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The Effects of Three Types of Prophylactic Knee Bracing on Abduction Angle and Abduction Moment of Knee Joint in Foot Rotation Positions during Single Leg Landing in Anterior Cruciate Ligament Injury?

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Original Article

Abstract

Introduction: Anterior cruciate ligament injury is one of the most common sport injuries that happen during repeated landing movements. The aim of the present study was to investigate the effect of three preventive knee joints on the variables of abduction angle and abduction moment in three types of single leg landing in healthy young people.

Materials and Methods: 15 healthy young people participated in this research. These participants were asked to descend from a platform with height of 30 cm on a force plate in three directions of forward, inward, and outward. Data were recorded during synchronization of camera and force plate, and maximum abduction angle and abduction moment were calculated using MATLAB software. To test research hypotheses, repeated measures ANOVA with a significance level of more than 0.05 was used to evaluate the interactive effect of different types of knee-braces on different landing.

Results: The interactive effect of different types of knee-braces on abduction (P = 0.416) and abduction moment (P = 0.442) did not depend on the type of landing. There was no significant difference between different knee braces in knee abduction (P = 0.759) and knee joint abduction moment (P = 0.657). There was significant difference between types of landing in knee abduction angle (P = 0.007) and abduction moment (P = 0.001).

Conclusion: Regarding the findings of this research, it seems that between the two variables of landing and knee brace, the first one is more important, and athletes should avoid landing with external leg rotation as far as possible.

Keywords: Knee, Braces, Landing, Abduction angle, Abduction moment, Anterior cruciate ligament injuries

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Introduction

Anterior cruciate ligament (ACL) injury often occurs in sports such as basketball, volleyball, football, and badminton (1-3). Initial ACL function prevents anterior transfer and tibial rotation relative to the hip. Accordingly, ACL rupture increases the anterior transfer and tibial rotation (4,5). Most of the major known risk factors in ACL injury such as lower knee flexion angles, increased hip adduction and internal rotation, increased knee abduction, and internal and external tibial rotation, which take place on the sagittal plane, are involved in the increased ACL load in the noncontact form during landing (6-8). It seems that the smallest changes in the lower limb during a change in the leg position affect the dynamic variables of the knee.

Researchers have designed and examined various knee braces to prevent and reduce injuries caused by the effects of foot landing, with multiple uses including knee stability, prevention of knee joint injury, and acceleration of the recovery of the injured joints. Prophylactic knee braces are one of the types of the knee braces used to prevent and reduce the knee injury (9,10). Findings of studies suggest that the use of semi rigid knee braces at the sagittal landing plane reduces knee abduction angle further compared to the elastic braces (11-14), while the use of the hinge braces increases the abduction angle

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(15), however no difference is observed in the knee abduction angle with the elastic braces. In addition, the results of studies showed a decrease in the knee abduction moment using the elastic brace (16,17), but there was no difference in the knee abduction moment with the TriZone brace (18). Distributing the load away from the knee joint, the brace causes changes in neuromuscular control, hence protecting the joints against impact loads and valgus pressures (19). Factors such as the use of different knee braces, differences in the participant groups, association with a particular sport, or different landing conditions, may be the causes of inconsistency in the findings on applying different braces in the knee joint dynamic variables.

Most of the studies on knee variables have focused on the direct landing and less on the foot rotation in the internal and external landing. Depending on the racing situations and sports activities, the landing may be executed with different functional needs and the individual may land with the foot internal or external rotation when performing the sport skills based on the different conditions. Since there has been no comprehensive study regarding landing with common prophylactic knee braces in the Iranian market, there is no specific rule in their prescription. Moreover, there is insufficient information on how the knee variables dynamically respond to the rotational movements of feet with braces. Furthermore, there are no specialized investigations on the effects and interactions among different types of braces on the foot landing rotation status and dynamic risk factors for knee joint injury. Therefore, the present study is carried out with the objective to examine and compare the effects of foot landing in terms of the dominant force applied on the knee (internal, external, and forward rotation) with and without the use of prophylactic knee braces on some knee dynamic variables selected (knee joint abduction angle and abduction moment).

Materials and Methods

This was an applied and quasi-experimental study in which the subjects included 15 male students of University of Mazandaran, Babolsar, Iran, who had chosen a general physical education course and were not part of any sports team. The participants were enrolled in the study using a physiotherapist using the convenience sampling method and were selected using G*Power software (version 3.1.5, University of Düsseldorf, Düsseldorf, Germany) with $\beta = 0.80$ and $\alpha = 0.05$ (20). The research project was approved by the ethics committee of University of Mazandaran. Before the test, the informed consent form was completed and signed by the volunteers and their demographic and anthropometric information was recorded. The inclusion criteria included healthy male students, right dominant leg, and no history of abnormalities, fractures, and lower extremity injuries. Similarly, the exclusion criteria were genu varum, genu valgum, and lower extremity antevergen. To measure the kinetic variable, the Kistler force plate device (Kistler force plate, Winterthur, Switzerland) with dimensions of 40 × 60 cm^2 and sampling rate of 1000 Hz was utilized and the data were recorded in the Simi Motion software (Sweden) in a synchronized manner. In order to record the landing kinematics components, 6 imaging cameras (Basler, Motion Analysis, Japan) with 200 Hz sampling rate were used. This information was then made available as raw information using the Simi Motion software.

The prophylactic knee braces in the present study (with two springs, four springs, and no springs or plain) were used with open patella design and upper and lower sticking straps (Khazar Teb Tabarestan Co., Iran). Supportability, stability, and adjustability of these knee braces are provided by flexible metal parts and the supporting pads and are made of neoprene fabric and differ only in the number of metal springs (Figure 1).

Figure 1. Knee brace of neoprene fabric

In the present study, markers with a diameter of 22 mm were used. Based on the study requirements and previous studies, markers were located in the “left and right anterior iliac spine, center of sacroiliac joint, internal-external epicondyle, internal and external ankles, heel center, distal end of the first and fifth finger bones, distal end of the third phalanx bone of the second finger” and eight markers in two clusters along the outer thigh and leg (21).

The present study was carried out in the Biomechanics Laboratory, Department of Sport Biomechanics, School of Sport Sciences, University of Mazandaran. Prior to starting the study, the participants signed the consent form. Initially, the anthropometric characteristics including height and weight were measured and after warm-up and landing exercise for 10 minutes, the markers were attached to the spots on the limbs. After ensuring the accuracy of the devices (force plate and camera) and calibrating (using a fixed 12-point cube) and synchronizing them, the subjects stood on a 30-cm high platform and landed with their hands free and bare right dominant leg at an angle of 30° on the force plate in three modes (forward, inward, and outward) and with various knee braces (four-spring, two-spring, simple, or spring free braces, and without braces). In this way, one of the knee braces was randomly fastened, and the subject landed in the forward, inward, and outward directions, then another knee brace was fastened, and three types of landing were performed. Each landing was repeated several times, and three successful landings (as balanced and without the contact of the non-dominant foot with the ground) in each direction, with and without the various knee-brace types were selected for analysis. A 5-minute break was given between the two landings with the knee brace. To prevent the effect of primacy of performing the knee braces on the results, fastening them was performed randomly among the subjects to measure only the effect of the independent variable (Figure 2).

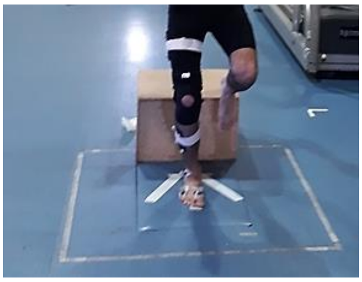

Figure 2. An overview of the three types of landing

After recording the images with six calibrated cameras, the 3-dimensional coordinates of the markers were extracted from the Simi Motion software. Additionally, the relative angles of the knee joint were calculated by subtracting the absolute angles of two adjacent organs in three planes and knee maximum abduction angle and abduction moment by inverse dynamics in MATLAB Software Version 15 (Matlab software, Mathworks Authors and Developers, USA). In the present study, the XYZ Cardan rotation sequence was used. Based on the rules, the first, second, and third rotation around the X-axis, Y-axis, and Z-axis at the sagittal plane, frontal plane, and horizontal plane are obtained as flexion-extension, adduction-abduction, and internal-external rotation, respectively (22).

The main objective was to examine the interaction effect of the different types of the knee braces on the type of landing, i.e. did the type of landing vary depending on the type of the knee brace applied? Accordingly, the repeated measures analysis of variance (ANOVA) test was employed. If the interaction effect was significant, it would indicate the effectiveness of the type of the knee brace on the landing type. In this case, the one way ANOVA test was used to compare the difference of each landing type with each type of knee brace (4 × 3). If the interaction effect was not significant, then the main effect was used to investigate the landing type independently of the brace type as well as the brace type independently of the landing type. Accordingly, since the interaction effect was not significant in the present study, the landing type was evaluated independently of the brace type and the brace type independently of the landing type.

Descriptive statistics and Shapiro-Wilk test (inferential statistics) were used to determine the mean and standard deviation (SD) of the data and normality of the data distribution, respectively, moreover, the repeated measures ANOVA at the significant level of 0.05 was exploited to evaluate the difference between different landing states with the various knee brace types. Finally, the data were analyzed in SPSS software (version 23, IBM Corporation, Armonk, NY, USA).

Results

The mean age, weight, height, and body mass index (BMI) of participants of the subjects were 21.60 ± 2.29 years, 12.32 ± 74.40 kg, 176.53 ± 8.49, and 23.77 ± 2.82 kg/m^2 respectively.

Given the results of the repeated measures ANOVA, the effect of various types of the knee braces on the knee joint abduction (P = 0.435) and moment (P = 0.442) did not depend on the landing type (Table 1).

Table 1. Interaction of types of knee brace in three types of landing on knee joint dynamic variables

P value	Abduction	Abduction moment
Knee brace	0.699	0.657
Landing	≤ 0.001	0.001
Knee brace × Landing	0.435	0.442

Table 2. Comparison of mean peak knee abduction angle with and without knee braces

Variable	Knee brace type	Mean ± SD	F	Eta	Two-by-two comparison of knee braces	P value
Abduction (degree)	Two spring	-13.481 ± 13.560	0.478	0.330	Two spring-four spring	> 0.999
	four spring	-14.660 ± 12.148			Two spring-simple	> 0.999
	Simple	-12.982 ± 10.468			Two spring-spring free	> 0.999
	Spring-free	-13.206 ± 9.992			Four spring-simple	> 0.999
					Four spring-spring free	> 0.999
					Simple-spring free	> 0.999
Abduction moment (N.m/kg)	Two spring	-1.411 ± 0.568	0.387	0.027	Two spring-four spring	> 0.999
	Four spring	-1.326 ± 0.615			Two spring-simple	> 0.999
	Simple	-1.317 ± 0.633			Two spring-spring free	> 0.999
	Without knee brace	-1.445 ± 0.870			Four spring-simple	> 0.999
					Four spring-spring free	> 0.999
					Simple-spring free	> 0.999

SD: Standard deviation

There was not a significant difference between the types of the knee braces and without knee braces in the knee joint abduction variable (P = 0.759) and abduction moment (P = 0.657) (Table 2).

There was no significant difference between the knee brace-free state and with various knee braces in the dynamic variables of knee joint abduction angle and abduction moment (P < 0.050). Additionally, there was a significant difference between the various landing types in the variables of the knee joint abduction angle (P = 0.007) and abduction moment (P = 0.001). The difference between the three types of landing in the variables of the knee joint abduction angle and abduction moment was significant (P < 0.050) (Table 3).

Discussion

The objective in this study was to investigate the effect of three prophylactic knee braces on the variables of the knee joint abduction angle and abduction moment in three types of forward, inward, and outward rotation. The findings suggested that the effects of different knee braces on these variables did not depend on the type of landing and no significant interaction effect was observed between them. The results of studies have shown that there is no interaction effect between the brace-free and brace use states with jumping-landing functional movements (12,23). Therefore, it can be claimed that the effect of the knee brace does not depend on the type of landing and the two variables are independent and there is no interaction between them in the variables of abduction angle and abduction moment. Based on the results of the present study, it can be stated that knee braces had no effect on decreasing or increasing the dynamic variables, but the landings played an important role in the changes of the dynamic variables and reducing and preventing ACL injury. There has been no study investigating the foot landing state with internal and external rotation with the knee brace.

Table 3. Comparison of mean peak knee abduction moment in three types of single leg landing

Variable	Landing type	Mean ± SD	F	Eta	Two-by-two comparison of landings	P value
Abduction (degree)	Forward landing	-5.596 ± 3.176	24.883	0.640	Forward landing-Inward landing	0.041*
	Inward landing	-27.417 ± 14.277			Forward landing-Outward landing	> 0.999
	Outward landing	-7.734 ± 7.173			Inward landing-Outward landing	0.049*
Abduction moment (N.m/kg)	Forward landing	-1.345 ± 0.485	13.297	0.487	Forward landing-Inward landing	0.036*
	Inward landing	-0.914 ± 0.792			Forward landing-Outward landing	0.025*
	Outward landing	-1.838 ± 0.738			Inward landing-Outward landing	0.004*

* Significant difference
SD: Standard deviation

There was no significant difference between the mean peak abduction angle of the knee joint with and without the various knee brace types. In the study by Teng et al., the knee joint abduction angle with a knee brace was higher compared to without a knee brace (2). Lack of significant differences in the results of studies by Wu et al. (11), Yang and Lim (16), Ewing et al. (24), and Yu and Garrett (25), reduction of knee abduction angle in the study by Hanzlikova et al. (26), and reduction of abduction moment in the study by Yang and Lim (16) were reported, which can be attributed to differences in the type of the knee braces and functional movement. Given the results of studies, knee braces do not restrict the acute angles of the knee joints, but they may interfere with their physiological movements, and the protective effects of the knee brace may lead to another physiological mechanism (12). Findings of studies have suggested that knee braces are not useful in reducing pain (27), knee motion range (27), performance, and muscle strength (28), however they can improve neuromuscular electromyographic and proprioceptive activity (28-30).

In a study, Mortaza et al., investigated the effect of prophylactic knee braces on the performance of individuals using isokinetic and functional tests (cross-over and vertical jumping) in four states of without a knee brace, simple neoprene knee brace, four-spring neoprene knee brace, and prefabricated knee brace. They concluded that there was no significant difference in the indices studied with all three types of knee braces compared to the control group and that athletes could use prophylactic knee braces without affecting their performance (31). Sinclair et al. stated that there was no significant difference between the kinetic and kinematic variables in exercises with and without a knee brace, however the use of the knee brace increased the knee stability in the participants. They also reported that the use of the knee brace in the biomechanical indices associated with the knee injury is dependent on the tool used (23) and these observations are related to the mechanical structure of the knee brace that cannot provide sufficient physical restriction for changes in the knee joint loads.

One of the reasons for the lack of difference in the knee brace effect in the present study can be attributed to the study population and the physical condition and muscle strength of the healthy young subjects. It can be claimed that these individuals may have sufficient muscle strength in the lower limbs to overcome the resistance that may be applied by the knee braces to these changes, or that the level of restriction of these knees was unclear. The American Academy of Orthopedic Surgeons (AAOS) holds that knee braces can control the abnormal intensity or movements only in low or static load conditions and cannot protect the joint from injuries with severe activity or accidents (12). Studies have suggested that the knee braces protect ACL against low and weak forces, but do not resist to high-intensity force conditions (32). Thus, the mechanical structure of the knee braces applied in the present study may have been such that they could not provide sufficient physical restraint for the variations of different loads applied on the knees.

In a study, Ishida et al. found that external foot rotation with the knee abduction angle in the brace-free conditions increases the risk of knee injury due to its collision with the thigh condyle, besides, the internal rotation with the knee abduction angle compared to the knee abduction angle alone, leads to more ACL stretching. Therefore, they considered the forward-landing movement to be better than the inward and outward landing types (33). Teng et al. reported that the knee abduction angle increases with external foot rotation, and during the initial landing contact in the external rotation, the flexion angle is low and the screw-home mechanism occurs, causing the tibia external rotation on the thigh (2). As a result, landing in the rotation mode may increase the risk of ACL injury during single leg landing. Therefore, athletes should avoid leg landing in the outward mode during exercise.

The findings in the present study showed that leg landing in the inward mode had less abduction moment compared to forward and outward landing, with the highest abduction moment in the outward landing. In the outward foot landing, the knee joint abduction moment increases. Thus, landing in this situation increases the risk of ACL injury in the single leg landing. From a biomechanical point of view, an increase in the abduction moment arm increases the knee joint abduction moment, which is associated with the likely ACL rupture. In many studies, muscle weakness and greater involvement of the external side of the foot landing have been associated with the increased abduction angle and abduction moment at landing time, reduced joint control, and increased risk of ACL rupture (34). With the higher increase in the knee joint abduction angle and abduction moment during the outward landing, the rotation estimates become relatively larger as well. The larger joint rotation means stretching the position of the knee joint and ACL, leading to increased knee joint instability and ACL injury. Therefore, given the findings of the present study, it can be said that the effect of the knee brace in dynamic variables does not depend on the type of landing and does not exhibit an interaction with landing. There was no significant difference among the knee brace conditions in the dynamic variables of the knee joint and they had less role in the ACL injury, but there were differences among the three types of landing in both dynamic variables of the knee joint which could have a more significant role in the incidence or reduction of the ACL injury.

Limitations

The comparison of knee joints in few studies without comprehensive findings was one of the limitations of the present study. There were few studies in this field with various types of landing, hence further investigation is needed. Longer-term studies with larger sample sizes are required in order to achieve better results.

Recommendations

To better understand the compensatory function of other joints, the ankle and thigh joints should be examined simultaneously with the knee joint. In addition, to better understand the mechanism of this function, it is suggested to use electromyography of the lower limb muscles simultaneously.

Conclusion

The results of the present study showed that dynamic variables of the knee joint do not change using the knee brace; meaning that the knee brace could not provide an effective protection in the landing activity. Therefore, the landing variable seems to be more important to reduce the ACL injury in performing the movement, and athletes should avoid landing with the external foot rotation as much as possible since in the present study, forward landing reduced the abduction angle and the inward foot landing was along with the lowest knee joint abduction moment, hence athletes and coaches should focus more on the landing direction relative to the knee brace in their exercises.

Acknowledgments

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Authors’ Contribution

Hossein Goldashti: Study design and ideation, study executional and scientific services, providing study equipment and samples, Data collection, analysis and interpretation of results, manuscript arrangement, responsibility for maintaining the integrity of the study process From beginning to publication, and responding to referees’ comments; Mansour Eslami: Study design and ideation, specialized statistics services, specialized manuscript evaluation in scientific terms, confirmation of the final manuscript content for submission to the journal office; Mohammad Taghipour: specialized manuscript evaluation in scientific terms, confirmation of the final manuscript content for submission to the journal office.

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The present study was developed based on the analysis of part of the information extracted from the doctoral dissertation with code of ethics IR.UMZ.REC.1397.061 at University of Mazandaran. This university did not comment on data collection, analysis, and reporting, manuscript preparation, and final approval of the paper for publication.

Conflict of Interests

The authors declare no conflict of interest. Dr. Mansour Eslami received funding for basic studies related to this study from the University of Mazandaran and is active at this university. Hossein Goldashti is a PhD Student, Department of Sport Biomechanics, School of Sport Sciences, University of Mazandaran.

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