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REVIEW ARTICLE

Systematic review and meta-analysis of the inter-recti distance on ultrasound measurement in nulliparas

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ABSTRACT

The objective is to evaluate the inter-recti distance on ultrasound measurement at different locations in healthy nulliparas. Electronic databases were searched for studies describing the inter-recti distance measured by ultrasound in healthy nulliparas. We excluded studies without descriptions of the measurement position or the condition of the abdominal wall. A meta-analysis was performed to evaluate the inter-recti distance on ultrasound measurement. Seven eligible studies with 295 healthy nulliparas were included. The location of the inter-recti distance measurement by ultrasound was not uniform. The pooled data divided the measurement locations into three areas. The meta-analytic summary values of the umbilical inter-recti distance of the nulliparas was 8.77 mm (6.56–10.99 mm), the distance at the epigastric area was 7.22 mm (2.76–11.68 mm), and that at the infraumbilical area was 4.09 mm (1.55–6.64 mm). The maximal reported inter-recti distance in healthy nulliparous women is smaller than 10 mm on ultrasound measurement at all locations and the range in the umbilical area is larger than that in the epigastric, infraumbilical areas. The values for the inter-recti distance reported in this systematic review can be used as the reference of feasible and desirable distance of the rectus muscles after rectus fascia plication. The limitation was that the methodological quality of the assessment in most studies was unclear or low.

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Rectus abdominis diastasis (RAD) is an anatomical term describing a condition in which an abnormal distance separates the two rectus abdominis muscles along the linea alba [1,2]. RAD most commonly occurs during gestational week 35 and 6 months postpartum [3–5]. RAD has been postulated to be associated with adverse health consequences such as lumbopelvic instability, lower back pain, and incontinence [4,6]. Ultrasonography is a validated noninvasive, repeatable method that can be used to measure the distance between the rectus abdominis, exclude other sources of such a bulge, and plan surgery [7].However, thus far, no consensus has been reached regarding a feasible and desirable distance of the rectus muscles after rectus fascia plication in plastic and reconstructive surgery. Given this controversy, the question arises as to what the normal width of the linea alba is and from which width on a physiological rectus diastasis can be addressed as a myoaponeurotic deformity [7,8]. Accordingly, this systematic review aimed to assess the mean and range of inter-recti distances on ultrasound measurement in healthy nulliparas.

Materials and methods

Search strategy

We conducted a systematic search of the Embase (Ovid), Cochrane Library, CINAHL (EBSCO), and Web of Science databases as well as Pubmed and Google Scholar for studies describing ultrasound measurement of the inter-recti distance in healthy nulliparas. We used the following search terms: rectus abdominis diastasis, rectus diastasis, diastasis of the rectus abdominis muscle, diastasis recti abdominis, diastasis recti, diastasis rectus abdominis, rectus abdominis muscle diastasis, rectus abdominis muscle separate, inter-recti distance, combing with ultrasound, ultrasonography, and sonography. We restricted our search to 30 January 2020, and excluded articles not written in English. Excluded reviews, letters, and comments items.

Studies including individuals with the following conditions were excluded from this review: without descriptions of the measurement position, without an explanation of the state of the abdominal wall, with abdominal wall deformation, with clinically diagnosed RAD; and without measurement of inter-recti distance.

Two investigators independently searched the databases and screened the articles. A third investigator resolved disagreements.

Data extraction

We extracted data from the included studies and assessed methodological quality. Extracted information included the number of patients, demographic details, study design, ultrasound technique (brand, probe, patient position preparation), and inter-recti distance at all measured reference points.

Methodological quality

To assess methodological quality, we used the Checklist for Cross-Sectional/Prevalence Studies from the Agency for Healthcare

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Research and Quality Methodology [9]. We added two questions based on recommendations from the Cochrane Handbook for Systematic Reviews on Diagnostic Test Accuracy [10]: 'Did test operators have the appropriate training?' and 'Was the ultrasound technique described properly?'

Data analysis

To calculate the mean inter-rectus distance at all measured reference points overstudies, we performed a meta-analysis. The sample-size weighted pooled mean and pooled standard deviation (SD) scores were calculated with Stata (version 16.0, Stata Corp LLC). We used I^2 statistics for consistency evaluation. I^2 of 0% indicates good homogeneity; I^2 of 100% indicates great heterogeneity. When I^2 was >50%, it used a random-effects model; otherwise, a fixed-effects model [11].

Results

Included studies

After removing duplicates, we identified 74 records. After screening the titles/abstracts, we assessed 33 full-text articles (Figure 1), and further excluded 26. The reasons for exclusion were inter-recti distance measurement by non-ultrasonic methods ($n = 12$); clinically diagnosed with RAD or distortion of the abdominal wall ($n = 2$); subjects were nulliparous (i.e. postpartum or parous, $n = 7$); and reviews and conference abstracts($n = 5$). Finally, we included seven studies with a total of 295 healthy nulliparas in this systematic review. The study characteristics are depicted in Table 1.

Methodological quality

Approximately 50% of the studies were cross-sectional. All studies clearly described the inclusion and exclusion criteria with the exception of Coldron's [12] study, but the subjects were not consecutive. Most studies reported that the operator had appropriate training. All studies described the ultrasound technique for measuring the inter-recti distance, including the probes used, measurement locations, and abdominal muscles state (at rest or contracted) when the inter-recti distance was measured.

Only two studies (Liaw [13] and Iwan [15]) reported measures for quality assurance, such as assessing intra- or inter-observer agreement before measuring the inter-recti distance. Chiarello [14] conducted a consistency study of ultrasonic and caliper measurements. Two studies evaluated the methodological quality of several other essential features of the assessment (Table 2).

Ultrasound technique

Lee used high-frequency probes but did not indicate the specific frequency. The remainder of the studies indicated the instrument model and probe frequency. Among the probes used, Chiarello [14] used a 5 MHz convex array probe, and the rest of the studies used linear array probes.

Inter-recti distance measurement

As indicated in Table 3, the location of the inter-recti distance measurement by ultrasound was not uniform. With the exception of the umbilicus, the location above and below the umbilicus varies greatly, from 2 to 4.5 cm. Beer measured the inter-recti distance immediately below the xiphoid process, while Lee selected

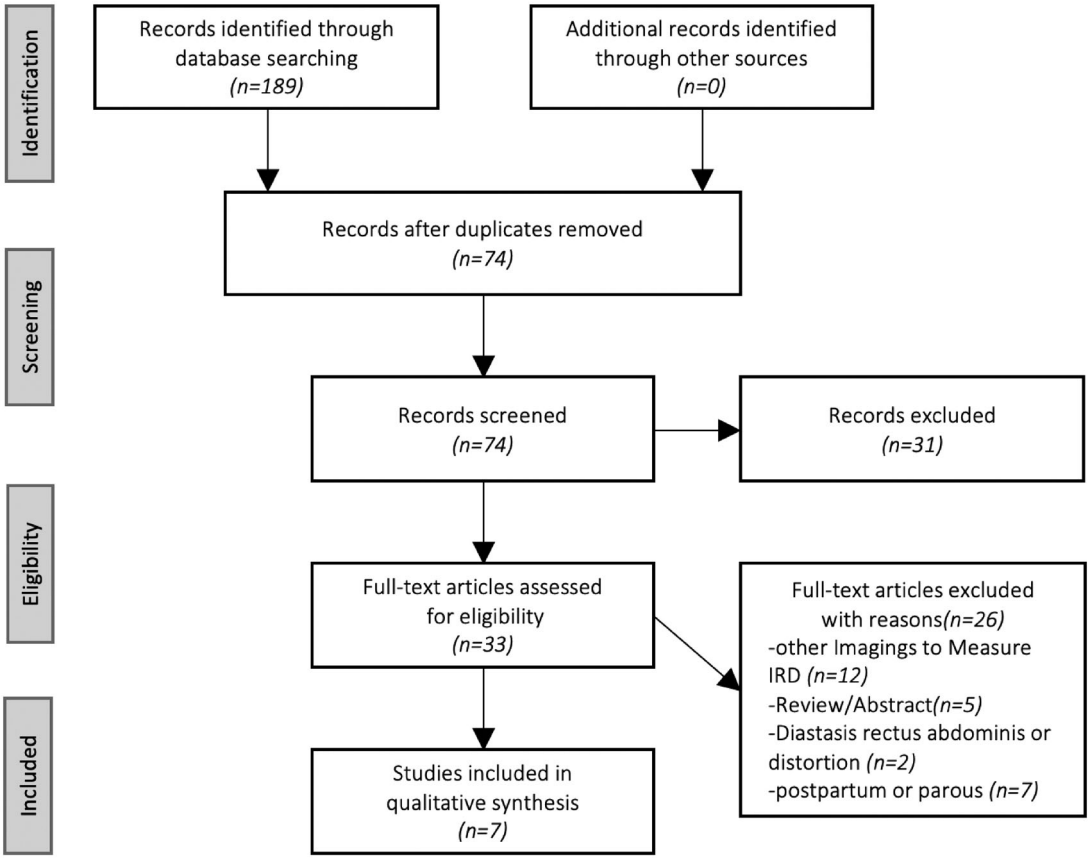

Figure 1. PRISMA (preferred reporting items for systematic reviews and meta-analyses).

Table 1. Characteristics of included studies.

Author (country)	*N*	Age (years)	BMI (kg/m^2)	Participants	Brand US	Transducer and frequency	Measurement condition	Measurement locations	Study design
Coldron et al. 2008 (UK) [12]	69	18–45	/	Nulliparous women of childbearing age	Aloka SSD	5MHz linear probe	Rest	The lower border just cephalad to the umbilicus	Prospective cross-sectional cohort study
Beer et al. 2009 (Switzerland) [7]	150	29 ± 6	21.4 ± 2.7	Nulliparous women	/	High-resolution linear Array transducer	Rest	The origin at the xiphoid, 3 cm above the umbilicus, 2 cm below the umbilicus.	/
Liaw et al. 2011 (Taiwan, China) [13]	20	31.9 ± 4.1	20.7 ± 2.7	Nulliparous women	Aloka SSD 550	7.5 MHz, 38mm linear transducer	Rest	Upper and lower margins of the umbilical ring, 2.5 cm above the upper margin of the umbilical ring, and 2.5 cm below the lower margin of the umbilical ring.	Prospective longitudinal study
Chiarello et al. 2013 (USA) [14]	22	28.5 ± 6.0	23.4 ± 4.0	English speaking individuals (the ethnicity of the sample was 66% Caucasian, 12% Asian, 9% Hispanic, 9% mixed, 2% African American, and 2% Middle Eastern.	LOGIQ Book XP (GE Healthcare)	5MHz curvilinear transducer	Abdominal muscles at rest and contracted	4.5 cm Above the umbilical midpoint and 4.5 cm below the umbilical midpoint	Clinical measurement, concurrent validity criterion standard
Iwan et al. 2014 (New Zealand) [15]	13	21.85 ± 1.88	23.92 ± 2.81	Healthy nulliparous females over the age of 18 years	Philips iu22 (Royal Philips Electronics)	12–5MHz linear transducer	Abdominal muscles at rest and contracted	At 2 cm above the umbilicus and at 2 cm below the umbilicus	A cross sectional, observational study
Pascoal et al. 2014 (Portugal) [16]	10	28 ± 2	21.7 ± 5.3	Healthy nulliparous females	Siemens, Sonoline Prime SLC	60mm Linear array transducer at 7.5 MHz	Abdominal muscles at rest(supine resting position) and during an abdominal isometriccontraction,	2 cm Above the umbilicus	Preliminary case–control study
Lee *et al.* 2016(AUS) [17]	11	25 ± 2	/	nulliparous women	MyLab 25 (Esaote Spa)	12MHz linear transducer	Rest, automatic curl-up, curl-up with preactivation of TrA	2 Points were just above the umbilicus and halfway between the U point and the xiphoid	Cross-sectional repeated measures

Table 2. Methodological quality assessment.

Author, year	Did test operators have appropriate training?	Did authors list inclusion and exclusion criteria?	Did authors indicate time period used for identifying patients	Did authors indicate whether or not subjects were consecutive?	Did authors describe any assessments undertaken for quality assurance purposes?	Did authors describe methodology research?	Was ultrasound technique described properly?
Coldron et al. 2008 (UK) [12]	U	N	Y	U	N	N	Y
Beer et al. 2009 (Switzerland) [7]	Y	Y	Y	U	N	N	Y
Liaw et al. 2011 (Taiwan, China) [13]	Y	Y	Y	U	N	Y	Y
Chiarello et al. 2013 (USA) [14]	Y	Y	N	U	Y	Y	Y
Iwan et al. 2014 (New Zealand) [15]	Y	Y	Y	U	Y	Y	Y
Pascoal et al. 2014 (Portugal) [16]	U	N	U	U	Y	N	Y
Lee et al. 2016 (AUS) [17]	U	Y	N	U	N	N	Y

Y: yes; N: no; U: unclear.

the midpoint between the umbilicus and the xiphoid process to measure the inter-recti distance. With reference to the Classification of Rectus Diastasis-A Proposal by the German Hernia Society (DHG) and the International Endohernia Society (IEHS) (2019) [18], we divided the measurement locations into three areas when pooled the data, namely the umbilical area (umbilical as the center, within 3 cm above and below the umbilicus), epigastric area (3–5 cm above the umbilicus), and infraumbilical area (3–5 cm below the umbilicus). We classified the midpoint between the umbilicus and the xiphoid process as the epigastric area (Table 4). After pooling the data, the umbilical inter-recti distance of the nulliparas was 8.77 mm (6.56–10.99 mm), the distance in the epigastric area was 7.22 mm (2.76–11.68 mm), and that in the infraumbilical area was 4.09 mm (1.55–6.64 mm) (Figure 2).

All studies measured the inter-recti distance from the anterior abdominal wall at rest (supine position). Besides, three studies (Chiarello, Iwan, and Lee) measured the inter-recti distance during an abdominal isometric contraction, with the subject actively performing an abdominal crunch (crook lying position). One study (Lee) measured the inter-recti distance with a 'drawing-in' action that activated the transversus abdominis. In this review, we selected the measurement at rest with the subject in the supine resting position, and knees bent at 90°, feet resting on the plinth, and arms alongside the trunk.

The results of two studies (Liaw and Iwan) indicated that the intra-rater measurement of the inter-recti distance demonstrated good to excellent reliability. One study (Chiarello) found that inter-recti distance measurements taken above the umbilicus with calipers were similar to those made with ultrasound, with intra-class correlation coefficients of 0.79 with abdominal muscles at rest and 0.71 with abdominal muscles contracted. Below the umbilicus, the inter-recti distance measurements using calipers were significantly larger than those using ultrasound for both abdominal muscles at rest and in the contracted state. In addition to the inter-recti distance, Coldron measured the cross-sectional area, thickness, and shape (indirectly using a shape value) of the rectus abdominis. Lee calculated the distortion index, which is the area bounded by the linea alba path and the shortest path divided by the shortest distance.

Discussion

In this systematic review, we assessed the inter-recti distance as measured with ultrasound in healthy nulliparas. We found that the reported values of the inter-recti distance in healthy nulliparas range from 6.56 to 10.99 mm at the umbilical area, from 2.76 to 11.68 mm at the epigastric area, and from 1.55 to 6.64 mm at the infraumbilical area when measuring the distance of linea alba. Although all included studies had some methodological flaws, these values can be used as defining the quantitative border between the physiological breadth of the linea alba and a feasible and desirable distance of the rectus muscles after rectus fascia plication.

The average value of the inter-recti distance is of great significance in the diagnosis of RAD Ultrasound may be considered the gold standard for the clinical measurement of the inter-recti distance with a low standard error of measurement. There was no significant difference between the values obtained by ultrasound and those measured during surgery at the supra-umbilical levels and umbilicus levels [19,20]. Two issues should be clarified for the measurement of the inter-recti distance by ultrasound: The first is regarding measurement location. The inter-recti distance is not equidistant from the pubic symphysis to the inferior xiphoid process. In the studies included in this review, the measurement location of the inter-recti distance by ultrasound is diverse, with the umbilical upper margin of the umbilical ring and 2.5 cm above the umbilical ring being the most frequently measured locations. When pooled the data, grouped the measurement locations into three areas, namely the umbilical, epigastric, and infraumbilical areas. We did not use the data of studies measuring the distance at the xiphoid process (Beer [6]), as RAD has little effect on the inter-recti distance at the xiphoid process, and the distance was due to anatomical variation. The results indicated that the inter-recti distance of healthy nulliparous women as measured by ultrasound did not exceed 10 mm in all three areas, and the inter-recti distance in the umbilical region was the widest. The inter-recti distance was significantly smaller at the infraumbilical area than the umbilical and the epigastric areas (4.09 mm vs. 8.77 and 7.22 mm, respectively).

About the second issue is regarding the condition of the rectus abdominis muscle, i.e. measurement at rest or during an abdominal isometric contraction, or during activation of the transversus abdominis. The condition is critical, as different conditions will result in different measurements [21]. In the studies included in this review, the results of the studies by Chiarello and Lee indicated that the inter-recti distance increases when the rectus abdominis contracts. Iwan's study revealed that when the rectus abdominis contracted, the inter-recti distance decreased at 2 cm

Table 3. Reported inter-recti distance per location in mm.

Author(country)	*n*	Xi Mean (SD)(mm)	UX Mean (SD)(mm)	US4.5cm Mean (SD)(mm)	US3cm Mean (SD)(mm)	US2.5cm Mean (SD)(mm)	US2cm Mean (SD)(mm)	U Mean (SD)(mm)	UI2cm Mean (SD)(mm)	UI2.5cm Mean (SD)(mm)	UI4.5cm Mean (SD)(mm)
Coldron et al. 2008 (UK) [12]	69	—	—	—	—	—	—	11.17 (3.62)	—	—	—
Beer et al. 2009 (Switzerland) [7]	150	7(5)	—	—	13 (7)	—	—	—	8 (6)	—	—
Liaw et al. 2011 (Taiwan, China) [13]	20	—	—	—	—	8.5 (2.6)	—	9.9 (3.1)/6.5(2.3)	—	4.3 (1.7)	—
Chiarello et al. 2013 (USA) [14]	22	—	—	7.5 (4.3)	—	—	—	—	—	—	2.2 (2.9)
Iwan et al. 2014 (New Zealand) [15]	13	—	—	—	—	14.6 (5.7)	—	—	—	5.3 (2.8)	—
Pascoal et al. 2014 (Portugal) [16]	10	—	—	—	—	—	9.63 (2.84)	—	—	—	—
Lee et al. [17] 2016 (AUS)	11	—	6.1 (2.9)	—	—	—	—	7.7 (3.4)	—	—	—
Total cases	295										

SD: standard deviation; US: above the umbilical; U: umbilical; UI: below the umbilical; Xi: xiphoid; UX: halfway between the U point and the xiphoid.

Table 4. Pooled inter-recti distance per location in mm.

Author (country)	n	US3–5cm Mean (SD)(mm)	U Mean (SD)(mm)	U I3–5cm Mean (SD)(mm)
Coldron et al. 2008 (UK)	69	—	11.17 (3.62)	—
Beer et al. 2009 (Switzerland)	150	13 (7)	8 (6)	—
Liaw et al. 2011 (Taiwan, China)	20	—	9.9 (3.1)	4.3 (1.7)
Liaw et al. 2011 (Taiwan, China)	20	—	8.5 (2.6)	—
Liaw et al. 2011 (Taiwan, China)	20	—	6.5 (2.3)	—
Chiarello et al. 2013 (USA)	22	7.5 (4.3)	—	2.2 (2.9)
Iwan et al. 2014 (New Zealand)	13	—	14.6 (5.7)	5.3 (2.8)
Pascoal et al. 2014 (Portugal)	10	—	9.63 (2.84)	—
Lee, et al. 2016 (AUS)	11	6.1 (2.9)	7.7 (3.4)	—
Total cases	335	183	313	55

SD: standard deviation; US: above the umbilical; U: umbilical; UI: below the umbilical; Xi: xiphoid; UX: halfway between the U point and the xiphoid.

above the umbilicus, but increased at 2 cm below the umbilicus. These results differed from those of other studies. The Mota team [16,22,23] found that abdominal isometric contraction can reduce the inter-recti distance, and activating the transversus abdominis can increase the inter-recti distance when measuring the distance in women in the third trimester and within six months postpartum. Chiarello's study indicated that rectus abdominis muscle contraction could reduce the inter-recti distance of males and females, nulliparous or parturient. Rezazadeh's study [24] also indicated that inter-recti distance of nulliparas could be reduced during rectus abdominis contraction, even in postpartum women. The reason for the controversy may be due to the different subjects included in these studies; that is, the rectus abdominis contraction has different effects on the inter-recti distance between nulliparous women and postpartum women. The other potential reason for this difference is the difference of the ending motion and duration of the contraction. Further study is needed.

Three included studies carried out a methodological evaluation of measurements. The results indicated that the intra-rater agreement of measurement of the inter-recti distance demonstrated good to excellent reliability for at rest or during crunch, for measurement at the location of both the epigastric and infraumbilical areas. There were no significant differences between the novice and experienced sonographers' measurements. The intra-rater intraclass correlation coefficients of the infraumbilical area were excellent (0.89–0.98) but slightly lower than those of epigastric measurements. This decreased accuracy at the infraumbilical area has been suggested to be due to the constitution of the rectus sheath affecting the formation of the linea alba and making identification of the borders more challenging. It has also been suggested that in the infraumbilical area, there is a reduced definition of the posterior layer of recti muscles and the presence of sizeable abdominal laxity. In addition, there is typically more subcutaneous fat in this region. The fatty deposits at the infraumbilical area may attenuate the sound beam to a greater extent, which can lead to reduced image clarity.

Chiarello's study carried out a validity study to compare the consistency between ultrasonic measurements and caliper measurements. Above the umbilicus, the measurements of the inter-recti distance with calipers were similar to those made with ultrasound. The values of the inter-recti distance obtained with the

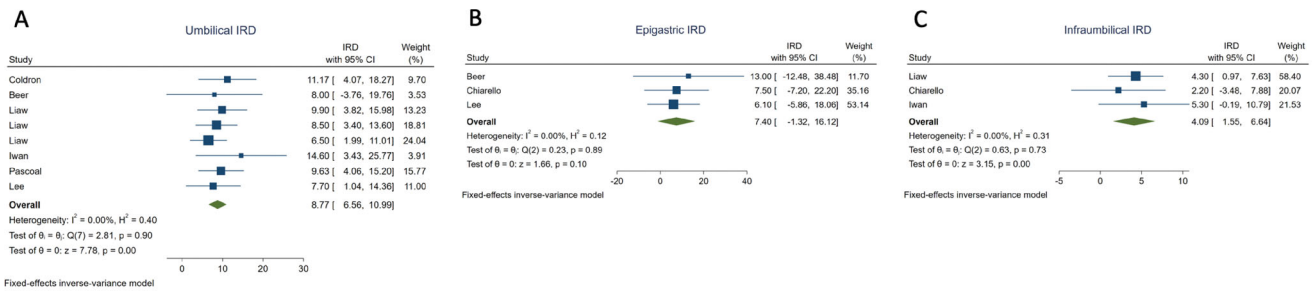

Figure 2. Forest plots of ultrasound for Inter-rectus distance (IRD) in millimeters (mm) per location. (A) IRD measured at umbilical area by ultrasound; (B) IRD measured at epigastric area by ultrasound; (C) IRD measured at infraumbilical area by ultrasound.

caliper and ultrasound were not comparable when obtained below the umbilicus. It is also possible that the caliper jaws produce a slight outward pressure against the muscle belly, thus increasing the inter-recti distance, particularly if the tissue is more extensible, as is likely in those with a greater inter-recti distance. This slight outward pressure may also explain why the caliper measurements were larger than the ultrasound measurements when taken with the abdominal muscles at rest. Further, Chiarello's research revealed that the measurement repeatability of the convex array probe is the same as that of the linear array probe, which has excellent reliability. Given that the convex array probe is more general than the linear array probe, using a convex array probe to measure the inter-recti distance when a linear array probe is not available.

In most studies, the methodological quality of the assessment was unclear or low. Additionally, the subjects were not consecutive. Most of the studies were retrospective, and 50% did not carry out methodological studies. With the exception of Beer's study, the sample size was relatively small. In this review, the sample size of studies measuring the inter-recti distance at the umbilical region reached 313 (including the Beer sample size), which is twice the sample size of Beer's study. Although the subjects were all nulliparous females, the effects of age and abdominal circumference on the inter-recti distance were not considered. Further studies that take these variables into account will need to be undertaken. In addition, in order to study the criteria for ultrasound diagnosis of RAD, it is not sufficient to include only the measurement range of nulliparous females. Although pregnancy and childbirth are risk factors for RAD, the human body has a self-repairing function. As the postpartum time increases, the inter-recti distance gradually decreases. Although studies have demonstrated that the inter-recti distance may not revert to the pre-pregnancy state until 12 months postpartum, most of the postpartum women who have not recovered rectus abdominis muscle spacing have no clinical symptoms. Further research should be undertaken to investigate the ultrasound measurement of the inter-recti distance at various postpartum periods.

Conclusion

We found that maximal reported inter-recti distance in healthy nulliparous women is smaller than 10 mm in the umbilical, epigastric, and infraumbilical areas. Furthermore, we found that the range in the umbilical area inter-recti distance in healthy nulliparas is larger than in that in the epigastric, infraumbilical areas. The intra-examiner repeatability of measurement at the infraumbilical area and the inter-examiner consistency are poor, while the repeatability of measurement at the epigastric area is excellent. The values for the inter-recti distance reported in this systematic review can be used as the reference of feasible and desirable distance of the rectus muscles after rectus fascia plication. The limitation was that the methodological quality of the assessment in most studies was unclear or low.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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