Abdominal exercises affect inter-rectus distance in postpartum women: a two-dimensional ultrasound study

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Abstract

Objectives To compare inter-rectus distance (IRD) at rest between women who had a vaginal delivery with women who had a caesarean section, and to describe the effect of different abdominal exercises on IRD.

Setting Physiotherapy practice.

Design Cross-sectional experimental study.

Participants Thirty-eight postpartum primiparous mothers with a singleton baby (vaginal delivery: n = 23; caesarean section: n = 15).

Interventions Two-dimensional ultrasound images from the abdominal wall were recorded at rest and at the end position of abdominal crunch, drawing-in and drawing-in + abdominal crunch exercises. IRD measurements at rest, above and below the umbilicus, were compared between the two groups (vaginal delivery and caesarean section). IRD was also measured above and below the umbilicus during three abdominal exercises in both groups.

Main outcome measures IRD 2 cm above and below the umbilicus.

Results No significant differences in IRD, either above or below the umbilicus, were found between the vaginal delivery and caesarean section groups. IRD above the umbilicus was significantly reduced during abdominal crunch exercises compared with at rest {mean 21.7 [standard deviation (SD) 7.6] mm vs 25.9 (SD 9.0) mm; mean difference 4.2 mm; 95% confidence interval (CI) 0.5 to 7.9}. IRD below the umbilicus was significantly greater during drawing-in exercises compared with at rest [16.0 (SD 8.1) mm vs 11.4 (SD 4.9) mm; mean difference 4.5 mm; 95% CI 1.6 to 7.4].

Conclusion In contrast to existing recommendations for abdominal strength training among postpartum women, this study found that abdominal crunch exercises reduced IRD, and drawing-in exercises were ineffective for reducing IRD. Further basic studies and randomised controlled trials are warranted to explore the effect of abdominal training on IRD.

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Keywords: Diastasis recti; Exercise; Inter-rectus distance; Caesarean section; Postpartum Women; Ultrasound

Introduction

During pregnancy, the linea alba weakens as the bellies of the two rectus abdominis muscles curve around the abdominal wall, increasing their midline separation [1,2]. This gap, the inter-rectus distance (IRD), is often referred to as ‘diastasis recti abdominis’ (DRA) [3]. It has been suggested that the muscles and fascia of the lumbopelvic region are important in trunk movements and in intersegmental and intrapelvic stabilisation [4,5]. In addition, it has been suggested that women who undergo a caesarean section are at greater risk for increased IRD than women who have a vaginal delivery [6]. The drawing-in exercise, which mainly activates the transverse abdominal and internal oblique muscles, is thought to be an important exercise for the prevention and treatment of lower back pain [5], and has been recommended as a gentle exercise to narrow the diastasis recti [7,8].

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Moreover, women with DRA have been discouraged from performing abdominal crunch (AC) exercises in the supine position as it has been suggested that this could open up and increaseIRD [1]. However, data on the effectiveness of different abdominal exercises during pregnancy and in the postpartum period are lacking [7,9]. In a recent systematic review, Benjamin et al. [7] were only able to find one randomised controlled trial (RCT), and the physiotherapeutic intervention only involved one session of a combination of several exercises directly after childbirth [10]. Hence, to date, there is not only scant knowledge regarding the effect of different physiotherapeutic approaches to prevent and treat DRA, but also a lack of basic research into how different abdominal exercises affect IRD. Recently, ultrasound imaging has been suggested as a useful method to assess muscular geometry, and as an indirect measure of muscle activation via changes in muscle thickness [3,11]. Ultrasound images have also been used to measure IRD in postpartum women [3,12]. Recently, Mota et al. [12] found that ultrasound is a reliable method to measure IRD in women at rest, and during abdominal crunch and drawing-in exercises.

As such, the aim of this study was two-fold: (1) to compare IRD at rest between women who had a vaginal delivery and women who had a caesarean section; and (2) to compare IRD at rest and at the end position of abdominal crunch, drawing-in and drawing-in + abdominal crunch exercises.

**Methods**

This cross-sectional experimental study assessed IRD during three different abdominal exercises in the postpartum period in women who had given birth vaginally or via caesarean section.

Participants were recruited from postnatal classes at a private physiotherapy clinic. The inclusion criteria were: 10 to 12 weeks postpartum; willing to participate in one additional session for training in how to perform the exercises; able to perform the exercises correctly; and primigravida with a singleton baby. Exclusion criteria were: abdominal hernia; previous abdominal surgery; and history of regular abdominal training during the previous 6 months.

The study was approved by the Ethics Council of the Technical University of Lisbon, Faculty of Human Kinetics. Signed informed consent was obtained before participation in the study.

Ultrasound images (B-mode) from the anterior abdominal wall were recorded by an ultrasound scanner (LOGIQ e; General Electric Healthcare, Hatfield, UK, 4 to 12 MHz, 30 mm linear transducer) at rest in a supine position, and at the end position of three abdominal exercises: abdominal crunch (crook lying position), drawing-in and drawing-in + abdominal crunch. The investigator was a senior physiotherapist who had been trained in image capturing and measurement of IRD. The method has been tested for test–retest and intra- and inter-rater reliability and found to be very good (intraclass correlation coefficient >0.9) [12]. For each condition, a set of three measurements was performed above and below the umbilicus.

The best of three images was exported in JPG format for further offline processing and analysis.

In order to standardise the position of the transducer, each measurement location was marked on the skin with the subject in a supine resting position, with knees bent at 90°, feet resting on the plinth and arms alongside the body. The transducer was placed transversely along the midline of the abdomen at two locations: 2 cm above and 2 cm below the umbilicus, measured from the centre of the umbilicus.

During image acquisition, the bottom edge of the transducer was positioned to coincide with the corresponding skin marker, and moved laterally until the medial borders of both rectus abdominis muscles were visualised. The orientation of the transducer was adjusted to optimise image visualisation. 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. [11]. Particular attention was paid to the pressure imposed on the probe to avoid a reflexive response by the participants.

The measurements were performed at a mean of 12 weeks postpartum (standard deviation 2.4 weeks, range 8 to 16 weeks).

A semi-automated image analysis was conducted offline to determine IRD following the procedures described by Mota et al. [12] and Pascoal et al. [9].

**Procedure**

Participants were instructed how to perform the three abdominal exercises: abdominal crunch, drawing-in and drawing-in + abdominal crunch. All exercises were performed in the supine position.

For the abdominal crunch exercise, subjects were asked to raise their head and shoulders upwards until the shoulder blades cleared the table and their fingertips touched their knees.

For the drawing-in exercise, subjects were instructed to inhale and, while exhaling, to draw in the abdominal musculature towards the spine. Activation of the transversus abdominis was confirmed by placing the transducer laterally between the iliac crest and the rib cage [13].

For the drawing-in + abdominal crunch exercise, subjects were instructed to combine the procedures used when drawing-in and abdominal crunch exercises were performed separately.

**Statistical analysis**

IRD (dependent variable) was analysed using standard tests for normality (Shapiro–Wilk’s test) and was found to satisfy the assumptions of normality [14]. A separate
Demographic analysis was performed for data recorded above and below the umbilicus.

An independent-samples t-test was performed to examine differences in IRD at rest, above and below the umbilicus, between women who had a vaginal delivery and women who had a caesarean section.

Repeated-measures analysis of variance (ANOVA) was used to compare mean IRD recorded at rest with mean IRD recorded during the three abdominal exercises. Bonferroni’s post-hoc test was used to address multiple comparisons.

Effect size was reported assuming a qualitative assessment whereby a small, moderate or large change/difference was defined by partial Eta square >0.20, 0.50 or 0.80, respectively [15].

Statistical Package for the Social Sciences Version 19.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses, and $P < 0.05$ was considered to indicate statistical significance.

### Results

In total, 38 postpartum women (23 in the vaginal delivery group and 15 in the caesarean section group) participated in the study. Demographic data for the participants are presented in Table 1. There were no significant differences in background variables between the two groups, with the exception of height; women in the caesarean section group were taller. In order to analyse the influence of subject height on IRD, a Pearson correlation was performed. At rest, no relationship was found between height and IRD at any of the probe locations.

Table 2 shows IRD measurements (mm) at rest for each probe location for the vaginal delivery group and the caesarean section group. No significant differences in IRD at rest were found between the two groups, either above $[t(36) = −0.30; P = 0.76]$ or below $[t(36) = −1.69; P = 0.10]$ the umbilicus.

IRD measurements for the whole group of women, above and below the umbilicus, in each exercise condition (rest, abdominal crunch, drawing-in and drawing-in + abdominal crunch) are presented in Table 3.

Differences between IRD at rest and during abdominal crunch, drawing-in and drawing-in + abdominal crunch exercises are presented in Table 4.

Above the umbilicus, there were significant differences between IRD at rest and IRD during the abdominal exercises $[F(3,148) = 3.645; \text{effect size } = 0.43; P < 0.05]$. A Bonferroni post-hoc test revealed that IRD above the umbilicus was reduced significantly during abdominal crunch exercises in comparison with IRD below the umbilicus at rest $[\text{mean } 21.7 (SD 7.6) \text{ mm vs } 25.9 (SD 9.0) \text{ mm}; \text{mean difference } 4.2 \text{ mm;} 95\% \text{ confidence interval (CI) } 0.5 \text{ to } 7.9; P < 0.05]$. No significant differences were found in IRD above the umbilicus between rest and during drawing-in exercises, and between rest and during drawing-in + abdominal crunch exercises.

Below the umbilicus, there were significant differences between IRD at rest and IRD during the abdominal exercises $[F(3,148) = 4.184; \text{effect size } = 0.25; P < 0.05]$. IRD below the umbilicus was increased significantly during drawing-in exercises compared with IRD at rest $[\text{mean } 16.0 (SD 8.1) \text{ mm vs } 11.4 (SD 4.9) \text{ mm}; \text{mean difference } 4.5 \text{ mm;} 95\% \text{ CI } 1.6 \text{ to } 7.4; P < 0.05]$. No significant differences were found between IRD below the umbilicus at rest and during abdominal crunch

### Table 1

Demographic data from all participants ($n = 38$) recorded at 12 weeks postpartum.

<table>
<thead>
<tr>
<th></th>
<th>Vaginal delivery group ($n = 23$)</th>
<th>Caesarean section group ($n = 15$)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>31.2 (3.6)</td>
<td>32.3 (4.4)</td>
<td>0.49</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.0 (6.2)</td>
<td>63.2 (9.5)</td>
<td>0.82</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.6 (4.9)</td>
<td>166.4 (7.5)</td>
<td></td>
</tr>
<tr>
<td>Postpartum BMI (kg/m²)</td>
<td>22.9 (2.7)</td>
<td>22.8 (2.8)</td>
<td>0.25</td>
</tr>
<tr>
<td>Birth weight (kg)</td>
<td>3.1 (2.5)</td>
<td>3.2 (2.7)</td>
<td>0.38</td>
</tr>
</tbody>
</table>

BMI, body mass index; SD, standard deviation. Bold values, significant ($P < .05$).

### Table 2

Inter-rectus distance (mm) at rest measured above and below the umbilicus in the vaginal delivery and caesarean section groups, and differences between the groups.

<table>
<thead>
<tr>
<th>Probe location</th>
<th>Vaginal delivery group ($n = 23$)</th>
<th>Caesarean section group ($n = 15$)</th>
<th>Differences between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>$P$-values</td>
</tr>
<tr>
<td>Above the umbilicus</td>
<td>25.5 (9.0)</td>
<td>26.5 (9.3)</td>
<td>0.76</td>
</tr>
<tr>
<td>Below the umbilicus</td>
<td>10.4 (4.4)</td>
<td>13.0 (5.2)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

SD, standard deviation; CI, confidence interval.
Table 3

<table>
<thead>
<tr>
<th>Probe location</th>
<th>Abdominal exercise</th>
<th>Inter-rectus distance (mm)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Above the umbilicus</td>
<td>Rest</td>
<td>25.9</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>Abdominal crunch</td>
<td>21.7</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Drawing-in</td>
<td>26.9</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>Drawing-in + abdominal crunch</td>
<td>27.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Below the umbilicus</td>
<td>Rest</td>
<td>11.4</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Abdominal crunch</td>
<td>11.5</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Drawing-in</td>
<td>15.9</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Drawing-in + abdominal crunch</td>
<td>12.6</td>
<td>8.1</td>
</tr>
</tbody>
</table>

SD, standard deviation; CI, confidence interval.

Table 4

<table>
<thead>
<tr>
<th>Probe location</th>
<th>Abdominal exercise</th>
<th>Mean difference</th>
<th>95% CI of the difference</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above the umbilicus</td>
<td>Rest vs AC</td>
<td>4.3</td>
<td>0.4 to 8.3</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Rest vs DI</td>
<td>−1.1</td>
<td>−4.3 to 2.2</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Rest vs DI + AC</td>
<td>−1.1</td>
<td>−5.0 to 1.4</td>
<td>0.77</td>
</tr>
<tr>
<td>Below the umbilicus</td>
<td>Rest vs AC</td>
<td>−0.3</td>
<td>−3.2 to 2.6</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Rest vs DI</td>
<td>−4.2</td>
<td>−7.9 to −0.5</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Rest vs DI + AC</td>
<td>−1.2</td>
<td>−4.3 to 2.0</td>
<td>1.00</td>
</tr>
</tbody>
</table>

CI, confidence interval. Bold values, significant (P < .05).

exercises, and between IRD below the umbilicus at rest and during drawing-in + abdominal crunch exercises.

**Discussion**

There were no significant differences in IRD between the caesarean section and vaginal delivery groups. The abdominal crunch was the only exercise to reduce IRD above the umbilicus in comparison with the rest position. Below the umbilicus, the drawing-in exercise increased IRD compared with the rest position. These findings are contradictory to published theories in the area, where the drawing-in exercise has been considered to be a more gentle and effective exercise than the abdominal crunch exercise, especially during pregnancy and postpartum [5,7]. However, these results are in accordance with previous studies from the authors’ group showing a reduction in IRD during abdominal crunch exercises [9], and widening of IRD during drawing-in exercises [12].

According to the literature, the lowest width considered to indicate the presence of DRA is 22 mm measured 3 cm above the umbilicus and 16 mm measured 2 cm below the umbilicus [16]. According to this cut-off point, no women in the present study had DRA. The authors were unable to find any other studies that have compared IRD between women who had a vaginal delivery and women who had a caesarean section. Candido et al. [6] reported that caesarean section is a risk factor for increased postpartum IRD. However, this was not supported by the present results, which found no difference in IRD between women who had a vaginal delivery and women who had a caesarean section, above or below the umbilicus. In common with other studies, the present study found a narrower IRD below the umbilicus than above the umbilicus [8,16]. Also, the present study was in agreement with Coldron et al. [3], who found that IRD above the umbilicus was wider in parous women at 8 weeks postpartum compared with nulliparous women. Results from Liaw et al. [8] suggest that, below the umbilicus, the linea alba has greater ability to resist stresses imposed over a longer period of time. The collagen fibres have a similar three-dimensional construction at both measurement locations, but there are more transverse fibres below the umbilicus, which may provide greater ability to resist tensile stresses imposed on the linea alba [17,18].

Abdominal exercises are encouraged during pregnancy, supported by the theory that abdominal strength during pregnancy may reduce the incidence of DRA [1,4]. Exercise is also recommended in the postpartum period to counteract the effects of pregnancy on a woman’s anterior abdominal wall and body posture. The rationale behind these strengthening training programmes is the assumption that contraction of all abdominal muscles will reduce the abdominal horizontal diameter in such a way that a horizontal force will be generated, producing the approximation of both rectus abdominis muscles, particularly at umbilical level.

The abdominal crunch exercise is used by most clinicians as a test to measure IRD and to diagnose DRA during pregnancy and postpartum [1,19]. The drawing-in exercise is considered to be an important exercise in recruiting the deep abdominal muscles (e.g. the transversus abdominis which is
considered important in trunk stability) [5]. It was hypothesised that the drawing-in exercise would reduce IRD, and performing a drawing-in exercise before an abdominal crunch would decrease IRD further and counteract an expected separation of the muscle bellies of the two rectus abdominis muscles during the abdominal crunch.

To date, only one RCT has been undertaken to evaluate the effect of exercise on IRD and DRA [10]. In this RCT, 50 postpartum women were randomised to one session of different types of abdominal and hip adduction exercises, as well as pelvic tilt and pelvic floor muscle exercises and diaphragmatic breathing. The session was conducted 6 hours after childbirth and the post test was performed 18 hours later. This global approach shortly after childbirth was found to lead to a significant reduction in IRD [10]. However, no conclusion could be drawn about which exercises may have caused the effect. Additionally, in Mesquita et al. [10], IRD was measured using a calliper, and therefore the results cannot be compared directly with the ultrasound measurements made in the present study.

This study only found a significant approximation of the two muscle bellies during the abdominal crunch exercise. Based on these results, it is hypothesised that the abdominal crunch exercise may be effective in reducing IRD above the umbilicus. However, this needs to be investigated in an RCT of high methodological and interventional quality [20].

Given the results of the present study, which show an increase in IRD below the umbilicus during the drawing-in exercise, the recommendation of this exercise for women who have undergone a caesarean section is questioned. At this measurement point, the muscle bellies and abdominal fascia are moved apart, which may reduce the ability of the muscles to generate enough tensile force. It is assumed that the tension generated by the deepest abdominal muscles will reduce the abdominal horizontal diameter in such a way that a horizontal force will be generated, which reduces the distance between both rectus abdominis muscles, particularly at the level of the umbilicus [8]. However, there is no evidence that this horizontal tension will produce an approximation of the rectus abdominis muscles. The horizontal force is the result of the overall action of the deep abdominal muscles (internal and external oblique and transversus muscles), which are attached anteriorly to the lateral side of each rectus abdominis muscle [21] and connected posteriorly to the lumbar vertebral column via the thoracolumbar fascia. Thus, during the drawing-in exercise, both rectus abdominis muscle bellies could be pulled laterally, towards the thoracolumbar fascia and the vertebral column, as a consequence of the horizontal component of the force generated by the active deep abdominal muscles, particularly the transversus muscle.

The increased IRD during the drawing-in exercise is in accordance with findings from a previous study of 24 healthy women, 12 of whom were in the postpartum period [12]. Nevertheless, the isometric contraction of the rectus abdominis muscles seems to reduce the effect of the drawing-in exercise on IRD. In fact, IRD below the umbilicus was significantly smaller when drawing-in and abdominal crunch exercises were combined compared with when an isolated drawing-in exercise was performed [mean 12.6 (SD 6.8) vs 16.0 (SD 8.1) mm; mean difference 3.3 mm; 95% CI 0.4 to 6.2; \( P < 0.05 \)].

The reliability of IRD measured using ultrasound in a crook lying position (abdominal crunch) was established previously by the authors’ team [12] as an intrasession intraclass correlation coefficient (ICC1,1) of 0.94 (95% CI 0.88 to 0.98), 2 cm above the umbilicus, and an ICC of 0.97 (95% CI 0.93 to 1.00), 2 cm below the umbilicus. Above the umbilicus, the standard error of measurement (SEM) was 1.6 mm and the minimum detectable change, at the 95% confidence level (MDC95), was 4.3 mm. Below the umbilicus, the SEM was 1.2 mm and the MDC95 was 3.2 mm.

The reliability of IRD measurements during a drawing-in exercise was also determined [12] as an intrasession ICC of 0.93 (95% CI 0.85 to 0.97), 2 cm above the umbilicus and an ICC of 0.99 (95% CI 0.97 to 1.00), 2 cm below the umbilicus. Above the umbilicus, the SEM was 2.0 mm and the MDC95 was 5.6 mm. Below the umbilicus, the SEM was 0.7 mm and the MDC95 was 1.8 mm. In this study, the difference between rest and abdominal exercise conditions was 2.2 mm; therefore, the error of measurement was smaller than the comparison between conditions.

The strengths of this study were the inclusion of a homogenous group of primiparous postpartum women, the differentiation between women who had undergone vaginal delivery and caesarean section, and the use of two-dimensional ultrasound to measure IRD. A trained physiotherapist conducted all the measurements, and IRD measurements with ultrasound imaging have been found to be reliable, with ICC values >0.90 [19]. Furthermore, the exercise instructions were standardised, and all analyses were performed offline by an experienced women’s health physiotherapist. The physiotherapist was blinded to the type of delivery and the different abdominal exercises.

One limitation of this study was the lack of a priori power calculation and the estimated sample size. In an attempt to minimise the effect of this limitation when interpreting the results, a post-hoc power analysis was conducted using G*power computer software [22] to calculate the sample size required to detect large effects (\( \eta^2 = 0.8 \)) with 80% power using independent t-test and repeated-measures ANOVA with alpha at 0.05 and an expected variance of 6.0 mm in IRD measurements. The results indicated that a total sample of 46 participants (23 per group) would be needed to detect differences between groups (independent t-test), and a total of 31 participants would be needed to detect large effects of the exercises on IRD (repeated-measures ANOVA). According to this analysis, the sample size in the caesarean section group may cause a type II error when comparisons are made between the two groups of participants. On the other hand, multiple testing may cause type I error, finding significant differences due to chance. Bonferroni adjustments were performed to control
for the latter, and the authors are confident that the significant findings are genuine. The results in this study are limited to a single time point during the postpartum period, and may differ if obtained more than 12 weeks postpartum. Some studies have found that most changes to IRD occur between 6 and 12 months postpartum, although improvements can be detected even after 24 months without exercise [3,8]. The present study was limited to primiparous women and women without DRA, and therefore should not be generalised to multiparous women or the general female population. Another limitation may be related to the order of which the exercises were presented. However, as the results showed narrowing of IRD during the first exercise (abdominal crunch), one would expect that this would facilitate further narrowing during the drawing-in exercise, and not the opposite.

**Conclusion**

The results suggest that the magnitude of postpartum IRD is not affected by the mode of delivery (caesarean section or vaginal delivery), and IRD was found to increase during drawing-in exercises and decrease during abdominal crunch exercises. However, there is an urgent need for high-quality RCTs to investigate the effect of different abdominal exercises on IRD, and to compare abdominal exercises with no exercise.

**Ethical approval:** Ethics Council of the Technical University of Lisbon, Faculty of Human Kinetics (CEFMH-UL nº 3/2012).

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**Conflict of interest:** None declared.

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