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The Relationship of Anatomical Alignment and Strength of Some Lower Extremity Muscles with Jump-landing Biomechanics: A Landing Error Scoring System Study

Mohammad Fallah Mohammadi, M.Sc.[1], Sadroddin Shojaadin, Ph.D.[2], Amir Letafatkar, Ph.D.[3], Esmail Ebrahimi, Ph.D.[4], Mansour Eslami, Ph.D.[5]

1- PhD Candidate, Department of Biomechanics and Sports Medicine, Faculty of Physical Education and Sports Sciences, University of Kharazmi, Tehran, Iran (Corresponding author; E-mail: mohammad1671@yahoo.com)

2- Associate Professor, Department of Biomechanics and Sports Medicine, Faculty of Physical Education and Sports Sciences, University of Kharazmi, Tehran, Iran

3- Assistant Professor, Department of Biomechanics and Sports Medicine, Faculty of Physical Education and Sports Sciences, University of Kharazmi, Tehran, Iran

4- Professor, Department of Rehabilitation, Faculty of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

5- Associate Professor, Department of Sport Biomechanics, Faculty of Physical Education and Sports Sciences, University of Mazandaran, Babolsar, Iran

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Abstract

Background: The purpose of the present study was to investigate correlative and predictive relationship of lower extremity anatomical alignment, isometric hip abduction and external rotation strength with jump-landing biomechanics using Landing Error Scoring System (LESS).

Methods: Anatomical alignment and isometric lower extremity muscle strength of 30 active men (mean age of 21.27±2.12 years) have been assessed through goniometry and dynamometry tests, respectively. Then, subjects have performed LESS test for the analysis of their jump-landing biomechanics.

Results: There was no significant correlative or predictive relationship between overall LESS score and femoral anteversion angle, tibiofemoral angle, Q angle, navicular drop, tibial torsion, abduction and external rotation isometric strength (P>.05). However, statistically significant negative correlation has been found between knee hyperextension angle and LESS score (P= .01, r= -.4).

Conclusion: The findings of the present study showed that lower extremity anatomical alignment and isometric strength measurements has no significant relationship with dynamic biomechanics of jump-landing. This is probably due to the difference in nature of static and isometric measurements and dynamic functional movements.

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Introduction

Anterior Cruciate ligament (ACL) injury in sport is regarded as serious and those athletes suffered from this injury are predisposed to develop osteoarthritis (1). ACL injury happens frequently in non-contact situations such as deceleration, landing from a jump or during cutting maneuver (2). Kinematic patterns that are associated with increased risk of ACL injury include landing with erect posture of knee, hip and trunk which leads to increase of ACL shear force (3). One of the most dangerous and important movement patterns, especially when landing from a jump, is valgus collapse or medial movement of the knee (4). Researchers showed that valgus moment during jump-landing is a predictor of ACL injury and also ACL strain level during landing increases following valgus loading raising (5, 6). Moreover, combination of valgus loading and knee external or internal rotation moment will increase tensile force on ACL (7). It has been suggested that hip abductors and external rotators have a critical role in controlling this valgus movement (8, 9). Hashemi and colleagues (2011) reported that athletes with hip abduction and external rotation weakness are more exposed to lower extremity injuries during in-season period (10). Major muscles responsible for controlling knee dynamic valgus including gluteus medius, gluteus maximus and tensor fascia latae, all have important roles in gait phases and landing mechanics. Lacking sufficient strength in these muscles causes increased movements in frontal plane, especially knee abduction, which can make athletes prone to ACL injury. Furthermore, muscles involved in hip external rotation are responsible for protecting hip against excessive internal rotation produced in athletic movements in transverse plane. Gluteals are acting eccentrically to control hip excessive internal rotation so their strengthening may be effective in reducing potentially dangerous moments at knee (11).

In addition to muscle strength, anatomical attributes may also have a determinant role in increasing risk of ACL injury. Recently, Stiffler and coworkers (2015) demonstrated that there is a relationship between increased quadriceps angle (Q-angle), decreased navicular drop and active medial knee displacement during single leg squat (12). Increase in Q-angle may lead to decrease in muscular control and knee dynamic valgus during landing from a jump, though there are contradictory reports regarding relationship between Q-angle and ACL injury (13, 14). Moreover, knee hyperextension over 10 degrees is shown to have relationship with ACL injury (15). Also, femoral anteversion may affect lower extremity alignment through changing relative tensioning on lower body muscular structures (16). Shultz et al (2012) showed that increase in pelvic tilt can lengthen and weaken hamstrings and gluteals and also increase in anteversion may cause gluteus medius weakness (17). Theoretically, hamstrings weakness lets anterior shift of tibia, and decrease in gluteus medius strength may expose athletes to valgus collapse during rotation and cutting movements. Additionally, it is indicated that increase in femoral anteversion is associated with increase in subtalar pronation and navicular drop, both of which are among risk factors of ACL injury (15).

In fact, studies conducted on the relationship between either muscle strength or anatomical alignment and dynamic movement pattern such as jump-landing are very common and extensive, but a comprehensive research looking on all those variables altogether is rare. For instance, Beutler and coworkers (2009) examined the effect of anthropometric features and muscular strength on differences in jump-landing qualities in military males and females. Authors selected navicular drop, Q-angle and BMI as anthropometric measures and also assessed isometric strength of hamstrings, gluteus maximus, gluteus medius, quadriceps, hip external and internal rotators using a handheld dynamometer. After examining jump-landing techniques, it was shown that muscular strength and anthropometrics could not predict jump-landing techniques in none of the two genders (18).

Importantly, identification of athletes with poor jump-landing technique may be difficult for some professionals, especially if it is to be carried out in a large scale. In order to screen such athletes, it is essential to examine their movement patterns in all planes. This is primarily done by expensive and complicated three-dimensional motion analysis systems. In recent years, a valid and efficient tool has been established that can be an appropriate alternative to complicated laboratory systems. Landing Error Scoring System (LESS) is a valid and reliable tool for the assessment of jump-landing biomechanics in large groups. The validity and reliability of LESS compared to 3D motion analysis system have been confirmed (19-23), but it is more applicable and less time-consuming to be operated in large scale studies. In this method, by reviewing recorded videos of jump-landing maneuver from frontal and sagittal views, the quality of athlete's technique is scored through a 15-item questionnaire. The overall score shows athlete's jump-landing quality (19).

Authors could not find any study carried out on the correlation of anatomical alignment (femoral anteversion angle, tibiofemoral angle, Q-angle, navicular drop, knee hyperextension, tibial torsion) and muscle strength with jump-landing biomechanics using Landing Error Scoring System. Therefore, the present study was done with the aim of finding correlative and predictive relationship of anatomical alignment and isometric hip abduction/external rotation with jump-landing biomechanics (overall LESS score) in active men.

Methods

Thirty active men (mean age of 21.27±2.12 years) who had regularly exercised 3 sessions per week, participated in this semi-experimental study. The number of subjects was determined using G-Power sample size calculation software (with effect size to be 0.50, power to be 0.80, and alpha to be 0.05). All subjects filled demographic and medical history forms prior to the test. Dominant foot was determined asking the question "by which foot do you prefer to kick a ball?" Exclusion criteria included ACL injury history, trunk or lower extremity surgery background, serious lower extremity injury since last year, and persistent pain. Before starting the tests, all subjects filled and signed the consent form and then test procedure was explained for them.

Measurement of Anatomical Alignment

Anatomical alignment variables involved femoral anteversion angle, tibiofemoral angle, Q-angle, navicular drop, knee hyperextension, and tibial torsion that were measured using Universal goniometer and according to protocol suggested by Lohmann et al. (1988)(24).

Femoral anteversion: Subject was in prone position with knee in 90° flexion. The angle between a line perpendicular to test table and a line drawn from tibial tuberosity and center of tibial articular surface to metatarsal bones was measured.

Tibiofemoral angle: This angle was measured according to femoral and tibial anatomical shafts. Superior landmark in the middle of a line between the most prominent area of greater trochanter and ASIS, medial landmark in the center of knee joint (middle of femoral condyles), and inferior landmark in the middle of tibial articular surface (middle of a line between lateral and medial malleoli) were determined using a caliper with the accuracy of 1 mm.

Knee hyperextension: This angle was measured in standing position. The angle between hip joint (line between center of greater trochanter and the center of femoral lateral epicondyle) and tibia (line between the center of knee joint laterally to the lateral malleolus) was measured using a goniometer.

Navicular drop: First, navicular prominence point was touched and marked in standing position. Then, as subtalar joint is in neutral position (position where lateral and medial aspects of talus are equally palpable), the distance between navicular bone and floor was measured by a ruler. Next, the subject was asked to stand in a way that the test foot was relaxed and non-weight bearing. Finally, the difference between navicular heights in neutral and relaxed positions was recorded in millimeter.

Q-angle: Subject was in the standing position while his knee and hip joints were in normal extension. First, a line was drawn from ASIS to the center of patella and another line was drawn from tibial tuberosity to the center of patella. The angle between these two lines was measured using a goniometer and considered as Q-angle.

Tibial torsion: Subject was in the prone position. The centers of malleoli were marked while knee was in 90° flexion. Next, a line between two malleoli was drawn in plantar surface of the foot. The angle between a line bisecting inter-malleoli line and a line from the center of hip joint was measured and considered as tibial torsion angle.

Measurement of Isometric Hip Muscles

Hip abduction: This measurement was in accordance with Bohannon protocol (26). Subject was side-lying on the test table and a handheld dynamometer (Nicholas, Lafayette, US) was placed on the lateral side of femur, 5 cm proximal to the lateral articular line of the knee. A large pillow was placed between subject's legs so that both hips were fixed in 0° abduction relative to the line connecting right and left ASISs. A strap was tied in the region proximal to the iliac crest and fixed the trunk to the test table. The center of dynamometer's surface was directly placed on the point marked over the knee. Dynamometer was tied to the table using another strap. Subject was asked to move his leg upward with maximal effort. Test-retest reliability of this method was determined to be 0.95 (25) (figure 1a).

Hip external rotation: This measurement was based on the procedure suggested by Cahalan et al. (1989) (27). Subject was sitting on the table with his hips and knees in 90° flexion. A strap was tied around the subject's hip and the table. A rolled towel was placed between knees to maintain the position and minimize rotation generated by hip adductors. Dynamometer was placed in a way that the center of its surface was fixed directly on the point 5 cm proximal to the medial melleolus of the test leg. A strap was tied the dynamometer to the table. The subject was asked to rotate his leg toward dynamometer with maximal effort. Test-retest reliability of this protocol was determined to be 0.83 (27) (figure 1b).

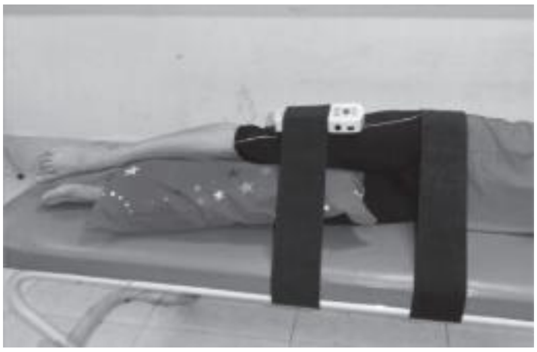

Figure 1a. Isometric hip abduction strength measurement

Figure 1b. Isometric hip external rotation strength measurement

Jump-Landing Test

Landing Error Scoring System was used for the assessment of jump-landing technique of subjects. The jump-landing task included a jump from a 30-cm high box to a distance of 50% of subject's height away from the box, down to the floor, and immediately rebounded for a maximal vertical jump on landing. During task instruction, emphasis was placed on subjects jumping as high as they could once they landed from the box. Subjects were not provided any feedback on their landing technique unless they were performing the task incorrectly. After task instruction, the subject was given as many practice trials as needed (typically 2) to perform the task successfully. A successful jump was characterized by (1) jumping off of both feet from the box; (2) jumping forward, but not vertically, to reach the floor; (3) landing with the entire foot of the dominant lower extremity on the floor; (4) landing with the entire foot of the nondominant lower extremity off the floor; and (5) completing the task in a fluid motion. Two standard video cameras (Canon-MD255, Japan) captured a frontal plane and sagittal plane view of each subject from 4.8 and 4 meters, respectively, as he performed the testing procedures.

There are 15 scored items in the LESS. One set of items addresses lower extremity and trunk positioning at the time of initial contact with the ground (items 1-6). A second set of items assesses errors in positioning of the feet (items 7-11) and are scored at initial ground contact (item 11), at the time the entire foot is in contact with the ground (items 7 and 8), and between the time of initial contact and maximum knee flexion (items 9 and 10). A third set of items assesses lower extremity and trunk movements between initial contact with the ground and the moment of maximum knee flexion angle (items 12-14) or the moment of maximum knee valgus angle (item 15). Finally, average overall score of 3 trials is recorded as subject's jump-landing score (19).

SPSS (version 21) was used for statistical analysis of the obtained data. Pearson correlation and multivariate regression tests were performed to examine predictive relationship of variables with LESS scores ($P \leq 0.05$).

Results

Descriptive data including subjects' weight, height, age, and BMI and also data regarding research variables are provided in tables 1 and 2, respectively.

Table 1. Subjects' biometrics

Variable	Mean (±Standard deviation)
Age (year)	21.27 (2.12)
Height (cm)	177.7 (6.59)
Weight (kg)	69.42 (6.94)
BMI	21.98 (2.04)

Table 2. Descriptive data of research variables

	Mean (±Standard deviation)
LESS score	3.31 (1.85)
Femoral anteversion (degree)	10.92 (3.48)
Tibiofemoral angle (degree)	6.42 (1.41)
Q-angle (degree)	13.03 (1.82)
Knee hyperextension (degree)	2.23 (1.10)
Tibial torsion (degree)	8.28 (2.45)
Navicular drop (mm)	5.80 (1.76)
Hip abduction strength (kg)	12.90 (2.38)
Hip external rotation strength (kg)	10.72 (2.16)

According to the findings presented in table 2, average overall score of LESS was 3.31±1.85 (ranged 1 to 7) which is considered to be a relatively good score. Furthermore, findings from Pearson correlation and multivariate regression tests are provided in tables 3 and 4, respectively.

Table 3. Pearson correlation results related to the research variables and LESS score

	Femoral anteversion	Tibiofemoral angle	Q-angle	Knee hyperextension	Tibial torsion	Navicular drop	Hip abduction strength	Hip external rotation strength
Correlation with LESS	0.01	0.1	-0.01	-0.4	-0.24	0.05	-0.02	-0.287
P value	0.48	0.31	0.47	0.01*	0.11	0.39	0.44	0.078

* Shows significant correlation with dependent variable (P≤0.05)

Table 4. Multivariate regression results

Variable	B	Standard error	t value	P value
Femoral anteversion	0.04	0.16	0.15	0.88
Tibiofemoral angle	-0.03	0.54	-0.93	0.92
Q-angle	0.06	0.31	0.22	0.83
Knee hyperextension	-0.95	0.65	-2.42	0.04*
Tibial torsion	-0.01	0.41	-0.02	0.98
Navicular drop	0.18	0.48	0.4	0.7
Hip abduction strength	-0.61	0.12	1.10	0.28
Hip external rotation strength	-0.81	0.42	-1.64	0.11

* Shows statistically significant value

As is shown in tables 3 and 4, the only variable that has significant but negative correlation with LESS score is knee hyperextension (P = 0.01, r = -0.4). Moreover, this variable has significant predictive relationship with overall LESS score (P=0.04, r^2 = 0.16). However, other variables have no significant correlation or predictive relationship with LESS score.

Discussion

The purpose of the present study was to investigate the relationship of anatomical alignment and hip abduction/external rotation strength with jump-landing biomechanics using Landing Error Scoring System (LESS). Our findings showed that among all of the studied variables, knee hyperextension had a reverse correlation with jump-landing biomechanics.

Few studies have been conducted on association of anatomical alignment and muscular strength with jump-landing biomechanics. One of these studies has been carried out by Beutler and coworkers (2009) on the effect of anthropometric features and muscular strength on differences in jump-landing qualities in both sexes. They tested jump-landing techniques via LESS and found that in females, poor techniques were associated with lower knee flexion angles throughout landing period. But, poor techniques in males were related to toe-out landing, heel contact landing, and asymmetric landing. However, authors emphasized that according to univariate and multivariate analysis, muscular strength and anthropometrics could not predict LESS scores in either of the two genders. They noted that the reason was due to differences between military cadets and ordinary people, and also due to the importance of LESS weakness that is substituting movement patterns with "errors" (18).

LESS is a qualitative scoring system that regardless of its undeniable and evidence-based shortcomings, can assess jump-landing quality as fast as possible and its reliability and validity compared to 3-dimensional motion analysis systems has been confirmed (22). In fact, precise and quick identification of people at risk of injury is a critical step to prevention, especially in athletic settings. Since high risk movement patterns are related to ACL injury probability, the possibility of quick screening of these patterns may facilitate implementation of preventative efforts in large scale.

Several studies indicated the relationship between muscular strength and lower extremity alignment during functional movements such as landing from a jump (28-31). Wilson and colleagues (2006) probed the association between strength of some lower extremity muscles and lower body alignment during single leg squat in men and women. After measuring isometric trunk flexion/extension/lateral flexion, hip external rotation and knee flexion/extension, authors found high risk movement pattern in women due to lower isometric trunk, hip and knee strength. Also, hip external rotation had the highest relationship with these patterns (25); a conclusion that is not compatible with the present study.

Researchers have introduced a dynamometry technique for assessing hip abduction and external rotation that is highly feasible. The ICC of this technique is more than 0.90 which is acceptable (29). This level of reliability enables professionals to screen those athletes who are at risk of knee injury and engage them in a strengthening program. The present study has enjoyed these techniques to determine hip abduction and external rotation profiles in order to test the effect of this factor on jump-landing technique.

However, in this study, anatomical lower extremity alignment and hip abduction/external rotation strength showed no significant correlative and predictive relationship with LESS scores. One of the reasons for this finding may be that anatomical measurements in this study have been performed in static condition, while jump-landing maneuver is a dynamic quality and these measurements do not reflect loading aspect of lower extremity during dynamic situations.

So regarding aforementioned factors, it is recommended that future studies focus on dynamic assessments of anatomical alignments and isokinetic muscular strengths. Furthermore, increasing sample size and also conducting comparative studies between two genders may help in achieving more accurate results. In general, it seems that practicing such studies –that focus on screening at risk athletes- is vital in order to prevent serious injuries which may threaten athletic career and life of an athlete. It is undoubtedly a helpful suggestion to use practical methods in assessment of high risk patterns which may be considered as alternatives to expensive and complicated laboratory systems.

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