The effects of Suspension (TRX) versus core stabilization training on postural stability, lumbopelvic control and proprioception in women with DiastasisRecti Abdominis: A Randomized Controlled Trial

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Research Article

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Abstract

Background: This study compared the effectiveness of eight weeks of suspension training (TRX) with that of isometric-isotonic (ISOM-ISOT) core stabilization exercises in the treatment of diastasis recti abdominis (DRA) and its secondary complications such as impairment in proprioception, postural stability, and lumbopelvic control as well as low back pain and the disability in doing daily activities.

Methods: Thirty-six women with DRA with a mean age of 29.11 (4.85) from whose delivery 2 to 4 months had passed participated in this study. They were divided into the three groups of TRX, ISOM-ISOT training, and control. DRA, proprioception, lumbopelvic control, postural balance, low back pain, and disability were respectively assessed with a digital caliper, a goniometer, a lateral step-down test, a Biodex balance system, VAS, and Oswestry questionnaire. Then, two intervention groups from these subjects underwent training for 8-week and the subjects in the control group resumed their normal lives.

Results: After eight-week of intervention, significant differences were observed in the inter-recti distance (IRD) (p=0.001), lumbopelvic proprioception (p=0.001), lumbopelvic control (p=0.001), static balance (overall stability) (p=0.010), dynamic balance (overall stability) (p=0.012), pain (p=0.001), and disability (p=0.001). The results of the LSD test showed that there was no significant difference between the TRX and ISOM-ISOT training groups in the studied parameters (P≥0.05).

Conclusion: It seems that the TRX exercises had a positive effect on women with DRA and like the ISOM-ISOT exercises can be used to treat this disorder.

Trial registration: The Iranian Registry of Clinical Trials (code: IRCT20190219042761N1; 06/07/2019).

Background

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)(1). This disorder begins in the late second trimester of pregnancy and peaks immediately after childbirth and a few weeks later(2, 3). The prevalence of DRA has been reported to be 35-39% six months after delivery. However, its highest prevalence (98%) is immediately after delivery especially in women with multiple births(4). 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. It also appears that women with DRA are more prone to pain in the lumbopelvic region after childbirth(5). According to these studies, DRA is considered as a severe weakness of the abdominal muscles that causes more secondary complications in the core region if it is not treated in time(5, 6). 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(7-9), the authors of the current paper investigated these variables in women with and without DRA after childbirth in a case-control study (2020). The results showed that the patients with diastasis recti 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(6, 10). DRA is not usually accompanied by pain at the site of the disorder (the linea alba region). Hence, it 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(11). 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(12, 13). In a study, Walton et al. (2016) investigated the effects of abdominal stabilization exercises along with plank and Kegel exercises for 6 weeks after childbirth. The results of this study showed that isometric abdominal exercises such as plank and Kegel were effective in reducing DRA and the weakness of pelvic floor muscles(14).

One of the exercise programs used in this study was isometric-isotonic training (ISOM-ISOT). In isometric training, no change occurs in muscle length by creating tension in the muscle. Isotonic training is an exercise in which the muscle length is increased and reduced with eccentric-concentric contractions. 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 results of some studies have shown that these exercises have a positive effect on improving DRA and such complications as low back pain, disability, and abdominal muscle strength(13, 15).

TRX suspension training was another intervention used in the current study. Nowadays, 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 benefits of these exercises include practicality, low space, attractiveness, simplicity, and easiness of use in the lack of a gym and sports equipment(16). Suspension training 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(17). Byrne et al. (2014) reported that TRX suspension training has a positive effect on the functional stability of the abdominal muscles and the muscles around the pelvis(18). Some studies have shown that suspension training 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(17, 19, 20). Mok et al. (2015) studied the electromyographic activity of core muscles during TRX training. They reported that suspension training can considerably activate the transverse and rectus muscles and have a significant effect on them(17).

Thus, due to the specific conditions of women with DRA, the researchers in this study designed a suspension training program called TRX-DRA with the aim of treating this disorder and restoring postural stability in postpartum women.

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 suspension training 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 suspension training program (TRX-DRA) with that of isometric-isotonic core stabilization 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 retrospective, double-blind, randomized, and controlled. 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 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 post-test phases, this number was reduced to 36 patients(3). 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 (Fig 1).

In this study, the inclusion criteria were women who had more than one delivery 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 above the umbilicus, vaginal delivery, and the BMI of less than 30 kg/m2(14, 21, 22). 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. The participants in each group were also unaware of the existence of the other groups and the results of their own tests until after the post-test stage. The participants were randomized with Random Number Generator software and allocation concealment was done by sequentially numbered opaque sealed envelopes (SNOSE). The participants were divided into the three groups of TRX-DRA (n=15), ISOM-ISOT (n=15), and 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 TRX-DRA 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, TRX-DRA 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 consecutive 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.

TRX-DRA exercises

The TRX-DRA exercises were designed using the book *Complete Guide to TRX Suspension Training(23)*. This exercises consisted of the 3 phases of beginner (the first session to the sixth session), intermediate (the seventh session to the fifteenth session), and advanced (the sixteenth session to the twenty-fourth session). The difficulty level of the exercise was adjusted by changing the ‘working angle’ (for example, tilting the body from a standing position). Since the women in this study did not have exercise activities, simple exercises such as TRX glute bridge and TRX 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 (Table 1 & Fig 2).

ISOM-ISOT core stabilization exercises

The exercise program used in this study was a modified protocol of Litos et al. (2014)(24). This exercises consisted of the three different training phases of beginner (the first to the sixth session), intermediate (the seventh session to the fifteenth session), and advanced (the 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 (Table 2 & Fig 3).

Primary outcomes

The inter-recti distance

The inter-recti distance was assessed with a tool called digital caliper (model: E325-101, Iran) with the measurement accuracy of 0.01 mm. 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(3, 25). The measuring point was 4 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(22, 26). Moreover, the validity of this test compared to ultrasonography was reported as 0.84 and its interclass correlation coefficient (ICC) above the umbilicus was reported as 0.71%(22). 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 middle fingers instead of a digital caliper(12).

Secondary outcomes

Lumbopelvic proprioception

To evaluate the lumbopelvic proprioception of the women participating in this study, the Newcomer test (r=0.91 and ICC=0.87) was used(27). This test was performed by an Iranian-made goniometer. The validity and reliability of this device were reported to be 0.97 and 0.87, respectively(28). 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 (Fig 4-a). This test was repeated three times and the error rate of the subjects (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(27, 29).

Lumbopelvic control

The lateral step-down test at the frontal level was used to assess the lumbopelvic control (ICC=0.95)(30). 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 Kinovea 8.15 software to analyze the movements were used. After ASIS was found on both sides and light-reflecting markers were installed in these areas, the subjects were asked to stand on the step, to 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. Hip joint flexion and right knee flexion were 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 foul (Fig 4-b). This test was repeated 5 times and the average of the angles was recorded in Kinovea 8.15 software. It should be noted that this test was randomly performed on only one side(30).

Static and dynamic balance

The static and dynamic balance test was performed on the subjects using the Biodex balance system (SD) made by the Biodex Company (USA) (ICC=0.95)(31). In this study, the postural stability test was used to measure the static and dynamic balance(32). A stable support surface was used to measure the static balance and an unstable (with the instability degree of 7) support surface was used to measure the dynamic balance(32). Both tests were performed in a double-leg stance. The participants were asked to stand in a way that the 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 (Fig 4-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.

Low back pain and disability

In order to assess the pain intensity in people with low back pain, the visual analog scale was used. The pain intensity scale is a 100 mm (10 cm) long ruler one end of which is zero (without pain) and the other end is 10 (the most severe pain). The subjects were asked to indicate their pain intensity on the ruler. The ICC of this scale was reported to be 0.95(33). The Oswestry questionnaire (r=0.94 and ICC=0.99) was used to assess the degree of disability in postpartum low back pain. 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 (optimal performance without pain) to five (disability in performance due to severe pain). The Oswestry Disability Index 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(34).

Ethical considerations

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 rules and 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.

Statistical analysis

The Shapiro-Wilk test was used to evaluate the normality of data distribution and the Levene 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 ANOVA test was used to evaluate the differences between the groups in the pre-test. The analysis of covariance (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(35). Data analysis was performed at a significance level of 0.05 using IBM SPSS 24 and Microsoft Excel 2016.

Results

Results of the demographic characteristics

The results of the Levene and Shapiro-Wilk tests demonstrated that the presuppositions were not violated (P>0.05). The results of the one-way ANOVA (Table 3) showed that the subjects were homogenous in terms of demographic characteristics (P>0.05).

Results of the ANCOVA test

The results of the ANCOVA test showed that there was a significant difference among the three groups in the variables IRD (P=0.001), lumbopelvic control (P=0.001), lumbopelvic proprioception (P=0.001), low back pain (P=0.001), disability (P=0.001), overall stability (P=0.001) and anterior-posterior stability (P=0.030) of static balance, and overall stability (P=0.012) and anterior-posterior stability of dynamic balance (P=0.012). However, there was not any significant difference among the three groups in the variables medial-lateral stability (P=0.170) of static balance and medial-lateral stability (P=0.065) of dynamic balance. In addition to the results of the ANCOVA test, the means of the pre-test and post-test variables of the study can be seen in Table 4.

Results of the LSD test

The results of the post-hoc LSD showed that there was not any significant difference between the two groups (TRX-DRA and ISOM-ISOT) in the variables IRD (MD=-2.76, P=0.12), lumbopelvic control (MD=1.53, P=0.14), lumbopelvic proprioception (MD=-0.50, P=0.48), low back pain (MD=-0.52, P=0.25), and disability (MD=-1.74, P=0.48). The same was true for the overall stability (MD=0.07, P=0.62), anterior-posterior stability (MD=0.01, P=0.90), and medial-lateral stability (MD=0.06, P=0.50) of static balance as well as for the overall stability (MD=0.33, P=0.27) and anterior-posterior stability (MD=-0.10, P=0.44) of dynamic balance. A significant difference was found only in the medial-lateral stability of dynamic balance (MD=0.55, P=0.03).

These results also showed that there was a significant difference between the two groups of TRX-DRA and control in the variables IRD (MD=-21.65, P=0.001), lumbopelvic control (MD=-10.68, P=0.001), lumbopelvic proprioception (MD=-7.83, P=0.001), low back pain (MD=-2.83, P=0.001), disability (MD=-17.57, P=0.001), overall stability (MD=-0.39, P=0.013) and anterior-posterior stability (MD=-0.46, P=0.002) of static balance, and overall stability (MD=-0.63, P=0.032) and anterior-posterior stability (MD=-0.74, P=0.004) of dynamic balance. However, no significant difference was found in the medial-lateral stability of static balance (MD=-0.12, P=0.210) and the medial-lateral stability of dynamic balance (MD=-0.01, P=0.93) (P>0.05).

Finally, the results of the LSD test showed that there was a significant difference between the ISOM-ISOT and control groups in IRD (MD=-18.89, P=0.001), lumbopelvic control (MD=-12.21, P=0.001), lumbopelvic proprioception (MD=-7.33, P=0.001), low back pain (MD=-2.31, P=0.001), and disability (MD=-15.83, P=0.001). The same was true for the overall stability (MD=-0.47, P=0.005) and anterior-posterior stability (MD=-0.48, P=0.002) of the static balance as well as for the overall stability (MD=-0.96, P=0.004), anterior-posterior stability (MD=-0.63, P=0.018), and medial-lateral stability (MD=-0.57, P=0.030) of dynamic balance. No significant difference was found in the medial-lateral stability of static balance (MD=-0.18, P=0.067) (Table 5).

Discussion

The aim of the present study was to investigate the effect of eight weeks of TRX-DRA suspension training and ISOM-ISOT core stabilization exercises on DRA and its postpartum complications. It was found that the TRX-DRA training for 8 weeks was able to have a positive effect on IRD, lumbopelvic proprioception, lumbopelvic control, reduction of low back pain and disability, overall stability and anterior-posterior stability of static balance, and overall stability and anterior-posterior of dynamic balance. The researchers also observed that performing ISOM-ISOT exercises had a positive effect on IRD, lumbopelvic proprioception, lumbopelvic control, reduction of pain and disability, overall stability and anterior-posterior stability of static balance, and overall stability, anterior-posterior stability, and medial-lateral stability of dynamic balance.

Interpretation

The results of this study showed that the TRX-DRA and the ISOM-ISOT training programs were equally effective in the treatment of DRA and its complications. This shows that the TRX-DRA training in this study can be used as a new treatment method for this disorder and can increase the variety of exercises in treating it. TRX 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. It seems that the major reason for the increase in motor unit recruitment and muscle activation in TRX exercises compared to other exercises is the imbalance and suspension characteristics of TRX bands. Moreover, the central nervous system and the body's proprioceptive receptors work together to correct the movement patterns in these exercises(3). In 2015, Atkins et al. examined the activation of core muscles in swimmers in the plank exercise with two types of suspension systems (TRX and Swiss ball) and concluded that in TRX exercises the activity of the core anterior muscles is more than that of the lateral and posterior muscles in this region(36). Compared to exercises performed on a stable surface, exercises performed on an unstable surface such as TRX 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(37). In addition, in this study, ISOM-ISOT exercises in stable and unstable surfaces were selected in order to activate the abdominal muscles and restore the proprioception of lumbopelvic muscles and joints. These exercises improve the multi-plane neuromuscular control and include movements with eccentric-concentric contractions to relearn postural control and restore the length and strength of muscles to their pre-pregnancy state(38, 39). In the third phase, some unstable exercises such as Bosu ball squat, bridge, and Kegel on Swiss ball were performed to restore balance and stability in these individuals. Instability exercises can facilitate the reflex pathways that start from the peripheral afferents(40, 41). It seems that one of the reasons for the lack of statistical differences between the two training programs was the existence of instability exercises in the third phase of ISOM-ISOT exercises, creating an equal condition with TRX-DRA suspension exercises. This raises the question that if unstable levels were eliminated in the ISOM-ISOT exercises, could these exercises still be as effective as TRX-DRA exercises? To answer this question, more research is needed in this field.

The instability exercises in this study resulted in significant improvements in lumbopelvic proprioception, lumbopelvic control, postural balance, pain, and disability in patients with DRA. Given that the bilateral activity of the abdominal transverse and internal oblique muscles helps stabilize the ribs, the spine, and the lumbopelvic region, the results of the present study showed that after exercise, the function of the abdominal transverse and internal oblique muscles which are the most important muscles in stabilizing the lumbopelvic region are restored and show a better performance than before. This indicates the importance of these muscles in the treatment of DRA. The return of strength to these muscles shortens and strengthens their fascia around the rectus abdominis muscle called the rectus sheath which is directly connected to the linea alba. This eventually closes the gap between the two bulks of the rectus abdominis muscle and reduces the IRD(11, 12). Regarding the increase in lumbopelvic proprioception in these people, one can mention the suspension characteristic of TRX-DRA exercises, their instability, and possibly doing these exercises on a slippery surface in the last phase of the ISOM-ISOT training. Doing exercises on slippery and 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(19). It seems that the most important reason for disturbance in lumbopelvic control 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(15, 42). Nervous afferents are important components in kinetic control and muscle spindles, which are the sensory receptors of the muscle, are greatly influenced by the information transmitted through the articular afferents. The adaptations of the neuromuscular mechanism such as proprioception and spinal reflex activity play a major role in improving balance through neuromuscular variables and timing coordination in the stimulation of agonist and antagonist muscles (abdominal transverse and multifidus muscles)(43). 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 (abdominal transverse and internal oblique muscles), the rectus abdominis global stabilizer muscles also synergistically act to maintain the normal function of the lumbopelvic region(44). Therefore, these exercises reduce DRA, increase the lumbopelvic control, 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. According to studies 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(45). Because these muscles direct the joints in different patterns of movement and the motor function resulting from these different patterns, their damage impairs the function of the lumbopelvic joints and ultimately causes movement dysfunctions(46, 47). 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(48). Increasing muscle support in this region was associated with a reduction in pain and disability. After 8 weeks of interventions, the participants reported that their low back pain and disability had significantly decreased.

Almost all studies in the field of women's health have shown that the linea alba is the most important unit for the stability of the anterior oblique subsystem(12, 25, 49) and the present research was 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 et al. (2017), Walton et al. (2016), El-Mekawy et al. (2013), and Litos (2014). 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(50-52).

The study of Kamel et al. (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(53). 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. Moreover, they also stated that these exercises activate proprioceptive inputs and nervous receptors, reducing pain and disability(14). In the study of El-Mekawy et al. (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(49). In a case study (2014), Litos also evaluated the effectiveness of isometric-isotonic exercises for 16 weeks (2 sessions per week) on a woman with severe IRD and reported a significant decrease in the width of the IRD after the intervention. The width of linea alba decreased from 110 mm to 20 mm and a significant improvement was also observed in the strength and endurance of the abdominal muscles compared with their status before the intervention(12). 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 TRX exercises on women with DRA. In this respect, it seems that the current study has considered new dimensions regarding exercise program and secondary DRA complications compared with previous studies.

Limitations

The participants' lack of cooperation, no separation of the instability exercises in the ISOM-ISOT training were some of the limitations of this study. Observing the pre-test and post-test means between the two training groups, it is likely that the TRX-DRA exercises performed slightly better than the ISOM-ISOT exercises. In order to determine the exact effect of the TRX-DRA training program, recommending that researchers compare it with stable exercises on fixed surfaces such as the ground. In this way, they can specify the different effects of stable and unstable exercises on DRA.

Conclusion

According to the results of the present study, it can be concluded that the TRX-DRA training program had a positive effect on the patients with DRA and like the isometric-isotonic training can be used to treat this disorder. In this study, it was observed that the abdominal transverse muscle had a strong fascia connection with the rectus abdominis muscle and linea alba and its weakness because of the increased anterior-posterior diameter of the core region due to pregnancy stretches fascia and leads to the IRD of the rectus abdominis muscle. Activating and training this muscle reduces IRD and increases the integrity of linea alba. As a result of improving DRA and increasing the strength of the abdominal muscles, the proprioceptive receptors, lumbopelvic control, and muscle balance are also improved. Therefore, lumbopelvic pain and the disability thereof are also reduced.

Abbreviations

DRA: Diastasis Recri Abdominis; IRD: Inter Recti Abdominis; TRX: Total Resistance Exercises; IsoM-IsoT: Isometric-Isotonic; BMI: body mass indx; MD: mean difference; SD: standard deviation; M: mean.

Declarations

Ethical approval

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). All the subjects signed a written consent form and were allowed to leave the research process if they wished.

Consent for publication

All the persons on the pictures has provided written consent for publication.

Availability of data and materials

The datasets collected during the current study are available from the corresponding author upon reasonable request.

Competing of interest

Ali Yalfani, Nahid Bigdeli, and Farzaneh Gandomi declare that they have no conflicts of interest relevant to the content of this review.

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Authorship contributions

AY collected the data, designed the TRX-DRA exercises, supervisor of the exercises, assessed the outcomes of the research, and reviewed the paper. NB recruited the patients, acted as the rehabilitator and executive supervisor in the interventions, and performed the statistical analyses. FG assessed the outcomes of the research and reviewed the paper. All the authors contributed to the writing of the paper.

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Tables

Table 1 TRX-DRA training program in 24 sessions.

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

Table 2 Isometric-isotonic training program in 24 sessions.

Training exercises	1-6 Session	Set/rep	7-15 Session	Set/rep	16-24 Session	Set/rep
	Drawing in (and holding)	3×15s*	Drawing in (and holding)	3×20 s*	Lunge walking with dumbbell	2×20m**
	Holding pelvic floor (Kegel)	3×20 s	Contraction and rest of the pelvic floor muscle	3×20 s*	Bosu alphabet	1 set WA***
	Contraction and rest of the pelvic floor muscle	3×15 s	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 (Theraband)	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	3×40 s	Half curl-up	3×8	Spinal rotation with thread the needle	3×12
	Alternate heel touch	3×12	Standing wall squats	3×15 s*	Hip abduction standing with Theraband	3×12
	SLR with external rotation	3×10	Plank position	3×15 s*	Supine crisscross	3×15
	Standing crisscross	3×12	Side plank	3×15 s*	bird-dog	3×15
	S: second; **M: meter; ***WA: writing the alphabet with a medicine ball.					

Table 3 The results of *ANOVA* for comparing the *demographic characteristics* of the subjects in the groups.

Variable	Mean (standard deviation)				F value	P value
	TRX-DRA 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
***Body Mass Index ** Waist-Hip-Ratio; *** Time After Child-Birth.						

Table 4 The results of analysis of covariance (ANCOVA) for comparing the variables of the study in the TRX-DRA, ISOM-ISOT, and control groups.

Variables			Pre-Test: Mean (SD)			Post-Test: Mean (SD)			ANCOVA		
			TRX-DRA group	ISOM-ISOT group	Control group	TRX-DRA group	ISOM-ISOT group	Control group	F value	P value	η^2
Primary outcome											
Inter-recti distance (mm)			42.51 (10.77)	36.33 (7.19)	38.01 (9.14)	13.92 (1.17)	16.69 (1.26)	35.58 (1.19)	97.33	0.001*	0.859
Secondary outcome											
Lumbopelvic control (degree)			20.03 (3.98)	20.80 (1.99)	19.72 (3.95)	12.12 (0.68)	10.59 (0.75)	22.80 (0.71)	84.64	0.001*	0.841
Lumbopelvic proprioception (degree)			9.12 (3.34)	5.33 (2.87)	6.80 (3.23)	0.84 (0.45)	1.34 (0.48)	8.68 (0.44)	97.39	0.001*	0.859
VAS pain intensity (0-10)			5.23 (1.23)	5.09 (0.94)	4.66 (1.07)	1.84 (0.30)	2.36 (0.33)	4.67 (0.32)	21.64	0.001*	0.575
Disability intensity (0-100)			28.88 (9.29)	23.02 (8.73)	23.51 (7.72)	9.28 (1.66)	11.02 (1.77)	26.85 (1.68)	32.72	0.001*	0.672
Postural stability	Static balance	Overall stability	0.97 (0.60)	0.99 (0.65)	1.28 (0.87)	0.52 (0.10)	0.45 (0.11)	0.92 (0.10)	5.31	0.010*	0.249
		Anterior-posterior stability	0.81 (0.67)	0.80 (0.65)	0.70 (0.52)	0.34 (0.09)	0.32 (0.10)	0.80 (0.10)	7.24	0.030*	0.312
		Medial-lateral stability	0.35 (0.20)	0.40 (0.18)	0.53 (0.32)	0.29 (0.06)	0.23 (0.06)	0.41 (0.06)	1.84	0.170	0.104
	Dynamic balance	Overall stability	1.58 (0.87)	2.10 (0.76)	1.43 (0.72)	1.20 (0.19)	0.87 (0.22)	1.83 (0.20)	5.14	0.012*	0.243
		Anterior-posterior stability	1.27 (0.92)	1.32 (0.56)	0.71 (0.23)	0.60 (0.15)	0.71 (0.17)	1.34 (0.17)	5.14	0.012*	0.243
		Medial-lateral stability	0.69 (0.33)	1.49 (0.65)	0.75 (0.27)	0.95 (0.14)	0.40 (0.18)	0.97 (0.14)	2.93	0.065	0.155

* Significance differences; VAS: visual analog scale; TRX: total body resistance exercise; ISOM-ISOT: isometric-isotonic;

Table 5 The LSD test results for comparing the between-group differences.

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

* Significance differences; LSD: least significant difference; VAS: visual analog scale; TRX: total body resistance exercise; ISOM-ISOT: isometric-isotonic.

Figures

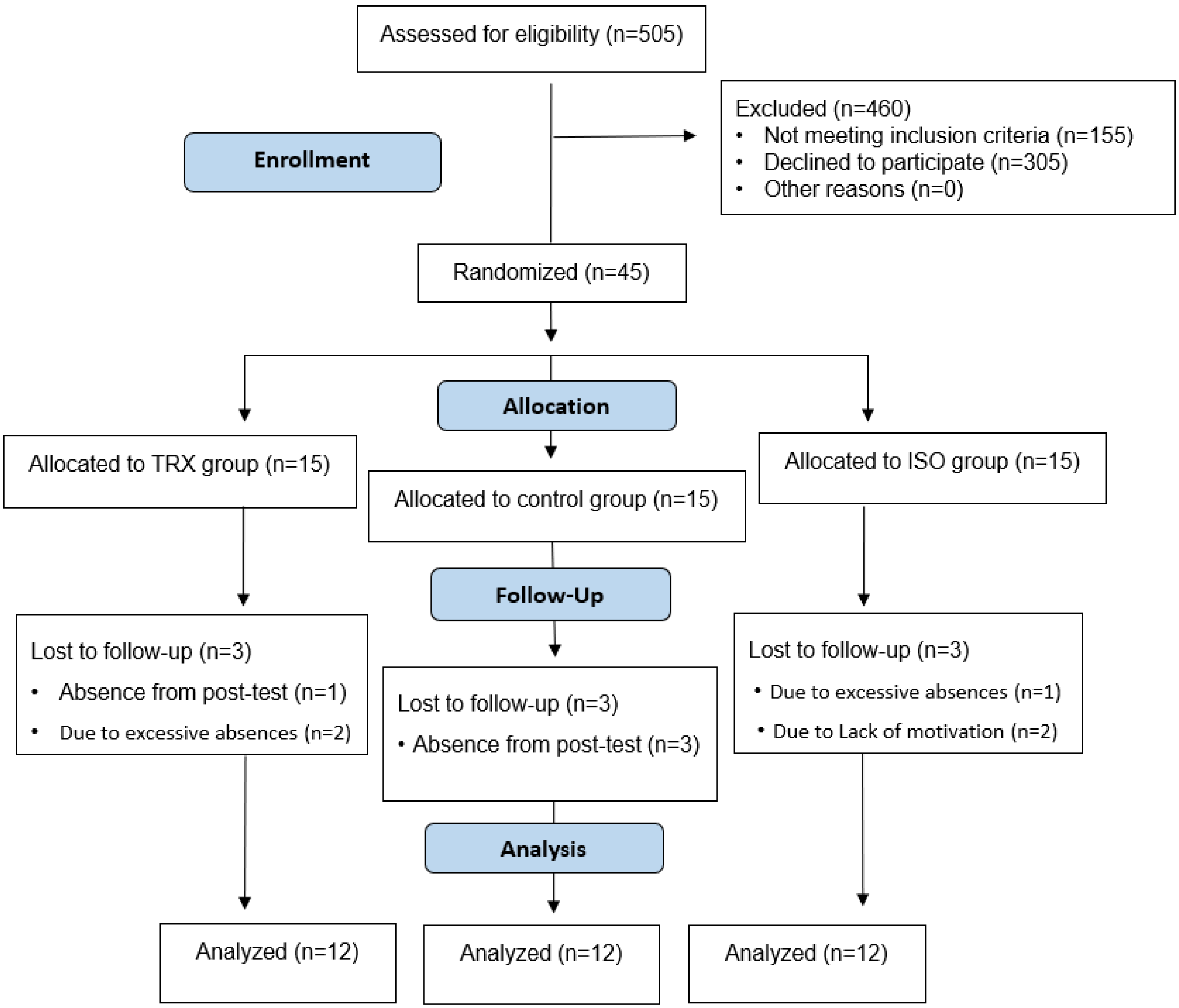

Figure 1

The Flowchart of the study

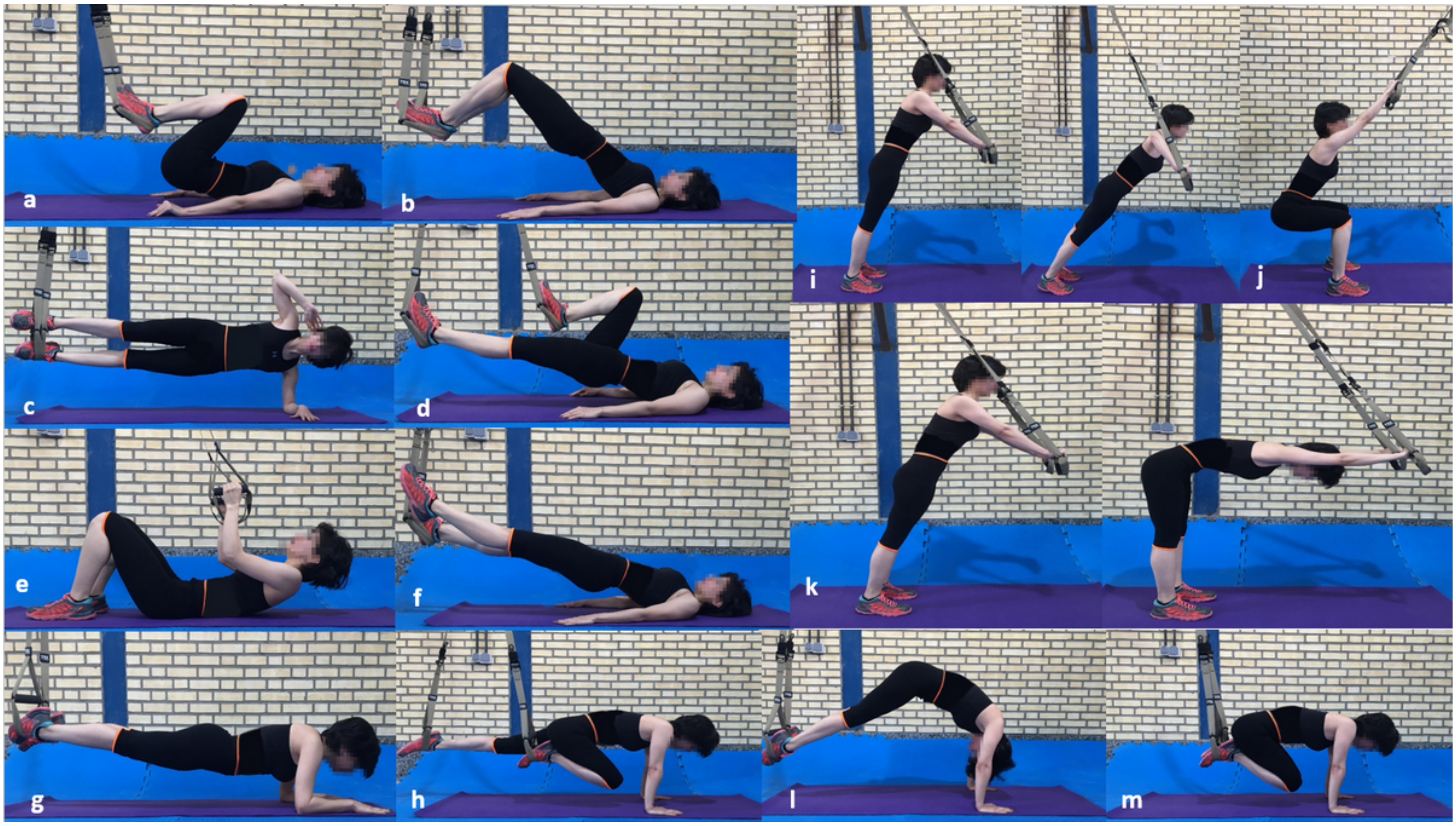

Figure 2

TRX-DRA training; TRX lying leg curl (a), TRX glute bridge (b), TRX side plank (c), TRX reverse mountain climber (d), TRX supine crunch (e), TRX single-leg supine

Figure 3

Isometric-Isotonic training; Half curl-up (a), Supine hip abduction (b), Supine hip adduction (c), Plank position (d), bird-dog (e), Single-leg glute bridge (f), Ball leg lifts

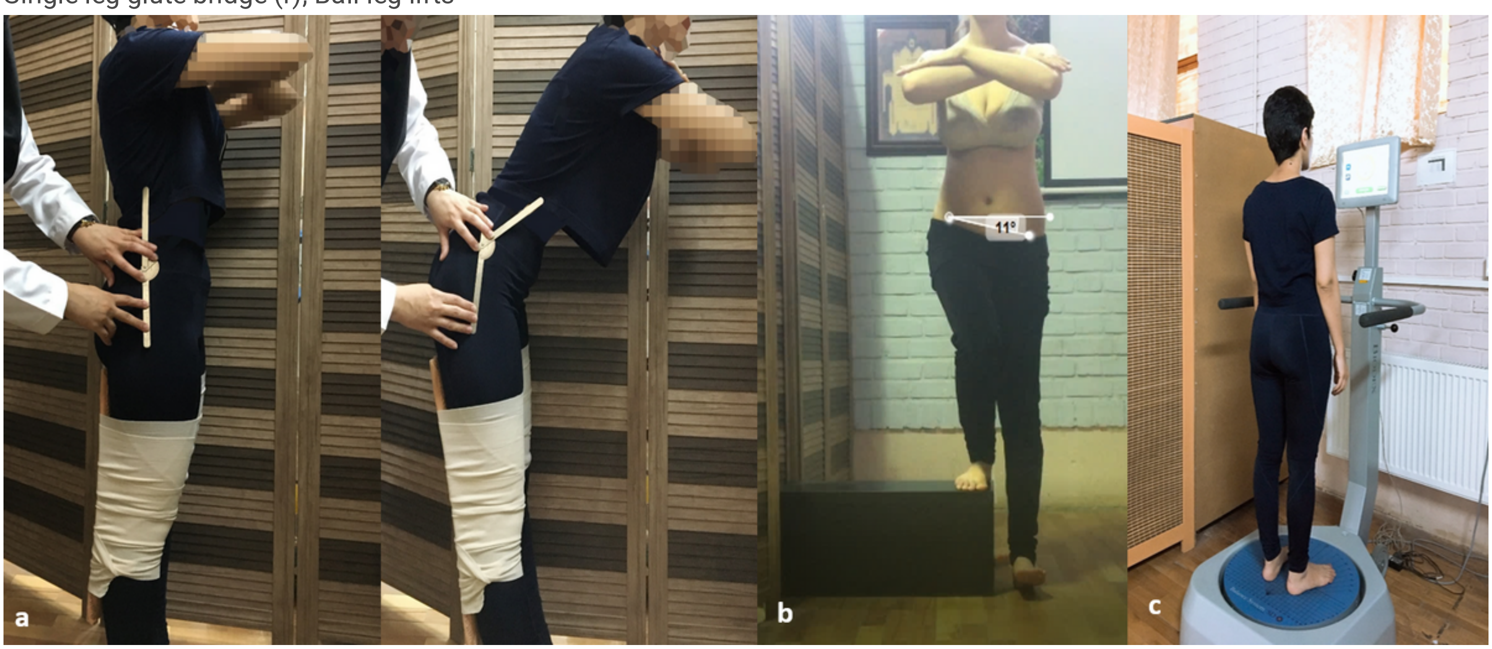

Figure 4

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