Research Paper

Comparing the Effect of 8 Weeks of Suspension Training and Core Stability on the Onset of Electromyography Activity of Selected Muscles and the Pain in Amateur Soccer Players With Non-specific Chronic Low Back Pain

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ABSTRACT

Purpose: Back pain is one of the most common injuries that affects many people worldwide. Core stability exercises are among the training methods for treating back pain. Suspension training with TRX (total body resistance exercise) has recently become popular among athletes and coaches. The present study aims to compare the effect of common core stability exercises with suspension exercises using TRX in amateur male soccer players with non-specific chronic back pain.

Methods: The current research is a clinical trial study. The study population comprised amateur male soccer players with non-specific chronic back pain. Of whom, 30 were selected as a sample using Cochran's formula and according to the inclusion criteria. Then, they were randomly divided into two equal groups of suspension exercises on the unstable level (15 people) and core stability on the stable level (15 people). The visual analogue scale (VAS) was used to obtain the pain intensity, and the surface electromyography device and force plate were used to check the activity start time. first, the pre-test evaluations were done in the Mofaghian Neurorehabilitation Laboratory, and then the subjects performed the study exercises for 8 weeks. Moreover, after 8 weeks of training, the post-test was performed. Descriptive statistics were used to analyze anthropometric characteristics, the Shapiro-Wilk test for normality of data, covariance, and the Mann-Whitney tests to compare the results between two groups at a significance level of 0.05.

Results: The results of the covariance analysis test showed a significant difference in the start time of the electromyography of the muscles between the two groups of suspension exercises and common core stability exercises after 8 weeks of exercises (rectus abdominis, P=0.01; multifidus, P=0.001; transverse abdominis, P=0.001, and external oblique, P=0.001). Also, the results of the Mann-Whitney U test for comparing the pain intensity between the two groups showed a significant difference (P=0.02).

Conclusion: Considering the greater effectiveness of suspension exercises compared to common core stability exercises and the existing reports that suspension exercises have a low risk of injury in connection with unnecessary high loads, the use of these exercises in people with low back pain is recommended than using a stable surface.

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Highlights

- The positive effect of core stability exercises at a stable level on people with low back pain.
- The positive effect of central stability exercises at the suspended level on people with back pain.
- The greater effect of exercises on a suspended surface than on a stable surface.
- Improving (onset) the start time of electrical activity of selected muscles in people with back pain.

Plain Language Summary

The current study is the difference in the effect of central stability exercises on stable and suspended levels in people with back pain. The subjects of the present study are male beginner soccer players with chronic back pain and were randomly divided into two training groups including common central stability exercises and suspension exercises using TRX or tension bands. The results of the study showed that exercises related to suspension exercises are more effective than common central stability exercises

1. Introduction

Back pain is one of the most common injuries that affects many people worldwide. To reach high levels of sports, most athletes start doing sports exercises with high intensity and high volume from a very young age. These constant, repetitive, and intense physical exercises increase the risk of musculoskeletal problems such as back pain [1]. The incidence of back pain in athletes, like normal people, is high and about 30%, and in some sports, the incidence is higher and about 50% [2]. Back pain in athletes causes the loss of training, competition opportunities, high financial cost, and low performance, and ultimately leads to retirement from sports and makes the athlete susceptible to chronic injuries [2]. Researchers have divided different types of back pain into specific and non-specific back pain. Non-specific back pain has further been classified as acute (less than 4 weeks), sub-acute (between 4 weeks and 3 months), and chronic (more than 3 months) [3]. among which chronic back pain is highly important. About 10% to 20% of patients have chronic back pain [4]. In this case, the pain is between the twelvth rib and the gluteal sulcus, may have sciatic or pathologic causes and is non-acute back pain [4]. In people with back pain, the mechanism of using the abdominal muscles to maintain the stability of the back is changed so that the transverse abdominal muscle is activated with a little delay after the contraction of the internal and external oblique muscles of the abdomen [5]. The way of muscle activation in people with chronic back pain has changed in the form of a decrease in the different activity of the transverse abdominal muscle and an increase in the compensatory activity of the gluteal muscles, which leads to the disruption of joint stability in these patients [4, 5]. Chronic back pain leads to many clinical symptoms, such as atrophy of the multifidus muscles and inhibiting its reflexes, delay in the contraction of the transverse abdominis muscle and reducing its concentric contraction ability, functional disorder, lack of feedback response of the back muscles [6], and more fatigue of multifidus muscles compared to other muscles extending the spine [6].

This fatigue of the multifidus muscle increases the probability of back pain [7]. MacDonald et al. reported that the multifidus muscle function reduction in the control of vertebral column movements does not improve by itself, and this dysfunction is an important factor for the return of back pain [8]. About 85% of chronic back pains that do not have a definite diagnosis are classified as non-specific chronic back pain, and this event has led to a gap in proper diagnosis and treatment [8, 4]. Most of the common methods for treating back pain are control methods, and these methods include rest and drug therapy, application of superficial and deep cold and heat [9], training in sports such as Mackenzie [10], massage on the muscles [9], and teaching appropriate ways to avoid situations that cause back pain. In many studies, sports exercises have been recommended to improve back pain [9, 8, 4]. Previous research showed that training programs for low back injuries include core stability exercises [11], Mackenzie [10], balance exercises [12], stirring exercises [13], and hydrotherapy [14]. One of the exercises used to improve back pain in affected people is core stability exercises. These exercises mostly empha-

size the ability to stabilize the spine in different positions and strengthen the transverse abdominis, multifidus, and postural muscles [11]. Based on the studies, the activity pattern of the core stabilizing muscles changes in people with back pain. So far, many studies have investigated the effect of various exercises, including core stability exercises, on treating people with back pain. In one of the review studies that investigated the effect of stability exercises, it was found that if stability exercises are performed up to dynamic stages, they greatly improve the activity pattern of the trunk muscles of people with back pain [15]. Based on this finding, stability exercises with various interventions have been used to treat people with back pain [11]. One of the therapeutic interventions in the rehabilitation process and emphasizing the creation of dynamic conditions, is performing exercises on unstable surfaces such as a Swiss ball [16]. By destabilizing the balance, these types of therapeutic interventions provide unstable conditions for the person. To maintain balance, it is necessary to activate the stabilizing muscles [16].

It seems that the unstable conditions of stability exercises significantly affect the activity pattern of trunk muscles. Some studies conducted on healthy people have stated that performing exercises on unstable surfaces facilitates the activity of the neuromuscular system and is suggested as a suitable intervention for the treatment of back pain [16, 17]. Meanwhile, such a conclusion requires examining the pattern of muscle activity when performing exercises on unstable surfaces in people with back pain, which has been addressed in some studies [18, 16]. The question is whether exercises on unstable surfaces can increase the activity of the stabilizing muscles of the trunk in people with back pain and whether these exercises can be recommended as a suitable recommendation for rehabilitating people with back pain. Most studies in this field have only evaluated the effect of stability exercises as a therapeutic intervention on the quantitative and qualitative outcomes of people with back pain [19, 20]. However, in these studies, the exercises were performed in different environmental conditions. The effect of an unstable surface has not been investigated as an intervening environmental condition during stability exercises on the activity pattern of the trunk muscles of people with back pain. While there is a possibility that the surface condition is considered an interfering factor in improving the activity pattern of the trunk muscles during stability exercises in people with back pain. One of the tools and suspension-instability exercises that has recently been noticed by the communities that deal with sports and exercise is the use of suspension exercises with total body resistance exercise (TRX). It is a new type of training method that can be used to perform hundreds of different exercises by using the gravity of the earth or body weight and two rope-like levers with different goals. In this training method, the amount of challenge and force applied can be reduced or increased by moving and changing the body's position [21].

According to studies, the unique feature of TRX compared to other training methods is that both in the movements of the upper limbs and the lower limbs, by changing the position of the body, the core stabilizing muscles of the body can be strongly activated, and by using a series of comprehensive exercises, in a shorter time, the practitioner gets the most benefit from the training session [22]. Also, this device can be used as a destabilizing tool to engage and activate more core stabilizing muscles [22]. With the studies conducted concerning the comparisons made between core stability exercises on stable surfaces versus unstable surfaces, conflicting results were obtained. Some studies found stable surfaces to be more effective than unstable surfaces in people with chronic back pain [23-25], and some studies have acknowledged that exercises on unstable surfaces are more effective in improving people with chronic back pain [26-28]. With these conflicting results, a study that can investigate the effect of unstable surface conditions (TRX) during core stability exercises on the activity pattern of trunk muscles, pain, and functional disability of athletes with non-specific chronic low back pain seems necessary.

2. Materials and Methods

The current research is a type of clinical trial study. The statistical population of this research comprised the amateur male soccer players of Tehran City, Iran. A total of 30 were selected using Cochran's formula as a statistical sample and randomly divided into two training groups: one training group with TRX (n=15) and one group with exercise on a stable surface (n=15). Therefore, the research was designed with a pre-test and post-test in both training groups unstable and stable. The inclusion criteria comprised the male amateur athletes, aged between 20 and 35 years, and reported pain in the lower back between the pelvic crease and the chest (so that the pain in the visual analogue scale (VAS) index is between 3 and 7) at least during the last 6 months and confirmation by a specialist doctor [28]. The exclusion criteria were progressive arthritis of the spine, deformities, slipped vertebrae, disk herniation, and regular use of painkillers [28, 27]. Also, the exclusion criteria for exiting the research are failure to participate in the post-test for a maximum of one week after the end of the training program, absence in three consecutive sessions during

the training, and the researcher's determination that the person does not cooperate properly for the implementation of the research. This research has received. (Code: IR.UT.SPORT.REC.1401.015).

Before collecting the data and conducting the test, the subjects received training instructions and got familiar with the test method. They performed the necessary exercises to ensure proper execution. After determining the location of the electrodes and marking them for installing the electrodes, the excess hair was removed from the body using a disposable Gillette and cleaned with alcohol. Then, F-RG surface electrodes (made by SkinTact, Germany) were attached to the muscle ventricles parallel to the muscle fibers [29, 30]. Electrode placement on the selected muscles was done according to SENIAM protocol: the electrodes of the right abdominal muscles 2 cm to the right side of the navel and 3 cm above, transverse abdominis at a distance of 2 cm from the vertebrae, parallel to the third lumbar vertebra, and multifidus 2-3 cm from (midline) on the connecting line between the lower. Most of the upper posterior lumbar spine and the intervertebral space of the first and second vertebrae were placed at the level of the fifth lumbar vertebra, and the reference electrode was placed on the upper part of the sacrum [29, 30]. A surface electromyography device was used to record the start time of muscle activity.

Electromyography data are collected with a sampling frequency of 1000 Hz per second. These signals were first pre-amplified by 10 times and filtered in the bandpass range between 20 and 500 Hz. After connecting the stability and reference electrodes and initial heating, the maximum isometric contraction of the target muscles will be recorded to normalize the electromyography waves. For this purpose, each subject was asked to do an isometric contraction of each muscle three times with his maximum effort for six seconds. Then, the root means square of the middle three seconds of the highest recorded contraction value was calculated to normalize the electromyography waves. Recording the maximum voluntary isometric contraction for each muscle was done based on Kennard's method of evaluating muscle strength. In this regard, to record the maximum isometric contraction of the multifidus muscle, the person lay on his stomach while the hip is fixed; the person performed the isometric contraction of the lower back against resistance and with the greatest force. For the rectus abdominis, the person is lying on their back with their legs bent at 90 degrees (a sitting position with their legs fixed). They will try to pull themselves up against external resistance. In all the above cases, the external resistance was applied by a belt tied against the direction of the movement that prevents the person from rising. A common electrode is used to record the maximum isometric contraction of the transverse abdominal and internal oblique abdominal muscles. The person is lying on his back; the stabilization electrodes are located at a distance of 2 cm inside and below the spine of the upper anterior cruciate ligament. Then, against resistance and with maximum force, the person will try to rotate the trunk in the same direction while bringing the navel inside. After the end of the test, the electromyography device will be turned off, and the recorded signals will be saved as an Excel file [29, 30]. Components such as the onset of the activity (onset), the end of the activity (offset), and the order or turn of muscle activation are considered the timing of muscle activity.

Calculation of the start time of muscle activity (Onset)

To calculate the start time of muscle activity, we used the rectification method of muscle electromyography waves. By convention, when the muscle activity reaches the threshold and remains above the threshold level for at least 25 ms, this point is considered the start time of the muscle activity. In the current research, using the above method, three standard deviations of the baseline activity were calculated with the activity threshold in the time range of 300 millisecond (ms), before the foot hits the ground to determine the start time of muscle activity. Choosing the activity threshold with 3 standard deviations of the baseline activity has two reasons. Firstly, based on the research of Hodges and Bye, the standard deviation provides the most accurate time of the start of the activity with visual confirmation compared to other thresholds such as 1 and 2 standard deviations [29]. Secondly, this threshold was used in previous studies similar to this research, and choosing this threshold makes it possible to compare the results of this research with previous studies [29, 30]. In this research, a program was written in MATLAB version 11 with the help of an electronics expert to calculate the start time of muscle activity. To process information in this program, the researcher first converted and saved the raw electromyography signals recorded from muscle contractions into ASCII format using MegaWin version 3 software. Then, the saved file was opened in the MATLAB software environment. The researcher has specified a time interval of 300 ms before the moment of foot contact with the ground so that the program automatically calculates the average and 3 standard deviations of the baseline activity in this interval of 300 ms. The muscle activity threshold is where the muscle activity reaches more than the mean plus three standard deviations, and the activity remains above this threshold for 25 ms. The software automati-

cally sets the threshold point for the activity to begin and then calculates the time interval from this point to when the foot hits the ground and reports it as the activity's start time [30].

Step down task

In this research, the step-down task was used to record the start time of the electrical activity of selected muscles in the core part of the body. The step height was 25% of the subjects› leg length with a standard deviation of ±5% based on previous studies. In this way, the person was lying in supine position, and the length of his dominant leg was measured. The person was placed on the step with his hands on the hips and his feet shoulder-width apart, and he was asked to step down with the heel of his dominant foot, as shown on the force plate machine, while placing his entire sole on the ground. Furthermore, the angle of his knee, thigh, and supporting leg remains 90 degrees, and he must maintain his balance for 3 second from landing (Figure 1). Before doing the main test, the subject did 3 jumps as practice until they felt comfortable doing the task. In the end, each subject performed this task three times with an interval of 30 second, and the start time of the electrical activity of selected muscles in the core part of the body was recorded during these three repetitions. If the person lost his balance or there were too many fluctuations in the hands, trunk, and opposite leg that caused the leg of the test to lift off the force plate, the test was repeated [31].

Visual analogue scale

To measure the amount of pain, the visual analogue scale was used in the pre-test and post-test [17]. This scale is considered to be the most reliable and, at the same time, the easiest method to evaluate the intensity of pain subjectively. In this method, a 10-cm ruler is placed in front of the subject. Then he explained that the higher the number, the greater the pain intensity, so the number 0 indicates the absence of pain, and the number 10 indicates the greatest amount of pain in this area. According to the explanations given and the intensity of the pain in his back, the subject chooses the desired number, and the evaluator of this number is recorded [17].

Training protocol of suspended exercises

Suspended exercises were performed using TRX bands for 8 weeks in 24 training sessions by the subjects of the suspended exercises group. Each training session lasted between 30 and 45 minutes (Table 1).

It should be noted that the suspended exercises were designed in a way that they have enough similarities with the common core stability exercises to enable comparison in terms of the difficulty and intensity of the exercises, as well as the principles of exercise science. All the suspended exercises were based on books and articles published in the field of TRX exercises [32]. The exercises were designed to stimulate the selected muscles in the present study. From the first to the fourth week, exercises are planned to create muscle adaptation, and after creating adaptation in the first month, from the seconf month, the number of repetitions and the number of muscle sets were added based on Frequency, Intensity, Time, and Type (FITT) principles, and newer exercises were added to the program. Since the research results have shown that doing exercises in the presence of the researcher leads to better results, the researcher was present in all the training sessions [33].

Figure 1. Step down

Table 1. Training protocol for suspended exercises

Weeks	Movement	Set×Repetition
1-4	Sit-ups with TRX	10×2
	Single leg SLR	10×2
	Planks on elbows	10×2
	Planks on the palm	12×4
	Elbow crunches	10×2
4-8	Hip press	12×3
	Climber	12×3
	Saw on the elbow	12×3
	Saws on the palm	12×4
	Saw+crunch	12×4
	Side plank on the elbow	12×4

PHYSICAL TREATMENTS

Protocol of core stability exercises on a stable surface protocol

The core stability exercises of the current research suitable for the participants are including specific spinal stabilization exercises, proprioceptive retraining of the lumbopelvic region, abdominal hollowing with multifidus muscle contraction, and maintaining the said stabilization maneuver, using the dynamic stability obtained in the different positions (supination, pronation, kneeling). Core stability exercises suggested by Jeffrey include five levels [34]. Exercises start from level one, which includes static contractions in a fixed position; level two exercises include holding static contractions and slow movements in a stable environment; level three includes holding static contractions in an unstable environment and dynamic movements in a stable environment. Level four includes dynamic movements in an unstable environment, and finally, level five exercises include dynamic and resistance movements in a stable environment. The protocol of core stability exercises is mentioned in Table 2. It should be noted that the duration of both training protocols in each session was between 30 and 45 minutes.

Table 2. Protocol of core stability exercises on a stable surface protocol

Week	Movement	Set*Repetition
1-3	Raising the leg in the archer position with bent knees (second level) Movement of the leg from the back in the kneeling position (second level) bridging (second level) Forward Bend (Level 2) Backward Lounge (Level 2) Leg lift with bent knees while lying on the side (second level)	3 sets and 10 repetitions for each set 3 sets and 10 repetitions for each set 3 sets and 10 repetitions for each set 3 sets and 10 repetitions for each set 3 sets and 15 repetitions for each set 3 sets and 15 repetitions for each set
4-5	straightening the leg in the archer position with a bent knee (second level) Pushing the leg in the archer position with bent knees (second level) Lifting the pelvis from the floor in a palmar position with straight knees (second level) Leg raises with straight knees while lying on the side (second level)	3 sets and 20 repetitions for each set
6	Raising the leg in the archer position with bent knees (third level) Movement of the leg from the back in the kneeling position (third level) Bridging by raising the leg (third level) bending forward with straight hands in front of the body (third level)	3 sets and 10 repetitions for each set
7-8	Back lunge with straight arms in front of the body (3rd level) Moving the leg away from the pelvis in the position of four hands and feet (third level) Lifting and straightening the leg in the vault position with the bent knee (third level) Lifting and moving the leg in the vault position with bent knees (3rd level) Lifting the hips and legs from the ground in a palmar position with straight knees (third level) Straightening the opposite arm and leg in the kneeling position (third level)	3 sets and 15 repetitions for each set 3 sets and 15 repetitions for each set 3 sets and 15 repetitions for each set 3 sets and 20 repetitions for each set 3 sets and 20 repetitions for each set

PHYSICAL TREATMENTS

3. Results

In Table 3, the anthropometric characteristics related to age, height, weight, and body mass index and research subjects are reported separately in two groups of core and suspension stability exercises.

In Table 4, descriptive information related to the research variables in the pre-test and post-test is provided.

In Table 5, the results of the Shapiro-Wilk test were presented to check the normality of the data. The results showed that the data related to the start time before the activity has a normal distribution (P<0.05), but the data related to the pain index does not have a normal distribution (P<0.05). Therefore, the non-parametric test was used to analyze the data related to the pain index, and the parametric test was used to analyze the data related to the start time of muscle pre-activity

Table 6 shows the results of the covariance test between the groups. The results of covariance analysis comparing the start time of electromyographic activity of selected trunk muscles between the two groups of common suspension and core stability exercises showed a significant difference in the start time of electromyographic activity of muscles after performing 8 weeks of core stability exercises in all selected muscles (P<0.05). This result means that performing 8 weeks of core stability exercises on an unstable surface (TRX) has improved the start time of electromyographic activity of the rectus abdominal, multifidus, transverses, and external oblique abdominal muscles in people with non-specific chronic back pain. According to the results obtained concerning the impact factor, performing 8 weeks of exercises on unstable surfaces (TRX) improves the start time of the electrical activity of the transverse abdominal, multifidus, rectus abdominal, and external oblique muscles of athletes with back pain. Chronic non-specific had a negligible effect on core stability exercises on a stable surface.

Table 7 presents the results of the Mann-Whitney U test to compare the pain index between the two groups. The test was used to check the differences between groups in the post-test. The results of this test showed a significant difference between the two groups of core stability exer-

Table 3. Descriptive information of subjects (n=30)

Parameters	Mean±SD		F	P
	TRX Group	Stable Surface Group		
Age(y)	27.73±3.76	27.46±4.20	0.03	0.85
Hight (m)	1.75±0.05	1.76±0.06	0.08	0.77
Weight (kg)	73.26±4.80	73.86±5.27	0.04	0.83
BMI (kg/m²)	23.78±0.76	23.72±0.58	0.04	0.83

PHYSICAL TREATMENTS

Table 4. Comparison of pre-test and post-test average scores

Variables		Mean±SD			
		TRX		Stable Surface	
		Pre-test	Post-test	Pre-test	Post-test
VAS		1.60±0.91	4.13±0.74	2.86±1.59	4.46±1.18
Pre-activity start time of muscles (milliseconds)	Rectus abdominal muscle	63.86±4.40	48.60±4.65	60.46±4.18	50.26±4.44
	Abdominal external oblique muscle	68.33±4.35	53.80±4.67	62.40±5.35	54.00±4.73
	Transverse abdominal muscle	90.86±6.05	71.26±7.98	83.20±4.70	72.20±3.93
	Multifidus muscle	79.80±5.90	65.00±5.19	76.80±3.98	69.46±4.20

PHYSICAL TREATMENTS

Table 5. The results of the Shapiro-Wilk test to check the normality of the data related to the research variables

Variables		Pre-test	Post-test
VAS		0.0001	0.0003
Pre-activity start time of muscles (ms)	Rectus abdominal muscle	0.07	0.43
	Abdominal external oblique muscle	0.76	0.46
	Transverse abdominal muscle	0.31	0.80
	Multifidus muscle	0.34	0.96

PHYSICAL TREATMENTS

cises on the unstable surface (TRX) and the stable surface in the pain index (VAS) in athletes with non-specific chronic back pain (P=0.02). Therefore, 8 weeks of core stability training has reduced pain in athletes with non-specific chronic back pain.

4. Discussion

Regarding the first hypothesis of the research, many researchers considered the studied stability exercises to be effective in learning new calling patterns. These patterns can effectively call the muscles of the lumbopelvic area along with improved neuro-muscular control [35]. Impaired muscle function in patients with chronic low back pain may be due to a change in one of the neuromuscular control mechanisms that affect trunk stability. People with non-specific chronic low back pain have a lower maximum voluntary contraction (MVC) in the muscles of the core stability region when performing movements compared to healthy people [36]. The principal role of dynamic stability and segmental control of the spine result from the core stabilizing muscles. Therefore, strong core stability muscles can improve neuromuscular control through the motor chain and dynamic postural control. Brumagne et al. (2004) stated that suspension exercises of muscles that have become inactive and underactive in people with back pain gradually increase their activity, and the core nervous system provides appropriate and effective stimuli from afferents and receptors. It receives the deep sensations of these muscles [37]. The call of the muscle fibers increases and the involvement of more muscle units can lead to a greater increase in muscle activity.

Table 6. Covariance analysis test to compare the start time of selected muscles between two groups in the post-test (n=30)

Variables	Group	Post-test	F	P
Rectus abdominis muscle	TRX	-63.86	6.78	0.01
	Stable	-60.64		
Abdominal external oblique muscle	TRX	-79.80	18.25	0.001
	Stable	-76.80		
Transverse abdominis muscle	TRX	-90.86	32.60	0.0001
	Stable	-83.20		
Multifidus muscle	TRX	-68.33	20.29	0.0001

PHYSICAL TREATMENTS

Table 7. U-Mann-Whitney test to compare pain index (vas) between two groups (n=30)

Variables	U-Mann-Whitney	Z	P
VAS	59.00	- 2.30	0.02

PHYSICAL TREATMENTS

The nervous system is responsible for controlling the movement of the body with two feedforward and feedback mechanisms. In the feedback mechanism, the nervous system directly influences the function of the organ by refining the sensory signals of the organ and using such information. This moment-to-moment control to correct errors is called feedback control. The neuromuscular system plays a decisive role in muscle activation and injury prevention through the feedforward and feedback mechanisms [38].

The feedforward mechanism is such that the neuromuscular system activates the muscles before the stimulus enters. The nervous system activates the muscles based on previous experiences before performing a specific activity. Also, when the muscles are repeatedly stimulated, the sense of proprioception increases, and as a result, the awareness of the sense of joint position increases. It is another factor in the significant improvement of the feedforward activity of most muscles [38, 39]. The existence of a significant difference in the feedforward part of muscles such as rectus abdominis, external oblique and multifidus, and transverse abdominal, which are among the main muscles of the core region, is probably due to the tension produced more in TRX exercises. Most research on TRX exercises has been proposed because the body is in an incline position in most movements; the core stabilizer muscles are activated involuntarily to maintain the correct alignment of the body in this position. Also, the researcher who was present in all the exercises gave feedback to the subjects during the exercises to perform the correct movements and maintain the correct alignment of the body. One of these feedbacks was the contraction and relaxation of the core stability muscles in both groups, which can be one of the reasons for the increase in muscle activity after 8 weeks of doing the exercises in both groups, especially the TRX group. Also, the studies conducted on exercises with unstable devices and tools such as Swiss ball and TRX have concluded that by reducing the area of the person's contact surface with the ground, the activity of the core muscles increases. In other words, when the hands and feet are placed on an unstable surface, more challenge is created for the spine's stability [39].

One of the reasons for increasing the activity of the abdominal muscles when performing exercises on unstable surfaces can be the matter mentioned above, and it can also be pointed out that the role of the core muscles of the trunk is vital in ensuring the health of the spine and resistance to additional rotations of the trunk. Therefore, the increase in the activity of the rectus abdominis muscle during a plank, bridge, and other movements on unstable surfaces can be due to the increased demand on the vertebral column to create stability due to the instability caused by the reduction of the contact surface [39]. For example, the main role of the rectus abdominis muscle is flexion of the trunk, posterior rotation of the pelvis, and lateral flexion of the trunk. However, during training on unstable surfaces, it takes on another role as a stabilizer of the trunk against the resulting instability, leading to an increase in the activity of the right abdominal muscle. On the other hand, while performing exercises on unstable surfaces, the angle of the body relative to the ground and the effect of gravity on the person's body are different compared to performing exercises on a stable surface. According to Terry, the force of gravity increases the lumbar lordosis, and the abdominal muscles resist this increase, which leads to an increase in the activity of the abdominal muscles [40]. Marshall and Murphy claim that the greater the distance between the center of mass and the support surface and the smaller the area of the support surface, the greater the electrical activity of the core muscles [41].

The reasons for the high activity of the external abdominal muscle in the post-test compared to the pre-test on unstable surfaces can probably be justified due to the instability created in the legs in the use of TRX. The instability of the lower body causes the body to rotate to the sides, and the person tries to resist this rotation; this leads to an increase in the activity of the external abdominal muscles. In the feedforward mechanism, the nervous system controls movement and posture using different senses according to previous experiences and internal models. The muscle activiy that begins before ground impact represents a feedforward or core motor control strategy that prepares the muscles to absorb the contact force. The onset time and magnitude of this muscle response are predicted by the core nervous system and based on sensory-motor memory about the ground reaction force during landing. To prepare for the absorption of contact forces during landing, muscle activity in the lower limb occurs before contact with the ground. Such activity recorded by electromyography is called pre-activity. it is pre-planned and controlled by the Supraspinal centers. Controlling the pre-activity timing of this muscle is vital to control the stiffness of the lower limb at the moment of contact with the ground [42]. Exercises performed with instability, such as stability exercises, create more integration in the muscles by co-contracting local and global muscles and increasing the strength [39]. The research results have shown that increasing the activity of the abdominal and trunk muscles to create stability shows the importance of the sensory aspect of the motor of these muscles compared to the strength and endurance

of these muscles. The activity of these muscles should be adjusted so that the muscles be fully coordinated at the right time, for the right duration, and with the right combination of forces. Kaji et al. (2010) reported that functional thoracic exercises are engaged in the stability system (which includes the muscles of the trunk, spine, and pelvis) and reduce the displacement of the center of pressure during standing. The intersection of the proprioceptive inputs of the trunk and the proximal parts of the lower limbs leads to the correction of disturbances and the creation of balance [43]. Deep trunk muscles, such as the multifidus and rotator muscles, have a high density of muscle spindles. The density of the muscle spindles of the rotator muscles is 4.6 to 3.7 times higher than that of the spinal muscles. For this reason, these muscles are called kinesiology monitors. They provide much proprioceptive feedback to the core nervous system. Therefore, functional stability exercises have the necessary features of muscle control and proprioception and facilitate intersegment movement control [43]. Studies of motor control of the trunk have shown that the core nervous system quickly interrupts the upcoming voluntary movement programs until the postural control movement programs are carried out first if the stability exercises are performed functionally and designed in a way that is accompanied by unexpected disturbances. The muscles are required to respond to these disturbances, the pathways in question are stimulated, and the muscle activation delay is reduced [44].

This finding can be one of the reasons for improving the start time of the selected research muscles in the post-test compared to the pre-test in each group and especially in the TRX group. The ultimate goal is to automatically call the required muscles and obtain sufficient coordination of the activation of the segment, which is a part of the movement chain [43]. Regarding the results of this research, after implementing the training programs, the pre-activity start time of the selected trunk muscles improved in both training groups. However, the effect size of the exercises on the amount of activity and the start time of the said muscles was small and medium, which may be due to the low training load and also the fact that the research subjects are athletes, and the amount of changes is less in athletes compared to inactive people. However, despite the difference in the start time of the pre-activity of the selected muscles in the research between the two exercises, TRX exercises can have a more practical effect on the pre-activity start time of the selected muscles than the exercises on the ground. However, further research is necessary in this regard. On the other hand, studies showing immediate changes in the feed-forward performance of deep abdominal muscles following voluntary contractions in a training session have been reported in people with back pain. This research showed improvement in the start time of the activity of transverse abdominal muscles, external oblique muscle, gluteus medius, and rectus abdominis by performing exercises in both groups of exercises on stable surfaces and TRX. These results indicate that training sessions involving the core muscles of the body can improve feed-forward activation in people with back pain.

Regarding the second hypothesis, there is no significant difference between the effect of 8 weeks of core stability exercises in unstable (TRX) and stable levels on pain levels in people with non-specific chronic low back pain.

Mock et al. (2015) reported an increase in the activity of transverse abdominal muscles and internal and external obliques in TRX exercises in the plank position and high thigh abduction (MVC <60%) and rectus abdominal activity higher than 40% MVC. Also, previous studies have shown that the activity of the multifidus muscles, which is atrophied in people with non-specific chronic back pain and is weakened by its nature, is high (MVC >50%) in the knee flexion movement (hamstring curl) and since this movement is part of the protocol, a research exercise was present so that it can be one of the reasons for the reduction of pain and disability of people [44]. In this movement, the pelvis is moved up, the waist is extended, and the activity of the multifidus muscles on both the right and left sides of the spine leads to balance. The pelvis prevents the rotation of the pelvis to the left and right [43]. Therefore, it seems logical to increase the activity of the multifidus muscles after 8 weeks of doing the exercises, as well as to increase the strength of these muscles in both groups and finally to reduce the pain. Kim et al. (2016) compared core stability exercises with slings to traditional core stability exercises. They concluded that suspension exercises with slings improved pain and disability in people with non-specific chronic low back pain compared to traditional exercises, even after 3 months of exercise [45].

Kim et al. (2013) conducted research titled investigating the effect of Norak suspension exercises on postural balance and muscle response patterns in patients with non-specific chronic back pain. This research was conducted with a sample size of 23 people. The samples were divided into two groups: normal physiotherapy and Norak suspended exercises. The results showed decreased pain in both groups, which was more evident in the suspended exercise group [46].

The presence of back pain puts the patient in a vicious cycle in such a way that patients with chronic back pain due to long-term pain (more than 3 months) with limitations in movement performance face problems even in performing daily movements. Their physical activity is severely limited. From the possible mechanisms of the impact of suspension exercises on pain relief, it can be said that suspension exercises are a special form of exercise for stabilization. However, with their unstable nature, they involve sensation and movement at the same time and reduce pain and normalize the response pattern. Muscles are closed in the chain of motion. Another advantage of suspension exercises is the unstable nature of these exercises, which involve local and deep muscles at the same time [47].

Among the possible mechanisms of the effect of suspension exercises with TRX on the improvement of pain intensity in this research, it can be pointed out that the exercises used in this research are stabilization exercises. In these exercises, the emphasis is on using multiple muscles, including multifidus, transverse and oblique abdominal. When back pain occurs, these muscles are the first muscles to experience dysfunction, and since these muscles guide the joint in different patterns of movements and these different patterns cause movement performance, their damage impairs the joint function and, ultimately, results in disability. Therefore, the mentioned muscles need to be retrained. In other words, when back pain occurs when there is instability in the spine, the risk of injury in this area increases. Therefore, this type of exercise increases the fatigue threshold, improves proprioceptiveness, strength, coordination, static and dynamic stability, and finally, according to the factors mentioned, it reduces the pain of people suffering from non-specific chronic back pain. Considering that the current study is a cross-sectional type of research, its long-term effect is unclear, so the long-term effects of exercise can be measured retrospectively in future research. Also, because these exercises have been performed on the adult age group, it is suggested that the effects of these exercises can be performed on the adolescent age group as well. It is also suggested that in future research, the effect of prolonged exercises should be measured, and on the other hand, considering that gender can be an important factor for back pain, the same research should be carried out on women.

5. Conclusion

According to the results obtained from the research, we conclude that performing 8 weeks of core stability exercises on both stable and unstable surfaces increases electrical activity and the onset time of the rectus abdominal, multifidus, and internal oblique and transverse abdominal muscles, as well as reducing pain and disability. Athletes with non-specific chronic back pain and experts, trainers, and occupational therapists are suggested to use these exercises to improve the mentioned variables in athletes with non-specific chronic back pain, but considering the greater effectiveness of TRX exercises compared to exercises on the ground. Also, based on the available reports, these exercises have a low risk of injury in connection with unnecessary high loads, and when performing these exercises, compressive loads are not applied to the spine, which is why these exercises are used in people with back pain. More than exercises on a stable surface is recommended.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the University of Tehran (Code: IR.UT.SPORT.REC.1401.015).

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Authors' contributions

Conceptualization and supervision: Farhad Ranjbarzadeh Yamchi and Hooman Minoonejad. Methodology: Farhad Ranjbarzadeh Yamchi - Mohammad Karimizadehardekani. Investigation, writing – original draft, and writing – review & editing, funding acquisition and resources: All authors; Data collection: Farhad Ranjbarzadeh Yamchi, Yusef Moghadas Tabrizi and Hooman Minoonegad; Data analysis: Farhad Ranjbarzadeh Yamchi and Mohammad Karimizadehardekani.

Conflict of interest

The authors declared no conflict of interest.

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