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Comparing the effects of suspension and isometric-isotonic training on postural stability, lumbopelvic control, and proprioception in women with diastasis recti abdominis: a randomized, single-blinded, controlled trial

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ABSTRACT

Background: Diastasis recti abdominis (DRA) affects a significant number of women in the postpartum period.

Objective: This study compared the effectiveness of suspension training system (STS) with that of isometric-isotonic (ISoM-ISoT) exercises in the treatment of DRA and its secondary complications.

Methods: Thirty-six women with DRA participated in this study. They were divided into the three groups of STS, ISoM-ISoT, and control. Inter-recti distance (IRD), proprioception, lumbopelvic control, postural stability, low back pain, and disability were assessed using a digital caliper, a goniometer, a lateral step-down test, a Biodex balance system, a visual analogue scale (VAS), and the Oswestry Disability Index (ODI), respectively. Two intervention groups underwent training for 8-week and the control group resumed their normal lives.

Results: Positive effects were observed in the STS and ISoM-ISoT groups compared with the control group in: IRD ($P = .001$); lumbopelvic proprioception ($P = .001$); lumbopelvic control ($P = .001$); overall static balance ($P = .010$); overall dynamic balance ($P = .012$); low back pain ($P = .001$); and disability ($P = .001$). However, there was no significant difference between the training groups in: IRD ($P = .12$, MD = -2.76); lumbopelvic proprioception ($P = .48$, MD = -0.50); lumbopelvic control ($P = .14$, MD = 1.53); static balance ($P = .62$, MD = 0.07); dynamic balance ($P = .27$, MD = 0.33); pain ($P = .25$, MD = -0.52); and disability ($P = .48$, MD = -1.74). The results of the minimal clinically important difference (MCID) and minimal detectable change (MDC) suggested that the STS exercises outperformed ISoM-ISoT training regarding IRD, pain, disability, and proprioception, whereas ISoM-ISoT training had a better effect in lumbopelvic control and balance.

Conclusion: The results of our study showed that the STS had a positive effect on women with DRA and like the ISoM-ISoT exercises can be used to treat this dysfunction.

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Intra rectus diastasis; pregnancy; disability; low back pain; childbirth

Introduction

The most noticeable physical change during pregnancy is the increase in the weight and size of the uterus which changes the musculoskeletal morphology of the core region. This in turn increases the length of the abdominal muscles and separates them from the fascia especially in the rectus abdominis muscle and is called diastasis recti abdominis (DRA) (Fast et al., 1990). This disorder begins in the late second trimester of pregnancy and peaks immediately after childbirth and a few weeks later (Coldron, Stokes, Newham, and Cook, 2008; Liaw et al., 2011). The prevalence of DRA has been reported to be 66% after delivery (Pascoal, Dionisio, Cordeiro, and da Mota, 2014). The results of studies show that DRA is associated with complications such as change in the trunk biomechanics,

disability to perform daily tasks, change in pelvic stability, spine injury, reduced functional strength and abdominal wall integrity; and in severe cases abdominal hernia (Fast et al., 1990; Pascoal, Dionisio, Cordeiro, and da Mota, 2014). It also appears that women with DRA are more prone to pain in the lumbopelvic region after childbirth (Parker, Millar, and Dugan, 2009). Due to the fact that the weakness of core muscles can lead to the instability of the trunk and pelvis, change in breathing pattern, hypermobility in the lumbopelvic region, and postural imbalance (Bursch, 1987; Kendall et al., 2005; Lee, Lee, and McLaughlin, 2008) the authors of the current paper investigated these variables in women with and without DRA after childbirth in a case-control study (Yalfani, Gandomi, Anvari, and Bigdeli, 2020).

The results showed that the patients with DRA had more disturbance in their lumbopelvic control and postural balance than their healthy counterparts. In addition, lumbopelvic proprioception was also significantly reduced in these patients compared with healthy individuals. The mentioned complications can lead to a lack of muscle support in the lumbar spine, followed by pain and disability in daily activities (Yalfani, Bigdeli, Gandomi, and Anvari, 2020, 2020). DRA is not usually accompanied by pain at the site of the disorder (i.e. the linea alba region) and thus is often overlooked. Nevertheless what is clear is that it causes postural instability and decreases muscle function in the lumbopelvic region. Given the important role of the core muscles in providing the stability of the lumbar and pelvic region, it is necessary to correct DRA in patients suffering from it (Pascoal, Dionisio, Cordeiro, and da Mota, 2014). The results of two systematic review studies demonstrated that the inter-recti distance (IRD) of pregnant women who participated in a training course for the isometric-isotonic strengthening of the abdominal muscles with focus on transverse muscle contraction was significantly less than that of those who did not exercise or had no training. In addition, the strength and endurance of the abdominal muscles in the core region were recovered to the pre-pregnancy period more quickly in women who started these exercises immediately after childbirth recovery compared to those who were inactive (Benjamin, Van de Water, and Peiris, 2014; Yalfani, Bigdeli, and Ahmadi, 2019). One of the resistance exercise programs used in this study was isometric-isotonic training (ISoM-ISoT). This method of training includes traditional abdominal exercises such as drawing in, three-dimensional breathing, Kegel, crunch, plank, Bosu alphabet, and Bosu ball squat.

The suspension training system (STS) was another intervention used in the current study. Suspension training has led to a new approach in the exercise and rehabilitation of patients with low back pain especially those whose low back pain is due to weakness in the core muscles. The STS uses gravity for the stimulation of neuromuscular reactions, takes advantage of changes in body position and its mechanical properties, and with its unstable nature involves both sense and movement (Mok et al., 2015). Some studies have shown that the STS can significantly activate the transverse and rectus muscles, reduce pain, normalize the pattern of muscle response, improve postural disorders, and enhance the strength and endurance of the muscles as well as proprioception in patients with low back pain (Mok et al., 2015; Snarr and Esco, 2013; Snarr, Hallmark, Nickerson, and Esco, 2016). Mok et al. (2015) studied the electromyographic activity of core muscles during the STS and reported that STS can considerably activate the transverse and rectus muscles and have a significant effect on them.

Due to the small number of studies on improving DRA with physical therapy, the inconsistency between studies regarding some therapeutic exercises, little research on the secondary complications of this disorder, and the reports about the positive effects of the STS for the activation and strengthening of core muscles, the researchers conducted the present study to solve these problems. In general, the aim of the researchers in this study was to compare the effectiveness of the STS with that of ISoM-ISoT exercises in the treatment of DRA, impairment in lumbopelvic proprioception, low back pain and the disability thereof, and postural instability.

Methods

Study design

The current study is a clinical trial study. In addition, it has three parallel groups and is single-blind, randomized, and controlled. The ethical process in this study followed the Helsinki-Tokyo Declaration and was approved by the Ethics Committee of Hamadan University of Medical Sciences (ethics number: IR. UMSHA.REC.1397.825) and the Iranian Registry of Clinical Trials (code: IRCT20190219042761N1). After ensuring that the ethical considerations were observed in the research, all the subjects signed a written consent form and were allowed to leave the research process if they wished. The participants were selected according to the inclusion and exclusion criteria and were given some information about the purpose of the research and how the study is conducted.

Sample size and recruitment

This study started with patient recruitment from Fatemieh Obstetrics and Gynecology Hospital, Hamadan, Iran from August 2019 to January 2020. Using the mean and standard deviation of IRD above the umbilicus in the study of Liaw et al. (2011) the effect size of 0.75, the alpha coefficient of 0.05%, the power of 85%, and the analysis of covariance (ANCOVA) statistical test, the sample size was examined. With a drop probability of 20%, the sample size was estimated to be 45 patients. However, at the end, due to the absence of some patients in the intervention and posttest phases, this number was reduced to 36 patients (Liaw et al., 2011). These patients were selected and invited to cooperate after they came to the hospital and their IRD levels were determined through the manual examination of DRA. Figure 1 shows the patient flow chart.

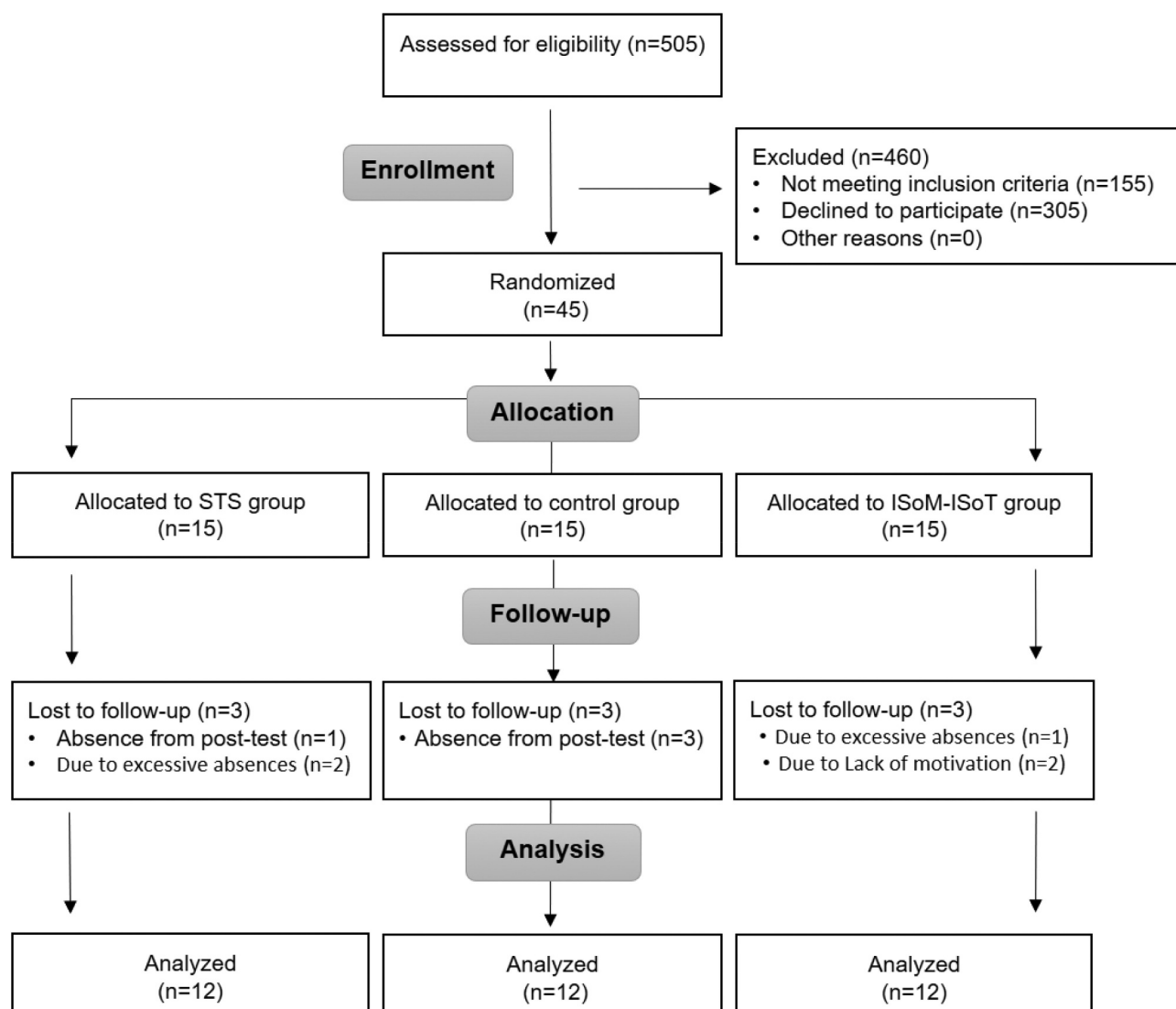


Figure 1. The flow chart of the study.

In this study, the inclusion criteria were women who had more than one delivery (i.e. multipara) with a period of approximately 2 to 4 months after their delivery, the age range of 20 to 40 years, the IRD of above 20 mm at 4.5 cm above the umbilicus, vaginal delivery, and the body mass index (BMI) of less than 30 kg/m² (Khandale and Hande, 2016; Van de Water and Benjamin, 2016; Walton et al., 2016). The exclusion criteria were: cardiopulmonary diseases; postpartum depression; cesarean delivery; multiple birth abdominal hernia; disc hernia; abdominal or spine surgery; anxiety and stress; gestational diabetes mellitus; smoking and alcohol consumption; history of fracture in the lumbopelvic region; and doing exercise before and during pregnancy.

Randomization and blinding

To prevent any bias, the assessors performed the tests without knowing the disorder under study and the allocation of the groups. Because the consent form explained all the objectives and details of the study, we could not blind the study participants. The participants were randomized with Random Number Generator software and allocation concealment was done by sequentially numbered opaque sealed envelopes. The participants were divided into the three groups: 1) STS (n = 15); 2) ISoM-ISoT (n = 15); and 3) control (n = 15). In this random allocation method, based on the sample size, a number of envelopes were prepared and each of the randomly generated sequences was

recorded on a card and the cards were placed in the envelopes. Finally, the envelopes were sealed and placed inside a box. After the evaluation of each participant, one of the envelopes was opened and the group to which that participant was assigned was revealed.

Interventions

The subjects in the STS group performed the interventions for eight weeks (3 sessions a week) on odd days and the subjects of the ISoM-ISoT group performed the same interventions on even days. Before starting the main training program, a general warm-up program including jogging as well as static and dynamic movements was performed for 10 minutes. Then, the STS and ISoM-ISoT exercises were performed for 50 minutes. Finally, cool-down exercises were performed for 10 minutes for recovery. Each subject had to attend at least 22 sessions out of the 24 practice sessions and absence in more than two sessions led to the exclusion of the individual from the study process. The people in the control group also engaged in their daily life activities. Furthermore, the intensity, set, and repetition of these exercises varied according to the overload principles and the ability of the participant in each training session. The rest time between each set was 1 to 1.5 minutes. All the exercises were performed under the supervision of a rehabilitator. The details of the exercise therapy sessions including the prescription parameters are provided in [Tables A1 and A2](#).

Suspension training system

TRX® FORCE™ were used for the STS, which includes two strong straps for suspension training. This method of exercise consisted of 3 phases: beginner (i.e. first session to the sixth session); intermediate (i.e. seventh session to the fifteenth session); and advanced (i.e. sixteenth session to the twenty-fourth session). The difficulty level of the exercise was adjusted by changing the 'working angle' (e.g. tilting the body from a standing position). Since the women in this study did not have exercise activities, simple exercises such as suspension glute bridge and suspension hip hinge along with drawing in were used in the first phase. In the second phase of the exercises, such exercises as plank were added to the exercise program after it was ensured that the participants were well able to contract the abdominal muscles against gravity in the prone position. This exercise usually has a good effect on the abdominal local muscles whose weakness is the main factor in causing DRA. In the third phase, after it was ensured that the strength of the abdominal muscles was increased, resistance

training with a relatively high torque such as crunch was added to the program and integrated with such exercises as plank ([Figure 2](#)) ([Dawes, 2017](#); [Mok et al., 2015](#)).

Isometric-isotonic core stabilization exercises

The exercise program used in this study was a modified protocol of [Litos \(2014\)](#). These exercises consisted of three different training phases: beginner (i.e. first to the sixth session); intermediate (i.e. seventh session to the fifteenth session); and advanced (i.e. sixteenth session to the twenty-fourth session). In the first phase, these exercises were performed with the least intensity and the focus was on the transverse, internal oblique, and pelvic floor muscles. Drawing in the abdomen, Kegel on the ball, and three-dimensional breathing were some instances of these exercises. In the second phase, plank, shoulder curl-up, and bird-dog exercises were added to the program when the patient was able to draw in the abdominal muscles flawlessly. These individuals first learned how to contract their abdominal muscles properly against gravity. The focus of the third phase was on balance training, proprioception, and isotonic training with a relatively high torque in the lumbopelvic region. The focus of these exercises was more on increasing the proprioceptive receptors as well as the strength of the muscles. The training exercises were performed with different repetitions and durations, body weight, elastic band, and ball.

Primary outcomes

The IRD was assessed using a tool called 'digital caliper' with the measurement accuracy of 0.01 mm (Model: E325-101, Iran). Moreover, the validity of this test compared to ultrasonography was reported as 0.84 ([Liaw et al., 2011](#)) and its interclass correlation coefficient ($ICC_{3,1}$) above the umbilicus was reported as 0.98 ([Chiarello and McAuley, 2013](#)). In this test, the participant was placed on the examination bed in a supine position with knees bent (45 degrees) and the arms at the side of the body. The measuring point was 4.5 cm above the umbilicus. The assessor asked the participants to lift their heads and shoulders off the examination bed so that the scapula was detached from the examination bed and the abdominal muscles were fully contracted. They had to hold this position for about 10 seconds so that the assessor could touch the rectus abdominis muscle with the index and middle fingers and place the caliper's internal arms between the two muscle bulks. The number recorded on the digital display was then recorded by another assessor. Three tests were performed for each assessment and then their mean was recorded ([Boxer and Jones, 1997](#); [Van de Water and](#)



Figure 2. Suspension lying leg curl (a), suspension glute bridge (b), suspension side plank (c), suspension reverse mountain climber (d), suspension supine crunch (e), suspension single-leg supine plank (f), suspension plank (g), suspension mountain climber (h), suspension chest press with drawing in (i), suspension Hip hinge with drawing in (j), suspension pike plank (k), suspension reverse crunch (l).

Benjamin, 2016). All the manual examination steps used for the initial diagnosis of DRA in the hospital were similar to the mentioned test except that the assessor used her three central fingers instead of a digital caliper (Benjamin, Van de Water, and Peiris, 2014).

Secondary outcomes

Evaluation of lumbopelvic proprioception

To evaluate the lumbopelvic proprioception of the women participating in this study, the Newcomer test was performed using a goniometer (Model: Noavaran, Iran). The validity and interrater reliability ($ICC_{2,1}$) of this device were reported to be 0.97 and 0.87, respectively (Rajabi and Karimizadeh Ardakani, 2013). The subjects were asked to stand comfortably and firmly on a flat surface without shoes or socks. The legs were spread shoulder-width apart and the arms were crossed in front of the chest aligned with the shoulders. The subjects were asked to close their eyes as they heard the auditory feedback so that the visual afferents were eliminated. By fixing a wooden

frame behind the knee, the proprioception feedback from the lower limb was reduced and the pelvis was prevented from retracting during flexion. The center of the goniometer was placed on the iliac crest, its fixed arm was placed in the direction of the hip lateral area, and its movable arm was placed upwards in the direction of the iliac crest. With their eyes closed the subjects were asked to flex 30° at a uniform and relatively slow speed and with a five-second pause to try to memorize the position. Then, they had to return slowly to the initial position and begin the next movement after a five-second pause (Figure 3(a)). This test was repeated three times and the error rate of the subjects (i.e. the absolute value of the difference of the reconstructed angle from the target angle) was recorded in degrees. The average amount of error in the state reconstruction in three repetitions was recorded as the amount of state reconstruction error. It should be noted that the subject's proprioception was considered healthy if the average error rate was less than three degrees (Alvani, Shirvani, and Shamsoddini, 2021).



Figure 3. Lumbopelvic proprioception test (a); lumbopelvic control test (b); static and dynamic balance tests (c).

Lumbopelvic control impairment

The lateral step-down test at the frontal level was used to assess the lumbopelvic control. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) were calculated with a two-way random effects model with single measure reliability ($ICC_{2,1} = 0.88$) (De Blaiser et al., 2019). In this test, a step with a height of 25 cm, a Canon D8 camera with a distance of 3 meters from the step and a height of 50 cm to record the movements, and the Kinovea software (version: 8.15) to analyze the movements were used. After anterior-superior iliac spine (ASIS) was found on both sides and light-reflecting markers were installed in these areas the subjects were asked to stand on the step, place their crossed arms on their chests parallel to their shoulders, and to keep their spines straight. The subjects were asked to place their heels on the ground with a lateral step. The flexion of hip and knee joints was allowed for the better access of the heels to the ground. Changing the position of the hands while performing the movement, the heels not reaching the ground, the subject leaving the step, or the toes hitting the ground were considered invalid attempts (Figure 3(b)). This test was repeated 5 times and the average of the angles was recorded in the Kinovea software. It should be noted that this test was randomly performed on only one side (De Blaiser et al., 2019). The moderate control of lumbopelvic was reported 10° to 20° by De Blaiser et al. (2019).

Static and dynamic balance test

The static and dynamic balance tests were performed on the subjects using the balance systemTM SD ($ICC_{3,1} = 0.95$) (The Biodex Company, USA) (Hinman, 2000). In this study the postural stability test was used to measure the static and dynamic balance (Schmitz and Arnold, 1998). A stable support surface was used to measure the static balance and an unstable support surface with the instability degree of 7 was used to measure the dynamic balance (Schmitz and Arnold, 1998). Both tests were performed in a double-leg stance. The participants were asked to stand in a way that the center of pressure (COP) index displayed on the monitor in front of them was in the center of the circle. The participants were then instructed on how to perform the test and were asked to place their hands next to their bodies and refrain from talking, laughing, taking deep breaths, or changing the position of their legs while focusing on keeping the COP in the center of the screen (Figure 3(c)). To acquaint the subject with how to perform the test, each subject performed the test three times. Each test was performed in 3 repetitions of 20 seconds and the resting time between each repetition was 10 seconds.

Pain intensity and disability due to low back pain

In order to assess the pain intensity in people with low back pain, the visual analog scale (VAS) was used. The pain intensity scale is a 100 mm (10 cm) long ruler one end of which is zero (i.e. without pain) and the other end is 10 (i.e. most severe pain). The subjects were asked to indicate their pain intensity on the ruler. The ICC (95%

Table 1. The ANOVA results for comparing the demographic characteristics of the subjects in the groups.

Variable	Mean (standard deviation)				F value	P value
	STS group	ISoM-IsoT group	Control group	Total group		
Age (years)	27.75 (5.15)	31.33 (4.39)	28.25 (4.55)	29.11 (4.85)	2.034	0.147
Height (cm)	165.75 (4.75)	162.33 (4.05)	158.83 (5.14)	162.30 (5.36)	6.573	0.054
Weight (kg)	66.54 (10.04)	67.08 (5.68)	61.50 (8.90)	65.04 (8.56)	1.605	0.216
BMI (kg/m²)	24.08 (2.72)	25.90 (2.11)	24.83 (3.09)	24.94 (2.71)	1.403	0.260
WHR(cm)	0.80 (0.42)	0.81 (0.40)	0.83 (0.20)	0.81 (0.37)	2.007	0.150
TACB(day)	54.75 (28.52)	73.33 (26.75)	69.25 (28.41)	65.78 (28.29)	1.468	0.245

BMI, Body Mass Index; WHR, Waist-Hip Ratio; TACB, Time After Child Birth; STS, suspension training system; ISoM-IsoT, isometric-isotonic

CI = 0.96 to 0.98) of this scale was reported to be 0.97 (Bijur, Silver, and Gallagher, 2001). Also, the results of previous studies showed that the VAS scores of 0.5 to 4.4, 4.5 to 7.4 and, 7.5 to 10.0 respectively represent mild, moderate, and severe of pain (Jensen, Chen, and Brugger, 2003).

The Oswestry Disability Index (ODI) was used to assess the degree of disability in postpartum low back pain. The Inter-rater reliability ($ICC_{2,1}$) of ODI was reported to be 0.95. This questionnaire consists of ten questions each with six options. These ten questions examined how the subjects do their daily activities. Each question ranked the disability rate from zero (i.e. optimal performance without pain) to five (i.e. disability in performance due to severe pain). The ODI is equal to the total score of the 10 questions multiplied by 2 or dividing the total score by 50 and then multiplying the result by 100 and has a value of zero to 100. A disability index of zero indicates that the subject is healthy and able to perform her daily activities without pain. The disability indices of zero to 20, 21 to 40, 41 to 60, 61 to 80, and above 80 respectively represent low, moderate, high, severe, and acute disabilities (Payares, Lugo, Morales, and Londoño, 2011).

Data analysis

The Shapiro-Wilk test was used to evaluate the normality of data distribution and the Levene's test was used for the homogeneity of variances. Descriptive statistics were used to report the mean and standard deviation of the data. The one-way analysis of variance (ANOVA) test was used to evaluate the differences between the groups in the pretest. ANCOVA was used to compare the intergroup and intragroup changes and the Eta square (η^2) (small: 0.01; medium: 0.06; large: 0.14) was employed to evaluate the intervention effect (Wu et al., 2012). Data analysis was performed at a significance level of 0.05 using IBM SPSS 24 and Microsoft Excel 2016.

Minimal clinically important difference and minimal detectable change analysis

Based on the 95% confidence level in the current study, the minimal clinically important difference (MCID) was assessed using the distribution-based approach and the reliable change index (RCI), while the minimal detectable change (MDC) was evaluated using the standard error of measurement (SEM) and the following equations: $SEM = SD_{pre} \sqrt{1 - r_{test}}$; $MDC_{95} = 1.96 \times \sqrt{2} SEM$; $MCID_{RCI} = 1.96 \times SD_{pre} \{ \sqrt{[2 \times (1 - r_{test})]} \}$ (Wright, Hannon, Hegedus, and Kavchak, 2012).

Results

The results of the Levene and Shapiro-Wilk tests in the three groups (each with 12 members) demonstrated that the presuppositions were not violated ($P > .05$). The results of the one-way ANOVA (Table 1) showed that the subjects were homogeneous in terms of demographic characteristics ($P > .05$).

Results of the analysis of covariance test

The results of the ANCOVA test showed that there was a significant difference among the three groups in the variables: IRD ($P = .001$); lumbopelvic control ($P = .001$); lumbopelvic proprioception ($P = .001$); low back pain ($P = .001$); disability ($P = .001$); overall static balance stability ($P = .001$); anterior-posterior static balance stability ($P = .030$); overall dynamic balance stability ($P = .012$); and anterior-posterior dynamic balance stability ($P = .012$). However, there was not any significant difference among the three groups in the variables: medial-lateral static balance stability ($P = .170$); and medial-lateral dynamic balance stability ($P = .065$). In addition to the results of the ANCOVA test, the means of the pretest and posttest variables of the study can be seen in Table 2.

Table 2. The results of the ANCOVA for comparing the variables of the study in the STS, ISoM-ISOt, and control groups.

Variables			STS group mean (SD)		ISoM-ISOt group mean (SD)		Control group mean (SD)		ANCOVA	
			Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	P value	η^2
Primary outcome										
IRD (mm)			42.5 (10.77)	13.92 (1.17)	36.33 (7.19)	16.69 (1.26)	38.01 (9.14)	35.58 (1.19)	0.001*	0.859
Secondary outcome										
Lumbopelvic control impairment (degree)			20.03 (3.98)	12.12 (0.68)	20.80 (1.99)	10.59 (0.75)	19.72 (3.95)	22.80 (0.71)	0.001*	0.841
Lumbopelvic proprioception impairment (degree)			9.12 (3.34)	0.84 (0.45)	5.33 (2.87)	1.34 (0.48)	6.80 (3.23)	8.68 (0.44)	0.001*	0.859
Pain intensity (0–10)			5.23 (1.23)	1.84 (0.30)	5.09 (0.94)	2.36 (0.33)	4.66 (1.07)	4.67 (0.32)	0.001*	0.575
Disability intensity (0–100)			28.88 (9.29)	9.28 (1.66)	23.02 (8.73)	11.02 (1.77)	23.51 (7.72)	26.85 (1.68)	0.001*	0.672
Postural instability	Static balance	Overall stability	0.97 (0.60)	0.52 (0.10)	0.99 (0.65)	0.45 (0.11)	1.28 (0.87)	0.92 (0.10)	0.010*	0.249
		Anterior-posterior stability	0.81 (0.67)	0.34 (0.09)	0.80 (0.65)	0.32 (0.10)	0.70 (0.52)	0.80 (0.10)	0.030*	0.312
		Medial-lateral stability	0.35 (0.20)	0.29 (0.06)	0.40 (0.18)	0.23 (0.06)	0.53 (0.32)	0.41 (0.06)	0.170	0.104
	Dynamic balance	Overall stability	1.58 (0.87)	1.20 (0.19)	2.10 (0.76)	0.87 (0.22)	1.43 (0.72)	1.83 (0.20)	0.012*	0.243
		Anterior-posterior stability	1.27 (0.92)	0.60 (0.15)	1.32 (0.56)	0.71 (0.17)	0.71 (0.23)	1.34 (0.17)	0.012*	0.243
		Medial-lateral stability	0.69 (0.33)	0.95 (0.14)	1.49 (0.65)	0.40 (0.18)	0.75 (0.27)	0.97 (0.14)	0.065	0.155

* Significant differences; IRD, intra recti diastasis; STS, suspension training system; ISoM-ISOt, isometric-isotonic; η^2 , Eta squared: a measure of effect size for use in the analysis of variance or covariance.

Results of the least significant difference test

The results of the least significant difference (LSD) showed that there was not any significant difference between the two groups mean differences (MD) (i.e. STS and ISoM-ISOt) in the variables: IRD (MD = -2.76, $P = .12$); lumbopelvic control (MD = 1.53, $P = .14$); lumbopelvic proprioception (MD = -0.50, $P = .48$); low back pain (MD = -0.52, $P = .25$); and disability (MD = -1.74, $P = .48$). The same was true for the overall static balance stability (MD = 0.07, $P = .62$); anterior-posterior static balance stability (MD = 0.01, $P = .90$); medial-lateral static balance stability (MD = 0.06, $P = .50$); overall dynamic balance stability (MD = 0.33, $P = .27$); and anterior-posterior dynamic balance stability (MD = -0.10, $P = .44$). A significant difference was found only in the medial-lateral stability of dynamic balance (MD = 0.55, $P = .03$) (Table 3).

Results of the minimal clinically important difference and minimal detectable change

The pretest and posttest mean difference in the ISoM-ISOt group in lumbopelvic control and static and dynamic balance compared with the changes in the MCID and the STS group demonstrated that the ISoM-ISOt group had a better performance than the STS group in the mentioned variables. The investigation of the Δ scores of the variables in the intervention groups and their comparison with the MCID showed that the STS had a significant effect on variables such as pain, disability, lumbopelvic proprioception, and IRD which are perceivable and disturbing for patients. Nevertheless, it had a small impact on lumbopelvic control and balance (Table 4).

Table 3. The LSD test results for comparing the between-group differences.

Variables		STS vs. ISoM-ISOt		STS vs. control			ISoM-ISOt vs. control		
		Mean difference	P value	Mean difference	P value	η^2	Mean difference	P value	η^2
Primary outcome									
IRD (mm)		- 2.76	0.12	- 21.65	0.001*	0.874	- 18.89	0.001*	0.846
Secondary outcome									
Lumbopelvic control impairment (degree)		1.53	0.14	- 10.68	0.001*	0.812	- 12.21	*0.001	0.851
Lumbopelvic proprioception impairment (degree)		- 0.50	0.48	- 7.83	0.001*	0.818	- 7.33	0.001*	0.850
Pain intensity (0–10)		- 0.52	0.25	- 2.83	*0.001	0.669	- 2.31	0.001*	0.546
Disability intensity (0–100)		- 1.74	0.48	- 17.57	0.001*	0.671	- 15.83	0.001*	0.720
Static balance	Overall stability	0.07	0.62	- 0.39	0.013*	0.190	- 0.47	0.005*	0.252
	Anterior-posterior stability	0.01	0.90	- 0.46	0.002*	0.312	- 0.48	0.002*	0.265
	Medial-lateral stability	0.06	0.50	- 0.12	0.210	0.045	- 0.18	0.067	0.164
Dynamic balance	Overall stability	0.33	0.27	- 0.63	0.032*	0.152	- 0.96	0.004*	0.262
	Anterior-posterior stability	- 0.10	0.44	- 0.74	0.004*	0.233	- 0.63	0.018*	0.158
	Medial-lateral stability	0.55	0.03*	- 0.01	0.93	0.002	- 0.57	0.030*	0.268

* Significant differences; IRD, intra recti diastasis; STS, suspension training system; ISoM-ISOt, isometric-isotonic; η^2 , Eta squared: a measure of effect size for use in the analysis of variance or covariance.

Table 4. The MDC and MCID values of the study variables.

Variable	SD _{pre} intervention groups	Δ Score of STS	Δ Score of ISoM-ISoT	SEM	MDC ₉₅	MCID (RCI)
IRD (mm)	9.64	28.58	19.64	5.10	14.09	14.35
Pain intensity	1.09	3.39	2.73	0.23	0.63	0.66
Disability intensity	8.81	19.6	12	0.88	2.42	2.44
Lumbopelvic control impairment	3.18	7.91	10.21	0.69	1.90	1.93
Lumbopelvic proprioception impairment	3.46	8.28	3.99	1.24	3.42	3.46
Overall static balance stability	0.63	0.45	0.54	0.13	0.35	0.38
Overall dynamic balance stability	0.85	0.38	1.23	0.18	0.49	0.51

IRD, intra recti diastasis; Δ score, (mean_{pre}-mean_{post}); SEM, standard error of measurement; MDC₉₅, minimal detectable change; MCID, minimal clinically important difference; RCI, reliable change index; SD, Standard deviation.

Discussion

The aim of the researchers in this study was to compare the effectiveness of the STS with that of ISoM-ISoT exercises in the treatment of DRA, impairment in lumbopelvic proprioception, low back pain and the disability thereof, and postural instability. It was found that both the STS and the ISoM-ISoT exercises for 8 weeks were able to have a positive effect on IRD, lumbopelvic proprioception, lumbopelvic control, reduction of low back pain and disability, overall static balance stability, and overall dynamic balance stability.

Both exercises had a statistically similar effect and no significant difference was found between them. Nevertheless, they were clinically different according to MCID scores and mean differences. Based on previous studies, there are two important conditions in the clinical examination of a study. First, an MCID is valid when its value is at least equal to or higher than that of the MDC (Copoly et al., 2007; Wright, Hannon, Hegedus, and Kavchak, 2012). This condition holds in the current study. Second, the mean difference (Δ score) of the intervention group must be higher than the MCID so that it can be said with certainty that the intervention has been effective on the desired variable (Wright, Hannon, Hegedus, and Kavchak, 2012). This condition also holds in the current study.

In this study, the subjects who had more than one delivery were selected because the IRD of the women who experienced their first delivery was less than 2.5 cm. This indicates the ability of the abdominal muscles to recover themselves in the first pregnancy. However, the recovery of these muscles was lower in the women in our study.

Interpretation

The results of this study showed that the STS in this study can be used as a new treatment method for this dysfunction and can increase the variety of exercises in treating it. Suspension exercises are considered an

effective means for improving the stability of the core region in healthy people and those with musculoskeletal disorders. These exercises include multi-plane and multi-joint movements with body weight as resistance against gravity (Snarr and Esco, 2013). One of the reasons for using the suspension system was its reasonable cost compared to the GYM, bodybuilding equipment, etc. In addition to having a significant effect on the core region, STS has less risk for women who have just given birth.

It seems that the major reason for the increase in motor unit recruitment and muscle activation in the STS compared to other exercises is the imbalance and suspension characteristics of TRX straps. Moreover, the central nervous system and the body's proprioceptive receptors work together to correct the movement patterns in these exercises (Liaw et al., 2011). Compared to exercises performed on a stable surface, exercises performed on an unstable surface such as TRX straps present a greater challenge to maintain the stability of the central muscles. This indicates an increase in the activity of the core muscles of the body. Consequently, these exercises increase the function of proprioceptive receptors and the pressure on the core muscles which are important in balance and stability (Cosio-Lima et al., 2003). In addition, ISoM-ISoT exercises on stable and unstable surfaces were used in order to activate the abdominal muscles and restore the proprioception of lumbopelvic muscles and joints. In the third phase, some unstable exercises were performed to improve balance and stability in these individuals. Instability exercises can facilitate the reflex pathways that start from the peripheral afferents (Brumagne, Cordo, and Verschuere, 2004; Prentice, 2004).

It can be said that the suspension characteristic of the STS and its instability as well as doing ISoM-ISoT exercises on a slippery surface in the last phase of training probably increase lumbopelvic proprioception in these people. Doing exercises on unstable surfaces stimulates unconscious adaptations and can increase endurance and muscle strength while simultaneously activating

these muscles and stimulating proprioceptive receptors. As a result, weak muscles are more actively involved and the central nervous system receives more signals from the peripheral afferents of these muscles (Snarr and Esco, 2013). It seems that the most important reason for disturbance in lumbopelvic proprioception and balance in people with DRA is the changes in the information transmitted by the mechanical receptors, decreased proprioception due to linea alba tension, and delay in the activation of weak lumbopelvic muscles due to childbirth (Benjamin et al., 2019; Hills, Graham, and McLean, 2018). Therefore, it is possible that the exercises of the present study affected the postural control of the body through the co-activation of agonist and antagonist muscles. With the co-activation of local muscles (i.e. abdominal transverse and internal oblique muscles), the rectus abdominis global stabilizer muscles also synergistically act to maintain the normal function of the lumbopelvic region (Zhang, 2018). So it seems, these exercises reduce DRA and increase lumbopelvic control to the average range, reduce the load on the spine, and increase postural stability probably by increasing the tonic activity, maintaining the contraction ability in the agonist muscle, and increasing the peripheral inputs.

Based on the studies conducted on people with low back pain, the most important causes of low back pain are instability in the spine and the dysfunction of the abdominal transverse and multifidus muscles (Sahrmann, 2002). Because these muscles direct the joints in different patterns of movement, their injuries impairs the function of the lumbopelvic joints and ultimately causes movement dysfunctions (Akuthota and Nadler, 2004; Ferreira, Ferreira, and Hodges, 2004). Hence, it can be pointed out that one of the important factors in postpartum low back pain is DRA which leads to lack of muscle support for the bony structures in the lumbopelvic region and overload in them (Da Mota, Pascoal, Carita, and K, 2015). Increasing muscle support in this region was associated with a reduction in pain and disability. By reducing the severity of pain from moderate to mild, researchers in this study were able to achieve one of their main goals.

Almost all studies in the field of DRA have shown that the linea alba is the most important unit for the stability of the anterior oblique subsystem (Benjamin, Van de Water, and Peiris, 2014; Chiarello and McAuley, 2013; El-Mekawy, Eldeeb, El-Lythy, and El-Begawy, 2013) and the present research is a continuation of these studies. The results of this study regarding the effect of exercise on this disorder were consistent with the studies of Kamel and Yousif (2017), Walton et al. (2016) and El-Mekawy, Eldeeb, El-Lythy, and El-Begawy (2013). In their studies, they

emphasized postpartum physical therapy for treating this disorder and considered the progression of pregnancy in the later months, severe stretching and weakness of the abdominal muscles, and the decreased strength of the abdominal transverse and internal oblique muscles as the causes of DRA. In addition, no studies whose results were inconsistent with those of the current study regarding the effect of exercise on treating this disorder were found. In severe cases, abdominoplasty surgery and linea alba repair were given priority over abdominal exercises in a few studies (Coratti et al., 2020; Fiori et al., 2020; Michalska et al., 2018). The study of Kamel and Yousif (2017) which was conducted for 8 weeks on one physical therapy group and one electrical stimulation group showed the positive effect of exercise on this disorder and the pain and disability thereof. They stated that adding electrical stimulation to rehabilitation exercises can have a better effect. In a study, Walton et al. (2016) examined the effect of abdominal core stabilization exercises along with plank and Kegel at 6 weeks postpartum. The results of this study showed that abdominal isometric exercises such as plank and Kegel had an effect on reducing DRA and pelvic floor muscle weakness (Walton et al., 2016). In the study of El-Mekawy, Eldeeb, El-Lythy, and El-Begawy (2013) which was conducted for 6 weeks on the strength of abdominal muscles, one group used an abdominal belt and the other group used core stabilization exercises. At the end of the interventions, the physical therapy group showed a significant decrease in the width of the IRD. The researchers in this study noted that strengthening the core muscles in the first postpartum months is very important and necessary because it contributes to the muscle support of the spine, the rapid treatment of DRA, and the reduction of pain and disability (El-Mekawy, Eldeeb, El-Lythy, and El-Begawy, 2013). Given that there are few studies on the effect of exercise on the treatment of DRA, unfortunately, no studies were found whose results were consistent or inconsistent with those of the current study regarding the effect of the STS on women with DRA. In this respect, the current study considered new dimensions regarding exercise programs and secondary DRA complications.

Strengths and limitations

The participants' lack of cooperation in the intervention or posttest stages, lack of control on the participants' life style, and few sample sizes were some of the limitations of the current study. Therefore, more studies with higher sample sizes are needed.

The strengths of our study are as follows. The training program was designed through teamwork resulting in a high-quality training program targeting the DRA and core muscles. By using STS home exercises, the cost of the study was kept low for the subjects. Two experimental groups were compared with the control group. The exercises presented in this study are the first STS rehabilitation exercises for women with DRA.

Conclusion

According to the results of the current study, the STS was statistically similar to ISOm-ISOT exercises and was able to have positive effects on the treatment of DRA. Nevertheless, these exercises clinically outperformed the ISOm-ISOT exercises in variables such as IRD, pain, disability, and proprioception. In addition, the STS can be used for the treatment of DRA in clinics, gyms, and women's health care centers for postpartum rehabilitation.

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Table A1. Suspension training system in 24 sessions.

	1–6 Session	Set/rep	7–15 Session	Set/rep	16–24 Session	Set/rep
Training exercises	Suspension chest press with drawing in	3 × 8	Suspension hip hinge with drawing in	3 × 12	Suspension single-leg reaching Romanian deadlift	3 × 8 (ES)
	Suspension hip hinge with drawing in	3 × 10	Suspension lying leg curl	3 × 12	Suspension supine plank with drawing in	3 × 30s
	Suspension supine plank with Kegel	3 × 15s	Suspension power pull	3 × 8	Suspension reverse crunch	3 × 8
	Suspension lying leg curl	3 × 8	Suspension glute bridge	3 × 10	Suspension reverse mountain climber	3 × 8
	Suspension squat	3 × 12	Suspension side plank	3 × 15s	Suspension pike plank	3 × 8
	Suspension glute bridge	3 × 8	Suspension crab plank	3 × 15s	Suspension mountain climber	3 × 8
	Suspension single-leg supine plank	3 × 8 (ES)	Suspension plank	3 × 15s	Suspension supine crunch	3 × 10
	Suspension reverse mountain climber	3 × 8	Suspension single-leg supine plank	3 × 10	Suspension side plank	3 × 20s
			Suspension reverse mountain climber	3 × 10	Suspension plank	3 × 20s

ES: Each side.

Table A2. IsoM-IsoT training program in 24 sessions.

	1–6 Session	Set/rep	7–15 Session	Set/rep	16–24 Session	Set/rep
Training exercises	Drawing in (and holding)	3 × 15s*	Drawing in (and holding)	3 × 20s*	Lunge walking with dumbbell	2 × 20 m**
	Holding pelvic floor (Kegel)	3 × 20s	Contraction and rest of the pelvic floor muscle	3 × 20s*	Bosu alphabet	1 setWA***
	Contraction and rest of the pelvic floor muscle	3 × 15s	Anterior/posterior pelvic tilts	3 × 10	Bosu squats	3 × 8
	Contraction and rest of the abdominal muscle	3 × 15	Hip extension	3 × 8	D1/D2 PNF diagonals	3 × 8
	Supine marching	3 × 12	Supine hip abduction (Thera band®)	3 × 8	Single-leg glute bridge on the ball	3 × 8
	Supine SLR	3 × 8	Supine hip adduction	3 × 8	Ball leg lifts	3 × 8
	Supine bridge	3 × 8	Side-lying clamshells	3 × 8	Abdominal crunches	3 × 10
	Seated 3D breathing	3 × 40s	Half curl-up	3 × 8	Spinal rotation with thread the needle	3 × 12
	Alternate heel touch	3 × 12	Standing wall squats	3 × 15s*	Hip abduction standing with Thera band®	3 × 12
	SLR with external rotation	3 × 10	Plank position	3 × 15s*	Supine crisscross	3 × 15
	Standing crisscross	3 × 12	Side plank	3 × 15s*	bird-dog	3 × 15

S: second; **M: meter; ***WA: writing the alphabet with a medicine ball.