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Can eight weeks of stabilization exercise change the amount of knee flexion and anterior shear force?

The effect of stabilization exercise on the knee

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Abstract

Aim: This study aimed to evaluate the effect of eight-week stabilization training on knee flexion and anterior shear force during a single leg drop landing to prevent ACL injury. Material and Method: Thirty basketball athletes were randomly assigned to a training group (n = 15) and a control group (n = 15). Training group performed the Core stability training for 8 weeks, but control group did not perform these exercises. Lower extremity kinetics and kinematics variables during single-leg drop landing were collected by motion analysis and force plate in pre and post-test. Data were analyzed by using mixed ANOVA repeated measure test with significance level of $P \leq 0.05$. Results: The results showed that the amount of knee flexion significantly increased after conducting the 8 weeks of core stability training ($P < 0.05$), while there was no significant decrease in anterior shear forces ($P > 0.05$). Discussion: Based on the results, the core stability training by increasing the core stability can improve the core muscles recruitment during landing. Therefore, it can be concluded that core stability training can reduce the ACL injury risks during the dynamic movements.

Keywords

Stabilization Training; Kinetics; Kinematics; Single Leg Drop Landing; Acl Injury

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Introduction

Anterior cruciate ligament (ACL) injury is known as one of the most common injuries not only in athletes but also in active non-professionals [1]. ACL injury can lead to long-term disability [2]. Children and youth are more prone to ACL injury [3]. Moreover, athletes who play team sports such as football, volleyball, and basketball are four to six time more at the risk of ACL injury due to jump, cutting and rotational movements [4]. At least 70% of ACL injuries occur in non-contact conditions [3]. Research findings confirm that the condition of lower extremities during high-risk activities such as running, cutting maneuver, rotation, and landing may be predisposing risk factors for ACL injuries [5,6]. It is believed that lower extremities condition which affects directly the force applied to the ACL, plays a vital role in increasing the risk of ACL injury. Most non-contact ACL injuries happen during sports which include single-leg landing [7]. Single leg drop landing is a common maneuver which is an important part of the majority of sports such as basketball, volleyball, handball, badminton, and football [8].

The single leg-drop landing needs too much motion in short time. Sudden movements and high amounts of loads during landing can cause injuries in the knee and ankle joints [9]. Studying the mechanism of injury and kinematic analysis shows that the movements and body condition can increase the risk of injury [10]. For instance, previous studies showed the increase of knee valgus angle [11,12], the decrease of the knee flexion [11,13], and reducing of the hip flexion angle [6,8] during the landing can cause more damage to the ACL. Indeed, the common movement (motion) pattern of non-contact ACL injuries includes the decrease of the knee, hip, and trunk flexion along with the increase of knee valgus and the tibia rotation [14,15]. Although knee valgus angle and rotation of the knee increase the ACL strain [16], quadriceps muscle contraction increases much more ACL strain by creating anterior proximal shear force [17,18]. Research findings show that anterior shear force is the main mechanism for the load applied to the ACL [16]. There is a kinetic relationship between proximal lower extremities and the knee movements. Therefore, changes in the kinematics of proximal part and their muscles movement (motion) pattern may affect the moments and forces applied on the tibiofemoral joint. Although the core muscles do not act directly on the knee joint, its muscle activities can affect the lower extremities alignment and load-bearing capacity of the knee.

Studies showed that the core muscles stabilize the pelvis during single leg stand and play an important role in the kinematic control of the hip joint [1]. Ineffectiveness or weakness of core during landing may cause increase adduction and internal rotation which can lead to increase the ACL moments and strain. Moreover, inadequate neuromuscular control of trunk (body) or core stability may affect the dynamic stability of lower extremities and increase the knee ligaments strain. The increased strain in ligaments can bring about some injuries [19]. Yu et al. showed that the angular velocity of the hip joint could change the anterior shear force during landing [8]. Therefore, it is possible that proximal muscles affect the force applied to the knee joint.

It seems that core stability training can reduce the risk of non-contact ACL injury[20]. Hewett et al. showed that lower limb and trunk strength and neuromuscular control of lower extremities and body can be boosted by neuromuscular training [21]. Researchers used various intervention trainings to change lower extremities and body mechanics during dynamic activities [22]. Meyer et al. found that neuromuscular trainings which are included balance and core stability trainings reduce the forces applied to the knee [23]. They mentioned that plyometric trainings cannot reduce the knee forces. Despite emphasizing the implementation of intervention training to improve core stability [24], the effects of trunk intervention and especially core stability training have not been specified. According to the previous studies, it seems that the core muscles can play a key role to reduce the forces applied to ACL during landing. Therefore, due to the lack of information about the effect of stability training on the reduction of the injury risk, this study aimed to evaluate the effect of 8 weeks stability training on knee flexion and anterior shear force during single-leg landing.

Material and Method

This study was a quasi-experiment study with selective sampling and pre-posttest design. Based on previous studies and the fact that in quasi-experiment studies usually 20 or 30 samples are used [25], 30 professional basketball players have been recruited for this study. Subjects were divided randomly into a training group (n=15) and control group (n=15). All 30 athletes were enrolled voluntarily, and before entering the study, informed consent and demographical information was obtained from each subject. Ethical approval for this study has been granted by the ethics committee of Musculoskeletal Research Center of the Isfahan University of Medical Science. The selection criteria were: Not having any musculoskeletal disorders such as previous ankle sprain, neuromuscular disorder, pes planus and pes cavus. Lower extremity injuries were also defined as injuries which lead to the absence of more than one day of physical activities [26].

Subjects were asked to perform one jump from 40 cm height box to the force platform (5060, Kistler, Switzerland) with a single leg. The initial contact onto the ground was defined as the moment which the magnitude of vertical reaction forces is more than 30N [27]. Each jump task was performed 3 times, and there was 1 minute of rest between each jump in order to eliminate neuromuscular fatigue [28].

The 3D kinematic data were collected using a 7-camera optoelectronic motion capture system (Proreflex, Qualysis, Savedalen, Sweden); Therefore 34 reflecting skin markers with 4 mm diameter were placed on two sides of the body based on Visual 3D marker set [29] (over first and fifth metatarsal, medial and lateral malleolus, heel, lateral and medial epicondyle, great trochanter, anterior and posterior superior iliac spine (ASIS and PSIS respectively), iliac crest, sacrum, wrist, elbow joint, acromioclavicular joint (AC), sternum, C7 and on the vertex of the head). Also, four rigid plastic clusters containing three markers on each cluster were placed on the shin and thigh for tracing the segmental movements [30].

After warming up, each participant was instructed to jump from box to force plate with single leg drop landing. They should perform the single leg drop landing with the preferred (premier) leg.

The box height was 40cm, located 10 cm behind the force plate (figure 1). The subjects stood in balance condition close to the edge of the box in such a way that the preferred (premier) foot is suspended in the air. Kinematic data and the forces were collected at 200 Hz [31] and were filtered by using a low-pass filter (fourth-order zero-lag Butterworth filter) with the cut-off frequency of 6 Hz. Then, the lower extremity joint kinematics and kinetics were calculated using OpenSim (v.3.0.2, Stanford University) software. The posterior ground reaction force obtained from force platform was used to calculate maximum posterior reaction force for each subject. The forces were normalized to be unbiased based on the subjects weights. Moreover, in the coordination system of the laboratory, x, y and z axis belong to anterior-posterior, internal-external and vertical directions, respectively.

The training protocol included 8 weeks of (3 sessions in each week and each session 25-50 minutes) core stability training under the supervision of researchers for training group and ordinary training for the control group. In this study the training

Figure 1. Single leg drop landing test

protocol of Willardson et al. and Araujo et al. were employed [32,33] (Table 1).

Table 1. Structure of the eight-week training program

Activity	1st, 2nd week	3rd, 4th week	5th, 6th week	7th, 8th week
Reverse pendulum	3×30 seconds	3×35 seconds	3×40 seconds	3×45 seconds
medicine ball seated chest pass	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
medicine ball rotational throw	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
medicine ball slam	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
diagonal plate chop	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
medicine ball pullover pass	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
medicine ball underhand throw	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat
side double-leg lift	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat	3×30 seconds repeat

Statistical analysis: The data were statistically analyzed by using SPSS v22.0. For data distribution analysis, the Shapiro-Wilk test was used. For knee flexion angle, and anterior shear force comparison the mixed repeated measure ANOVA test was employed. Assessment assumption was made with 95 percent significance and α≤0.05.

Results

Demographical variables obtained from 30 professional basketball players are presented in table 2. Also, mean values and standard deviations of knee flexion angles and anterior shear forces during single-leg landing at the moment of touching the ground are presented in table 3.

Table 2. Demographical information of subjects (Mean ± SD)

	Training group	Control group	t	p
Age (year)	16.6±0.9	16.8±0.7	0.344	0.79
Height (cm)	185.25±3.4	186.45±4.3	0.743	0.48
Weight (kg)	69.5±6.3	70.2±5.3	0.870	0.43

Table 3. The results of mixed repeated measure ANOVA test for comparing the Knee flexion and Anterior Shear Force of two groups before and after intervention (Mean ±SD)

Variable		Training group	Control group	Time	Group	Time & Group
Knee flexion (angle)	Pretest	3.08±2.71	4.23±1.71			
				F=17.88 P=0.03	F=0.14 P=0.039	F=32.37 P=0.01
	Posttest	8.32±2.71	4.17±2.45			
Shear Anterior Force (N)	Pretest	5.6±0.9	5.8±1.9			
				F=11.8 P=0.12	F=12.9 P=0.09	F=0.05 P=0.81
	Posttest	4.9±0.67	5.7±0.9			

Table 2Table 3The mean values of knee flexion angle in training and control group before and after participation in core stability training increased 5.24 degree in the training group and decreased 0.06 degree in the control group. The results of mixed repeated measure ANOVA test dedicated significant difference before and after training (F=17.88, P=0.003). The results also showed a significant difference between 2 groups (F=0.14, P=0.039). Moreover, these results highlighted a significant interactive effect of time before and after intervention for both training and control groups (F=32.37, P=0.01). The results of mixed repeated measure ANOVA test for knee shear force showed that there was no significant difference before and after training (F=11.8, P=0.12) and between groups (F=12.9, P=0.09). The results also showed there was no significant interaction between the time before and after intervention for both groups (F=0.05, P=0.81).

Discussion

This study aimed to evaluate the effect of 8 weeks core stability training on the knee flexion angle and anterior shear force during single-leg landing. Since the tibia proximal anterior shear force has the most significant effect on ACL loading [34], this was chosen as a variable to study and was considered as the maximum posterior force of the ground reaction force. Yu et al. explained how the tibia proximal anterior shear force can be regarded as the ACL force [8]. The results of this study showed there was a significant increase in knee flexion angle while there was no significant drop in anterior shear force during single-leg landing after conducting the 8 weeks of core stability training.

To decrease the ground reaction force, the body has to predict and prepare itself for landing. This can be achieved by the muscle contraction. The body disability in contraction generation and also disability in movement prediction can increase the ground reaction force dramatically [35].

Based on previous studies the increase of knee flexion angle leads to decrease in proximal anterior shear force [8,10]. Also, these studies showed that the maximum knee extensor moment corresponds to the knee anterior shear force [8]. Shelburne et al. demonstrated that when the anterior shear force is high enough, the force applied on the ACL is also very high [36].

There are some studies that assessed the mechanism of the ACL injury and reported the single leg drop landing is one of the most common mechanisms of ACL injury [11,12]. The body acceleration increases and the lower limb muscles contract eccentrically during landing to support the body weight and acceleration. Therefore, these muscle forces can increase the anterior shear force by extensor mechanism [10]. Co-contraction of the lower limb muscles can absorb the forces applied on the knee, and as a result, it can reduce the forces applied on the knee ligaments [5].

Using lower limb muscles and knee flexion decrease the anterior shear force [37]. Gastrocnemius and quadriceps muscles contribute to the increase of the anterior shear force while the Hamstring muscles try to decrease these force [37-40]. The abilities of these muscles to affect the cruciate ligaments force can be changed by the knee flexion angle [41,42]. Therefore, the ability of quadriceps muscles increases for anterior force generation in low knee flexion angles when the ability of hamstring muscles decreases to neutralize the force generated [10].

The core stability trainings increase the trunk flexion ability and muscle recruitment strategy of the core muscles by increasing the stability of the core. Trunk flexion during single-leg landing potentially reduces the ability of quadriceps muscle utilization which can result in decreasing of its loading on the ACL upon touching the ground by foot. Also, Trunk flexion during landing compared to a landing posture with trunk flexion leads to more flexion in hip and knee joint and results in the lower limb position which has less risk of ACL rupture [43]. In addition, the trunk flexion increases by the hamstring muscle utilization and consequently decreases the force applied on cruciate ligaments. Kulas et al. reported that Hamstring muscle activation by trunk flexion leads to tibia shear force [44].

The increase of knee flexion brings about the decrease of force applied on cruciate ligaments and the increase of energy absorption during landing. During functional activities especially landing, the range of knee motion most likely offers better functions [45,46]. Previous studies confirm that the core feed forward muscles are employed before distal muscles [47]. As an example Hodges et al. made efforts to demonstrate that the trunk muscles activities are prior to limb muscles, while this state cannot be correct for subjects with disabilities [48,49]. This has been thought that the core feed forward muscles recruitment can provide the body with better neuromuscular function. The trunk muscles can act as feedforward muscles and work prior or with mover's muscles to reduce the moments resulted from disturbances [50]. The postural adjustment can provide distal movement with proximal stability. The increased stiffness in body produces proximal stability for lower and upper limbs and also distal force absorption [51]. Kulas et al. reported that the feedforward muscles control during landing is based on abdominal muscles before touching the ground by foot. They concluded that the trunk muscles activities aimed to prepare the body for landing [52]. Iida et al. showed an increase in the activities of external oblique, rectus abdominis and Gastrocnemius muscles before touching the ground by foot. They claimed that those muscles so as to prepare the body for landing, are activated by the increase of ankle joint stiffness and can act as a predictive postural control to absorb the force [53]. There are some other studies that considered the neuromuscular control in pelvic as an effective criterion for knee joint kinematics [24,54-56]. Following the interpretation of knee flexion during core preparation as distal mobility, the results of current study verify the proximal stability theory which improves the distal mobility of limbs. Whereas, the importance of the core muscles on the lower limb movement was not understood properly. Matthew et al. showed that the using of core muscles can increase knee flexion angle [57]. The core muscles activities affect the injury risk of cruciate ligaments. Following a decrease of trunk movement to carry the body weight, the activity of the quadriceps muscle increases to preserve the stability of the body [57]. Regarding the landing, the vertical forces in sagittal plane are oriented in the direction of hip to knee which results in producing moments in these joints [58]. The core activities can increase absorbed energy and decrease the force applied on the knee during landing [59]. Stevens et al. assessed the core stability lumbar training on the pattern of muscle recruitment in healthy subjects and showed that there was an increase at the level of local abdominal muscle activities and also a slight change in the global muscle activities [60]. They revealed that the pattern of muscle recruitment can change by using a training program which emphasizes on neuromuscular control. Tsao and Hodges also confirmed that there was a recovery in patients with back pain after 8 weeks training with transverse abdominis activities [61].

Following points above, it can be concluded that the core stability training used in this study had a positive effect on the feedforward muscles activities and force absorption by increasing the core stability.

Conclusion

The current study results showed the core stability training increases the knee angle flexion while it does not have a significant effect on the anterior shear force. Therefore, these trainings can act as a support for anterior cruciate ligament and the increase of core activities leads to decrease of the load applied on cruciate ligaments. These results can help sports coaches and physiotherapists to design the training programs.

Competing interests

None of the authors had any conflict of interest during this study.

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