ABDOMINAL EXERCISES AFFECT INTER-RECTUS DISTANCE IN POSTPARTUM WOMEN: A 2D ULTRASOUND STUDY

Citation: Sancho, M. F., Pascoal, A. G., Mota, P., & Bo, K. (2015). Abdominal exercises affect inter-rectus distance in postpartum women: a two-dimensional ultrasound study. *Physiotherapy, 101*(3), 286-291.

MARIA FÁTIMA SANCHO (Msc; PT)
Department of Physiotherapy, Escola Superior de Saúde de Alcoitão, PORTUGAL
Email address: mfsancho@clix.pt

AUGUSTO GIL PASCOAL (Ph.D.; PT)
Univ. Lisboa, Fac Motricidade Humana, CIPER, LBMF, P-1499-002 Lisbon, PORTUGAL
Email address: gpascoal@fmh.ulisboa.pt

PATRÍCIA MOTA (Ph.D.; PT)
Univ. Lisboa, Fac Motricidade Humana, CIPER, LBMF, P-1499-002 Lisbon, PORTUGAL
Email address: patimota@gmail.com

KARI BØ (Ph.D.; PT)
Department of Sports Medicine, Norwegian School of Sports Sciences, NORWAY
Email address: kari.bo@nih.no

Correspondent Author:

AUGUSTO GIL PASCOAL (Ph.D.; PT)
Address: Universidade de Lisboa
Faculdade de Motricidade Humana
Estrada da Costa
1499-002 Lisboa
PORTUGAL

Phone: + 351965453476
Fax: + 351 214149236
Email: gpascoal@fmh.ulisboa.pt

WORD COUNT: 3000 words

ABDOMINAL EXERCISES AFFECT INTER-RECTUS DISTANCE IN POSTPARTUM WOMEN: A 2D ULTRASOUND STUDY

ABSTRACT

Objectives: Compare inter-rectus distance (IRD) at rest between women with vaginal delivery vs Caesarean section. Describe the effect produced by different abdominal exercises on IRD.

Setting: Physiotherapy practice.

Design: Cross-sectional experimental study.

Participants: 38 postpartum women (vaginal delivery: N=23; Caesarean section: N=15), primiparous with a single baby.

Interventions: 2D ultrasound images from the abdominal wall were recorded at rest and at the end-position of the abdominal-crunch, drawing-in and drawing-in with abdominal-crunch. The supra and infraumbilical rest IRD was compared (Independent-samples t-test) between groups, vaginal delivery and Caesarean section, and with IRD at the abdominal exercises (Repeated Measurements ANOVA).

Main outcome measures: Inter-rectus distance 2 cm above and below the umbilicus.

Results: No significant differences were found in IRD either above or below the umbilicus when comparing women with a vaginal delivery and a Caesarean section. The supraumbilical IRD was significantly reduced in the abdominal-crunch compared with rest condition [mean 21.7 (SD 7.6) mm vs. 25.9 (9.0) mm; mean differences (MD) 4.2 mm; 95% confidence interval (CI) 0.5 to 7.9]. The infraumbilical IRD was significantly increased in drawing-in compared with rest condition [16.0 (8.1) mm vs 11.4 (4.9) mm; MD 4.5 mm; 95% CI 1.6 to 7.4].

Conclusion: Contradictory to existing recommendations for abdominal strength training among postpartum women, the present study found that the abdominal-crunch exercise reduces IRD while the drawing-in exercise was ineffective in reducing the IRD. Further basic studies and randomized controlled trials are warranted to explore the effect of abdominal training on IRD.

Key words: diastasis abdominis; exercise; inter-rectus distance; caesarean section; postpartum; ultrasonography

Abdominal Exercises Affect Inter Rectus Distance in Postpartum Women: A 2D Ultrasound Study

INTRODUCTION

During pregnancy there is a weakening of the linea alba as the two bellies of the rectus abdominis curve round the abdominal wall, increasing the midline separation of the two rectus abdominis muscles [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 stabilization [4, 5]. In addition, women that undergo Caesarean section have been hypothesized to be at greater risk for increased IRD than women delivering vaginally [6]. The drawing-in maneuver, mainly activating the transverse abdominal and internal oblique muscles, is suggested to be an important exercise in the prevention and treatment of lower back pain [5], and has been recommended as a gentle exercise to narrow the diastasis recti [7, 8]. Moreover, women with DRA have been discouraged from doing abdominal-crunch exercises in the supine position as it has been suggested that this might open up and increase the IRD [1] .However, there is a paucity of research on the effectiveness of different abdominal exercises both during pregnancy and in the postpartum period [7, 9]. In a recent systematic review, Benjamin et al. [7] found only one randomized controlled trial (RCT), and the physiotherapy intervention involved only one session of a combination of several exercises directly after childbirth [10]. Hence, to date, there is not only scant knowledge on the effect of different physiotherapeutic approaches to prevent and treat DRA, but also a lack of basic research on how different abdominal exercises influence the 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 during rest, abdominal-crunch and drawing-in exercises.

Thus, the purpose of this study was twofold: 1) to analyze if there were differences in the IRD at rest between women who delivered vaginally or by Caesarean section; and 2) to compare the IRD measured at rest and at the end position of the abdominal crunch, the drawing-in maneuver and the combination of drawing-in plus the abdominal crunch.

METHODS

This is a cross-sectional experimental study assessing the IRD during three different abdominal exercises in the post-partum period in women delivering vaginally or by Caesarean section.

Participants were recruited from postnatal classes in a private physiotherapy clinic. The inclusion criteria were being between 10^{th}-12^{th} postpartum weeks; agreeing to participate in one extra session where they were taught how to perform the exercises; being able to perform the exercises correctly; being primiparous with a singleton baby. Exclusion criteria were having abdominal hernias, previous abdominal surgery and having performed 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, 4-12 MHz,

30mm linear transducer) in a rest supine position and at the end-position of three abdominal exercises: abdominal-crunch (crook lying position), drawing-in and a combination of drawing-in with abdominal crunch. The investigator was a senior physiotherapist with special training in image capturing and measurement of IRD. The method has been tested for test-retest and intra- and interrater reliability and found to be very good (ICC > 0.9) [12].

For each condition a set of three measurements was performed at two locations: above and below the umbilicus.

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

In order to standardise the position of the transducer, each measurement location was marked on the skin with the subject in a rest supine resting position, with knees bent at 90 degrees, 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 center of the umbilicus.

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 rectus abdominis muscles were visualised. The orientation of the transducer was then adjusted to optimizse 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]. Additionally, particular attention was paid to the pressure imposed on the probe to avoid reflexive response from the participants.

The measurements were performed at mean post-partum week 12 (± 2.4) range 8 to 16 weeks.

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

Procedure

Participants were instructed on how to perform the three abdominal exercises: abdominal-crunch (AC), drawing-in (DI) and the combination of drawing-in with abdominal-crunch (DI+AC).

All exercises were performed in the lying supine position starting with assessment at rest and followed by measurement during AC, DI and DI+AC.

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

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

For the DI+AC exercise, subjects were instructed to combine the procedures used when DI and AC exercises were singly performed.

Statistical analysis

The IRD dependent variable was analysed using standard tests for normality (Shapiro-Wilk Test) and was found to satisfy assumptions of normality [14].

A separate analysis was performed for data recorded in each probe location: above and below the umbilicus.

An independent-samples *t*-test was run to examine differences in the IRD measured at rest below and above the umbilicus, between women that delivered vaginally and by Caesarean section.

A repeated measurements ANOVA test was used to compare the mean IRD recorded at rest to that recorded during the three abdominal exercises. A Bonferroni post-hoc test was used to address multiple comparisons.

Effect size (ES) was reported assuming a qualitative assessment whereby a small, moderate or large change/difference was defined by *Partial Eta Square* greater than 0.20, 0.50 or 0.80 respectively [15].

For all statistical tests, specific software (SPSS Statistics 19.0) was used and critical level of $P < .05$ was considered statistically significant for all analyses.

RESULTS

A total of 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 both groups with the exception of height where women in the Caesarean 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 1

Table 2 shows IRD measurements (mm) at rest for each probe location, amongst women delivering vaginally and by Caesarean section. No significant differences were found in IRD at rest between women who delivered vaginally and women who underwent Caesarean section, either above [t(36) = -0.30;P = 0.76] or below [t (36) = -1.69; P = 0.10] the umbilicus.

TABLE 2

The IRD for the whole group of women, measured below and above the umbilicus, in each abdominal condition (rest, AC, DI and DI + AC) is presented in Table 3.

TABLE 3

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

TABLE 4

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

Below the umbilicus, there were statistically significant differences between IRD at rest and IRD during the three abdominal exercises [$F(3,148) = 4.184$; ES = 0.25; $P < 0.05$]. The infraumbilical IRD was significantly increased during drawing-in condition when compared to IRD measurements at rest [mean 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, $P < 0.05$]. No significant differences were found between IRD measurements below the umbilicus at rest and the abdominal-crunch and between rest and drawing-in combined with abdominal crunch.

DISCUSSION

There were no significant differences in IRD between the Caesarean section and the vaginal delivery groups. Our observations show that the abdominal-crunch was the only exercise reducing the IRD above the umbilicus compared to the rest position. Below the umbilicus the drawing-in exercise increased the IRD compared to rest. These findings are contradictory to published theories in the area, where the drawing-in exercise has been considered a more gentle and effective exercise than abdominal crunch, especially during pregnancy and after childbirth [5, 7]. However, these results are in accordance with previous studies from our group showing reduction of the IRD during abdominal-crunch exercise [9] and widening of the IRD during the drawing-in exercise [12].

In the literature, the lowest width for presence of DRA is 22 mm measured 3 cm above the umbilicus and 16 mm at 2 cm below the umbilicus [16]. According to this cut-off point, no women in our study had a DRA condition. We have not been able to find other studies comparing the IRD in women after vaginal delivery and Caesarean section. Candido et al. [6] considered the Caesarean section a risk factor for increased postpartum IRD. This is not supported by our results where the IRD at rest was not different between women that underwent vaginal delivery and Caesarean section, above or below the umbilicus. The results are in accordance with other studies showing that the IRD is narrower below the umbilicus than above the umbilicus [8, 16] and with Coldron et al. [3] who also found that the IRD measured at 8 weeks postpartum above the umbilicus was wider in parous women than in a nulliparous control group. Results from Liaw et al. [8] suggest that, below the umbilicus, the linea alba has a greater ability to resist stresses imposed over a longer period of time. The collagen fibers have a

similar three-dimensional construction at both measurement locations, but below the umbilicus there is a greater amount of transverse fibers, which may provide a 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 post-partum period to counteract the effects of pregnancy on a woman's anterior abdominal wall and body posture. The rationale behind these strengthening training programs is the assumption that the 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, 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 in the post-partum period [1, 19]. The drawing-in exercise is considered an important exercise in recruiting the deep abdominal muscles e.g. the transversus abdominis which is considered important in trunk stability [5]. It was hypothesized that the drawing-in exercise would reduce the IRD, and performing the drawing-in exercise before the abdominal crunch would decrease the IRD further and counteract an expected separation of the two muscles bellies of the rectus abdominis during abdominal crunch.

To date only one RCT has been carried out to evaluate the effect of exercise on IRD and DRA [10]. In this RCT, 50 postpartum women were randomized to one session of different types of abdominal and hip adduction exercises as well as pelvic tilt, pelvic floor muscles exercises and diaphragmatic breathing. The session was conducted 6 hours after childbirth and the post test was 18 hours later. The effect of this global approach shortly after childbirth was reported as a significant reduction of the IRD [10].

However, no conclusion could be drawn on which exercises might have caused the effect. Additionally, the IRD reported in Mesquita et al. [10] was measured by means of a caliper which cannot be directly compared to the ultrasound measurements performed in our study.

We found that there was a significant approximation of the two bellies muscles during the abdominal-crunch exercise only. Based on our results, we hypothesize that the abdominal crunch exercise may be effective in reducing IRD above the umbilicus. However, this needs to be investigated in a RCT of high methodological and interventional quality [20].

Following the results of the present study, which show a widening of the IRD below the umbilicus during the drawing-in exercise, we question the recommendation of this exercise for women that have undergone Caesarean section. At this measurement point the muscles bellies and abdominal fascia are moved apart which may reduce the muscles ability 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 belly muscles could be pulled laterally, towards the thoracolumbar fascia and the vertebral

column, in consequence of the horizontal component of the force generated by the active deep abdominal muscles, particularly the transversus muscle.

The increased IRD during drawing-in is in accordance with findings from previous studies, where 24 healthy women, 12 of which in the postpartum period [12]. Nevertheless, the isometric contraction of the rectus abdominis seems to reduce the effect of the drawing-in exercise on IRD. In fact, the IRD below the umbilicus was significantly smaller when drawing-in and abdominal-crunch exercises were combined than the IRD measured when an isolated drawing-in 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, $P < 0.05$].

Reliability for IRD measured using ultrasound in a crook lying position (abdominal crunch) had been previously established by our team [12] as an intrasession intraclass correlation coefficient ($ICC_{1,1}$) of 0.94 (95%CI =0.88-0.98), 2 cm above the umbilicus, and an ICC of 0.97 (0.93-1.00), 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 (0.85-0.97), 2 cm above the umbilicus and an ICC of 0.99 (0.97-1.00), 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 and, therefore, the error of measurement is smaller than the comparison between conditions.

The strengths of the present 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 2D ultrasound to measure the IRD. A trained physiotherapist conducted all the measurements, and the IRD measurements with ultrasound imaging have been found to be reliable, with very good ICC values above 0.90 [19]. Furthermore, the exercise instructions were standardised, and all analyses were performed off line by an experienced women's health physiotherapist. The physiotherapist was blinded towards the type of delivery and the different abdominal exercises.

One limitation of the study was the lack of a-priori power calculation and the estimated sample size. In an attempt to minimize the effect of this limitation when interpreting the results, a post hoc power analysis was conducted using the G*power computer software [22] to calculate the sample size required to detect large effects (d=.8) with 80% power using independent t-test and repeated measured ANOVA with alpha at .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 to detect large effects of the exercises on IRD (repeated measured ANOVA). According to this analysis, the sample size in the Caesarean section group may cause a type II error when comparisons are made between both groups of participants. On the other hand, multiple testing may cause type I error, finding statistically significant differences due to chance. Bonferroni adjustments were performed to control for the latter, and we are therefore confident that the statistically significant findings are real. Our results are limited to only one time point during the postpartum period, and results may differ if obtained later than 12 weeks postpartum. Some studies have found that most changes to the IRD occur between 6 and 12 months though improvements can be detected even after 24 months without exercise [3, 8]. Our study is limited to primiparous women and women without

DRA, and therefore should not be generalized to multiparous women or the general female population. Another limitation may be related to the order by which exercises were presented. However, as our results showed a narrowing of the IRD during the first exercise (abdominal crunch), one would expect that this would facilitate a further narrowing during in-drawing and not the opposite.

CONCLUSION

The main findings of this study are two-fold: 1) the magnitude of the post-partum IRD is not affected by the delivery mode (Caesarean or vaginal delivery); 2) the IRD increased when drawing-in is performed and reduced during the abdominal-crunch exercise. 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

Funding: This study was part of the research project "*Effects of biomechanical loading on the musculoskeletal system in women during pregnancy and the postpartum period*", supported by the Portuguese Foundation for Science and Technology (PTDC/DES/102058/2008).

Conflicts of interest: None declared

REFERENCES

[1] Boissonnault JS, Blaschak MJ. Incidence of diastasis recti abdominis during the childbearing year. Phys Ther. 1988;68:1082-6.

[2] Gilleard WL, Brown JM. Structure and function of the abdominal muscles in primigravid subjects during pregnancy and the immediate postbirth period. Phys Ther. 1996;76:750-62.

[3] Coldron Y, Stokes MJ, Newham DJ, Cook K. Postpartum characteristics of rectus abdominis on ultrasound imaging. Man Ther. 2008;13:112-21.

[4] Lee DG, Lee LJ, McLaughlin L. Stability, continence and breathing: the role of fascia following pregnancy and delivery. J Bodyw Mov Ther. 2008;12:333-48.

[5] Richardson CA, Snijders CJ, Hides JA, Damen L, Pas MS, Storm J. The relation between the transversus abdominis muscles, sacroiliac joint mechanics, and low back pain. Spine. 2002;27:399-405.

[6] Candido G, Lo T, Janssen PA. Risk factors for diastasis of the recti abdominis. J Ass Chartered Physiotherapists in Women's Health 2005;97:49–54.

[7] Benjamin DR, van de Water ATM, Peiris CL. Effects of exercise on diastasis of the rectus abdominis muscle in the antenatal and postnatal periods: a systematic review. Physiotherapy. 2014;100:1-8.

[8] Liaw LJ, Hsu MJ, Liao CF, Liu MF, Hsu AT. The Relationships Between Inter-recti Distance Measured by Ultrasound Imaging and Abdominal Muscle Function in Postpartum Women: A 6-Month Follow-up Study. J Orthop Sports Phys Ther. 2011;41:435-43.

[9] Pascoal AG, Dionisio S, Cordeiro F, Mota P. Inter-rectus distance in postpartum women can be reduced by isometric contraction of the abdominal muscles: a preliminary case-control study. Physiotherapy. 2014;100:344-8.

[10] Mesquita LA, Machado AC, Andrade AV. Fisioterapia para Redução da Diástase dos Músculos Retos Abdominais no Pós-Parto. Rev Bras Gin & Obst. 1999;21:267-72.

[11] Teyhen DS, Gill NW, Whittaker JL, Henry SM, Hides JA, Hodges P. Rehabilitative ultrasound imaging of the abdominal muscles. J Orthop Sports Phys Ther. 2007;37:450-66.

[12] Mota P, Pascoal AG, Sancho MF, Bo K. Test-retest and intra-observer reliability of 2D ultrasound measurements of distance between Rectus Abdominis in women. J Orthop Sports Phys Ther. 2012;42:940-6.

[13] Teyhen DS, Rieger JL, Westrick RB, Miller AC, Molloy JM, Childs JD. Changes in deep abdominal muscle thickness during common trunk-strengthening exercises using ultrasound imaging. J Orthop Sports Phys Ther. 2008;38:596-605.

[14] Portney LG, Watkins MP. Foundations of clinical research: applications to practice. 3rd ed. Upper Saddle River, N.J.: Pearson/Prentice Hall; 2009.

[15] Cohen J. Quantitative methods in Psychology. Psych Bull. 1992;112:155-9.

[16] Beer GM, Schuster A, Seifert B, Manestar M, Mihic-Probst D, Weber SA. The normal width of the linea alba in nulliparous women. Clin Anat. 2009;22:706-11.

[17] Axer H, Keyserlingk DGv, Prescher A. Collagen Fibers in Linea Alba and Rectus Sheaths: II. Variability and Biomechanical Aspects. J Surg Res. 2001;96:239-45.

[18] Grassel D, Prescher A, Fitzek S, Keyserlingk DG, Axer H. Anisotropy of human linea alba: a biomechanical study. J Surg Res. 2005;124:118-25.

[19] Mota P, Pascoal AG, Sancho F, Carita AI, Bø K. Reliability of the inter-rectus distance measured by palpation. Comparison of palpation and ultrasound measurements. Man Ther. 2013;18:294-8.

[20] Bo K, Herbert RD. There is not yet strong evidence that exercise regimens other than pelvic floor muscle training can reduce stress urinary incontinence in women: a systematic review. J Physiother. 2013;59:159-68.

[21] Stokes IA, Gardner-Morse MG, Henry SM. Intra-abdominal pressure and abdominal wall muscular function: Spinal unloading mechanism. Clin Biomech. 2010;25:859-66.

[22] Faul F, Erdfelder E, Lang A-G, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39:175-91.

ABDOMINAL EXERCISES AFFECT INTER-RECTUS DISTANCE IN POSTPARTUM WOMEN: A 2D ULTRASOUND STUDY

Table 1 - Demographic data from all participants (N= 38) recorded at 12 weeks postpartum week.

	Vaginal Delivery Group (N = 23)	Caesarean Section Group (N = 15)	P -value
	Mean (SD)	Mean (SD)	
Age (years)	31.2 (3.6)	32.3 (4.4)	0.49
Weight (kg)	61.0 (6.2)	63.2 (9.5)	0.82
Height (cm)	163.6 (4.9)	166.4 (7.5)	0.03 (*)
Postpartum BMI (kg/m2)	22.9 (2.7)	22.8 (2.8)	0.25
Birth weight (kg)	3.1 (2.5)	3.2 (2.7)	0.38

BMI: Body Mass Index
SD: standard deviation
(*) Significant (P<0.05)

ABDOMINAL EXERCISES AFFECTS INTER-RECTUS DISTANCE IN POSTPARTUM WOMEN: A 2D ULTRASOUND STUDY

Table 2 – The inter-rectus distance (mm) at rest on each probe location across groups, vaginal delivery and Caesarean section group, and differences between groups.

Probe Location	Groups of Participants				Differences between groups		
	Vaginal Delivery Group (N=23)		**Caesarean Section Group** (N=15)		P-values	Mean (SD)	95% CI
	Mean (SD)	95% CI	Mean (SD)	95% CI			
Above the Umbilicus	25.5 (9.0)	21.7 – 2.5	26.5 (9.3)	21.4 – 31.6	0.76	0.9 (9.1)	-7.0 - 5.2
Below the Umbilicus	10.4 (4.4)	8.5 – 12.3	13.0 (5.2)	8.0 – 1.,2	0.10	-2.7 (4.8)	-5.9 - 0.5

SD: Standard Deviation

95% CI: 95% confidence interval

ABDOMINAL EXERCISES AFFECT INTER-RECTUS DISTANCE IN POSTPARTUM WOMEN: A 2D ULTRASOUND STUDY

Table 3 - The inter-rectus distance at rest measured below and above the umbilicus in the whole group (vaginal delivery and caesarean groups) and at three different abdominal exercises: abdominal crunch, drawing-in and a combination of drawing-in with abdominal crunch.

Probe location	Abdominal contraction modality	Inter-Rectus Distance (mm)		95% CI	
		Mean	SD	Lower	Upper
Above the Umbilicus	Rest	25.9	9.0	23.0	28.9
	Abdominal Crunch	21.7	7.5	19.3	24.2
	Drawing-in	26.9	8.7	24.4	29.4
	Drawing-in + Abdominal Crunch	27.3	7.6	24.5	30.2
Below the Umbilicus	Rest	11.4	4.9	9.8	13.0
	Abdominal Crunch	11.5	5.3	9.8	13.2
	Drawing-in	15.9	6.8	13.3	18.6
	Drawing-in + Abdominal Crunch	12.6	8.1	10.4	14.9

95% CI: 95% confidence intervals
SD: Standard Deviation

Table 4 - Pairwise comparisons between IRD at rest and at each abdominal exercise (abdominal crunch; drawing-in and drawing-in plus abdominal crunch).

Probe location	Abdominal exercise	Diff	SEM	P-value	95% CI for difference	
					Lower bound	Upper bound
Above the Umbilicus	Rest vs AC	4.3	1.4	0.02 [(a)]	0.4	8.3
	Rest vs DI	-1.1	1.2	1.00	-4.3	2.2
	Rest vs DI + AC	-1.1	1.2	0.77	-5.0	1.4
Below the Umbilicus	Rest vs AC	-0.3	1.0	1.00	-3.2	2.6
	Rest vs DI	-4.2	1.3	0.02 [(a)]	-7.9	-0.5
	Rest vs DI + AC	-1.2	1.1	1.00	-4.3	2.0

AC: Abdominal crunch

DI: Drawing-in

DI+AC: Drawing-in combined with abdominal crunch

95% CI: 95% confidence intervals

Diff: Mean differences

SEM: Standard Error of Mean

[(a)] Significant *(P < 0.05)*