm above and 2 cm below the center of the umbilicus. Initially, each measurement location was marked on the skin to standardize the position of the transducer. Ink marks were drawn with the subject in the supine resting position, with knees bent at 90° and feet resting on the plinth, and arms alongside the body (**FIGURE 1**).

During image acquisition, the bottom edge of the transducer was positioned to coincide with the correspondent skin marker and moved laterally until the medial borders of both RA muscles were visualized. The orientation of the transducer was then adjusted to optimize visualization of the image. Images were collected immediately at the end of exhalation, as determined by visual inspection of the abdomen, following the procedures recommended by Teyhen et al.[29] Additionally, particular attention was paid to the pressure imposed on the probe to avoid reflexive response from the participants.

Still images were obtained with subjects in the supine resting position (knees bent at 90° and feet resting on the plinth, arms alongside the body) and during 2 abdominal-contraction conditions: the abdominal crunch (**FIGURE 2**) and the drawing-in (**FIGURE 1**) exercises. One image was taken at each location under each condition. The abdominal crunch exercise was started from the resting position and the subjects were instructed to raise their head and shoulders upward until their shoulder blades cleared the table.

TABLE 2	Verbal Instructions for Exercises Performed
Rest/start position	Flex your knees; keep your feet on the plinth. With your hands, push your knees up to your chest and then let them go down until your feet reach the plinth again. Arms along your body and breathe normally.
Abdominal crunch	Inhale and exhale. Lift your head and slide your hands along the front of your thighs to touch your knees with the fingertips, until you feel your shoulder blades off the table. Hold there for 3 seconds.
Drawing in	Inhale and exhale. Pull your belly button in and back toward the spine. Do not move your pelvis. Hold there for 3 seconds.

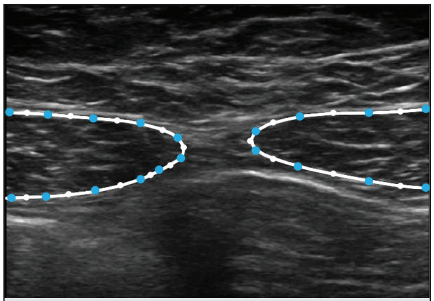

FIGURE 3. Rectus abdominis ultrasound image. Points digitized by the examiner on the muscle contour (blue dots).

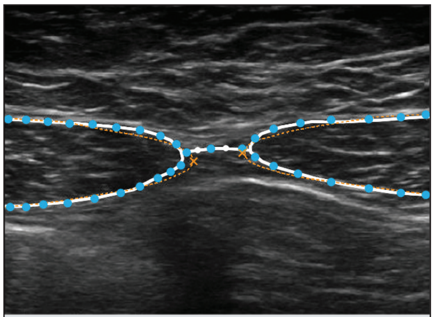

FIGURE 4. Rectus abdominis ultrasound image. Interpolated points using an algorithm according to a parabola-like curve (orange points). The parabola inflection point (orange Xs) suggests the end points for interrectus distance measurement on the medial margin of both rectus abdominis muscles.

Subjects held this position until they were told to return to the starting position. The drawing-in exercise also started from the resting position. The subjects were instructed to inhale and, after exhaling, to draw in the abdominal musculature toward the spine. Before starting the procedure, the subjects were verbally instructed in the correct performance of the 2 exercises. The verbal instructions are provided in **TABLE 2**. During the drawing-in maneuver, activation of the transversus abdominis muscle was confirmed by placing the transducer laterally between the iliac crest and rib cage.[28] Each contraction was held for 3 seconds for data collection, with a resting time of 6 to 10 seconds between repetitions. After the test, a convenient day for retesting was scheduled with the participants.

A set of 12 images per subject from each of the 3 conditions (rest, abdominal crunch, and drawing in) from 2 locations (2 cm above and 2 cm below the umbilicus) on 2 days was exported into jpeg format for further offline processing. Reliability was analyzed on IRD measurements during session 1 (intra-image reliability) and between sessions (test-retest reliability). The investigator was blinded to the subjects' identification and to the values of the IRD measurements.

IRD Measurement Analyses of 2-dimensional ultrasound distances were conducted offline by the same investigator, using a customized code made on MATLAB image-processing software (The MathWorks, Inc, Natick, MA). Ultrasound images were assumed as a pixel-based coordinate system, with the origin in the top left-hand corner of the image. In this system, x and y coordinates can be used to locate a point in the image, and the distance between 2 or more points can be calculated. On ultrasound images, the IRD is characterized by the transverse linear distance from the medial border of the RA on one side to the corresponding position of its counterpart on the other side. Using this procedure, 2 points, corresponding to the medial muscular insertion sites of both RA muscles on the LA, are identified on the ultrasound images. From our observations, these points are close to the inflection point of a parabola-like curve that can be assumed for the ultrasound image of each RA muscle contour (**FIGURE 3**). To improve the accuracy of the identification of these 2 points, an algorithm was developed and implemented using a customized MATLAB code. Thus, the first step in the algorithm was to interpolate a set of 8 to 10 points, manually digitized by the examiner on the visible contour of both muscle bellies, and to fit them to a parabola-like curve. Using the coordinates of the digitized points, a fourth-order polynomial equation was fitted to determine the coefficient of the polynomial and the inflexion point of the interpolated curve. The discrete derivative of the interpolated x coordinate and the point at which the sign changed were considered the parabola point of inflexion (**FIGURE 4**, orange exes). The determined inflection point and the interpolated parabola curve were overlapped on the original ultrasound image to guide the examiner in the identification of the medial margins of the RA and to improve the accuracy of IRD measurements. Though the location of the medial margins of the RA muscles was suggested by the software, the examiner had the final decision regarding that used on the IRD measurements.

Statistical Analysis

The intraclass correlation coefficient ($ICC_{1,1}$) for the 1-way random-effects model was used to assess the level of consistency across the 2 IRD measurements on 2 different ultrasound images and on the 2 different days (test-retest), and across the 2 IRD measurements made on the same ultrasound image (intra-image). The scale from Altman[1] was used in the classification of the reliability values. ICC values less than or equal to 0.20 were considered poor, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, 0.61 to 0.80 good, and 0.81 to 1.00 very good. Standard error of measurement (SEM) was used to exam-

TABLE 3 IRD Measures During Rest, and Abdominal Crunch and Drawing-in Exercises (n = 24)*

Condition/Probe Location	IRD Test 1A	IRD Test 1B	IRD Test 2
Rest			
2 cm above	17.44 ± 7.34	17.51 ± 7.51	18.93 ± 7.88
2 cm below	8.01 ± 4.82	7.54 ± 4.98	8.35 ± 4.80
Abdominal crunch			
2 cm above	16.99 ± 6.75	17.01 ± 6.03	18.45 ± 6.07
2 cm below	9.22 ± 6.66	9.37 ± 6.81	7.93 ± 5.49
Drawing in			
2 cm above	19.38 ± 7.57	19.11 ± 7.62	19.51 ± 7.58
2 cm below	9.91 ± 6.54	9.90 ± 6.61	9.44 ± 5.87

Abbreviation: IRD, interrectus distance.
**Values are mean ± SD mm for each dependent measure, based on condition (rest, abdominal crunch, and drawing in) and site (2 cm above and below the umbilicus). Tests 1A and 1B represent the measurements made on different days on the same stored image. Test 2 represents the measurements made on a different image collected across days.*

TABLE 4 Interrectus Distance Measures During Rest, Abdominal Crunch, and Drawing-in Exercises in Women Postpartum and Women With Different Parity

Condition/Probe Location	Postpartum (n = 12)*	Different Parity (n = 12)*	Mean Difference†	t Test‡
Rest				
2 cm above	18.26 ± 7.59	16.62 ± 7.31	–1.64 (–7.95, 4.67)	0.595
2 cm below	8.87 ± 4.92	7.15 ± 4.77	–1.72 (–5.82, 2.38)	0.394
Abdominal crunch				
2 cm above	19.55 ± 7.00	14.44 ± 5.64	–5.12 (–10.50, 0.27)	0.061
2 cm below	7.49 ± 5.33	10.93 ± 7.60	3.45 (–2.12, 9.01)	0.212
Drawing in				
2 cm above	22.32 ± 8.05	16.43 ± 6.01	–5.89 (–11.90, 0.12)	0.055
2 cm below	11.16 ± 7.50	8.87 ± 5.46	–2.49 (–8.05, 3.06)	0.363

**Values are mean ± SD mm for each dependent measure, based on condition (rest, abdominal crunch, and drawing in) and site (2 cm above and below the umbilicus) during test 1.*
†Values are mean (95% confidence interval) difference between groups.
‡There is no significant difference in interrectus distance between groups (P<.05).

ine the precision of measurement and was calculated as pooled SD × $\sqrt{1 - \text{ICC}}$. To represent a difference in IRD beyond measurement error, the minimal detectable change (MDC) was calculated as 1.96 × SEM × $\sqrt{2}$.[23] These analyses were performed for each of the outcome variables: IRD during rest, the abdominal crunch, and the drawing-in exercise, and 2 cm above and 2 cm below the umbilicus.

The Bland-Altman[4] plot of difference against the mean was also used to compare the limits of agreement and mean bias between plots. The standard deviation of the differences between test and retest was calculated, then multiplied by 1.96 to obtain the 95% random error component.[2] To verify the differences in IRD related to the postpartum condition, the 12 postpartum women were compared to the women with different parity using an independent *t* test. All statistical analyses were made using SPSS Version 19 (SPSS Inc, Chicago, IL), and a critical level of $P<.05$ was considered statistically significant.

RESULTS

All participants returned for the second test after a mean ± SD of 3.9 ± 3.9 days (range, 1-16 days), and all reported that they complied with the request not to practice any of the exercises between tests. There were no dropouts. The IRD values for each measurement are shown in **TABLE 3**. No significant differences were found in the IRD between women in postpartum and the women with different parity (**TABLE 4**). In general, the smallest IRD values were from the abdominal crunch exercise, and the greatest were from the drawing-in exercise.

Intratester Reliability of the Ultrasound Analyses (Intra-image)

The ICC values for the IRD measured on the same image at 2 different occasions revealed very good reliability for every condition tested (**TABLE 5**). The rest condition demonstrated less variability than the measurements conducted during the abdominal crunch and drawing-in exercises, but the ICC values were all above 0.90. The precision of repeated measurements of the same images was higher (revealed by lower SEMs) compared with recaptured images. The MDC values ranged from 1.80 to 5.52 mm. The Bland-Altman plot (**FIGURE 5**) showed that the mean of the differences in IRD on test-retest (0.052 mm) was closer to 0 mm, and the limits of agreement were narrower compared to the values found on different images (–1.95 and 2.05 mm).

Test-Retest Across Days (Interimage)

The ICC values for the IRD during the rest condition demonstrated good reliability at 2 cm below the umbilicus, with an ICC of 0.78 (95% confidence interval [CI]: 0.56, 0.90), and very good reliability at 2 cm above the umbilicus, with an

TABLE 5 Intrarater Reliability Across Repeated Measurement of the Same Image

Condition/Probe Location	$ICC_{1,1}$ Intra-image*	SEM, mm	MDC_{95}, mm
Rest			
2 cm above	0.98 (0.95, 1.00)	1.04	2.88
2 cm below	0.96 (0.90, 0.98)	0.97	2.69
Abdominal crunch			
2 cm above	0.94 (0.88, 0.98)	1.55	4.29
2 cm below	0.97 (0.93, 1.00)	1.15	3.20
Drawing in			
2 cm above	0.93 (0.85, 0.97)	1.99	5.52
2 cm below	0.99 (0.97, 1.00)	0.65	1.80

Abbreviations: $ICC_{1,1}$, intraclass correlation coefficient 1-way random-effects model; MDC_{95}, minimal detectable change at the 95% confidence level; SEM, standard error of measurement.
**Values are mean (95% confidence interval).*

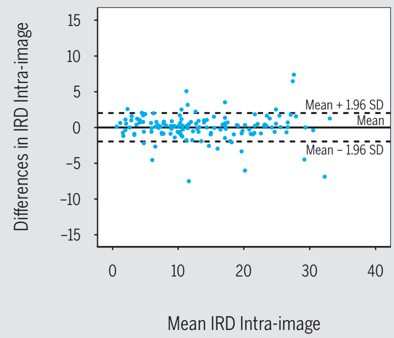

FIGURE 5. Plot of difference against mean (in millimeters) for measurements of the same stored images, with mean difference and 95% limits of agreement indicated.

ICC of 0.87 (95% CI: 0.73, 0.94) (**TABLE 6**). The IRD for the rest condition demonstrated higher ICC values than the measurements from the abdominal crunch, which showed very good reliability above the umbilicus, with an ICC of 0.83 (95% CI: 0.65, 0.92), but moderate reliability below the umbilicus, with an ICC of 0.50 (95% CI: 0.14, 0.75). For the drawing-in exercise, the ICC value was very good at 2 cm above the umbilicus (0.90; 95% CI: 0.79, 0.96) and good 2 cm below the umbilicus (0.74; 95% CI: 0.48, 0.88) (**TABLE 6**). SEM values were very similar across all conditions, but 2 cm below the umbilicus during the drawing-in and abdominal crunch exercises they showed higher variability, with values of 3.15 and 4.36 mm, respectively. The MDC values ranged from 6.32 to 12.08 mm. The Bland-Altman plot showed that the mean of differences in IRD on test-retest was −0.33 mm, and that the limits of agreement were between −8.67 and 8.34 mm (**FIGURE 6**).

DISCUSSION

The present study demonstrated very good reliability for the intratester measurements in the same image for all the conditions tested, with ICC values above 0.90 and low SEM (range, 0.65-1.99) and MDC (range, 1.80-4.29) values. These results are in line with the values found by Liaw et al.[19] The test-retest measurements across days showed good reliability during rest and the drawing-in exercise below the umbilicus, with ICC values of 0.78 and 0.74, respectively, and very good reliability during rest, the abdominal crunch exercise, and the drawing-in exercise above the umbilicus, with ICC values of 0.87, 0.83, and 0.90, respectively. The lowest ICC value (0.50) was found below the umbilicus during contraction, with moderate reliability for the abdominal crunch exercise. The higher values for the SEM (range, 2.28-4.36 mm) and the MDC (range, 6.32-12.08 mm) revealed lower precision of the IRD measurements.

The lower values found below the umbilicus may be explained by the influence of the amount of subcutaneous fat[19] in this location. This could have interfered with the determination of where to mark the skin, the positioning of the probe, and the ability to maintain a constant pressure during image acquisition. During the abdominal crunch exercise, the participants had to move the upper body, and this might have induced movements under the transducer. Nevertheless, the ICC was moderate to good.

In general, there were several potential sources of measurement errors: the subjects, the testing, the scoring, the instrumentation, and factors such as the instructions from the examiner and participant motivation. The participants' skill and motor control might also have affected performance on different days.[18] To mitigate some of these potential sources of errors, the position of the subject, the examiner's instructions, the transducer location and its inclination, the pressure applied to the transducer on the abdominal wall, and the room temperature were standardized.

Criteria for the diagnosis of DRA vary in the literature.[3,5,7,8,15,25-27] Beer et al[3] suggest that in nulliparous women, the LA could be considered "normal" when the width is less than 1.5 cm at the xiphoid level, 2.2 cm at 3 cm above the umbilicus, and 0.6 cm at 2 cm below the umbilicus. In our study, we found higher mean values for IRD at 2 cm below the umbilicus in 12 subjects. An explanation for this difference is that we also included parous women, who are expected to have wider or greater IRD.[5,10,15,20] However, no significant differences were found in the IRD between women in postpartum and women with different parity.

In studies of postpartum women, DRA has been defined as the LA having a width greater than 2 finger breadths (1.5 cm) when measured with palpation,[5,15,27] or 2 cm when measured with a dial caliper at or above the umbilicus during a partial sit-up.[19] However, the inaccuracy and possible low reliability of these measurement tools are possible limitations of

TABLE 6 Intrarater Reliability Across 2 Days

Condition/Probe Location	$ICC_{1,1}$ Interimage*	SEM, mm	MDC_{95}, mm
Rest			
2 cm above	0.87 (0.73, 0.94)	2.75	7.63
2 cm below	0.78 (0.56, 0.90)	2.28	6.32
Abdominal crunch			
2 cm above	0.83 (0.65, 0.92)	2.48	6.89
2 cm below	0.50 (0.14, 0.75)	4.36	12.08
Drawing in			
2 cm above	0.90 (0.79, 0.96)	2.38	6.59
2 cm below	0.74 (0.48, 0.88)	3.15	8.74

Abbreviations: $ICC_{1,1}$, intraclass correlation coefficient 1-way random-effects model; MDC_{95}, minimal detectable change at the 95% confidence level; SEM, standard error of measurement.
**Values are mean (95% confidence interval).*

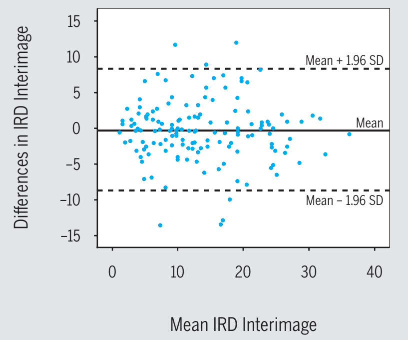

FIGURE 6. Plot of difference against mean (in millimeters) for the recaptured images, with mean difference and 95% limits of agreement indicated.

previous studies. Computed tomography and magnetic resonance imaging are currently considered the methods of choice to examine the abdominal wall. However, they are expensive, and computed tomography exposes the patient to radiation,[12] making it impossible to use in pregnant women. Hence, ultrasonography has been proposed as a noninvasive technique that can be repeated several times[12] during pregnancy.

The current investigation examined many aspects of reliability of the ultrasound measurements. The 2 RA muscles were identified under both relaxed and contracted conditions. Furthermore, repeated measurements were conducted from the same stored images, as well as across images collected and measured on 2 different days. It would be expected that measuring the IRD repeatedly, even on different days from stored images, would be associated with higher ICC values. This is because measuring the distance between 2 well-defined muscles in the ultrasound images is a relatively straightforward task. Our results from the IRD and the results of Hides et al[16] regarding the thickness of the internal oblique and transversus abdominis muscles support this premise, with both studies reporting very high ICC values from repeated measures of the same image. However, accurately reimaging the subject to obtain comparable images may require a higher level of skill. In the current study, the measurements from recaptured images showed good to very good reliability, with the only exception being the moderate reliability during the abdominal crunch exercise. The lower precision shown by higher SEM and MDC values and the wide 95% limits of agreement confirm the inferior reliability of recaptured images compared to repeated measurements of the same stored image.

Interestingly, the IRD values demonstrated greater separation during the drawing-in exercise than during rest or the abdominal crunch (**TABLE 3**). This requires further study, as this exercise is considered to be gentler than the abdominal crunch and is commonly recommended for low back pain both during pregnancy and after childbirth. However, to date, there are no randomized controlled trials on the effect of different abdominal exercises to treat DRA in the peripartum period. A follow-up study on the IRD in pregnancy and postpartum in different muscle contraction conditions is being conducted.

The current study is unique in its reliability tests on the IRD measurements and its use of different locations and contraction conditions to better objectively quantify the separation between the 2 RA muscles. A strength of this study is the blinding of the observer to all the results of IRD measurements until the end of the process. To ensure external validity, 12 subjects in the postpartum period and 12 women with different parity were included in the study. In general, the IRD was greater in postpartum women, but no significant differences were found in the IRD between the 2 groups. Consistent with our findings, Liaw et al[19] also noted that the medial margins of the RA appear to be indistinct where the fascial borders become less clear in postpartum women. We used a customized MATLAB code to implement a method of ultrasound image segmentation based on explicit shape representation defined by a known point-distribution model.[11] In fact, a semi-automated ultrasound image-segmentation method was used to help the examiner identify the medial margins of both RA muscles and to improve the accuracy of IRD measurement. However, the examiner always had the final decision. We believe that in the near future, this MATLAB code could be implemented in the ultrasound scanner software, helping clinicians to accurately measure the IRD or other muscular morphometric parameters (eg, muscle cross-sectional area).

The limitations of this study include the use of only 1 rater with limited experience in ultrasound imaging and inclusion of only healthy subjects with no musculoskeletal or neurological symptoms. It may be more difficult to reliably measure subjects with symptoms that can interfere in the performance of the exercises across the days or in the last gestational weeks, in which wider IRD may require a broader view of the abdominal wall to include both RA muscles on the same image. Because the main goal of this study was to evaluate test-retest and intrarater reliability of the IRD in different contraction conditions, we excluded pregnant women, in whom the IRD is constantly changing with the progress of pregnancy and movement/position of the baby.[21] This might have influenced the reliability of the test-retest. Only the intrarater test-retest reliability of IRD measurements with ultrasound imaging was studied. Data on interrater reliability are needed, especially in longitudinal studies including more than 1 investigator.

CONCLUSION

Two-dimensional ultrasound imaging proved to be a reliable method to measure IRD in women. We suggest the use of ultrasound imaging in future studies to reliably measure the changes in the IRD during rest and abdominal crunch and drawing-in exercises. ◉

ACKNOWLEDGEMENTS: *The authors thank the subjects studied, Professor Isabel Carita (Faculty of Human Kinetics, Technical University of Lisbon, Portugal) for statistical advice, Dr José Luís García (Centro Hospitalario Policlinico San Carlos, Denia, Spain) for counseling on ultrasound imaging issues and suggestions for data collection, and R'Equilibrius Clinic (Oeiras, Portugal) for access facilitation to the postpartum women.*

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