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Relationship between inter-recti distance, abdominal muscle endurance, pelvic floor functions, respiratory muscle strength, and postural control in women with diastasis recti abdominis

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ABSTRACT

Objective: The main objective was to assess the relationship between inter-recti distance (IRD) and abdominal muscle endurance, pelvic floor functions, respiratory muscle strength, and postural control in women with Diastasis Recti Abdominis (DRA). Additionally, the secondary purpose of the study is to investigate the independent predictors of IRD in women with DRA.
Study design: Fifty-one women who were diagnosed with DRA participated to the study. IRD assessment with a caliper, abdominal muscle endurance test, Pelvic Floor Distress Inventory Questionnaire-20 (PFDI-20), maximum inspiratory and expiratory pressure (MIP and MEP, respectively) tests, Clinical Test of Sensory Integration of Balance (m-CTSIB) under eyes open on a firm surface (EOFS), eyes closed on a firm surface (ECFS), eyes open on a foam surface (EOFoS), and eyes closed on a foam surface (ECFoS) conditions, and Limits of Stability (LOS) tests were performed for all subjects. Pearson or Spearman correlation analyses were used to determine the relationship between IRD and static abdominal flexion endurance test, PFDI-20, MIP and MEP, m-CTSIB, and LOS scores depending on the distribution properties of the data. Additionally, linear regression analysis was utilized for analyzing the independent predictors of IRD among the age, BMI, parity, time since last birth, birth weight, weight gains last pregnancy, and mode of delivery.
Results: IRD had correlations with Colorectal–Anal Distress score of PFDI-20 ($r = -0.317$, $p = 0.03$) and EOFS, ECFS, EOFoS, ECFoS and composite score of m-CTSIB ($r = 0.356$, $p = 0.01$; $r = 0.337$, $p = 0.02$, $r = 0.279$, $p = 0.04$; $r = 0.265$, $p = 0.04$; $r = 0.413$, $p = 0.004$, respectively) and LOS scores ($r = 0.422$, $p = 0.003$). Increased IRD did not influence abdominal muscle endurance and respiratory muscle strength in women with DRA ($p < 0.05$). Age, BMI, time since last birth, weight gains last pregnancy, and mode of delivery were not determined as the factors that influence IRD in women with DRA ($p < 0.05$).
Conclusion: We concluded that increased IRD is associated with worse postural control, but better colorectal functions in women with DRA. Additionally, IRD does not show a clear association with abdominal muscle endurance, pelvic floor functions, and respiratory muscle strength. According to our results, postural stability assessments may perform in the physiotherapeutic management of women with DRA.

Introduction

Diastasis recti abdominis (DRA), defines as midline inter-recti separation. It occurs primarily in women because of the progressive and prolonged abdominal distension during the second and third trimesters of pregnancy and that may persist to afflict in the postpartum period [1,2]. In some cases, DRA spontaneously heals in the first 8 weeks after delivery [3]. The cut-off points for diagnosis of DRA are varying in the studies but, the presence of more than 2 or 2,5 cm IRD at one or more points of the linea alba or a visible midline bulge with exertion is generally accepted as DRA [2,4].

Although numerous studies have investigated possible risk factors of DRA, the results are still uncertain [5–10]. Age, body mass index before, during and after pregnancy, parity, baby weight birth, abdominal circumference in the last trimester, delivery mode, hypermobility, heavy lifting, and exercise habits are the most frequently evaluated factors in

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the literature [6]. On the other hand, there is limited evidence about the factors that influence the amount of IRD [11]. Body mass index and waist circumference have been reported as independent characteristics of IRD [11,12].

The linea alba is the central insertion region of the rectus abdominis (RA), internal obliques, external obliques, and transversus abdominis (TA) muscles, and also connects with the fascia that shields the RA muscles [13]. It is known that the core system of the body also consists of the muscles of the pelvic floor, RA, TA, multifidus, and diaphragm. The core system is attributed as responsible for supporting the spine and the pelvis, and stabilization of the trunk [14]. According to these biomechanical connections and the theory of pelvic dynamics, it has been postulated that the presence of DRA may affect abdominal and pelvic floor muscles strength, body dynamics, pelvic floor, and inner core functions. The studies have investigated the effect of DRA on abdominal muscle strength or pelvic floor functions or pain, but there is no consensus [11,15]. Furthermore, defects of RA such as a separation of muscle, may limit the role of RA on trunk mobility and stability, posture, and respiration.

As the presence of functional and anatomical interactions between diaphragm, abdominal and pelvic floor muscles, we hypothesized that the strength and functions of these structures might be associated with IRD in women with DRA. Therefore, the aim of our study is to determine the relationship of IRD with abdominal muscle endurance, pelvic floor functions, respiratory muscle strength, and postural control in women with DRA. Additionally, the secondary purpose of the study is to investigate the independent predictors of IRD in women with DRA.

Material and methods

Fifty-nine primi- and multiparous women who were delivered between 5 months to 5 years participated to the study between October 2019-August 2020. The women who were diagnosed with DRA and presented with at least 2 cm IRD at one or more points of the linea alba using caliper tests, were enrolled to the study. Exclusion criteria were having less than two months postnatal period, a history of any neurological or acute musculoskeletal injuries or acute/chronic physical or mental illness and being pregnant.

This cross-sectional study was authorized by the Human Research Ethics Committee of Bezmialem Vakif University (Approval number: 18/353) and carried out in accordance with the Declaration of Helsinki. All subjects signed a written informed consent. The study was registered to the ClinicalTrial.Gov website with the registration number of NCT04181554.

The demographic information which includes age, height, weight, and weight gain during pregnancy, having single or multiple births, time since delivery was collected via an assessment form. IRD, the static abdominal flexion endurance, pelvic floor functions, respiratory muscle strength, and postural stability tests were assessed for all subjects.

IRD was assessed using a standard caliper by the same physiotherapist. While the subjects were in the supine position, knees bent and feet resting position on the table and hands positioned to contralateral shoulders, the subjects were asked to elevate the head and shoulders upwards until the inferior angles of the scapulae were just off the table. The physiotherapist palpated the medial edges of RA muscles and IRD was measured by caliper in previously marked five-point: on the umbilicus, 5 cm, and 2 cm above and below the umbilicus [4]. The largest IRD of five measurement sites was used in the statistical analyses as an outcome measurement. The severity of DRA was determined according to Ranney et al.; IRD $<$ 3 cm, IRD between 3 and 5 cm, and IRD $>$ 5 cm are named mild, moderate, and severe DRA, respectively [16].

The static abdominal flexion endurance test was also performed once in the same position as the DRA test. The subjects were asked to raise their head and shoulders upwards until the scapulae cleared the table and keep the position as long as possible. The time was recorded as the score of the test [17]. Three warm-up repetitions were given before the test.

Every subject completed the Turkish version of the short-form of Pelvic Floor Distress Inventory (PFDI-20) which consists of three subscales: the Pelvic Organ Prolapse Distress Inventory short-form (POPDI-6), the Urogenital Distress Inventory short-form (UDI-6), and the Colorectal–Anal Distress Inventory short-form (CRADI-8) to assess prolapse and pelvic pressure, urinary symptoms, and bowel symptoms, respectively [18]. The maximum scores of each subscale are 100 and the total score ranges from 0 to 300; lower scores indicate better pelvic health [19].

Respiratory muscle strength was measured via a mouth pressure meter (MicroRPM, MicroMedical). The subjects were asked to perform inspiration and expiration with a maximum effort for each assessment of maximal inspiratory (MIP) and expiratory (MEP) mouth pressures, respectively. The maximum value of three efforts, which vary by less than 5 %, was accepted as MIP and MEP values of subjects. The subjects had a rest for about 1 min between each test [20].

The postural balance was tested with the Clinical Test of Sensory Integration of Balance (m-CTSIB) and Limits of Stability (LOS) tests using Biodex Balance System (Shirley, NY, USA). m-CTSIB was performed in four test conditions; eyes open on a firm surface (EOFS), eyes closed on a firm surface (ECFS), eyes open on a foam surface (EOFoS), and eyes closed on a foam surface (ECFoS). The subjects were asked to stay stable as possible on their feet on the force platform during the 30 s test, with a rest of 10 s between the different conditions. The outcome parameters of m-CTSIB are a score for each condition and a composite score. Higher sway indicates poorer balance [21]. LOS is a sensitive measurement of dynamic balance, with higher scores defining better postural control. The feet of subjects have been placed on the platform which has shown on the screen as the center of the eight directions. During tests, the subjects tried to reach the highlighted direction by changing their center of gravity. For all balance tests, the hands of the subjects were positioned on their contralateral shoulders.

The statistical procedure was carried out by using SPSS software (Version 16.0; SPSS; Chicago, IL, USA). The normality of all variables was tested using the Kolmogorov-Smirnov test. Pearson or Spearman correlation analysis was used to evaluate the relationship between IRD and static abdominal flexion endurance test, PFDI-20, MIP and MEP, m-CTSIB, and LOS scores depending on the distribution properties of the data. The strength of correlations was categorized as strong ($>$0.5), moderate (0.3–0.5), weak (0.1–0.3), or very weak ($<$0.1) according to r value [22]. In addition, linear regression analysis was performed for analyzing the independent predictors of IRD among the age, BMI, parity, time since last birth, birth weight, weight gains last pregnancy, and mode of delivery. $p < 0.05$ was accepted as statistically significant.

The sample size was determined using G*Power software (v. 3.0.10; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). At least twenty-one subjects were required to achieve the statistical power of 80 %, at a 5 % probability threshold, and an estimated correlation coefficient of 0.5 based on a previous study that reported on the relationship between IRD and abdominal muscle function [17].

Results

Fifty-one women who provided inclusion criteria were included to the study. Eight subjects who had$<$2 cm inter-recti distance, vestibular diseases, or knee pain were not accepted into the study (Fig. 1). The age ranges of women were between 25 and 46 years. The demographic and clinical characteristics of the subjects are presented in Table 1. Linear regression analysis on 51 subjects revealed that age, BMI, time since last birth, weight gains last pregnancy and mode of delivery were the independent predictor for IRD ($R = 0.514$, $p = 0.02$; $R = 0.566$, $p < 0.001$; $R = 0.562$, $p = 0.03$; $R = 0.538$, $p = 0.02$; $R = 0.647$, $p = 0.02$, respectively). The parity and birth weight did not have a significant relationship with IRD ($p > 0.05$).

Any relationship was determined between the static abdominal

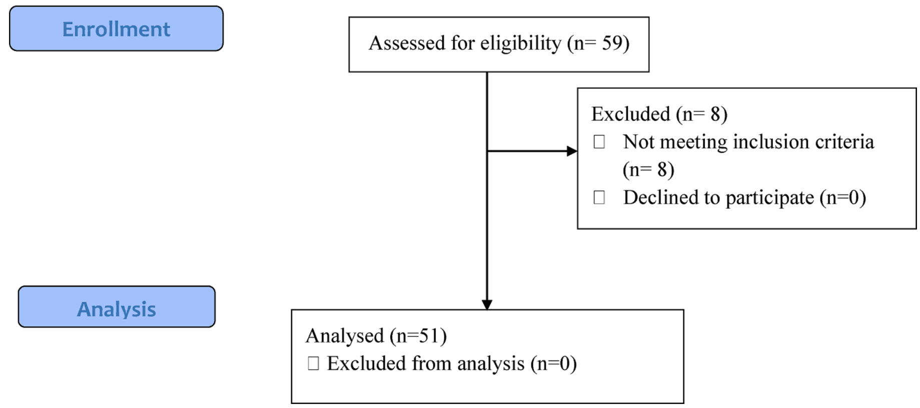

Fig. 1. Flow chart of the study.

Table 1
Demographic and clinical characteristics of the subjects.

Demographic Characteristics	Mean ± SD (n = 51)
Age (year)	35.1 ± 4.9
Weight (kg)	61.4 ± 9.5
Height (cm)	163.1 ± 5.3
Body mass index (kg/cm^2)	23.1 ± 4.0
Primiparous (n) (%)	29 (57 %)
Multiparous (n) (%)	22 (43 %)
Twin pregnancy (n) (%)	9 (18 %)
Time since last birth (month)	29.3 ± 19.3
<6 months (n)	3
6–11 months (n)	5
12–36 months (n)	29
>36 months (n)	14
Birthweight (gm)	3832.5 ± 613.6
Weight gains last pregnancy (kg)	17.9 ± 7.1
Mode of delivery (n) (%)	
Vaginal	11(21 %)
Cesarean	40(79 %)
Severity of diastasis recti abdominis (n) (%)	
Mild	6 (11.8 %)
Moderate	35 (68.6 %)
Severe	10 (19.6 %)

kg: kilograms; cm: centimetres; gm: gram; SD: Standard deviations.

flexion endurance test score and IRD in women with DRA (r = -0.150, p = 0.17). Alterations in IRD were negatively associated with the CRADI-8 score (r = -0.317, p = 0.03), but either PFDI total score or other sub-score did not show any correlation with IRD (p < 0.05). Respiratory muscle strength values were not related with IRD (r = 0.023, p = 0.45; r = -0.031p = 0.43 for MIP and MEP, respectively). EOFS, ECFS and composite scores of m-CTSIB of women with DRA showed a moderate relationship with IRD (r = 0.356, p = 0.01; r = 0.337, p = 0.02; r = 0.413, p = 0.004). A weak correlation was found between EOFoS, ECFoS scores of m-CTSIB and IRD (r = 0.279, p = 0.04; r = 0.265, p = 0.04). The total score of the LOS test correlated with IRD (r = 0.422, p = 0.003) (Table 2).

Discussion

Our study aimed to reveal the relationship between IRD and static abdominal flexion endurance, pelvic floor functions, respiratory muscle strength, and postural control. The results of our study showed that IRD had correlations with colorectal–anal symptoms, and static and dynamic postural stability of women with DRA, but no relation was determined between IRD and abdominal muscle endurance, and respiratory muscle strength. Additionally, it is revealed that age, BMI, time since last birth, weight gains last pregnancy, and mode of delivery were the independent predictors of IRD in women with DRA.

Table 2
Clinical characteristics of the subjects and correlations with IRD.

Clinical Characteristics	Value (SD) (n = 51)	*r*	*p*
IRD[a] (cm)	4.3 (1.9)		
Static abdominal flexion endurance test (s)	74.3 (51.9)	−0.150	0.165
PFDI-20[b] scores			
POPDI-6	12.0(15.0)	−0.146	0.32
UDI-6	10.5(14.0)	0.025	0.87
CRADI-8	14.2(14.3)	−0.317	**0.03***
PFDI-total	36.7(34.0)	−0.188	0.2
Respiratory Muscle Strength[c]			
MIP (cmH2O)	78.4(18.0)	0.023	0.45
MEP (cmH2O)	101.8(20.8)	−0.031	0.43
m-CTSIB[d]			
EOFS	0.38(0.13)	0.356	**0.01****
ECFS	0.82(0.26)	0.337	**0.02***
EOFoS	0.84(0.31)	0.279	**0.04***
ECFoS	2.69(0.62)	0.265	**0.04***
Composite Score	1.17(0.21)	0.413	**0.004****
LOS Overall Score[e]	55.9(12.8)	0.422	**0.003****

[a]IRD: Inter-recti distance; [b]PFDI-20:Pelvic Floor Distress Inventory, POPDI-6: Pelvic Organ Prolapse Distress Inventory; UDI-6: Urogenital Distress Inventory; CRADI-8: Colorectal–Anal Distress Inventory; [c]MIP: Maximal inspiratory mouth pressure; MEP: Maximal expiratory mouth pressure; [d]m-CTSIB: Clinical Test of Sensory Integration of Balance; EOFS:Eyes open on a firm surface; ECFS: eyes closed on a firm surface; EOFoS:Eyes open on foam surface; ECFoS:Eyes closed on foam surface; [e]LOS:Limits of Stability. SD: Standard deviation. Pearson or Spearman correlation analyses were used. *r*: The correlation coefficient. *p < 0.05 is statistically significant. ** p < 0.01 is statistically significant.

The linea alba which supports RA, TA, internal and external obliques muscles is widening and thinning in DRA [1]. Despite this anatomical connection, the relationship between IRD and abdominal muscle strength is unclear. Liaw et al presented a relationship between these variables for the first 6 months of postpartum and abdominal muscle strength has been evaluated by the manual muscle test [17]. A recent study reported a reduction in abdominal force and endurance according to the severity of DRA in primiparous women with pelvic floor trauma [23]. Furthermore, two studies revealed contrasting results in the comparison of abdominal strength between postpartum women with and without DRA [24,25]. In our study, the static abdominal flexion endurance test score did not show any correlation with IRD. Using different assessment tools or positions and including subjects in varied timepoint postpartum may cause these differences in the literature.

The strength or endurance of abdominal muscles may explain a small part of the thoracopelvic abdominal system which is suggested to be considered in the assessment and treatment of DRA [2]. Another part of the thoracopelvic abdominal system is the pelvic floor muscles.

According to the theory of pelvic dynamics, the insufficiency of the abdominal wall may alter the distribution of the forces in the thoracic, abdominal, and pelvic dynamics. It was assumed that women with DRA have pelvic floor muscle weakness and impaired pelvic floor functions. Recent studies did not find a higher incidence of urinary incontinence or weakness of the pelvic floor muscles in women with DRA even with augmentation in the IRD [15,25–29]. In accordance with the studies, we did not determine any correlation between IRD and POPDI, and UDI scores. Interestingly, most of the studies mentioned above focused on the gestational and early postpartum period, but Harada et al investigated the effect of DRA on pelvic floor functions between women in *peri-* and postmenopausal periods (aged above 50 years). They stated that pelvic floor muscle strength and functions were worsened in women with DRA compared to women without DRA [30]. The changes in the elasticity of connective tissue and muscle strengths due to aging may explain the contrast in the results of the studies about the relationship between pelvic floor functions and DRA. Also, age and time since last birth were found as independent predictors of IRD in the recent study. In agreement with our study in terms of PFDI, Keshwani et al showed no correlation between IRD and the total score of PFDI in the early postpartum period but did not analyze sub-scores of PFDI [11]. Besides, Eisenberg et al revealed that only the UDI score was different between DRA and non-DRA groups in primiparous women with pelvic floor trauma [23]. On the other hand, a study about exercise treatment has obtained improvement in CRADI scores in subjects with DRA [31]. Interestingly, we found a negative relationship between IRD and CRADI scores of women with DRA. CRADI consists of questions associated with lower gastrointestinal disorders, which mainly investigate obstruction, incontinence, pain/irritation, and rectal prolapse and higher scores define worse colorectal-anal symptoms. Actually, we have expected contrary results because of insufficient support of the bowels according to the impaired abdominal wall in DRA. However, with the colorectal-anal system being a complex system and it is supported by a greater muscular component, we could not explain the staggering relationship which has been found between IRD and colorectal functions in women with DRA by using current literature and the data of the present study.

The optimized intra-abdominal pressure and an intact abdominal wall are important to enhance the contraction of the diaphragm because they provide an effective pre-contraction diaphragm length and configuration by ascending the diaphragm cephalad. To our best knowledge, this biomechanical phenomenon has not been investigated yet in women with DRA. However, it is reported that when abdominal compliance is getting higher as a result of a flaccid abdominal wall due to a large ventral hernia, the diaphragm is shortened, and becomes "weaker" because of length-tension properties, and MIP and MEP values decreased [32]. Both MIP and MEP values presented no correlation with IRD in our study. Although thinning and widening of linea alba may cause abdominal wall instability, the abdominal wall in DRA is not exactly the same as the ventral hernia [1,6]. Furthermore, the number of subjects with severe DRA was low in our study.

It is known that the core system structures which have an important role in postural control, harmoniously contract or relax during postural tasks [14]. Not only the related musculature, but also other anatomical links of the linea alba, fascia, and intra-abdominal pressure may alter these coordination and force distribution and integrity of the thoracopelvic abdominal system. To the extent of our knowledge, although no study has directly focused on DRA and postural control, it was usually expected that women with DRA have poor balance [2]. In the present study, the different aspects of postural stability were assessed in women with DRA; static and dynamic balance in eyes-open and -closed conditions and limits of stability. We found a relationship in composite and each condition's scores of m-CTSIB with IRD. Antoniadou et al explained that the m-CTSIB test consists of balance information by visual, somatosensorial, and vestibular inputs [33]. Both muscle groups and soft tissues surrounding the thoracoabdominal region are involved in the modulation of intra-abdominal pressure and the trunk response during daily activities and postural tasks [34,35]. According to our results, it seems that wider IRD worsened the postural equilibrium demands of the thoracopelvic abdominal system because of insufficient muscular function and deep sensation. On the other hand, LOS evaluates underlying motor systems, functional stability limits, and anticipatory postural control which is related to the direction-specific patterns of activation or inhibition of postural muscles in healthy adults [36]. All of the abdominal muscles have to be active during limits of stability movements to prepare the trunk and spine for perturbation [34]. The women with DRA had deteriorated LOS scores in line with widening IRD in this study. We speculated that altered muscle position, intra-abdominal pressure requirements, and fascial directions affected anticipatory postural control during dynamic conditions.

Another finding is that while the age, BMI, time since last birth, weight gains last pregnancy, and mode of delivery were determined as the independent predictors of IRD, the parity and birth weight did not have any interactions with IRD in women with DRA. The predictors of DRA are an arguable topic, there is a lot of contrasting evidence about the factors increasing the risk of DRA such as birth weight or mode of delivery [9,10,15]. Furthermore, the factors which affect the amount of IRD are rarely investigated in the literature [11]. In contrast with our study, Keshwani et al revealed that BMI was not significantly correlated with IRD in the early postpartum period, but the low BMI of subjects was mentioned as a limitation of the study [11]. Another study presented differences between women with and without DRA in pre-pregnancy and post-delivery BMI, gestational age, and birth [15]. In that study, the range of age of the participants and also the postnatal duration is very small. However, in our study, the participants are in a wide range in terms of age and postpartum duration. According to our result, we speculated that an increment in IRD in time might occur because of daily habits or loads with related increased intra-abdominal pressure and forces on the thoracoabdominal region.

The potential limitations of the study are the lack of a control group that consists of women without DRA and small subgroups of DRA. These parameters could provide additional information to the outcomes of the study.

Conclusions

We concluded that increased IRD was associated with worse postural control, but better colorectal functions in women with DRA. However, IRD does not show a clear interaction with abdominal muscle endurance, pelvic floor functions, and respiratory muscle strength. Furthermore, age, BMI, time since last birth, weight gains last pregnancy, and mode of delivery were determined as the factors which influence IRD in women with DRA. These factors should consider preventing increment of IRD during pregnancy and post-partum period. Additionally, our study suggests performing the postural stability assessment for physiotherapeutic management of women with DRA. However, further studies are needed to understand colorectal-anal functions of women with DRA.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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