DOI: *10.22122/jrrs.v14i4.3121* *Published by Vesnu Publications*

The Effect of Trunk Core Stability Training and Total-Body Resistance Exercise (TRX) on the Performance, Balance, and Strength of Athletes with Ankle Sprain: A Clinical Randomized Trial Study

Fatemeh Hozhabrpour-Fereydani[1], Farzaneh Taghian[2], Mohamad Saleki[3]

Original Article

Abstract

Introduction: Ankle sprain is one of the common injuries among athletes, and is associated with imbalance. Therefore, the purpose of the present study was to compare the effect of trunk core stability training and total-body resistance exercise (TRX) on the performance, balance, and strength of athletes with ankle sprain.

Materials and Methods: 40 women athletes with ankle sprain (age: 24.02 ± 2.99 years and weight: 58.52 ± 4.08 kg) were randomly divided into four equal groups including trunk core stability training, TRX, combined training (core stability training + TRX), and control. Experimental groups were trained for eight weeks and 3 sessions/week. The balance, performance, and strength of the subjects before and after the exercises were evaluated using balance (Stork balance stand test and Y test), performance (side-hop test and figure-of-8 hop test), and strength (isokinetic machine) tests. One-way ANOVA and Bonferroni post hoc test were used for data analysis at the significance level of $P < 0.05$.

Results: All three training models resulted in improvement of performance as well as static and dynamic balance compared to the control group ($P < 0.001$). Moreover, there was a significant difference between the two groups of combined and trunk core stability training in performance, and dynamic and static balance, and also between the TRX and trunk core stability training groups in static balance ($P = 0.014$). However, only combined training resulted in increased muscle strength in athletes ($P = 0.001$), and there was no significant difference between the other groups ($P < 0.001$).

Conclusion: All three training models lead to improved performance and static and dynamic balance in athletes with ankle sprain. However, it seems that the combined training (core stability training + TRX) has more significant effects on improvement of balance, performance, and muscle strength in these athletes.

Keywords: Trunk core stability, Resistance training, Postural balance, Ankle sprains

Citation: Hozhabrpour-Fereydani F, Taghian F, Saleki M. **The Effect of Trunk Core Stability Training and Total-Body Resistance Exercise (TRX) on the Performance, Balance, and Strength of Athletes with Ankle Sprain: A Clinical Randomized Trial Study.** J Res Rehabil Sci 2018; 14(4): 239-47.

Received date: 25.07.2018 Accept date: 26.09.2018 Published: 07.10.2018

Introduction

Today, with the increasing participation of people in competitive and leisure sports, the incidence of joint injuries, particularly the ankle and knee joints, has increased dramatically, with ankle injuries being one of the most common injuries in the body and the ankle being the most vulnerable joint in the body (1,2). Studies suggest that ankle sprains are the most common ligamentous lesion among the young and adults, especially athletes. Ankle sprain is more common in sports that involve jumping and cutting techniques, and generally accounts for 15 to 45% of sports injuries, with a recurrence rate estimated as 70% (3). Functional ankle instability is considered to be one of the most common complications following ankle sprain and the most common debilitating complication of acute ankle sprain. Functional ankle instability refers to ankle tendency to dislocate and

1- Department of Physical Education and Sport Sciences, School of Physical Education and Sport Sciences, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
2- Associate Professor, Department of Physical Education and Sport Sciences, School of Physical Education and Sport Sciences, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
3- Assistant Professor, Department of Sports Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
Corresponding Author: Farzaneh Taghian, Email: f_taghian@yahoo.com

repeated sprains and is caused by the inability to maintain the ankle joint stability during exercise (4). Although ankle instability is influenced by the interaction of internal risk factors (age, gender, weight, previous injury, aerobic fitness, superior limbs, flexibility, muscle strength, sex hormones) and external risk factors (level of competitiveness, skill, shoe type, and weather), as a multifactorial condition, it includes neurological, musculoskeletal, sensory, and motor factors that are associated with insufficiency, loss of balance, and increased postural oscillations in these individuals (6-8).

Given the high prevalence of ankle sprains and its subsequent outcomes, in order to prevent injury or its recurrence, various therapeutic modalities such as strengthening the ankle sensory-motor control system, strengthening the ankle muscles, bandaging and brace are applied (9). One of the areas effective in the body balance is the core body (trunk), the stability of which is important for proper balance of the forces applied to the vertebrae, pelvis, and kinetic chains. Trunk strengthening exercise techniques improve performance and prevent musculoskeletal injury, in addition to reducing recurrent injuries (10). Rehabilitation programs for ankle sprains include strength training, balance training, neuromuscular training, and proprioceptive training protocols. Moreover, given the importance of pelvic stability in lower limb movement in people with chronic ankle instability, proximal (near the trunk) muscles are used to compensate for the neuromuscular defect of the distal region muscles (11). Similarly, in a study by Rojhani Shirazi et al., it was concluded that balance exercise can improve the time of balance on one leg and proprioception in the knee and ankle joints (12). Furthermore, the results of a study by Moradi et al. indicated that the core stability exercises had a short-term effect on ankle postural oscillation in athletes with functional ankle instability in the eyes-closed (EC) mode and significantly reduced postural oscillation, but these exercises had no significant effect on the postural oscillation in the eyes-open (EO) mode (13).

It seems that core stabilizing muscles play an important role in controlling the proximal and distal joints to reduce postural oscillation in athletes with functional ankle instability in the EC state and performing these exercises in the short term can have a positive effect on decreasing the postural oscillation in athletes with functional ankle instability. Additionally, researchers believe that in comparison to the routine physiotherapy, performing trunk stabilization exercises significantly improved the dynamic balance of athletes with chronic ankle sprains and suggested that stabilization exercises alongside the common physiotherapy be considered in these athletes (14).

In recent years, a great deal of attention has been devoted to achieving proper training methods to improve various aspects of performance, especially for the rehabilitation of athletes. Various exercises are used to strengthen the dynamic and static balance as well as strengthening the trunk muscles, with the resistance training being part of this type of exercises nowadays (15). The resistance training is included in training programs mainly in order to increase muscle strength, however, in recent years it has been found that functional training has similar and even greater effects on increasing muscle strength as well as other beneficial exercise effects including balance improvement (16,17). In this type of exercise, there is a tendency to use multiple muscle and joint groups to achieve greater adaptation through neuromuscular adaptations when performing dynamic and isometric contractions (18).

One of the new forms of functional training is the total-body resistance exercise (TRX), in which people use body weight resistance, so that the exercise associated with the activity of the muscle groups and multiple motor programs (19). The effect of TRX exercises has been investigated on the activation of the trunk muscles and increasing the strength and balance of different individuals such as the elderly. In this regard, Gaedtke and Morat conducted a 12-week training program on 11 old participants and concluded that strength and balance were significantly increased (15). In addition, in another study, they compared TRX exercises with stretching exercises in 24 elderly subjects and concluded that strength and balance were improved (20).

Since in the TRX exercises balance is maintained in the closed kinetic chain and relies on integrated feedback of pelvis, knee, and ankle joint movements, the mechanical strength of each joint or structure belonging to the lower limb may be impaired due to the sensory information transmission. Achieving proper training to improve the function and balance conditions of athletes is of great importance, especially in injury situations, in particular in women because of their greater vulnerability. However, the role of the core stability training and TRX on the functional and balance status of athletes with ankle sprains has not been understood. Therefore, the present study was accomplished aiming to investigate the effect of two types of core stability training and TRX on the performance, balance, and strength of athletes with ankle sprain.

Materials and Methods

This study was a clinical trial with pre-test and post-test design with a control group. For this purpose, 40 professional female athletes with ankle sprain (due to restricted access to the desired community) were selected using the convenience sampling method from badminton, volleyball, and handball teams in Tehran Province, Iran, based on the previous studies (12,14). Then, the subjects were randomly assigned to different groups including the core stability training group (n = 10), TRX group (n = 10), combined practice group (core stability + TRX) (n = 10), and control group (n = 10) using a third person with simple random method using the random number table. The study inclusion criteria included a history of ankle sprains leading to pain or limp for more than one day, feeling of weakness, pain, or chronic instability attributable to primary sprain, and experience of ankle emptying during the six months prior to the study (21). The exclusion criteria were ankle fractures and bilateral ankle sprains, as well as anterior cruciate ligament (ACL) injury. To check the presence of any sprain, the ankle drawer test was performed on the subjects. After signing the written consent, the subjects in the exercise groups performed exercise for each protocol for 8 weeks as 3 sessions per week.

Training protocols: The training protocol for the core stability training group included 10 minutes of warm-up (fast walking and stretching movements), core workout (maintaining plank state, cobra, heel dig bridging, open arch bridging, and abdominal endurance exercises) and 10 minutes cool-down (walking and stretching movements) (22).

Similarly, the exercise protocol for the TRX training group based on the semi-volume core stability exercise method, consisted of 10 minutes of warm-up (fast walking and stretching), core exercise (squat, lunges, bench press, low row and push up, bicep squat, plank, etc.) and 10 minutes of cool-down (walking and stretching) (13).

Furthermore, the training protocol for the combined group (core stability + TRX) included 10 minutes of warm-up (fast walking and stretching), core workout of combined core stability and TRX stability (squat, lunge, bench press, low row motion, push-up, plank, cobra, heel dig bridging, open arch bridging, and abdominal endurance exercises), and 10 minutes of cool-down (walking and stretching).

During the 8 weeks, the control group did not experience any exercise and the dependent variables were measured 48 hours before and after the implementation of the protocols.

Evaluation of study variables: Functional tests were employed to evaluate the functional status of the subjects. Among the tests, the side-hop and figure-of-8 hop tests were used in the present study. These tests were used to apply pressure on the external structures of the feet (lateral ligaments of the ankle and proneuslongus muscles) and to apply rotational pressure to the ankle in an 8 form, as well as to reveal functional deficits in the injured individuals. The Smith sport-research center and several other prestigious institutes have used these performance tests in their studies, which have presented good accuracy and validity (23).

For this purpose, the side-hop test was performed in a figure-of-8 course with a length of 5 m outlined with two cones. Prior to the test, the participants were provided with the information about how it would be performed by the researcher. After the warm-up and stretching exercises, the subjects participated in the test for 5 minutes. The subjects hopped as hopscotch twice on their foot examined. They were then asked to jump the course with their highest speed with the bare foot. The subjects' record was recorded by a stopwatch with an accuracy of 0.01. For the side-hop test, The subjects had to jump the 30 cm course above the ground 10 times as a go-and-return manner on their examined ankle. After the warm-up and stretching movements, the participants took the test for 5 minutes. They were then asked to jump the course as fast as they could with the bare foot, and their record was recorded in seconds (Figure 1). Each subject performed the test twice and his best record was recorded.

The Y Balance Test (YBT) was adopted to examine the subjects' balance. In addition, the adjusted Star Excursion Balance Test (SEBT) and Stork Balance Stand Test were utilized to evaluate the dynamic balance and static balance, respectively. This test is one of the most reliable and valid methods of dynamic postural control assessment used to determine sensory-motor deficits associated with chronic ankle instability.

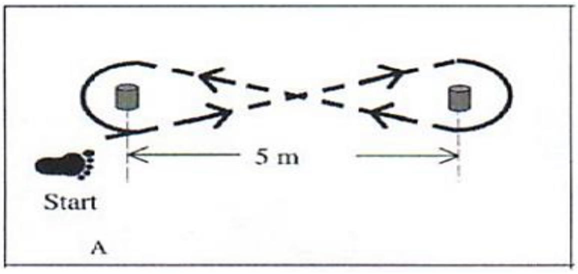

Figure 1. Figure-of-8 hop test

Plisky et al. invented YBT to stabilize the SEBT evaluation method and reduce its errors. The intra-rater and inter-rater reliability coefficients for different directions ranged from 0.85 to 0.91 and 0.99 to 1.00, respectively, moreover, the intra-rater and inter-rater reliability coefficients for the combined score (overall test score) were reported as respectively 0.91 and 0.99 by Plisky et al. (24).

The test has three lines with an angle of 120°. The direction of these three lines was named based on the position of the line relative to the foot on the ground, including the anterior, posterior external, and posterior internal directions. To perform the test, the subjects' foot length was measured first. They were then instructed to stand in the intersection of the three directions, with one foot on the dominant leg, with the other foot touching the farthest distance possible. Six training attempts were performed in each direction with 15 seconds rest between each. To obtain the dynamic balance score, the access distance was divided by the length of the limb and multiplied by 100. To assess the static balance, the subjects were placed on a flat surface without shoes with their eyes open in such a way that the hands were positioned on the hip joint and the non-support leg adjacent to the knee of the support leg. Next, the heel was raised and the balance was established on the toes. The maximum time the subject could maintain this condition was recorded as the score. In the present study, an isokinetic testing machine (BIODEX Multi-Joint System-4 PRO, Biodex Medical Systems, New York, USA) was utilized to evaluate the strength of the ankle muscles. For this purpose, the subjects were placed in the sitting position so that the subject's knee was bent 60 to 90° and his hip and chest were fully fixed on the chair to prevent knee rotation, and the sole was in complete contact with the force application plate. The speed of the test was 45 to 90° per second in two sets and the resting time between the sets was 10 to 15 s. The present study was approved with the code IR.IAU.KHUISF.REC.1397-018 in Research Committee, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran, and with the IRCT20170510033909N4 code on the Iranian Registry of Clinical Trials (IRCT) site.

Descriptive statistics and standard deviation (SD) were used for data purification and sorting, and the Shapiro-Wilk test was employed to check the normal distribution of data. After determining the normal distribution of the data, the analysis of covariance (ANCOVA) test was employed to examine the intergroup changes by eliminating the pretest effect. The data collected were analyzed in SPSS software (version 20, IBM Corporation, Armonk, NY, USA) and $P < 0.050$ was considered as the significance level of data.

Results

The Shapiro-Wilk test results indicated that the data were normally distributed in four stages at the independent variable levels ($P < 0.050$). The characteristics of the subjects by groups are presented in table 1. The history of ankle injury in the groups was 2.20 ± 0.93 years.

Given the data in table 1, there was no significant difference among the groups in terms of age, height, weight, and body mass index (BMI) before the intervention. The ANCOVA analysis results for the figure-of-8 hop test showed that there was a significant difference among the groups ($\eta^2 = 0.681$, $P = 0.001$, $F_{(35,3)} = 0.292$). The test power to detect this difference was 1.00. The Bonferroni post-hoc test suggested that all three training protocols resulted in a significant decrease in the figure-of-8 hop test time compared to the control group ($P < 0.050$). Besides, the combined exercise significantly reduced the figure-of-8 hop test time compared to the core stability exercise ($P = 0.001$). However, there was no significant difference between the other groups ($P > 0.050$) (Figure 2).

Significant differences were observed among the groups in the results of the side-hop test ($\eta^2 = 0.709$, $P = 0.001$, $F_{(35,3)} = 28.47$). Accordingly, the test power to detect this difference was 1.00. Based on the Bonferroni test results, all three types of exercises reduced the side-hop test time compared to the control group ($P < 0.050$). Moreover, the combined exercise resulted in a significantly greater reduction in the side-hop test in comparison to the core stability exercises ($P = 0.001$), while there was no significant difference between the other groups ($P > 0.050$) (Figure 3).

Table 1. Characteristics of the subjects in the study groups

Groups	N	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m²)
TRX exercise	10	24.86 ± 2.90	165.12 ± 3.05	58.15 ± 3.82	21.32 ± 1.30
Core stability	10	25.00 ± 2.35	167.53 ± 4.55	60.18 ± 4.22	21.58 ± 1.50
Core stability + TRX	10	24.05 ± 3.70	167.05 ± 3.12	59.52 ± 2.93	21.22 ± 0.80
Control	10	23.80 ± 4.03	165.75 ± 3.85	57.93 ± 3.06	20.59 ± 1.20

TRX: Total-body Resistance Exercise

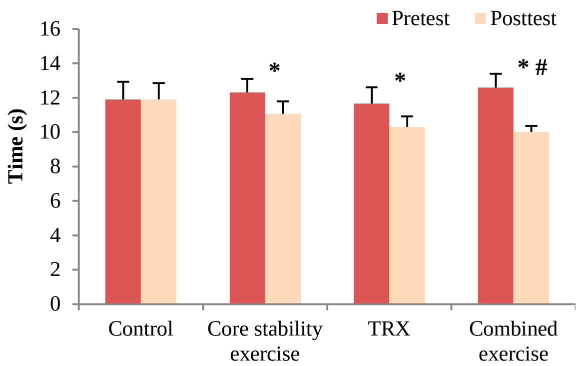

Figure 2. Figure-of-8 hop test time in the study groups
*Significant difference compared to the control group (P < 0.001),
Significant difference compared to the core stability training group (P < 0.050)

The results of the ANCOVA test for dynamic balance showed a significant difference among the study groups ($\eta^2 = 0.700$, $P \leq 0.001$, $F_{(35,3)} = 27.20$). The test power to detect this difference was 1.00.

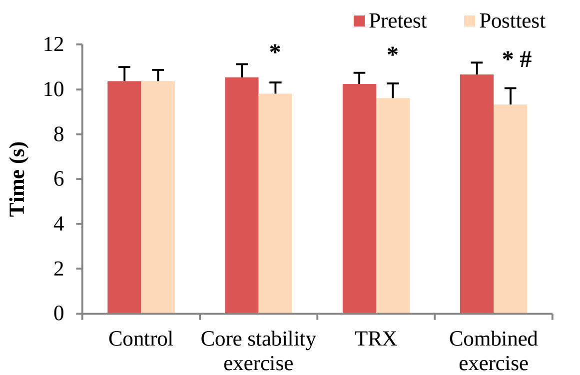

Figure 3. Side-hop test time in the study groups
*Significant difference compared to the control group (P < 0.050),
Significant difference compared to the core stability training group (P < 0.050)

The data analysis using the Bonferroni post-hoc test showed that all three training methods improved dynamic balance in comparison with the control group (P < 0.050). Furthermore, the combined training resulted in a significant improvement in both the core stability and TRX training groups (P = 0.001). However, there was no significant difference between the two groups (P < 0.050) (Figure 4).

Additionally, the results of the ANCOVA test for static balance indicated that there was a significant difference among the groups ($\eta^2 = 0.640$, $P \leq 0.001$, $F_{(35,3)} = 41.5820$). The test power to detect this difference was 1.00. Based on the Bonferroni post-hoc test, all three training protocols led to the improved static balance compared to the control group (P < 0.050).

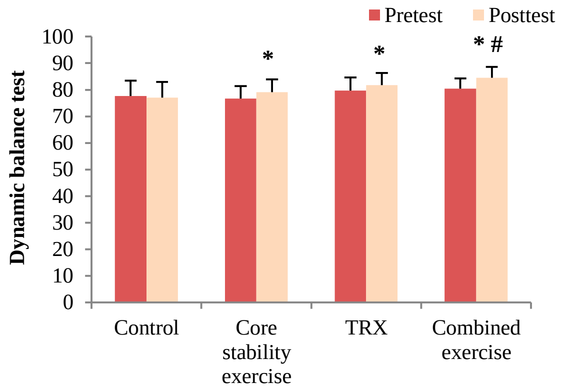

Figure 4. Dynamic balance test results in the study groups
* Significant difference compared to the control group (P < 0.050),
# Significant difference compared to the core stability training and TRX groups (P < 0.050)

In addition, both the combined training protocol and the TRX resulted in a higher significance compared to the core stability training (P = 0.001). However, there was no significant difference between the two types of combined training and TRX (P > 0.050) (Figure 5).

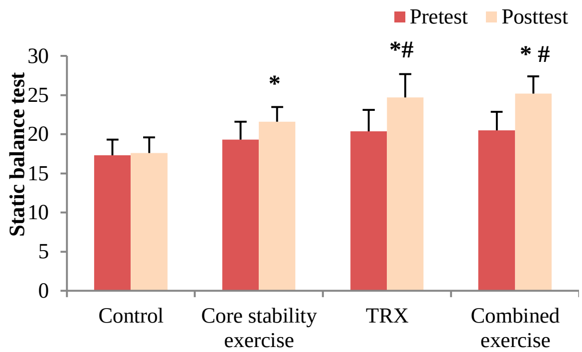

Figure 5. Static balance test results in the study groups
* Significant difference compared to the control group (P < 0.050),
# Significant difference compared to the core stability training group (P < 0.050)

On the basis of the results of the ANCOVA test for athletes' strength, there was a significant difference among the groups examined ($\eta^2 = 0.610$, $P \leq 0.001$, $F_{(35,3)} = 41.5820$). The test power to detect this difference was 0.99. The Bonferroni post-hoc test showed that only the combined training protocol significantly increased muscle strength compared to the control, TRX, and core stability groups

(P = 0.001), while there was no significant difference among the other groups (P > 0.050).

Discussion

The findings in the current study revealed that core stability, TRX, and combined exercises lead to significant improvement in the variables related to the functional status (time of the figure-of-8 hop and side-hop tests) in athletes with a history of ankle sprain. Hale et al. reported improvement in control status and lower extremity function as a result of comprehensive rehabilitation exercises [range of motion (ROM), strength, neuromuscular) in people with chronic ankle instability (25); this finding was in line with the findings of the present study. The study by McKeon et al. also examined the effect of a four-week balance workout program on individuals with chronic ankle instability (26), which was in agreement with the findings of the present study. The core stability exercises include a set of lumbar-pelvic-thigh muscle exercises (27) affecting the mechanics and neuromuscular stability of the core body and improve the function of the upper and lower extremities (1). Core stabilization exercises lead to strength, development of core body stability, and also the ability of the individual to maintain the body center of mass above the base of support (BOS) and, in turn, promote balance (27). It is believed that the core of the body, as the basis of the kinetic chain, is responsible for facilitating the transfer of forces and moments between the upper and lower extremities in gross motor tasks in daily life and exercise (28). Therefore, it seems that improvement in the functional status of individuals as a result of different exercises is due to the positive effects of these exercises on improving balance, strength, and core stability. Furthermore, on the basis of the results of the present study, the combined TRX and core stability training can have a better effect on performance. In this regard, Mok et al. found that TRX training had a positive effect on the functional stability of the abdominal and pelvic muscles (29).

The results of various investigations have shown that the TRX training can improve swimmers' performance by increasing the lumbar and trunk muscle strength and enhancing balance (30). In the stability exercises with an emphasis on the isolated and voluntary transverse abdominal muscle (TVA) contraction training, in addition to the number of repetitions, accuracy in individual training of muscles is also an important determinant of the quality of retraining which in turn is related to the activation of the stability muscle feed-forward mechanism (31). Conducting a study, Janot et al. concluded that TRX training increased endurance and strength of the core muscles (32), which was consistent with the findings of the current study. Since the core muscle weakness in sports that require rapid hopping, jumping, and running, is directly associated with the lower extremity injury, it seems that adding TRX training to core stability training significantly improves the function of the individuals with ankle sprains through improving the trunk muscle strength and endurance.

Another part of the results of the present study suggested that all three types of exercises improve static and dynamic balance in individuals with ankle sprains, which is in line with the findings of the study by Filipa et al. They reported that neuromuscular exercise had a significant effect on the SEBT test balance in the posterior-external and posterior-internal directions in the experimental group (33). Moreover, Mok et al. reported improvements in the dynamic balance and trunk muscle endurance as a result of the core body training (29), which was similar to the results of the present study. Samson et al. conducted a study to investigate the effect of strength training on the core stabilizing muscles on dynamic and semi-dynamic balance in female athletes and found that during the exercise, the core stabilizing muscles provided trunk stability and improved dynamic balance in athletes in the SEBT post-test in eight directions (34). Research results have shown that balance exercises activate different parts of the sensory and motor systems contributing to the joint stability and improve the function of the sensory-motor system. Exercises that require balance, weight transfer, stimulation of anti-gravity reflexes, and high coordination, facilitate and enhance the performance of the proprioception receptors, which may be the reason for the improved balance and performance of the individuals with functional ankle instability in the exercise group compared to the control group. Additionally, despite several sensory inputs (information from auditory, visual, and proprioceptive inputs), the central nervous system (CNS) often relies on a single sense for information organization at a moment.

Somatic sensation (detecting joint movement when contacting BOS) is the preferred source of information for balance control among the mature individuals. In orthopedic injuries, the somatic sensation system is of the highest importance (35). Furthermore, a series of processes that determine the temporal sequence and distribution of contractile activity in the leg and trunk muscles leads to supportive responses to maintain balance. Research findings suggest that balance deficits in individuals with nervous disorders may be due to inappropriate interactions among the three sensory inputs needed to organize postural control information. A patient may be inappropriately dependent on one sense in cases of conflict among different senses (29). In this regard, Zech et al. in a study claimed that the neuromuscular mechanism adaptations such as proprioception and spinal reflex activity contribute to the dynamic balance and that balance exercises improve balance using different neuromuscular and coordination variables in timing of the stimulation of different muscles (36). It seems that the combined exercises can help muscle coordination and sensory organization in athletes.

In the present study, there was a significant difference among the study groups in improving balance, so that the combined training had better effects on dynamic balance compared to the other two groups, and the combined training and TRX also had better effects on the static balance in comparison to the stability training. In general, the combined training appears to have more effects on improving balance. In this regard, the results of the study by Tantawi suggested that adding the core exercises to karate training could improve the level of some physical variables and the level of performance of compulsory kata at higher speed in the karate players (37). These findings have been reported in the study by Mok et al. regarding the effects of TRX training on functional stability of the abdominal and pelvic floor muscles, leading to the improved balance and functional stability (29). In a study carried out aiming to investigate the effect of strength, balance, and combined (strength and balance) exercises on the dynamic balance of the young male athletes, Mohammadi et al. reported a significant increase in the SEBT reach distance of the subjects in the strength, balance, and combined exercises. In addition, the combined training compared to the strength and balance training and also the balance training compared to the strength training led to more improvement in the dynamic balance of the subjects (38). Since the combination of the two types of exercises improves balance, this may be due to the kinematic adaptation of the hip, knee, and ankle joints, although further studies are needed to examine this issue. In fact, researchers believe that suspension training, compared to traditional resistance training, activates relatively high levels of core stability muscles on the stable and unstable BOSs. The TRX training techniques are specifically designed to move the body center of gravity that have muscle activity for both the core and lateral muscle groups. Other muscles are involved as well, depending on the position of the body and counteracting the gravity as well as maintaining balance in each movement. In TRX exercises, balance and strength are involved at the same time, helping the body nervous system to achieve neuro-muscular adaptations together (39).

Another finding of the present study showed that only the combined exercise resulted in a significant improvement in muscle strength in individuals with ankle sprains; these changes were significant in comparison with other exercise groups. Hall et al. conducted a study to investigate the effect of strength training on the dynamic and static balance as well as the function and proprioception in patients with chronic ankle sprains and found that the ankle muscle strength increased with exercise, but in the proprioception exercise group, in addition to strength, the joint instability was improved as well (40). Ankle sprains are often associated with the recurrent injury due to inadequate treatment. Given the complex anatomy and mechanics of the ankle joint as well as the pathomechanics and pathophysiology associated with chronic ankle sprain, complete and comprehensive rehabilitation of this injury is of paramount importance. Performing TRX exercises improves strength and balance together, in addition to leading to rapid and multilateral flexibility in various aspects of rehabilitation (39). In fact, such exercises can indirectly help increase strength by reducing joint instability. This indirect effect can be derived from the integration of proprioceptive receptors and muscle coordination, a decrease in the self-inhibitory effect of the Golgi tendon organs (GTO), as well as an increase in the coordination of the muscles involved. In fact, it can be said that more strength is gained by recalling more muscle fibers. Therefore, the useful effects of combined exercises (core stability training and TRX) on improving muscle strength can be attributed to the improvement in functional and physiological adaptations.

Limitations

In the present study, it was not possible to precisely control all influencing factors.

Recommendations

In future studies, it is suggested that the electromyographic (EMG) indices of the lower extremity muscles be recorded during TRX and core stability exercises and be compared.

Conclusion

Based on the findings in the current study, it seems that performing balance and resistance exercises including core stability training, TRX, and combined exercises can lead to the improvement in different functional and balance aspects in the subjects with ankle sprains. However, the combination of the core stability and TRX exercises may have more favorable effects on improving functional and balance aspects.

Acknowledgments

The present study was extracted from a M.Sc. thesis on pathology and corrective exercises No. 2382140294220 and code of ethics IR.IAU.KHUISF.REC.1397.018, approved by Isfahan (Khorasgan) Branch, Islamic Azad University, which was registered with IRCT20170510033909N4 on the Iranian Registry of Clinical Trials (IRCT) site. The authors would like to appreciate all individuals who contributed to this study.

Authors' Contribution

Fatemeh Hozhabrpour-Fereydani: Study design and ideation, attracting funding for the study, providing study equipment and samples, data collection, training supervision, analysis and interpretation of results, specialized statistics services, manuscript arrangement, manuscript expert assessment in scientific terms, final manuscript verification for submission to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the reviewers' opinions; Farzaneh Taghian: study design and ideation, data collection, training supervision, analysis and interpretation of results, expert statistics services, manuscript arrangement, expert manuscript evaluation in scientific terms, final manuscript verification for submission to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the reviewers' opinions; Mohamad Saleki: study design and ideation, support, executional, and scientific services of the study, providing study equipment and samples, data collection, training supervision, manuscript arrangement, final manuscript verification for submission to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the reviewers' opinions.

Funding

This study was extracted from a M.Sc. thesis on pathology and corrective exercises No. 2382140294220 and code of ethics IR.IAU.KHUISF.REC.1397.018, approved by Isfahan (Khorasgan) Branch, Islamic Azad University, which was registered with IRCT20170510033909N4 on the Iranian Registry of Clinical Trials (IRCT) site. Khorasgan Branch of Islamic Azad University did not comment on the data collection, analysis, and report.

Conflict of Interests

The writers declare no conflict of interest. The present study was extracted from a student thesis that was conducted, supervised, and consulted at Islamic Azad University, Isfahan (Khorasgan) Branch. The study was funded by Fatemeh Hozhabrpour-Fereydani.

References

1. Zoch C, Fialka-Moser V, Quittan M. Rehabilitation of ligamentous ankle injuries: A review of recent studies. Br J Sports Med 2003; 37(4): 291-5.
2. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: An audit of injuries in professional football--analysis of hamstring injuries. Br J Sports Med 2004; 38(1): 36-41.
3. Kaminski T, Gerlach T. The effect of tape and neoprene ankle supports on ankle joint position sense. Phys Ther Sport 2001; 2(3): 132-40.
4. Freeman MA, Dean MR, Hanham IW. The etiology and prevention of functional instability of the foot. J Bone Joint Surg Br 1965; 47(4): 678-85.
5. Trojian TH, McKeag DB. Single leg balance test to identify risk of ankle sprains. Br J Sports Med 2006; 40(7): 610-3.
6. Arnold BL, De La Motte S, Linens S, Ross SE. Ankle instability is associated with balance impairments: A meta-analysis. Med Sci Sports Exerc 2009; 41(5): 1048-62.
7. Docherty CL, Valovich McLeod TC, Shultz SJ. Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. Clin J Sport Med 2006; 16(3): 203-8.
8. Beynnon BD, Murphy DF, Alosa DM. Predictive factors for lateral ankle sprains: A literature review. J Athl Train 2002; 37(4): 376-80.
9. McGovern RP, Martin RL. Managing ankle ligament sprains and tears: Current opinion. Open Access J Sports Med 2016; 7: 33-42.
10. Akuthota V, Ferreiro A, Moore T, Fredericson M. Core stability exercise principles. Curr Sports Med Rep 2008; 7(1): 39-44.

11. Gribble PA, Hertel J, Denegar CR, Buckley WE. The effects of fatigue and chronic ankle instability on dynamic postural control. J Athl Train 2004; 39(4): 321-9.
12. Rojhani Shirazi Z, Shafaee R, Afarandide M. Survey on the effects of balance training on proprioception of knee and ankle joints and equilibrium time in single leg in healthy female students. J Rafsanjan Univ Med Sci 2012; 10(4): 289-98. [In Persian].
13. Moradi K, Minoonejad H, Rajabi R. The immediate effect of core stability exercises on postural sway in athletes with functional ankle instability. Rehabilitation Medicine 2015; 4(3): 103-12. [In Persian].
14. Sahranavard M, Aghayari A, Motealleh A, Farhadi A. The effect of core stability exercises on dynamic balance of athletes with chronic ankle sprain. J Res Rehabil Sci 2015; 11(3): 228-37. [In Persian].
15. Gaedtke A, Morat T. TRX suspension training: a new functional training approach for older adults - development, training control and feasibility. Int J Exerc Sci 2015; 8(3): 224-33.
16. Weiss T, Kreitinger J, Wilde H, Wiora C, Steege M, Dalleck L, et al. Effect of functional resistance training on muscular fitness outcomes in young adults. J Exerc Sci Fit 2010; 8(2): 113-22.
17. Milton D, Porcari J, Foster C, Gibson M, Udermann B. The effect of functional exercise training on functional fitness levels of older adults. Gundersen Med J 2008; 5(1): 4-8.
18. Tomljanovic M, Spasi-ç M, Gabrilo G, Uljevic O, Foretic N. Effects of five weeks of functional vs. traditional resistance training on anthropometric and motor performance variables. Kinesiology 2011; 43(2): 145-54.
19. Dawes J, Melrose D. Resistance characteristics of the TRX™ suspension training system at different angles and distances from the hanging point. J Athl Enhancement 2015; 4(1): 1000184.
20. Gaedtke A, Morat T. Effects of two 12-week strengthening programmes on functional mobility, strength and balance of older adults: Comparison between TRX suspension training versus an elastic band resistance training. Cent Eur J Sport Sci Med 2016; 13(1): 49-64.
21. Delahunt E, Coughlan GF, Caulfield B, Nightingale EJ, Lin CW, Hiller CE. Inclusion criteria when investigating insufficiencies in chronic ankle instability. Med Sci Sports Exerc 2010; 42(11): 2106-21.
22. Fong SS, Tam YT, Macfarlane DJ, Ng SS, Bae YH, Chan EW, et al. Core muscle activity during TRX suspension exercises with and without kinesiology taping in adults with chronic low back pain: implications for rehabilitation. Evid Based Complement Alternat Med 2015; 2015: 910168.
23. Demeritt KM, Shultz SJ, Docherty CL, Gansneder BM, Perrin DH. Chronic ankle instability does not affect lower extremity functional performance. J Athl Train 2002; 37(4): 507-11.
24. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the star excursion balance test. N Am J Sports Phys Ther 2009; 4(2): 92-9.
25. Hale SA, Hertel J, Olmsted-Kramer LC. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. J Orthop Sports Phys Ther 2007; 37(6): 303-11.
26. McKeon PO, Ingersoll CD, Kerrigan DC, Saliba E, Bennett BC, Hertel J. Balance training improves function and postural control in those with chronic ankle instability. Med Sci Sports Exerc 2008; 40(10): 1810-9.
27. Bliss LS, Teeple P. Core stability: The centerpiece of any training program. Curr Sports Med Rep 2005; 4(3): 179-83.
28. Colston MA. Core stability, part 1: Overview of the concept. Int J Athl Ther Train 2012; 17(1): 8-13.
29. Mok NW, Yeung EW, Cho JC, Hui SC, Liu KC, Pang CH. Core muscle activity during suspension exercises. J Sci Med Sport 2015; 18(2): 189-94.
30. Hangai M, Kaneoka K, Hinotsu S, Shimizu K, Okubo Y, Miyakawa S, et al. Lumbar intervertebral disk degeneration in athletes. Am J Sports Med 2009; 37(1): 149-55.
31. Kleim JA, Barbay S, Nudo RJ. Functional reorganization of the rat motor cortex following motor skill learning. J Neurophysiol 1998; 80(6): 3321-5.
32. Janot J, Heltne T, Welles C, Riedl J, Anderson H, Howard A, et al. Effects of TRX versus traditional resistance training programs on measures of muscular performance in adults. Journal of Fitness Research 2013; 2(2): 23-38.
33. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the star excursion balance test in young female athletes. J Orthop Sports Phys Ther 2010; 40(9): 551-8.
34. Samson KM, Sandrey MA, Hetrick A. A Core stabilization training program for tennis athletes. Int J Athl Ther Train 2007; 12(3): 41-6.
35. Paquette MR, Li Y, Hoekstra J, Bravo J. An 8-week reactive balance training program in older healthy adults: A preliminary investigation. J Sport Health Sci 2015; 4(3): 263-9.
36. Zech A, Hubscher M, Vogt L, Banzer W, Hansel F, Pfeifer K. Balance training for neuromuscular control and performance enhancement: A systematic review. J Athl Train 2010; 45(4): 392-403.
37. Tantawi SS. Effect of core stability training on some physical variables and the performance level of the compulsory kata for karate players. World J Sport Sci 2011; 5(4): 288-96.
38. Mohammadi V, Alizadeh MH, Gaieni A. The effects of strength, balance and combined (strength and balance) exercise programs on the dynamic balance of young male athletes. J Res Rehabil Sci 2013; 9(1): 113-23. [In Persian].
39. Hermens HJ, Freriks B, Merletti R, Stegeman DF, Blok JH, Rau G, et al. European recommendations for surface electromyography: Results of the SENIAM Project. Enschede, Netherlands: Roessingh Research and Development; 1999.
40. Hall EA, Docherty CL, Simon J, Kingma JJ, Klossner JC. Strength-training protocols to improve deficits in participants with chronic ankle instability: A randomized controlled trial. J Athl Train 2015; 50(1): 36-44.