Research Paper: The Effect of Selected Core Stability Exercises on the Jumping-Landing Pattern and Trunk Muscular Endurance in Adolescent Volleyball Players With Trunk Defect

Abdollah Tafakori[1], Hassan Daneshmandi[1], Nader Samami[1]

1. Department of Corrective Exercises and Sport Injuries, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran.

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ABSTRACT

Purpose: The anterior cruciate ligament is one of the most vulnerable knee ligaments. The biomechanical and neuromuscular differences of the trunk during sports activities are the main cause of non-collision injury. Therefore, the aim of the present research was to investigate the effect of six weeks selected core stability exercises on the jumping-landing pattern and trunk endurance in adolescent volleyball players with trunk defects.

Methods: The present semi-experimental study with pre-test and post-test design was conducted on 65 adolescent volleyball players from Shiraz, of whom 22 athletes with trunk defects were selected during the initial screening. Available sampling was done and the subjects were randomly divided into the experimental (n=11, average age: 16.36±0.41 years, height: 1.74±0.02 m, and weight: 61.54± 3.12 kg) and control (n=11, average age: 16.18±0.50 years, height: 1.70± 0.02 m, and weight: 61.27 ±2.36 kg). The tuck jump test was used to assess the subjects' trunk defect. Core stability exercises were performed for six weeks, three days a week. To evaluate the jumping-landing pattern and trunk muscular endurance, the Landing Error Scoring System (LESS) and McGill protocol were used, respectively, and to analyze the results, the Analysis of Covariance (ANCOVA) and independent t-test at a significant level of P<0.05 were used .

Results: A significant difference was observed in the jumping-landing pattern (P=0.001) and trunk muscular endurance (P=0.001) between the two control and experimental groups.

Conclusion: The results of the present research showed that six weeks selected core stability exercises improved the jumping-landing pattern of adolescent volleyball players with trunk defects and also improved their trunk muscular endurance. Therefore, sports coaches are recommended to use the trunk defect screening test, as well as the core stability exercises protocols to prevent sports injuries in adolescent volleyball players.

*** Corresponding Author:**
Abdollah Tafakori, MSc.
Address: *Department of Sport Injuries and Corrective Exercise, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran.*
Phone: *+98 (917) 4931336*
E-mail: *abdolahtafakori1994@gmail.com*

Highlights

● Volleyball is a sport with seldom physical contact between players, but there are severe injuries to the limbs, especially the joints, as a result of collisions with the playing field, as well as unbalanced jumps and landings.

● Neuromuscular defects are one of the main causes of non-collision anterior cruciate ligament injury, which increases the load on the joints of the lower extremities, and subsequently anterior cruciate ligament injury during sports activities.

● Increasing the stability of the central area causes neuromuscular recall to reduce back pain and prevent lower limb injury.

Plain Language Summary

Selective core stability exercises in volleyball athletes with trunk defects can reduce the risk factors for moderate anterior cruciate ligament injury, such as biomechanical and neuromuscular factors. The results of the present study showed a significant difference between the jump-landing pattern and the muscular endurance of the trunk of the subjects in the two control and experimental groups.

1. Introduction

Volleyball is a sport, in which there is basically very little contact between the players, but to a large extent, there are acute damages to the limbs, especially the joints, as a result of a collision with the playground, as well as unbalanced jumps and landings. Therefore, it seems that volleyball can be investigated as a high-risk sport [1]. The knee joint is one of the joints in the body that has an important role in moving and bearing weight while performing sports activities [2]. Strong muscles, long bones, and high torque imposed on the knee joint are possibly the major factors in causing injury [3]. Accordingly, the athlete's ability to maintain the correct dynamics of the lower limb on the motor plates is one of the important factors in knee injury during sports activities.

The abnormal neuromuscular function of the lower limb can increase the amount of knee valgus, and consequently Anterior Cruciate Ligament (ACL) damage [4, 5]. In other words, neuromuscular defects are one of the main non-collision factors of ACL injury [6] that increases the load imposed on the joints of the lower limb, and subsequently the ACL injury during sports activities [6]. This injury has more prevalence among young athletes aged 15-25 years, and about 70% of ACL injuries are non-collision and 30% are collision injuries [7].

In addition to the high cost of annual treatment, this injury results in the loss of athletic participation leading to secondary injuries, such as osteoarthritis, meniscus tear, and psychological and mental problems in the athlete [8]. In the video analysis of ACL injury in athletes, four neuromuscular defects have been introduced as a non-collision type, which includes quadriceps dominance, trunk dominance, leg dominance, and ligament dominance [9]. One of the neuromuscular control defects is the trunk control defect or dysfunction of the central area of the body, which has been defined as insufficient control and coordination to resist the inertia of the trunk during landing [10].

Improper control of the central area of the body and a defect in the ability to disperse forces can lead to excessive movement of the trunk, especially on the frontal plane, along with an increase in the reaction forces of the ground and the valgus in the knee joint or the same complication of knock-knees [11]. Also, the pre-activation decrease of trunk and thigh muscles results in the lateral curvature status of the trunk that can increase the probability of the valgus [12]. Under these conditions, the muscle limiters were unable to compensate and neutralize the increased forces [12] that in athletes, it is the main cause of knee injury, especially ACL [13]. A favorable central area can maintain the length-tension normal relation of the agonist and antagonist muscles, and this leads to optimal kinematics of the joints in the waist-pelvis set and thigh in the functional motor chain movements and the creation of maximum stability for lower limb movements [14].

The stability of the central area as an interface with the effective transfer of force produced in the lower limb to the upper limb through the trunk helps better sports performance [15]. Core stability in the athlete is also important when the center of gravity of the person moves outside the level of his reliance; therefore, the person by contracting the core muscles of the trunk must adjust his center of gravity to prevent the balance from upsetting and returning the center of gravity to the level of reliance. This process stabilizes the spine and creates movement in the joints [16].

Kibler et al. defined core stability in sports as the ability to control the position and trunk movement on the pelvis in order to produce, control, and transmit movement to the end limbs in integrated sports activities [17]. In this regard, Kibler et al. stated that the body center is considered as an essential component for optimal performance in most sports because it provides a basis for producing more force in the upper and lower limbs [18]. On the other hand, the stability increase of the central area increases the neuromuscular call to reduce pain in the lower and back area of the waist and prevent lower limb injury [19].

Mohammad Ali Nasab Firozjah et al. in a study entitled "The Effect of Selected Core Stability Exercises on Jumping and Landing Pattern in Male Basketball Players with Trunk Defect", observed that performing core stability exercises in basketball players with trunk defect improves kinetic and kinematic landing and moderates some risk factors of the ACL injury [20]. Also, Shahidi et al. (2018) investigated the effect of eight weeks selected exercise in the water on the ratio of landing error in active men prone to the ACL injury. Their research results showed that exercise in water improved the ratio of landing errors in men prone to ACL injury [21].

The strength and endurance ratio of the core stabilizing muscles is lower in people with lower limb injuries than in those without a history of injury [22]. Necessary measures to identify and evaluate athletes prone to injury by field and practical assessment tests can provide valuable and useful information and is an important step in injury prevention [12]. One of these tests is the Tuck Jump test, which has high validity and demonstrates important biomechanical components associated with the ACL injury. This test indicates the neuromuscular defects existing in the landing technique and biomechanics of athletes, and according to its results, these defects can be removed [12].

Despite studies conducted on the advantage of core stability and its importance in sports performance and the prevention of sports injuries in various sports, inconsistencies in the few studies performed and the lack of studies on the impact of core stability exercises on sports injury prediction through the Landing Error Scoring System (LESS), especially in volleyball sports, double the importance of addressing this issue. Therefore, the need for further studies to evaluate both knee angles from the frontal and sagittal view and maintaining their good performance while landing, especially in male volleyball players, is of great importance. Therefore, changes in knee valgus angles should be studied more accurately and relevant appropriate exercise programs should be provided. Therefore, the aim of the present research was to investigate the effect of a period of selected core stability exercises on the jumping-landing pattern and trunk endurance in adolescent volleyball players with the trunk defect.

2. Materials and Methods

The present semi-experimental study with pre-test and post-test design was conducted on 65 adolescent volleyball players from Shiraz, Iran, of whom 22 athletes with trunk defects were selected through the initial screening the tuck jump test [23]. The samples aged 14-19 years selected by available sampling and had at least 4 years of regular exercise performing through three sessions per week They were randomly assigned to the experimental and control groups (control=11 per group). Before the research, all subjects signed the consent form for participation in the research tests, and then during a session, the subjects were explained how to perform the tests. The subjects were all healthy and had no history of back pain, trunk or lower limb surgery, severe spinal abnormalities (scoliosis and kyphosis), and athletes who had trunk defects were included in the research [24].

The subjects were assessed using a tuck jump test to identify people with trunk control neuromuscular defect. To perform the tuck jump, the athlete stood with open legs shoulder-width apart and began to jump vertically, raising his knees as high as possible. At the highest point of the jump, the thighs were located parallel to the ground. When landing, the athlete would start the next tuck jumping. The test ran for 10 s [25]. To improve the accuracy of the assessment, two digital (30 Hz) video cameras were used. When the athlete was unable to land at the starting point of the jump, his thighs cannot be parallel to the ground at the peak of the jump, and the jumps are interrupted for 10 s, therefore, the person is considered to have trunk defect [26, 27]. The cameras were adjusted according to the height of the subject and parallel to the transverse and parabolic plates to the subject. After performing the test, special software was used to investigate the jump sequences, and the position of the trunk during the landing was investigated on transverse and parabolic plates [25].

To ensure the presence of trunk defect in men, the pilot experimental project of the tuck jump test pilot was performed before doing the research and the presence of trunk defect in men was confirmed. In addition, the subjects were investigated for other neuromuscular defects, and only samples with trunk defects were included in the research. To evaluate the landing error, the LESS test was used. It was performed as the pre-test session; the subject performed jumping from a 30 cm platform and landed in front of the platform at a distance of approximately 50% times of his height. He then immediately made a maximum vertical jump [28].

During the test, it was emphasized that the person should perform a maximum upward jump from the platform as soon as he lands. The subjects were allowed to have two jumping practices to learn it. Then, they did three right jumps. If the person did not reach the determined horizontal distance or did not make the maximum vertical jump after landing, that turn was deleted and the landing maneuver was repeated. Two video cameras with base recorded the images of people jumping from the frontal and sagittal views at 1.5 and 1 m, respectively. The videos recorded by the examiner were analyzed using the LESS standard scoring form, Quinoa software, and video analysis. Finally, the average of all three attempts of each subject was taken as a compound score, and the subject' score was recorded considering a total of 17 items [28].

To assess the endurance of the central area of the trunk, the McGill protocol, including tests, such as Biering-Sørensen, side-plank left, side-plank right, and sustained sit-up position at 60- degrees was used [29]. This protocol measures the endurance of flexor and extensor trunk muscles, including the right abdomen, spine straightening, multifidus, external oblique, and lumbar square.

In this research, Willardson (2013) exercise protocol designed for volleyball players [30], as well as the core stability exercise program developed by Weston et al. (2015) for young elite swimmers were used [31]. The control subjects performed volleyball exercises normally without any exercise and without knowing the conditions of other samples. In addition to regular volleyball exercises for six weeks (three sessions per week, 45 to 60 min per session), the subjects of the experimental group performed core stability exercises under the direct supervision of the researcher. Overload was applied by increasing the time and repetition of the sets and the complexity of the exercise (Table 1).

To investigate the normality of the data, the Shapiro-Wilk test and to analyze the pre-test and post-test results, Analysis of Covariance (ANCOVA), and independent t-test at a significant level of $P \geq 0.05$ were used using SPSS software V. 25.

Table 1. Core Stability Exercise Protocol

Protocols	Exercises	Step and Repetitions	Purpose
Introductory cycle 1: weeks 1-3	Stability ball crunch	3*20	Core flexion
	Cable high/low woodchop	3*20	Core rotation
	Cable low/high woodchop	3*20	Core rotation
	Back extension/hyperextension	3*20	Core extension
	Dumbbell side bend	3*20	Core extension/ rotation
	Full plank	3*30 sec	Core Lateral flexion
	Lateral plank	3*30 sec	Core flexion /extension
Strength cycle 2: weeks 4-6	Bicycle crunch	3*15	Core flexion
	Cable torso rotation	3*15	Core rotation
	Russian twist	3*15	Core rotation
	Glute-ham raise	3*15	Core extension
	Stability ball hyperextension with twist	3*15	Core extension/ rotation
	Full plank	3*45 sec	Core Lateral flexion
	Lateral plank	3*45 sec	Core flexion /extension

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3. Results

The demographic characteristics of the subjects are presented in Table 2. The results of the independent t-test did not show a significant difference in age, height, weight, and body mass index variables in the two control and experimental groups (Table 2).

The ANCOVA was used to compare the mean scores between the two groups, regarding the pre-test as a quantitative variable. A significant difference was observed in the LESS test and trunk endurance (P≥0.05). Thus, the experimental group showed better scores regarding trunk muscle endurance and the LESS test than the control group (Table 3). Independent t-test was used to investigate the difference between the two groups in pre-test and post-test and showed a significant difference in the LESS test scores (P<0.01) and trunk muscular endurance results (P<0.05) (Table 4).

4. Discussion

The aim of the present research was to investigate the effect of six weeks of core stability exercises on the jumping-landing pattern and the trunk endurance in adolescent volleyball players with trunk defects. The results of the present research showed that after six weeks of the selected core stability exercises, the ratio of LESS in the experimental group had a significant difference with that of the control group. Due to the lack of changes in the control group, the reduction ratio in landing error can be attributed to the effect of selected core stability exercises. As a result, landing mechanics improvement can reduce the risk of ACL injury.

Table 2. Demographic Characteristics of Subjects

Variable	Group	Mean±SD	T	P
Age (y)	Experimental	16.36±0.41	0.28	0.78
	Control	16.18±0.50		
Height (m)	Experimental	1.74±0.02	1.25	0.22
	Control	1.70±0.02		
Weight (kg)	Experimental	61.54±3.12	0.07	0.94
	Control	61.27±2.36		
BMI (kg/m²)	Experimental	20.08±0.79	-0.93	0.36
	Control	21.21±0.91		

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Table 3. Results of the analysis of covariance to compare the Landing Error Scoring System (LESS) test and trunk endurance in Post-test among the groups

Variable	Stage	Group	Mean*	F	df	P	Eta squared
LESS test	Post-test	Experimental	6.98	21.90	1	** 0.001	0.53
	Post-test	Control	8.83				
Sorensen test	Post-test	Experimental	82.49	24.90	1	** 0.001	0.56
	Post-test	Control	60.69				
Planck	Post-test	Experimental	77.84	6.31	1	** 0.02	0.24
	Post-test	Control	62.24				
Left Planck	Post-test	Experimental	53.07	23.52	1	** 0.001	0.55
	Post-test	Control	38.74				
Right Planck	Post-test	Experimental	51.79	9.64	1	** 0.006	0.33
	Post-test	Control	36.47				
60-degree trunk flexion	Post-test	Experimental	64.25	1.38	1	0.26	0.06
	Post-test	Control	54.28				
Muscle endurance of the trunk (total)	Post-test	Experimental	65.65	30.49	1	** 0.001	0.61
	Post-test	Control	50.74				

* Based on pre-test scores; ** Significant at P<0.01.

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Table 4. Difference between the mean scores of the Landing Error Scoring System (LESS) test and trunk muscular endurance results in subjects before and after the application of the exercise protocol

Variables	Groups							
	Control (n=11)				Experimental (n=12)			
	Mean±SD		T	P	Mean±SD		T	P
	Pre-test	Post-test			Pre-test	Post-test		
LESS test	8.90±0.63	8.90±0.70	0.001	1	8.72±0.77	6.90±0.59	5.16	0.001*
Sorensen test	59±9.49	58.59±9.47	0.12	0.90	63±7.01	84.27±6.24	-4.86	0.001*
Planck	51.81±6.47	51.27±7.59	0.15	0.88	72.36±11.78	88.90±13	-3.56	0.005*
Left Planck	40.27±6.15	36.81±6.64	0.97	0.35	72.44±5.92	55±5.48	-3.48	0.006*
Right Planck	40.09±5.29	38.36±5.77	0.86	0.40	35.90±5.34	49.90±4.69	-5.76	0.001*
60-degree trunk flexion	40.81±4.37	49.27±6.38	-1.48	0.18	55.72±5.99	69.27±6.68	-2.44	0.03*
Muscle endurance of the trunk (total)	46.40±4.90	46.92±5.17	-0.38	0.71	54.54±4.80	69.47±4.60	-6.86	0.001*

*Significant at the level of P<0.05.

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The results of the research are in line with the results of Mohammad Ali Nasab et al. [20], who investigated the effect of a period of selected core stability exercises on the jumping-landing pattern in male basketball players with trunk defect. The same results can be due to the type of performed exercises and also the conditions of the research samples because in both studies, core stability exercises were used, and also the subjects had trunk defects. According to the results of the present research, there is a clear link between core muscle stability and the emergence of lower limb injury. Using the applied exercises can improve the ratio of landing error, develop core muscle endurance, and reduce the ratio of injury in individuals prone to the ACL injury. Also the effect of exercise on landing error ratio are also consistent with the results of Shahidi et al. [21] who investigated the effect of eight weeks of selected exercises in the water on landing error ratio in active men prone to the ACL injury.

In another research, DiStefano et al. found similar results in a young and high school population. They investigated the landing techniques of 173 athletes at the beginning of the football tournament season and again after the exercise program. After the exercise program, there was a significant reduction in landing errors (including knee valgus), and athletes with the high scores at the beginning of the season showed the greatest improvement [32]. These results indicate that landing errors and risk factors that could increase the risk of ACL injury can be targeted and corrected through injury prevention programs. Brown et al. compared the effect of the two groups of core stability exercises with plyometrics on improving knee and thigh biomechanics during landing on sagittal and frontal plates. They found that the plyometric exercise improved the knee biomechanics on the sagittal plane and the thigh on the frontal plate, whereas the core stability showed no effectiveness [33]. The results of this research are in contrast with the present research regarding the effect of core stability exercises, which can be due to gender differences and the type of stability exercises performed. In the present study, the effect of exercise on adolescent boys was investigated; however, in the research by Tyler et al., female athletes were evaluated.

Exercise time is also important in the physiological changes of the body following the exercise, but the number of sessions and weeks can be considered important to accurately assess the effect of exercises. Some studies have shown that non-collision knee injuries depend on the angles at different levels of movement while landing from a jump. Also, a flattering knee while landing increases the angle between the patellar tendon and the tibia trunk, which in turn increases the amount of force towards anterior on the tibia and increases the transfer load to the ACL. This load enhancement, in turn, can increase the emergence of ACL injury [34]. Novice et al. (2005) assessing boys and girls between the age of 11 and 19 years reported that after neuromuscular exercises, the distance between the two knees at the moment of jumping and when landing in both genders increased significantly and approximated to its natural state [35].

The results of this study are consistent with the results of the present study because, in both studies, the used exercise improved the mechanics of the lower limb while landing, which can reduce the probability of the emergence of ACL injury. In a study, fatigue in core muscles increased the scores of the LESS test that means that an increase in landing errors and exposing athletes to the emergence of lower limb injuries. Since jumping and landing skill exists in most sports fields, this type of skill can be the cause of lower limb injuries in many cases; therefore, improper jumping and landing can cause valgus and internal rotation in the knee and several types of injury in this area [36]. In a study, Gandomi and Najafi [37] studied the effect of core muscle fatigue on landing mechanics and lower limb function and showed that after applying the fatigue protocol of the central area of the body, landing error scores and knee flexion dropped during landing.

Regarding the decline in lower limb function and changes in landing mechanics following muscle fatigue in the central area of the body, it can be acknowledged that fatigue in the central area that occurs during athletic competitions can probably provide the context of the emergence of lower limb injuries. Therefore, the application of central area reinforcement protocols can prevent lower limb injuries. These exercises can also reduce the occurrence of injury by increasing muscle endurance and spending less energy during landing and sports assignments. Under these conditions, the trunk muscles can resist the imposed pressures to some extent during landing [12].

5. Conclusion

According to the effectiveness of core stability exercises on the risk factors of ACL injury; therefore, it can be concluded that selected core stability exercises in volleyball athletes with trunk defects can reduce adjustable risk factors of the ACL injury, such as biomechanical and neuromuscular factors. Also, strengthening the muscles of the central area of the body can probably be effective in preventing lower limb injuries. In the present research, the gender of the subjects was limited to men with the age range of 14-19 years. Regarding our results, it is recommended that volleyball players and coaches use core stability exercises to improve the mechanics of landing in players with trunk defects. The experts in preventing the emergence of sports injuries are also suggested to include core stability exercises in the daily programs of their athletes, especially in the pre-season exercises.

Ethical Considerations

Compliance with ethical guidelines

This study ethically approved by Institute of Physical Education and Sports Sciences (Code: IR.SSRC.REC.1399.024). All ethical principles are considered in this article. The participants were informed about the purpose of the research and its implementation stages; they were also assured about the confidentiality of their information; moreover, they were free to leave the study whenever they wished, and if desired, the research results would be available to them.

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Authors' contributions

All authors were equally contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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