Research Paper

The Association of Trunk and Hip Kinematic With Knee Abduction Angle During Single-Leg Landing

Maedeh Taghizadeh Kerman[1], Ali Yalfani[1*], Ahmad Ebrahimi Atri[2]

1. Department of Sports Injury and Corrective Exercises, Faculty of Physical Education and Sport Sciences, Bu-Ali Sina University, Hamadan, Iran.
2. Department of Sports Physiology, Faculty of Sports Sciences, Ferdowsi University of Mashhad, Mashhad, Iran.

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ABSTRACT

Objectives: Children aged 10 to 12 years often show dangerous maneuvers during landing, which include increased knee valgus, placing them at higher risk of anterior cruciate ligament (ACL) injuries. The study aimed to investigate the relation of the trunk and hip kinematics with the peak knee abduction angle during single-leg landing among preadolescent female soccer players.

Methods: Thirty-six preadolescent female soccer players aged 10 to 12 years attended the study. Participants did a static trial and after that performed landing trials. A single-leg landing was applied to assess the landing kinematics. A three-dimensional motion capture system was applied to analyze trunk, hip, and knee kinematics.

Results: Pearson correlation coefficient demonstrated a significantly positive relationship between peak hip internal rotation angle (r=0.361) (P=0.03) and peak knee abduction angle. Furthermore, no significant relationship was identified between peak hip adduction (r=-0.102) (P=0.55), peak trunk rotation (r=0.239) (P=0.16), peak trunk lateral flexion (r=0.052) (P=0.76), and peak valgus knee.

Discussion: Peak hip rotation angle was correlated with the valgus knee with a weak correlation value among preadolescent female soccer players. Future studies should consider kinematic risk factors related to ACL injuries in combination with neuromuscular control trunk and hip during more demanding tasks.

*** Corresponding Author:**
Ali Yalfani, Professor.
Address: *Department of Sports Injury and Corrective Exercises, Faculty of Physical Education and Sport Sciences, Bu-Ali Sina University, Hamadan, Iran.*
Tel: *+98 (81) 38303243*
E-mail: *ali_yalfani@yahoo.com*

Highlights

- A positive significant relationship between peak hip rotation and peak valgus knee was observed.
- There was no significant relationship between peak hip adduction and peak valgus knee.
- A significant relationship was not observed between trunk kinematics and peak valgus knee.

Plain Language Summary

Children aged 10 to 12 years often show dangerous movement patterns during landing activities, comprising decreased knee flexion and increased knee valgus, placing them at higher risk of ACL injuries. In the current study, the association of the trunk and hip kinematics with knee abduction angle was investigated. The result of the study demonstrated a significant positive relationship between peak hip rotation and peak knee abduction.

1. Introduction

Among all team sports, soccer is one of the most exciting and renowned fields all around the world. There are currently more than 265 million soccer players worldwide, and the number of participants, especially female players, is growing rapidly. Fifty-eight percent of soccer players are under the age of 18 years, and almost three-quarters of the players, following this field are young individuals under the age of 14 years [1]. Anterior cruciate ligament (ACL) risk of injuries is not only one of the most devastating lesions in youth soccer players but also lead to osteoarthritis in 80% of players aged under 15 years [2]. Also, 70% of ACL tears happen in non-contact mechanisms, and jump landing is one of the most common risky movement patterns leading to injury [3]. Shea et al. discovered that teenage girls and female soccer players had a greater prevalence of ACL injuries than did male players [4]. and the risk began between 10 and 12 years [5]. Children at this age often show dangerous maneuvers during landing activities [5, 6], comprising decreased knee flexion and increased knee valgus [7, 8], placing them at a higher ACL risk of injury. Krosshaug et al. investigated video records of 39 basketball players suffering ACL injuries. They estimated the injury time to be 17-50 ms after the initial contact with the ground. Both males and females reduced the bending angle of the knee at initial contact (<15) and 50 ms after (<28). The study also found that females had more knee flexion angles than males and that females were more prone to valgus collapse than males [9].

Proximal biomechanical defects may expose the knee to vulnerable positions and increase the likelihood of injury to the knee joint. The relationship between suboptimal trunk position and hip and knee risk factors highlights the effect of trunk position on ACL injury. In addition, the collapse of the hip places the knee in the valgus position [8, 9]. Therefore, it can be said that trunk, hip, and knee mechanics have been supposed as key elements in the mechanism of ACL injury, particularly among females [10, 11]. Females demonstrate different neuromuscular control strategies than males during puberty. Puberty is accompanied by a sudden change in bone size and an increase in trunk volume. In males, this increase in volume has been related to an increase in neuromuscular control, muscle strength, and power. However, among females, the same increase in strength, power, and neuromuscular control does not occur [12].

According to the kinematic chain, the prior study suggested that knee kinematics were affected by proximal and distal joint motions [13, 14]. During jump landing, the peak valgus knee was connected to the peak hip adduction whereas the peak hip internal rotation angle was not [15]. Another study discovered that during a bilateral jump task, when ipsilateral trunk rotation occurred, valgus knee and internal rotation angle become greater, and the authors found that hip external rotation can be a logical justification for these findings [16]. Furthermore, a video evaluation study demonstrated that the hip internal rotation, flexion, and adduction angles did not alter during initial contact and could not lead to an ACL injury [17]. Considering the relationship between hip and trunk kinematics with the valgus knee in different tests, results may vary.

The kinematic relationships between the trunk and hip kinematics with knee abduction angle during landing remain uncertain among preadolescent females. Therefore, the study aimed to investigate the relation of the

peak hip kinematic angles and peak trunk angles with peak knee abduction during single-leg landing among preadolescent female soccer players.

2. Materials and Methods

Participants

In this study, 36 preadolescent female soccer players (Mean±SD age: 11.2±1.1 years, height: 148.4±5.4 cm, weight: 40.9±3.5 kg) participated. The inclusion criteria were healthy participants aged 10 to 12 years and playing football twice per week for at least six months. All testing procedures were explained to each athlete, and consent forms were signed by the participant or parents. Exclusion criteria were an injury history of knee ligaments or muscles of the lower extremities and impaired balance. It should be mentioned that the dominant leg of the whole athlete was the right limb and it had been tested and analyzed.

Data collection

An 8-camera motion capture (Qualisys; Goteborg, Sweden) collected kinematic data at 200 Hz using a marker set in a calibration area. Forty-five reflecting markers were put on the body (C7 and T10, shoulders, scapula inferior angles, sacrum, anterior and posterior superior iliac spine, iliac crest, greater trochanter, knee, ankle, and second and fifth metatarsal heads, heels) based on a visual 3D marker set [18] and four clusters were placed on the thigh and shank. Participants warmed up for 5 minutes on a stationary bicycle and after that, they did a static trial and performed landing trials. A single-leg drop landing was applied to assess the landing kinematics (Figure 1). The attendees received instructions to stand on non-leg dominance and then drop from a box with a height of 30 cm from the ground with leg dominance. Three successful trials of the single-leg landing were collected [19].

Data processing and statistical analysis

The phase of landing was the interval between the initial contact to peak knee flexion. The positive angles indicate hip adduction and internal rotation. Kinematic data were collected using visual 3D.

Pearson correlation coefficient was used to measure relationships between the peak trunk and hip kinematics and peak knee abduction angle. The statistical process was analyzed using SPSS software, version 25. The Kolmogorov–Smirnov test was used to identify the normal distribution of the data. Statistical significance was met at the level of $P \leq 0.05$.

3. Results

The means peak hip, trunk, and knee abduction kinematics data are reported in Table 1.

Pearson correlation coefficient showed a statistically significant positive relationship between peak hip internal rotation (r=0.361) (P=0.03) and peak knee abduction

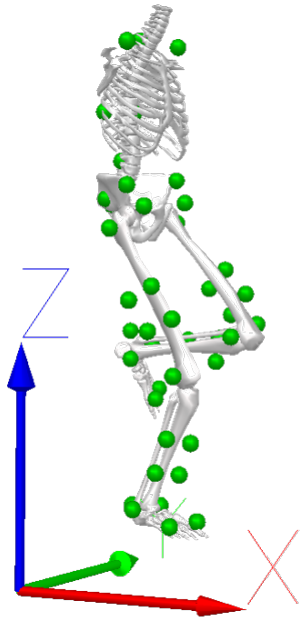

Figure 1. Single-leg drop landing task

Table 1. Kinematic data

Variable (°)	Mean±SD
Peak Knee abduction	-3.3±4.4
Peak Hip adduction	6.1±4.5
Peak Hip internal rotation	15.3±10.1
Peak Trunk rotation	-9.8±7.7
Peak Trunk lateral flexion	-12.2±4.8

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Table 2. Correlations (r) between kinematics data

Variable	Peak Hip Internal Rotation	Peak Hip Adduction	Peak Trunk Rotation	Peak Trunk Lateral Flexion
Peak Knee abduction	r=0.361	r=-0.102	r=0.239	r=0.052
	P=0.03*	P=0.55	P=0.16	P=0.76

*P≤0.05

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(Figure 2A). Moreover, there was no significant relationship between peak hip adduction (r=-0.102) (P=0.55) (Figure 2B), peak trunk rotation (r=0.239) (P=0.16) (Figure 3C), peak trunk lateral flexion (r=0.052) (P=0.76), and knee abduction angle (Figure 3D) (Table 2).

4. Discussion

This study aimed to determine the relationship between hip kinematics and trunk kinematics and peak valgus knee among female preadolescent soccer players during single-leg drop landing. There was a weak correlation between these two parameters but a significant relationship was found between peak knee abduction and peak hip internal rotation. In a previous study, knee abduction motion was a major indicator of ACL lesions in female players, and a smaller knee abduction angle was especially crucial to decrease ACL injuries [14]. In another study, females showed greater hip internal rotations combined with a greater knee valgus during weight-bearing movements of single-leg compared to males, which may be mechanisms of ACL injury [20-22]. Furthermore, a risky kinematic relationship known as the dynamic valgus knee goes along with hip internal rotation, which may produce ACL injuries [23]. In the present study, even though large peak hip internal rotation kinematics may contribute to large peak knee abduction, and future studies should consider several combined factors, such as neuromuscular control of the hip and trunk to avoid ACL injuries. Also, because the study was performed during the COVID-19 pandemic, we applied a small number of participants, which affects the results of the study.

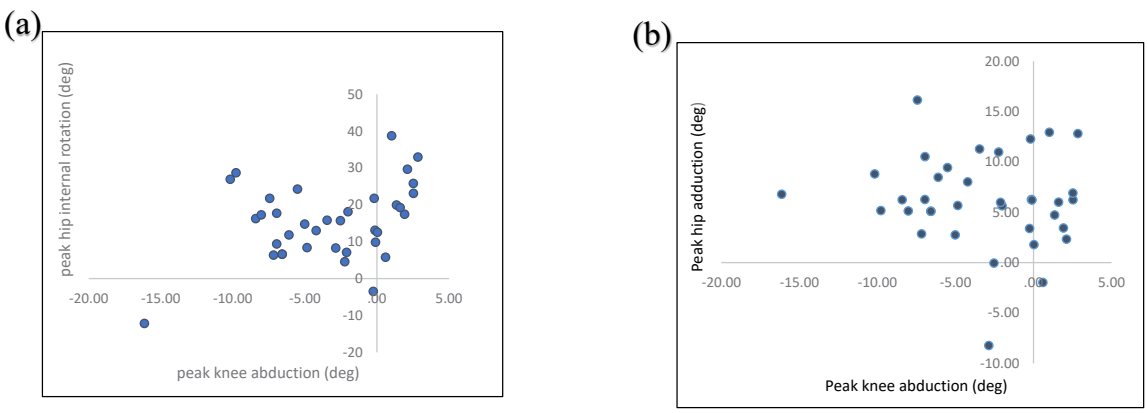

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Figure 2. The association between peak hip internal rotation and peak knee abduction (a) and the association between peak hip adduction and peak knee abduction (b)

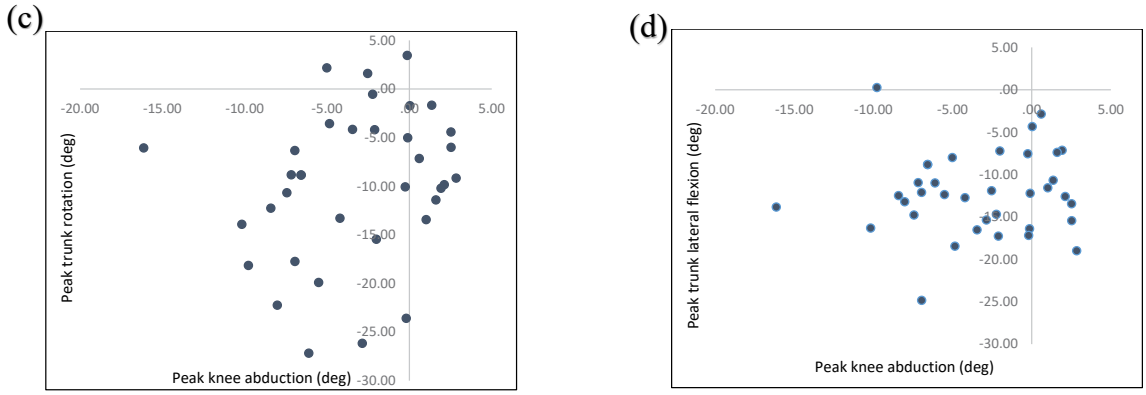

Figure 3. The association between peak trunk rotation and peak knee abduction (c) and the association between peak trunk lateral flexion and peak knee abduction (d)

Our study demonstrated that the peak hip adduction angle was not correlated with the peak knee abduction according to the Pearson correlation coefficient. The foot placed in maximum knee flexion and a hip adduction angle greater than 5° increased the ACL risk of injuries [24]. In the present study, during single-leg drop landing, preadolescent female soccer players possibly experienced considerable stress on the ACL in the dominant lower limb due to larger hip adduction and internal rotation as well as the combined dynamic valgus knee. However, we failed to find a significant correlation between peak hip adduction and peak knee abduction angles. During a single-leg task, a larger hip adduction angle but not a hip internal rotation angle was connected to a higher knee abduction angle [15]. The main reason for the difference is the type of tasks and the age of the subjects. Another remarkable point to be mentioned about this subject is that hip rotation is affected by the internal rotation of the tibia. To put it another way, when the tibia internal rotation happens with the hip external rotation with flexed knee, the knee abduction might be increased [16].

In the present study, preadolescent female soccer players landed with increased trunk lateral flexion, and rotation angles but no correlation was found between peak trunk rotation, lateral flexion angles, and peak knee abduction angle during single-leg drop landing. Nakagawa et al. reported that a large ipsilateral lateral trunk flexion was significantly related to higher knee abduction in healthy participants [25], which is inconsistent with the present study. Different tasks of assessing kinematics also lead to different results. When female athletes reach maturity, weak "core stability" may affect increased dynamic knee valgus during dynamic tasks [26]. It is stated that the development of poor movement patterns in early-pubertal females is because of an increase in height and weight, leading to more loading on ACL injuries [27]. Willy et al. reported that core strength training, including strengthened gluteal muscle exercises, can reduce ACL risk factors, like the valgus knee [28].

Additionally, higher hip external rotation and knee internal rotation angles may be associated with ipsilateral trunk rotation during bilateral jump tasks [16]. However, in the current investigation, the correlation between hip and knee rotations was disregarded. Next studies are essential to exhibit risky kinematic relationships among female soccer players in early puberty. In general, to control hip alignment properly, it is important to activate the contraction of hip external rotators eccentrically during landing [13]. Also, it was suggested that intervention programs to control knee abduction motion in early puberty may be an effective time during maturation [29].

5. Conclusion

This study investigated the relationship between hip kinematics and peak valgus knee in preadolescent soccer players. The Pearson correlation coefficient indicated that there is a kinematical connection between peak hip internal rotation angle and peak knee abduction with a weak correlation value. Therefore, kinematic risk factors related to ACL injuries in combination with neuromuscular control trunk and hip can be considered during more demanding tasks in future studies. Furthermore, the significant kinematic association of peak hip adduction, peak trunk rotation, and peak trunk lateral flexion with peak knee abduction angle was not determined. It is suggested that neuromuscular training to avoid a large knee abduction angle might be advantageous among female preadolescent soccer players.

Some limitations should be considered in this study. First, to the identification of ACL injury mechanisms, other landing tasks, like double-leg jump and vertical drop jump should be evaluated. Only kinematic variables were analyzed. Future studies should include kinetic assessments. Moreover, only preadolescent female soccer players were included in the present study and the findings cannot be generalized to males or other athletes.

Ethical Considerations

Compliance with ethical guidelines

The Local Ethics Committee (Ethical Code: IR.BASU.REC.1400.035) regarding the standards and guidelines of the Declaration of Helsinki confirmed and registered the study protocol.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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