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The Relationships Between Inter-recti Distance Measured by Ultrasound Imaging and Abdominal Muscle Function in Postpartum Women: A 6-Month Follow-up Study

STUDY DESIGN: A prospective longitudinal study.

BACKGROUND: Diastasis recti abdominis (DRA) is defined as an increase in the inter-recti distance (IRD), or width of the linea alba. It is a common occurrence in women postpartum. Little information exists on the short- and long-term recovery of IRD and the relationship between changes in IRD and the functional performance of the abdominal muscles.

OBJECTIVES: To investigate the natural recovery of IRD and abdominal muscle strength and endurance in women between 7 weeks and 6 months postpartum, and to examine the relationship between IRD and abdominal muscle function.

METHODS: Forty postpartum (25-37 years of age) and 20 age-matched, nulliparous females participated. IRD was measured at 4 locations (upper and lower margin of the umbilical ring, and 2.5 cm above and below the umbilical ring) with a 7.5-MHz linear ultrasound transducer. Trunk flexion and rotation strength and endurance were measured with manual muscle testing and curl-ups. Evaluation was conducted at 4 to 8 weeks and 6 to 8 months after childbirth in postpartum women, and only once for the nulliparous female controls.

RESULTS: During follow-up, the IRD at 2.5 cm above the umbilical ring and at the upper margin of the umbilical ring decreased ($P = .013$ and $P = .002$, respectively). The strength and static endurance of the abdominal muscles improved over time ($P<.05$). A negative correlation between IRD and abdominal muscle function at 7 weeks and 6 months postpartum was found ($r = 0.34$ to 0.51; $P<.05$, except for trunk flexion strength at 6 months postpartum [$P = .064$]). In addition, IRD changes between 7 weeks and 6 months postpartum were correlated with improvement in trunk flexion strength (Spearman rho = 0.38, $P = .040$). At 6 months after childbirth, postpartum women had greater mean ± SD IRDs at all 4 locations (from cranial to caudal: 1.80 ± 0.72, 2.13 ± 0.65, 1.81 ± 0.62, and 1.16 ± 0.58 cm) than those of nulliparous females (0.85 ± 0.26, 0.99 ± 0.31, 0.65 ± 0.23, and 0.43 ± 0.17 cm) (all $P<.001$). All abdominal strength and endurance measurements were less than those of nulliparous females (all $P<.001$).

CONCLUSIONS: The IRD and abdominal muscle function of postpartum women improved but had not returned to normal values at 6 months after childbirth. Future research is essential to explore the need for intervention and, if needed, the effectiveness of specific intervention to reduce the size of IRD in postpartum women. *J Orthop Sports Phys Ther 2011;41(6):435-443, Epub 2 February 2011. doi:10.2519/jospt.2011.3507*

KEY WORDS: *abdomen, linea alba, pregnancy, rectus abdominis, strength*

Diastasis recti abdominis (DRA) refers to the separation of the 2 recti abdominis muscles, and is quantified by the inter-recti distance (IRD). DRA can occur in women at the later stages of pregnancy[4,11] and remain immediately[4,8,16] and early postpartum.[4,6,9,11,16] Published case reports indicate a partial resolution of the DRA at 4 weeks,[11] 8 weeks,[11] or 12 weeks postpartum.[16] Coldron et al[9] also reported that most of the recovery of IRD occurred by 8 weeks.[9] No further improvement was noted at the end of the first year,[9] suggesting that partial recovery of DRA happens after childbirth but is incomplete even after 1 year.

The linea alba, separating the 2 recti abdominis, is a fibrous raphe extending from the xiphoid process to the pubic symphysis, and is formed by the interlacing aponeurotic fibers of the oblique and transverse muscles.[2,30] DRA, in pregnant women, might result from progressive stretching of the abdominal wall with

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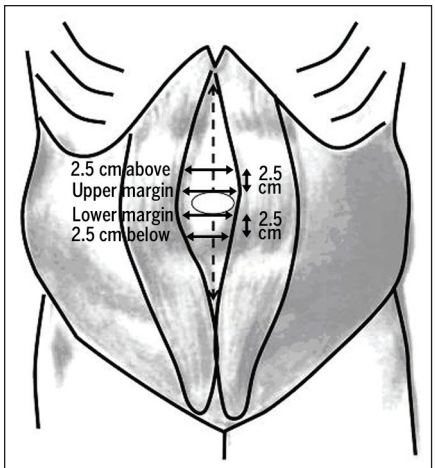

FIGURE 1. Schematic diagram of anterior abdominal wall, in which the arrows indicate the 4 locations of ultrasonographic measurements: 2.5 cm above the umbilical ring, upper margin of the umbilical ring, lower margin of the umbilical ring, and 2.5 cm below the umbilical ring.

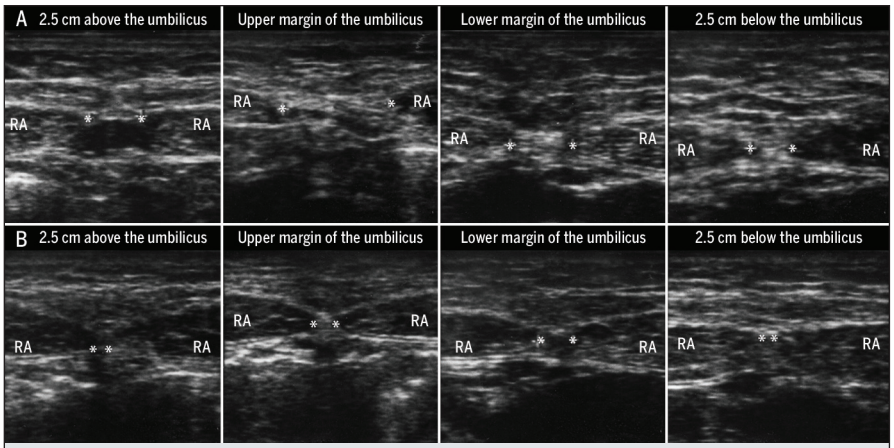

FIGURE 2. Sonogram of transverse view of the inter-recti distance between the inside border of the fascia, from one medial end of the rectus abdominis to the other, at 4 locations, in postpartum and nulliparous women. (A) Parous woman, the size from left to right locations: 0.9, 1.9, 1.1, and 0.6 cm. (B) Nulliparous woman, the size from left to right locations: 0.3, 0.4, 0.6, and 0.1 cm. Ultrasonographic image of the linea alba at upper margin of the umbilical ring in postpartum women. There appeared to be a linear defect from left to right, and the margins of the IRD were less delineated in the postpartum group than the control group. Abbreviation: RA, rectus abdominis. *Indicates the medial borders of the left and right rectus abdominis.

the growing fetus.[2,21,22] Given the current evidence supporting the important role of muscles and fascias of the lumbopelvic region in trunk movements and intersegmental and intrapelvic stabilization,[15,17,25] partial loss of integrity of the myofascial systems, as seen with DRA, may have the potential to affect the function of the abdominal muscles.[7,18,24] Gilleared and Brown[11] previously reported that morphological changes (DRA and muscle lengthening) and abdominal muscle functional deficits were present during pregnancy, and remained for at least 8 weeks postpartum. However, to our knowledge, there are no studies specifically examining the relationships among IRD, abdominal muscle strength and endurance, and the natural recovery of abdominal muscle function from a cohort of postpartum women across a 6-month span.

Therefore, this study aimed to investigate the natural recovery of IRD and abdominal muscle function by measuring changes in IRD and abdominal muscle strength and endurance in women between 7 weeks and 6 months postpartum. We also intended to examine the relationships between the width of the IRD and abdominal muscle function.

METHODS

Participants

Forty postpartum women (mean ± SD, 31.3 ± 3.3 years), both primiparous and multiparous, who had delivered single full-term fetuses vaginally, were recruited from Kaohsiung Medical University Chung-Ho Memorial Hospital from June 2006 through September 2008 to participate in the study. Twenty age-matched nulliparous women (±2 years; mean ± SD age, 31.9 ± 4.1 years) were recruited by convenience sampling from communities in Kaohsiung to serve as a comparison group.

All postpartum and nulliparous women had not received any abdominal muscle training or engaged in any other regular exercises within the previous 6 months. The postpartum women were also not engaging in any abdominal muscle training or regular exercises during the follow-up period. Individuals with the following conditions affecting the ability to perform activities of daily living or with symptoms that required medical attention were excluded from this study: (1) history of low back pain or injury, (2) scoliosis, (3) spinal or abdominal surgery (including cesarean birth), or (4) neuromuscular diseases.

The postpartum women were evaluated twice after childbirth: first at 4 to 8 weeks (average, 7 weeks) postpartum, then at 6 to 8 months (average, 6 months) postpartum. The age-matched nulliparous women were tested once.

This study protocol was approved by the Institutional Review Board of Kaohsiung Medical University Chung-Ho Memorial Hospital, Kaohsiung, Taiwan. Signed informed consent was obtained before participation in this study and the rights of the participants were provided verbally, as well as in written form.

Ultrasound Imaging

Criteria for the diagnosis of DRA vary in the literature.[4,8,11,23,26] Beer et al[3] suggest that in nulliparous women the linea alba 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 studies looking at women postpartum, DRA has been defined as the linea alba having a width of greater than a 2-finger breadth (1.5 cm) when measured with palpation,[4,11,26] or 2 cm when measured with a dial caliper[8] at or above the umbilicus during a partial sit-up. But the

influence of the thickness of the subcutaneous fat on measurements could not be eliminated by using the above methods. More recently, ultrasound imaging has been used to measure IRD in postpartum women[9] and women before and after abdominoplasty for postpartum DRA.[20,27] Mendes[20] demonstrated that ultrasonography is an accurate method for measuring IRD. Coldron et al[9] investigated the characteristics of DRA and concluded that ultrasound imaging is a more specific tool for measuring IRD in postpartum women; however, they did not provide specific criteria for the diagnosis of DRA. Thus we recruited a nulliparous control group in this study.

Instrumentation and Examiner An ultrasound imaging unit (SSD-550; Aloka Co, Tokyo, Japan), with a 7.5-MHz, 38-mm linear transducer, was used to assess the IRD. All ultrasound images of recti abdominis were obtained in brightness mode (B mode). All measurements were performed by the same examiner, a senior physical therapist with 13 years of experience, including 5 years assessing abdominal muscles using ultrasound imaging. Before the present study, the same physical therapist conducted a pilot study to establish reliability of the measurements. Twenty-six healthy nulliparous women were measured at 4 locations and the measurements were repeated within 7 days. Intraclass correlation coefficients ($ICC_{3,1}$) were between 0.85 and 0.95, the standard error of measurement (SEM) was between 0.07 and 0.10 cm, and the minimal detectable changes (MDCs) were between 0.20 and 0.29 cm, depending on the location measured.[19]

Procedures To standardize the position of the transducer, each measurement location was marked on the skin when the participant was resting in supine position with 2 pillows under the knees. The transducer was placed transversely across the abdomen without tilting. Still images in B mode were obtained in resting at the end of a normal expiration, to control the influence of respiration and provide consistency across participants.[29] Measurements were taken with an on-screen caliper to the nearest 0.1 cm. Three images were obtained from each location by the same examiner. The order of locations for image acquisition was randomized.

TABLE 1 DEMOGRAPHICS*

	6 mo Postpartum Women (n = 30)	Nulliparous Women (n = 20)	*P* Value
Age, y	32.1 ± 3.0	31.9 ± 4.1	.78
Height, cm	159.3 ± 5.2	160.5 ± 5.8	.45
Weight, kg	54.4 ± 6.3	53.5 ± 9.0	.67
BMI, kg/m^2	21.5 ± 2.8	20.7 ± 2.7	.34
Parity			
Primiparous, n (%)	17.0 (56.7)		
Multiparous, n (%)	13.0 (43.3)		
Baby birth weight, g (singletons)	2958.8 ± 615.0		

Abbreviation: BMI, body mass index
**Data are mean ± SD, except where otherwise indicated.*

IRD Measurement The transducer was placed transversely along the midline of the abdomen at the following 4 locations identified with skin markers: 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. During the actual image acquisition, the inferior border of the transducer was positioned to coincide with the marker for the 2 upper locations, and its superior border matched the marker for the 2 lower locations. The IRD of the linea alba was taken at these 4 locations using the medial margins of both rectus abdominis muscles, where it could be clearly identified (**FIGURE 1**). An on-screen caliper was used to measure the transverse linear distance from the medial border of the rectus abdominis of one side to the corresponding position of its counterpart on the other side.

Clinical Tests

Function of the abdominal muscles was determined by examining the strength and endurance for trunk flexion and rotation. Strength, using manual muscle testing, was graded based on the ability of the participant to raise the trunk against gravity in supine position, with arms at sides and only lift the head (poor grade), arms outstretched above the plane of body (fair grade), arms crossed over the chest (good grade), and hands clasped behind head (normal grade).[14] Static and dynamic endurance of the trunk flexors and rotators was measured in the hook-lying position, with the upper extremities stretched out above the plane of the body. For the static endurance test, the participant was instructed to lift neck and upper trunk from the table until the inferior angles of scapulae had risen clear of the table. The participant was then required to hold the testing position as long as possible, and the holding time was recorded in seconds. For the dynamic endurance test, the participant was instructed to perform the same movement as that of the static endurance test, except that the movement was repeated as many times as possible at a rate of approximately once every 3 seconds. The test was stopped if the inferior angles of the scapula could not be lifted clear of the table. All tests were performed in a random order and scored by the same physical therapist. Five-minute rests were taken between tests for recovery and to avoid fatigue.

Statistical Analyses

All analyses were conducted by using SPSS for Windows, Version 14 (SPSS Inc, Chicago, IL). The statistical signifi-

TABLE 2 The Interimage Reliability of Inter-recti Distance at 4 Locations in Postpartum Women at 7 Weeks and 6 Months Postpartum (n = 30)*

	7 wk Postpartum			6 mo Postpartum		
Locations	$ICC_{3,1}$ (95% CI)	SEM, cm	MDC_{95}, cm	$ICC_{3,1}$ (95% CI)	SEM, cm	MDC_{95}, cm
2.5 cm above	0.95 (0.91, 0.97)	0.16	0.45	0.97 (0.95, 0.99)	0.12	0.33
Upper margin	0.92 (0.86, 0.96)	0.17	0.47	0.92 (0.87, 0.96)	0.18	0.50
Lower margin	0.91 (0.84, 0.95)	0.20	0.55	0.93 (0.87, 0.96)	0.17	0.47
2.5 cm below	0.97 (0.95, 0.99)	0.13	0.36	0.95 (0.91, 0.97)	0.13	0.37

Abbreviations: ICC, Intraclass correlation coefficient; MDC_{95}, minimum detectable change at the 95% confidence level; SEM, standard error of measurement; MDC_{95}, minimal detectable change, calculated as $1.96 \times SEM \times \sqrt{2}$.
**Measurements were taken 2.5 cm above the umbilical ring, upper margin of the umbilical ring, lower margin of the umbilical ring, and 2.5 cm below the umbilical ring. Data were based on measurements made on 3 images taken on the same day (intrarater between-image reliability).*

cance level of all tests was set at $P<.05$. The demographic data of the postpartum women and nulliparous women were compared using a Student *t* test.

Inter-recti Distance $ICC_{3,1}$ was used to assess the level of consistency across the 3 IRD measurements at each location, and separate intrasession ICCs were computed for each location at 7 weeks and 6 months postpartum. The measurement error was examined by calculating the SEM [pooled SD $\times \sqrt{1 - ICC}$].[10,28] To represent a clinically meaningful difference in IRD beyond measurement error, the MDC_{95} was calculated as $1.96 \times SEM \times \sqrt{2}$.[10]

IRD for each location was calculated by the average value of the 3 images and used for the following comparisons. Two separate 2-by-4 analyses of variance (ANOVAs) with repeated measures were performed for the IRD data. The first ANOVA examined the effects of time (7 weeks and 6 months postpartum) and locations (2.5 cm above the upper margin of the umbilical ring, upper margin of the umbilical ring, lower margin of the umbilical ring, and 2.5 cm below the lower margin of the umbilical ring). The second ANOVA evaluated the effects of group (6 months postpartum women and nulliparous women) and the 4 locations. Differences in IRD among the 4 locations within each group were tested using 2 separate 1-way repeated-measures ANOVAs. When the main effect was significant, pairwise comparisons were performed using the Bonferroni adjustment for multiple comparisons. Pearson product-moment correlation coefficients were computed to examine the correlation of changes in IRD values between any 2 of the 4 locations.

Abdominal Strength and Endurance The Wilcoxon signed-rank test was used to compare the difference in abdominal muscle strength between the first and the second evaluation for postpartum women. The Mann-Whitney *U* test was used to analyze the difference in abdominal muscle strength between women who were 6 months postpartum and nulliparous female controls. Independent *t* tests were used to compare static and dynamic abdominal endurance between the 2 groups.

Relationship Between IRD and Abdominal Muscle Function in Postpartum Women The average of the IRDs obtained at the 4 locations on each participant was used to represent the overall effect of pregnancy on IRD at 7 weeks and 6 months. The associations between muscle strength (0-5 scores) obtained from manual muscle testing and IRD from ultrasound imaging were examined using Spearman rank correlation, and relationships between IRD and abdominal muscle endurance data were examined using Pearson product-moment correlation coefficients. The relationships between the average changes in IRD for the 4 locations and the improvement of muscle function between 7 weeks and 6 months were evaluated using the Pearson product-moment correlation or Spearman rank correlation.

RESULTS

Demographics

Among the 40 postpartum participants, 30 women, examined between 4 to 8 weeks after childbirth (mean ± SD, 7.1 ± 1.5 weeks), completed the 6-month postpartum follow-up (6.4 ± 0.4 months). Ten postpartum women dropped out of the study for personal reasons. Thus, data from 30 postpartum, 17 primiparous, and 13 multiparous women were analyzed. Descriptive statistics for the 30 parous and 20 nulliparous control women are shown in **TABLE 1**. The characteristics of the postpartum and nulliparous women were similar, with no significant differences between the 2 groups.

Reliability

ICCs for the IRD measurements ranged from 0.91 to 0.97 across the 4 locations at first and second evaluation. SEMs ranged from 0.13 to 0.20 cm at the first evaluation and from 0.12 to 0.18 cm at the second evaluation. MDC values ranged from 0.33 to 0.55 cm for all IRD measurements (**TABLE 2**).

Changes in IRD Between 7 Weeks and 6 Months Postpartum

The values of IRD for the 4 locations

measured ranged from 1.30 to 2.29 cm at 7 weeks postpartum and from 1.16 to 2.13 cm at 6 months postpartum (**TABLE 3**). No significant location-by-time interaction was found (P = .655). There was a main effect of location (P<.001), with the largest IRD measured at the upper margin of the umbilical ring. There was also a main effect of time, with the IRD significantly decreasing from 7 weeks to 6 months in postpartum women (P<.001). The mean ± SD decrease in IRD at the upper margin of the umbilical ring was 0.26 ± 0.41 cm (95% confidence interval [CI]: 0.11, 0.41; P = .002), and 0.17 ± 0.35 cm (95% CI: 0.04, 0.30; P = .013) at 2.5 cm above the umbilical ring. Changes in both locations were larger than their respective SEM values (**TABLE 2**).

Changes in Abdominal Muscle Function Between 7 Weeks to 6 Months Postpartum

The changes in abdominal muscle strength and endurance during the follow-up period are summarized in **TABLE 4**. Improvements in muscle strength were found in trunk flexion (P = .007) and rotation (P = .011). Improvements in static endurance were noted in the trunk flexors (mean change, 6.93 ± 8.96 seconds; 95% CI: 3.59, 10.28; P<.001) and rotators (mean change, 4.43 ± 9.42 seconds; 95% CI: 0.91, 7.95; P = .015). However, there were no significant changes in dynamic endurance of trunk flexors and rotators (P>.05).

Correlation Between IRD and Abdominal Muscle Function

The correlation matrix for the relationship between abdominal muscle function and the mean of the IRDs measured at the 4 locations at 7 weeks and at 6 months postpartum are presented in **TABLE 5**. Negative relationships are found between mean IRD values and abdominal muscle function at both 7 weeks and 6 months. The change in mean IRDs between 7 weeks and 6 months postpartum was only correlated with the change in trunk flexor strength during the same period (Spearman rho = 0.38, P = .040).

TABLE 3 The Changes of Inter-recti Distance at 4 Locations in Postpartum Women Between 7 Weeks to 6 Months Postpartum (n = 30)*

Locations	7 wk Postpartum	6 mo Postpartum	D	*P* Value
2.5 cm above	1.97 ± 0.71	1.80 ± 0.72	0.17 ± 0.35	.013†
Upper margin	2.39 ± 0.59	2.13 ± 0.65	0.26 ± 0.41	.002†
Lower margin	1.99 ± 0.65	1.81 ± 0.62	0.18 ± 0.41	.052
2.5 cm below	1.30 ± 0.77	1.16 ± 0.58	0.14 ± 0.40	.078

Abbreviations: D, mean difference between 7 weeks and 6 months.
**Data are mean ± SD cm. Measurements were taken 2.5 cm above the umbilical ring, upper margin of the umbilical ring, lower margin of the umbilical ring, and 2.5 cm below the umbilical ring.*
†Significantly different between 7 weeks and 6 months postpartum (P<.05).

TABLE 4 Strength and Endurance Data for Trunk Flexors and Rotators (n = 30)*

	7 wk Postpartum	6 mo Postpartum	*P* Value
Strength, median (Q1-Q3)			
Trunk flexors	3 (2-4)	4 (2-5)	.007†
Trunk rotators	3 (2-4)	4 (2-5)	.011†
Static endurance, s			
Trunk flexors	8.47 ± 10.17	15.40 ± 14.46	<.001‡
Trunk rotators	9.43 ± 9.77	13.87 ± 13.31	.015‡
Dynamic endurance (repetitions)			
Trunk flexors	6.77 ± 7.21	9.07 ± 9.59	.093
Trunk rotators	5.43 ± 7.06	7.20 ± 7.06	.160

Abbreviations: Q1, first quartile; Q3, third quartile.
**Data are mean ± SD unless indicated otherwise.*
†Ordinal data using 0-to-5 manual muscle testing scale were analyzed with Wilcoxon signed-rank test (P<.05).
‡Significantly different between 7 weeks and 6 months postpartum (P<.05).

Comparisons Between Women at 6-Month Postpartum and Nulliparous Women

A significant group-by-location interaction was found for IRD values between women at 6-month postpartum and nulliparous women (P = .001). The mean ± SD IRD values for the postpartum women at the 4 locations, from cranial to caudal, were 1.80 ± 0.72, 2.13 ± 0.65, 1.81 ± 0.62, and 1.16 ± 0.58 cm compared to 0.85 ± 0.26, 0.99 ± 0.31, 0.65 ± 0.23, and 0.43 ± 0.17 cm for the nulliparous women (P<.001) (**TABLE 6**). Moreover, the abdominal muscle strength and endurance in postpartum women was also significantly less than the nulliparous women (P<.001) (**TABLE 6**).

The IRD values measured for the 4 locations in both groups are presented in **FIGURE 4**. There was a significant difference in IRD among the 4 locations for both the nulliparous women (P<.001) and postpartum women (P<.001). The largest IRD values for both groups was at the upper margin of the umbilical ring and the smallest values 2.5 cm below the lower margin of the umbilical ring.

DISCUSSION

This study provides objective data that women at 6 months postpartum had larger IRD values and lesser abdominal muscle function compared to a control group of matched women without previous pregnancy. It also provides evidence that in postpartum women IRD is correlated with ab-

dominal muscle function, and that IRD measurements made with ultrasound are reliable.

Intrasession Reliability

The ICC values obtained were high (ICC>0.90), indicating excellent intrasession agreement; the SEM values at the 4 locations were small (6.7%-11.2%), indicating good precision.[28] SEM values for resting IRD measurements (0.13-0.20 cm) were lower than those reported previously (0.31 cm) by Boxer and Jones,[6] who measured the resting IRD with a dial caliper. We also calculated MDC, also called "smallest real difference," which indicates the occurrence of a real change as opposed to a random variation in measurements. MDC values for IRD measurements ranged from 0.33 to 0.55 cm (**TABLE 2**). Although the intrasession reliability in this study is good, it was noted that the medial margins of the rectus abdominis appear to be indistinct where the fascial borders become less clear in postpartum women (**FIGURE 2**). Between-day reliability data are needed.

Recovery of IRD and Abdominal Muscle Function

From 7 weeks to 6 months postpartum, a reduction in IRD values only occurred at the 2 measurement locations above the umbilicus. However, these improvements were relatively small, and all values at 6 months remained above those of the control group. In addition, while some aspects of abdominal muscle function, strength, and static endurance improved during that period, they remained below the values of their nulliparous counterparts. Therefore, when compared to a matched control group of women without prior pregnancy, both structural changes and functional deficits persisted at 6 months postpartum. Prospective longitudinal data are required to confirm this finding.

There are several reports of measurements of IRD in postpartum women.[4,6,11,26] Limitations of these studies include short follow-ups, small sample sizes, and inaccurate measurement tools, such as finger breadth and calipers, whose accuracy is affected by subcutaneous tissue thickness. While Coldron et al[9] measured IRD with ultrasound imaging at multiple postpartum times on a large sample (n =

TABLE 5 Relationship Between the Average Inter-recti Distances Measured at 4 Locations and Abdominal Strength and Endurance at 7 Weeks and 6 Months Postpartum*

	7 wk Postpartum	6 mo Postpartum
Strength (0-5)†		
Trunk flexor	−0.46 (.011)‡	−0.34 (.064)
Trunk rotator	−0.45 (.013)‡	−0.39 (.034)‡
Static endurance, s§		
Trunk flexors	−0.51 (.004)‡	−0.42 (.020)‡
Trunk rotator	−0.49 (.006)‡	−0.40 (.030)‡
Dynamic endurance (repetitions)§		
Trunk flexors	−0.41 (.026)‡	−0.36 (.049)‡
Trunk rotator	−0.41 (.026)‡	−0.37 (.045)‡

Abbreviation: MMT, manual muscle testing.
**Data are correlation coefficient r (P value).*
†*Strength rated using 0-to-5 manual muscle testing grading system and analyzed with Spearman correlation coefficient.*
‡P<.05.
§*Analyzed with Pearson correlation coefficient.*

TABLE 6 Comparisons of Inter-recti Distance and Abdominal Strength and Endurance Between Women Who Are 6 Months Postpartum (n = 30) and Nulliparous Women (n = 20)*

	6 mo Postpartum	Nulliparous	*P* Value
Inter-recti distance, cm			
2.5 cm above	1.80 ± 0.75	0.85 ± 0.26	<.001†
Upper margin	2.13 ± 0.78	0.99 ± 0.31	<.001†
Lower margin	1.82 ± 0.77	0.65 ± 0.23	<.001†
2.5 cm below	1.16 ± 0.59	0.43 ± 0.17	<.001†
Strength, median (Q1-Q3)			
Trunk flexors	4 (2-5)	5 (4-5)	.003‡
Trunk rotators	4 (2-5)	5 (4-5)	<.001‡
Static endurance, s			
Trunk flexors	15.40 ± 14.46	65.05 ± 48.60	<.001†
Trunk rotators	13.87 ± 13.31	37.05 ± 23.29	<.001†
Dynamic endurance (repetitions)			
Trunk flexors	9.07 ± 9.59	29.75 ± 9.30	<.001†
Trunk rotators	7.20 ± 7.17	37.05 ± 23.29	<.001†

**Data are mean ± SD, except where otherwise indicated. Measurements were taken 2.5 cm above the umbilical ring, upper margin of the umbilical ring, lower margin of the umbilical ring, and 2.5 cm below the umbilical ring.*
†*Significantly different from control (P<.05).*
‡*The ordinal data obtained using the 0-to-5 grading scale from manual muscle testing, and were analyzed with the Mann-Whitney U test (P<.05).*

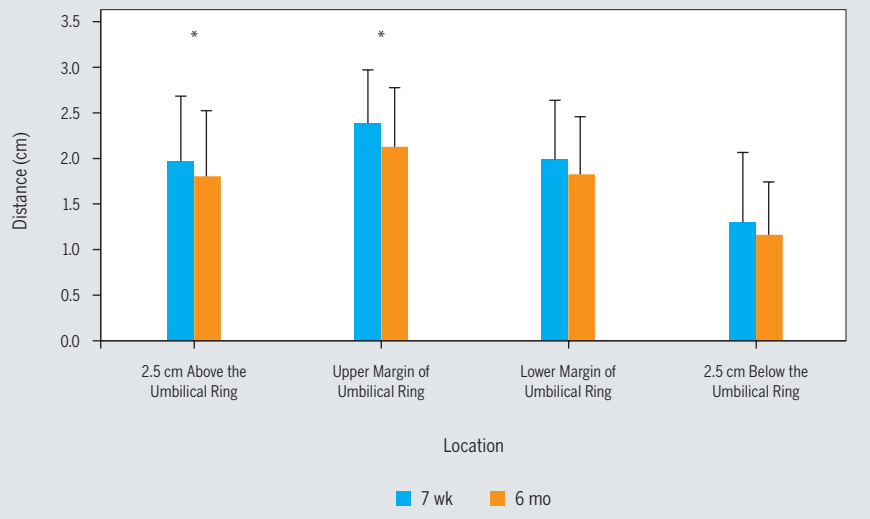

FIGURE 3. Inter-recti distance at 4 locations at 7 weeks and 6 months postpartum. Data are mean and standard deviations. *Significantly different between 7 weeks and 6 months postpartum ($P<.05$).

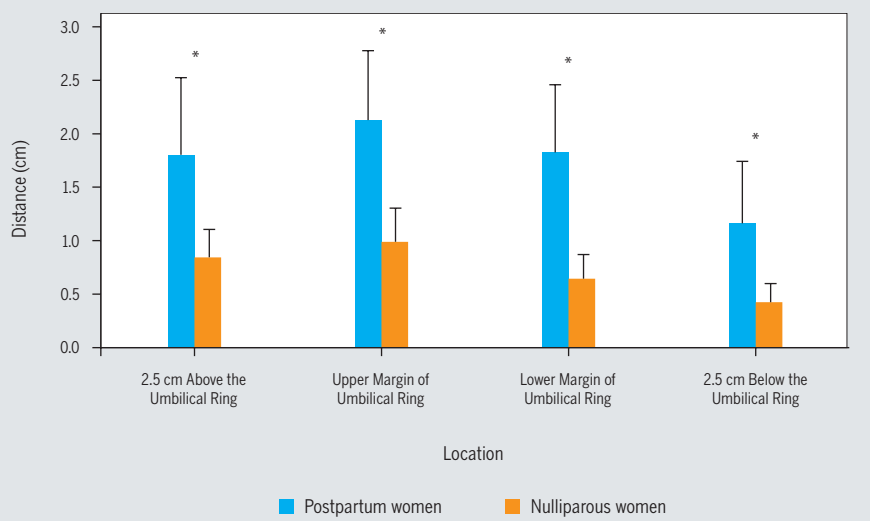

FIGURE 4. Inter-recti distance at 4 locations in nulliparous group and 6 months postpartum group. Data are mean and standard deviations. *Significantly different between groups ($P<.05$).

115), they only measured 1 location (the upper border of the umbilicus), and it is unclear how many women were followed longitudinally. Our study is unique in the number of participants followed longitudinally and the use of several locations to better objectively quantify the diastasis.

For several reasons, measuring IRDs above and below the umbilicus is essential to fully document the course of recovery of DRA after pregnancy. First, in nulliparous women, the width of the linea alba is smaller inferior to the umbilicus.[3] Second, while the collagen fiber architecture in both the supraumbilical (from xiphoid to umbilicus) and infraumbilical (from umbilicus to symphysis pubis) regions have a similar 3-dimensional construction, consisting of fibers arranged from superficial to deep in an oblique layer, a transverse layer, and an irregular layer,[1,12] the infraumbilical region has a greater amount of transverse fibers, which provides greater ability to resist tensile stresses imposed on the linea alba.[2,12] Third, during pregnancy, the growing uterus rises out of the pelvis at about 12 weeks of gestation and comes in direct contact with the abdominal wall, and the fundus of the uterus reaches the height of the umbilicus at about 20 weeks.[13] Consequently, the infraumbilical region of the abdominal wall might sustain a longer duration of stretch during pregnancy. Our data indicate that IRD values were larger for the 2 locations above the umbilicus as compared to those below the umbilicus. These results would suggest that the infraumbilical region of the linea elba has a greater ability to resist stresses imposed over a greater period. In postpartum females, at 6 months after childbirth, the averaged IRDs taken at the 2 supraumbilical sites and at the 2 infraumbilical sites were 2.1 and 2.7 times those of nulliparous women, respectively (**TABLE 6**). Our results suggest that, at 6 months postpartum, IRD has not yet fully recovered in both supraumbilical and infraumbilical locations of the linea alba.

At the supraumbilical site, Coldron et al[9] found that improvement in IRD measurements reached a plateau at 6 months postpartum. In our study, IRD values changed significantly between 7 weeks and 6 months. The IRD values at the 2 supraumbilical locations were smaller at 6 months compared to 7 weeks postpartum, but it is unclear if further improvement would continue to occur over time.

Coldron et al,[9] using ultrasound imaging, reported that the average ± SD IRD, measured at the upper margin of the umbilicus in nulliparous women (age range, 18-45 years), was 1.12 ± 0.36 cm. Beer et al[3] measured IRDs at 3 cm above and 2 cm below the umbilicus, using a high-resolution ultrasound unit in nulliparous females (age range, 20-45 years; height, 156-190 cm; weight, 43-88 kg) and found 90th percentile values of 2.2 and 1.6 cm, respectively. In our study, the mean IRD values ranged from 0.43 to 0.99 cm, which is a narrower range than those reported in previous studies. The subjects'

demographic and anthropometric data, such as age, body height, weight, and ethnic background, may contribute to the differences between studies. Therefore, a nulliparous control group should be included in postpartum studies for reference purposes.

Abdominal muscle strength and static endurance (expressed by holding time) were improved at 6 months compared to 7 weeks postpartum. However, postpartum females still had less strength and endurance than nulliparous females at 6 months after childbirth. In this study, the curl-up was used as a test procedure only and was performed under close monitoring. Curl-ups should not, however, be recommended as an exercise for postpartum women, as curl-ups performed with the valsalva maneuver can increase the intra-abdominal pressure and stress the already weakened abdominal wall after pregnancy, predisposing the abdomen to DRA.[5]

IRD and Abdominal Muscle Function

Gilleared and Brown[11] reported that the ability of postpartum women to raise their trunk during a curl-up and stabilize the pelvis was compromised during pregnancy and that this deficit lasted up to 8 weeks postpartum, especially in women with an IRD (measured by palpation) larger than 3.5 cm during pregnancy. In our study, postpartum women showed poorer trunk strength than nulliparous women at 6 months, with 12 (40%) of the 30 postpartum women given a grade of 3 or less, based on manual muscle testing.

In our sample of postpartum women, using the mean of the IRD values measured at 4 locations, we determined that IRD was moderately negatively correlated ($P<.05$) with the strength and endurance of the trunk flexors and rotators, except for the association between IRD and trunk flexor strength at 6 months postpartum ($P = .06$). We also found that a reduction in the size of IRD between 7 weeks and 6 months after childbirth was associated with an improvement in trunk flexor strength. These findings suggest that the incomplete recovery of the structural integrity (width) of the linea alba may lead to a mechanical deficit, resulting in a reduction in force production capacity of the abdominal musculature. Studies that investigate exercise as a means of improving IRD, thus abdominal muscle function, are needed.

Limitations of the Study

Only intrasession intrarater test-retest reliability of IRD measurements with ultrasound imaging in postpartum women was studied. Data on intersession test-retest reliability and interrater reliability are needed, especially with longitudinal studies. While manual muscle testing to assess abdominal muscle function reflects clinical practice, future studies may wish to consider more accurate and sensitive methods of measurements, such as instrumented dynamometers, functional tests, and self-report questionnaires that assess function with daily activities.

Given the residual abdominal muscle function deficits and remaining larger IRD at 6 months, a longer follow-up period would be needed to determine the extent of eventual recovery in women postpartum. Based on the work by Coldron et al,[9] who reported that increased width of the linea alba remains at 1 year, studies should extend their follow-ups beyond 12 months. That the present study only measured IRD at 7 weeks and 6 months postpartum is also a limitation. No prepregnancy or early-pregnancy baseline data were collected, therefore the assessment of recovery was based on data obtained from a nulliparous control group, as opposed to data obtained longitudinally from an experimental group. While our data and the data from Coldron et al[9] indicate that both structural and functional deficits remain at 6 to 12 months postpregnancy, it is not clear whether any intervention, including exercises, would help to prevent and/or facilitate the recovery of DRA that often occurs during pregnancy. Therefore, future research is essential to explore the need for interventions and, if there is a need, the effectiveness of specific interventions on reducing the size of IRD in postpartum women.

Finally, in our study, the only structural parameter measured was the width of the linea alba, which may not reflect all of the structural changes that may take place in the fascial and muscular structures of the abdominal wall. Measurement of other structures (muscle length, thickness, etc) and in other dimensions could be of value in future research.

CONCLUSION

The primary finding of this study is that the width of the linea alba and abdominal muscle function did not return to normal values by 6 months postpartum. In addition, the size of IRD was negatively correlated with abdominal muscle function, and improvement in IRD in the 6-month period postpartum was positively correlated with improvement in the strength of the trunk flexors. Future research is essential to explore whether interventions are needed in postpartum women and, if needed, the effectiveness of specific interventions on reducing the size of IRD and improving function. ◉

KEY POINTS

FINDINGS: Increased width of the linea alba and decreased abdominal muscle function remain 6 months postpartum, with a negative relationship between the width of the linea alba and abdominal muscle function both at 7 weeks and 6 months after giving birth.

IMPLICATIONS: While structural and abdominal function deficits continue to exist at 6 months, it is not clear to what extent these deficits could or should be addressed, or how to address them.

CAUTION: Judgment of final level of recovery was based on data from a control group, as opposed to data from a single-prepregnancy or early-pregnancy group. The study sample size was also small.

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