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Original Article

The Effects of Eight Weeks of TRX Exercises on Range of Motion and uneven shoulder in Beach Volleyball Players

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Abstract

Background: Shoulder joint injuries are common among athletes performing overhead movements, and studies have shown that repetitive small impacts during throwing motions lead to chronic negative adaptations in the soft tissues of the shoulder joint. Therefore, the present study aimed to investigate the effects of an 8-week TRX exercise program on the range of motion and degree of shoulder imbalance in beach volleyball players.

Methods: The study included 30 female beach volleyball players. After collecting demographic information, the participants were divided into control and experimental groups. Range of motion and degree of uneven shoilderwere measured using a goniometer and scoliometer. Following the 8-week exercise program, the same tests were conducted on both groups, and the data were recorded. In the statistical analysis, paired t-tests and independent t-tests were used to test the hypotheses after confirming the normal distribution of the data.

Results: The results showed a significant difference between pre-test and post-test measurements in the experimental group following the 8-week TRX exercise program, while no significant difference was observed between pre-test and post-test measurements in the control group. Additionally, the results of the independent t-test indicated a significant difference between post-test measurements of the experimental group and the control group.

Conclusion: Considering the effects of the TRX exercise protocol on the range of motion and uneven shoilderin female beach volleyball players, it is recommended for coaches and athletes in the beach volleyball field to incorporate TRX exercise protocols, specifically targeting the prevention of muscle injuries and addressing irregularities such as shoulder imbalances.

Keywords: TRX exercises, range of motion, shoulder imbalance, beach volleyball.

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1. Introduction

The shoulder joint is among the most crucial articulations involved in certain sports disciplines such as volleyball, handball, and swimming. The variation in the strength of different muscle groups is also a significant factor contributing to injuries in this joint. This joint, being a mobile component of the body, necessitates a delicate balance between stability and movement to enable a substantial range of motion for the upper limbs (1). Shoulder injuries are prevalent among athletes engaged in overhead movements. Studies have demonstrated that repetitive minor impacts during throwing motions lead to chronic negative adaptations in the soft tissues of the shoulder joint. The high velocity of repetitive overhead movements can induce alterations in stability, ultimately resulting in shoulder joint injuries (2). During a throwing motion, the humeral head can experience forces equivalent to 31% of body weight in anterior forces and up to 80% of body weight in separating forces (3). Specifically, the prevalence of shoulder injuries among volleyball players ranges from 12.5% to 42% (4). Many skills executed in this sport, such as spiking, serving, and blocking, require continuous upper limb interaction with the ball, especially in an overhead position. Among these skills, spiking and serving may be considered the most crucial in this sporting discipline (5). It is estimated that a skilled volleyball player executes approximately 40,000 spikes during a single season, underscoring the significant volume of repetitive shoulder movements in volleyball players (6). The performance of volleyball players' shoulders relies on the accurate, coordinated functioning of the rotator cuff muscles and shoulder stabilizers. These muscles need to be effectively trained and maintained under suitable conditions to withstand demanding and pain-free shoulder movements during sports activities. Unfortunately, repetitive actions in volleyball can lead to acute shoulder injuries due to the musculoskeletal structures being subjected to additional strain. Over time, fatigue-induced injuries, particularly from excessive neck use, can also develop (7).

One of the principal roles of the scapular bone is to act as a foundation for muscle attachment and can have a significant impact on the functioning of muscles around the shoulder girdle, particularly the stabilizing muscles of the shoulder. Furthermore, the positioning of the scapular bones has a direct relationship with the production of muscular forces and the range of motion within the shoulder girdle. Consequently, changes in the position of the scapular bone can influence the performance and muscular force production of the shoulder girdle, especially the stabilizing muscles of the shoulder. In volleyball

players, repetitive movements such as abduction and external rotation, accompanied by extension and internal rotation, as well as striking the ball in an abducted position, can increase the force of abduction. Additionally, it has been demonstrated that muscular imbalance and weakness in the rotator cuff muscles are risk factors for shoulder injuries in athletes engaged in overhead movements (8).

One of the critical components contributing to maintaining optimal physical condition is the scapular bone. The role of the scapular bone has gained substantial attention in recent years, resulting in an increased awareness of the shoulder and its surrounding structures. The scapular bone holds great importance in generating smooth and coordinated movements of the shoulder girdle (9). Some believe that the role of the scapular bone in throws and services lies in acquiring appropriate movements and positions to facilitate shoulder function. In essence, proper scapular movements are vital for natural shoulder mechanics and have a significant impact during throwing motions (10).

The positioning and orientation of the scapula also exhibit distinct differences between throwing athletes and non-throwing athletes, indicative of adaptations specific to their respective fields of activity. The inability of the scapular bone to fulfill these roles leads to a loss of physiological and biomechanical efficiency, thereby compromising the functionality of the shoulder. This phenomenon can lead to weakened performance and an increased susceptibility to shoulder injuries (10).

Researchers contend that alterations in the position of the scapular bone have a pronounced effect on the functioning of the muscles surrounding the shoulder girdle, particularly the stabilizing muscles. Research indicates that among the primary roles of the scapular bone is to serve as a foundation for muscle attachment (10, 11) and provide a significant site for the attachment of various crucial muscles. Furthermore, it is suggested that the positioning of the scapular bones has a direct relationship with the production of muscular forces and the range of motion within the shoulder girdle (11).

Researchers have stated that shoulder injuries in volleyball players result in the longest periods of absence from training and competition compared to injuries in other body areas (12). One of these injuries is shoulder imbalance. When evaluating the shoulder level with a reference horizontal line, in natural conditions, both shoulders should have an equal distance from this line. The condition where the distance of one shoulder from the horizontal reference line is not the same as the other is referred to as shoulder asymmetry or unequal

shoulders (13). Given the prevalence of shoulder injuries in volleyball players, if appropriate treatment for shoulder injuries is not administered and shoulder pain is disregarded, these injuries can become chronic and lead to long-term impairment in athletes (14).

Different types of rehabilitation interventions, such as strengthening, stretching, and motor control exercises, can have positive effects on shoulder injuries (15). One type of exercise that has gained significant popularity recently is full-body suspension resistance exercises. The unique characteristic of these exercises is the utilization of the body in an unstable environment, leading to the simultaneous development of balance, strength, and flexibility. In these exercises, individuals perform a variety of exercises against their own body weight while suspended in an unstable environment created by straps (16).

Research findings have demonstrated the effectiveness of various exercises in strengthening, improving strength, and reducing shoulder joint pain. The results of a study by Mohammad and colleagues (2016) indicated that suspension exercises are not only useful for enhancing strength, stability, and coordination but also beneficial for rehabilitating certain tendon and ligament injuries resulting from sports activities (17). Li and colleagues (2016) showed that suspension exercises improve the strength of shoulder rotator muscles in baseball players with impingement syndrome (18).

Given that rehabilitation researchers are seeking new exercise methods to reduce the duration of the rehabilitation period and enhance its effectiveness, and considering the limited studies conducted on the impact of TRX exercises on shoulder pain and imbalance in volleyball players, this study aims to investigate the effects of 8 weeks of TRX exercises on the range of motion and uneven shoulder in beach volleyball players.

Material and Method:

The execution of this study is semi-experimental and based on an applied objective. The study population consists of all beach volleyball athletes in Isfahan province with a minimum of 3 years of professional sports experience. A total of 30 participants were calculated and were randomly divided into two groups: experimental and control.

Initially, participants were homogenized regarding their eligibility to enter the study. Then, 30 beach volleyball players participated in the study voluntarily and through availability sampling. A briefing session was conducted for the participants where they became familiar with the research procedures. Preliminary information was collected from

each participant for their involvement in the study, and they completed informed consent forms. Subsequently, the participants were randomly assigned to two groups: 1) TRX exercise group, and 2) control group. On the test day, after completing the consent forms, participants' demographic information (height, weight, age, sports history, and leg length) and entry conditions were recorded in the selection and exclusion criteria form. One of the most important limitations of this research was the non-universality of beach volleyball, especially for girls.

For assessing the external rotation range of motion, participants were instructed to maintain their shoulder girdle muscles relaxed while lying supine on an examination table. The shoulder was positioned at 31 degrees of abduction, and the elbow was flexed at 31 degrees perpendicular to the table. The examiner passively rotated the participant's shoulder externally around the axis of the glenohumeral joint until the end of the range of motion, then released the arm gently. The examiner positioned the goniometer axis on the first metacarpophalangeal joint, keeping the participant's arm vertical and facing downwards, and the mobile arm along the midline of the forearm's lateral aspect. This way, the range of external shoulder rotation around the axial joint was measured.

or assessing the internal rotation range of motion, participants were instructed to keep their shoulder girdle muscles relaxed while lying supine on the examination table. The shoulder was positioned at 31 degrees of abduction, and the elbow was flexed at 31 degrees perpendicular to the table. The examiner passively rotated the participant's shoulder internally around the axis of the glenohumeral joint while placing the other hand on the participant's olecranon joint. As soon as the participant felt the initiation of movement in the olecranon joint, the internal rotation movement was halted, and the other hand was used to maintain the patient's arm (verbal feedback). The examiner positioned the goniometer axis on the ulnar styloid process, keeping the participant's stable arm perpendicular to the ground and the mobile arm along the midline of the forearm. This way, the range of internal shoulder rotation around the axial joint was calculated.

To increase measurement accuracy and reduce the test error, the assessment of external and internal shoulder rotation range of motion was repeated three times, and the average of these measurements was recorded. All stages were performed for both dominant and non-dominant shoulders (19).

Uneven shoulder Assessment

To examine and assess shoulder imbalance, the shoulder levels should be evaluated from the posterior view to determine whether they are inclined towards the left or right with respect to a horizontal reference line. In normal conditions, both shoulders should have an equal distance from a horizontal line. The inequality of distances between the shoulders and the horizontal reference line on one side is referred to as shoulder imbalance. The goniometer is equipped with two arms that are placed on the two olecranon joints and has a level in the middle. The fluid inside it is sensitive to changes in angles and indicates the slope. Validity (95%) and reliability (91%) have been reported for the measurement method using the goniometer.

For measurement, the individual was asked to stand in a natural posture with the upper body wearing minimal clothing and facing the examiner. Then, their olecranon joint was marked with a marker. While the individual is looking ahead, the examiner positions the goniometer's arms on the marked joints from behind. The participant must remain in this position for a minute for the device to stabilize. While the examiner's gaze is fixed on the level of the device, the number indicating the degree of imbalance and the deviation of the shoulder to the right or left is observed and recorded. This measurement is repeated three times, and their average is recorded (20).

The participants of the experimental group engaged in a TRX exercise protocol for eight weeks, with three sessions per week, each lasting 90 minutes. The exercises were performed by standing facing the TRX anchor point. Using both hands, the individual held onto the TRX handles and performed exercises according to the prescribed movements. The primary objective of the exercises was to strengthen the shoulder girdle muscles, particularly the external rotators of the arm as stabilizers, and the arm bone rotators. The exercises included exercises such as front deltoid raises, lateral deltoid raises, two-part deltoid fly, and chest press (handles from the sides). These exercises were chosen because they aimed to strengthen the muscles of the supraspinatus joint, which plays a fundamental role in the strength and prevention of injuries in athletes.

The exercises were performed uniformly, gradually increasing resistance. The intensity increased with each set or repetition until reaching a specified peak point. Warm-up and cool-down routines were performed for 25 minutes before and after completing the exercise program (Table -1) (21).

Table 1: Protocol of training Exercise

Week	Number of repetation	sets	Rest between sets (seconds)	Rest between exercises (minutes)
1	10	2	30-60	2-3
2	10	2	30-60	2-3
3	15	3	30-60	3-4
4	15	3	30-60	3-4
5	20	3	30-60	4-5
6	20	3	30-60	4-5
7	25	4	30-60	5-7
8	25	4	30-60	5-7

Descriptive and inferential statistical methods were employed to analyze the collected data. To assess the normality of the data, the Shapiro-Wilk test was utilized. For the inferential analysis, paired-sample t-tests were used to examine the research hypotheses. The data analysis was conducted at a significance level of 95% and a significance level of alpha less than or equal to 0.05, using SPSS software version 22.

Table 2. Mean value and standard deviation and results of paired t and independent t test for shoulder motion range

variable	test	Mean and standard deviation		Paired t test		Independent T-test	
		Pre-test	Post-test	T	P	T	P
Internal rotation range of motion	experimental	15.2±72.8	83.7±5.4	201.17	0.001*	0.402	0.003*
	control	16.98±71.8	72.7±21.29	290.11	0.147		
external rotation range of motion	experimental	1.45±98.5	107.7±10.17	114.23	0.031*	0.712	0.02*
	control	0.1±99.5	98.5±32.23	99.73	0.109		

The effects of eight weeks of TRX exercises have a significant impact on the range of motion of the shoulder in beach volleyball players. The paired t-test results indicate a significant difference between the pre-test and post-test measurements in the experimental group, while no significant difference exists between the pre-test and post-test measurements in the control group. Furthermore, the results of the independent t-test show a significant difference between the post-test measurements of the experimental group and the control group (Table 2).

The eight weeks of TRX exercises have a significant impact on the uneven shoulders in beach volleyball players. The results of the paired t-test indicated a significant difference between the pre-test and post-test measurements in the experimental group, while there was no significant difference between the pre-test and post-test measurements in the control group. Furthermore, the results of the independent t-test demonstrated a significant difference between the post-test measurements of the experimental group and the control group (Table 3).

Table 3. Mean value and standard deviation and results of paired t and independent t test for un even shoulder

variable	group	Mean and standard deviation		Paired t test		Independent T-test	
		Pre-test	Post-test	T	P	T	P
Uneven shoulder	experimental	7.69±4.1	8.34±1.0	21.09	0.031*	1.012	**0.02***
	control	4.98±3.1	12.7±4.1	19.71	0.29		

Results

Some studies have reported that a rapid decrease in internal rotation range of motion occurs after baseball pitching or engaging in activities involving the external rotator muscles of the shoulder joint (27). The reason for this has been attributed to fatigue and imbalances in these muscles' strength. Another study demonstrated that immediate stiffness is produced in muscles after strength training, leading to fatigue and microtrauma. It is possible that fatigue, trauma, and reduced flexibility in the infraspinatus and teres minor muscles may serve as secondary factors in repetitive throwing movements, leading to posterior capsule stiffness (28, 29).

Throwing movements require intense eccentric contraction in the teres minor muscle compared to the infraspinatus. The teres minor muscle is more susceptible to fatigue and injury, which can lead to an incomplete internal and external rotation range of motion in the shoulder joint. Therefore, the teres minor muscle plays a crucial role in individuals with posterior shoulder tightness (30).

Several studies have shown that prolonged periods of sleep and prone body interventions lead to an increased internal rotation range of motion in the shoulder joint (23, 25, 31). Supine stretching exercises reduce the stiffness of the teres minor muscle, while prone stretching reduces the stiffness of the infraspinatus muscle. Studies have indicated that both

supine and prone stretching lead to posterior capsule stretching and an increase in internal rotation range of motion (32). Akagi and colleagues demonstrated that a 5-week stretching program reduced muscle stiffness and increased external rotation range of motion. When range of motion increases, muscle stiffness decreases (Akagi et al., 2014). On the other hand, strengthening exercises strengthen the muscles and anterior capsule of the shoulder joint. Cable and colleagues showed that closed kinetic chain exercises can enhance the efficacy of therapeutic protocols. These exercises, due to their utilization of natural physiological activity and preservation of natural biomechanics of movements, may demonstrate a greater impact. Although they demonstrated their impact on knee and leg rehabilitation, they are also effective for shoulder and scapula recovery. Recently, closed kinetic chain exercises have been used as a rehabilitation protocol for the shoulder (34). These exercises can be advantageous due to their reduced shear stresses on injured or treated joints and the strengthening of deep sensation (34). Implementing suspension strengthening exercises on external rotator muscles contributes to joint function.

Furthermore, the results of the present study demonstrated that an 8-week TRX exercise program had a significant effect on the degree of uneven shoulder female beach volleyball players.

The findings of the current research are consistent with the studies conducted by Hasannavand (2011), Akbar Fahimi (2009), Shahdadi (2000), Kontaras (2012), Citz (2011), Borkhart (2003), and Sawicki (1990). TRX exercises are introduced as a recognized effort that addresses abnormal body conditions by coordinating opposing muscle groups through strength and stretching exercises to some extent (15).

Following the implementation of TRX exercises on skeletal muscles, changes such as an increase in total contractile protein, especially in myosin fibers, an increase in the amount and strength of connective, tendinous, and ligamentous tissues, an increase in the density of fascia in each muscle fiber, and an increase in the number of fibers due to the longitudinal division of muscle fibers occur. This leads to increased muscle strength and endurance, and it appears that strength exercises affect the length of muscle tendons. They rearrange different skeletal parts, resulting in ligament stability and support. On the other hand, stretching exercises act as coordinators for opposing and synergistic muscles. Therefore, these exercises increase the length of muscles on the shortened side, ultimately reducing the degree of abnormality (21).

Shoulder pain is a prevalent issue that can be considered a challenging problem and among the complex treatment cases discussed by medical professionals. The nature of shoulder pain may arise from degenerative changes in the ligament-capsular structures, joint cartilage, and shoulder tendons. These changes themselves may result from altered mechanics similar to the biomechanical changes in shoulder joints due to unequal shoulder imbalances. Additionally, degenerative changes may weaken the internal rotator muscles over time through the weakening of their tendons, influenced by both intrinsic and extrinsic risk factors, such as repetitive overhead movements, increased loads carried above shoulder level (e.g., carrying heavy shoulder bags), which impose extra stress on the shoulder muscles, particularly the internal rotator muscles, leading to functional impairment and shoulder pain.

Link and colleagues demonstrated that suspension exercises improve shoulder muscle strength in volleyball players (27). Chen and colleagues showed that suspension exercises improve balance in stroke patients (15). Goulet and colleagues also showed that suspension exercises enhance the strength of shoulder joint rotator muscles (24). Byron and colleagues indicated that suspension exercises increase muscular activity in the core and shoulder girdle region (31). Donnelly and colleagues investigated the effect of suspension exercises on the strength of internal and external shoulder joint rotator muscles in women and found that a 13-week exercise program improved the strength of these muscles. This increase in strength can also stimulate and strengthen sensory receptors in tendons and muscle fascicles (18). A training program that enhances neural and central adaptations can improve muscle function (26).

Chain exercises, especially those involving suspension (like TRX exercises), can lead to the regeneration of the proprioceptive system and central nervous system in response to sensory deficits following injuries. Effective shoulder exercises can improve sensory-motor mechanisms. Strengthening exercises, typically used in rehabilitation, especially those that stimulate the muscle-tendon unit, such as the Golgi tendon organs and muscle spindles, enhance muscle strength and muscular balance (12).

It has been demonstrated that closed and open chain exercises improve shoulder proprioception. Since TRX exercises are performed within a closed kinetic chain, where the distal segment remains stable and supports body weight, they can generate axial and compressive forces on the joint, inducing co-contraction in the rotator cuff, scapular muscles,

and facilitating sensory input. This can lead to faster recovery for injured athletes. Closed chain exercises promote greater coordination and co-contraction of anti-gravity muscles (10).

Due to their inherent instability, TRX suspension exercises can provide increased stimulation to proprioceptors, nerve roots, motor organs, and muscle activity. Suspension exercises maximize balance and core stability compared to open chain movements. Studies have shown that suspension exercises have better therapeutic effects compared to unstable open chain exercises such as exercises on a mat or using a ball (21,25). When performed on an unstable surface, they enhance overall trunk muscle performance and strength and ultimately increase sensory input. When the distal segment in closed chain exercises is placed on an unstable surface, it triggers feedback and feedforward corrective movements (14). Unstable exercises increase feedback and feedforward responses to the motor system, resulting in increased co-contraction, joint stability, and overall improvement (30).

Discussion:

The present study aimed to investigate the effect of 8 weeks of TRX training on the range of motion and shoulder imbalance in beach volleyball players. The results of this study demonstrated that eight weeks of TRX training had a significant impact on the internal and external rotational range of motion of the shoulder joint in female beach volleyball players. These findings are consistent with the results of studies by Lan et al. (2017), Min et al. (2012), Manske et al. (2013), and McClure et al. (2007) (22-25). These results suggest that movement impairments respond well to conservative treatments. Among athletes with overhead movements, a reduction in the range of motion of internal and external rotation occurs in the dominant arm compared to the nondominant arm (26). A study indicated that the infraspinatus and teres minor muscles are stiffer on the throwing side compared to the non-throwing side (23).

Conclusion

The present study's results demonstrate a significant impact of implementing a TRX exercise program on the range of motion and degree of uneven shoulder female beach volleyball players. Considering the effects of the TRX protocol on the range of motion and shoulder imbalance in female beach volleyball players, it is recommended that coaches and athletes

in the field of beach volleyball, especially for women, incorporate TRX training protocols to prevent muscle injuries and address anomalies like shoulder imbalances. Considering the effect of the TRX protocol on the range of motion and shoulder inequality of beach volleyball girls, it is suggested that the coaches and athletes of beach volleyball in the women's section use TRX training protocols with the aim of preventing the occurrence of muscle injuries and prevention and treatment of abnormalities such as uneven shoulders should be used. Also it is suggested that future researches evaluate and compare the effect of different protocols of TRX exercises with the effect of other exercises on research variables.

Competing interests

There is no competing of interest to disclose.

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