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Influence of Cleat Design on Knee Joint Moments During Cutting Maneuver and Instep Kick in Soccer

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SUMMARY

Background. This study aimed to compare the influence of different cleat designs on specific soccer movements.

Methods. The sample consisted of 10 recreational players who performed cutting and kicking movements using soccer shoes with three different cleat shapes: C1 (Circular), C2 (Rectangular) and C3 (Mixed). Kinematic data were collected using the Vicon system and an AMTI force platform. The moments were calculated by the Nexus System and the peaks extracted in Matlab at every 10% of the stance phase. Repeated measures ANOVA and the Bonferroni post-hoc test were conducted at $\alpha<0.05$ for statistical analysis.

Results. C1 exhibited a higher external rotation moment ($P<0.05$) at the onset of the stance phase than C2 and C3. In the kicking movement, C3 showed a higher valgus moment ($P<0.05$) than C2 and C1 in the first 10% of stance. C3 also obtained a higher internal rotation moment ($P<005$) at 60% of stance.

Conclusions. These results suggest that C1 may offer greater stability at the onset of the stance phase. In kicking, the different physical traits of C3 allow faster transition and deeper soil penetration.

Soccer cleats influence the knee joint moment during cutting movements and kicking. These results are important form to reduce the risk of injury.

KEY WORDS

Knee; Cutting; Kick; Soccer

INTRODUCTION

Soccer, one of the most popular sports in the world, is played in practically every country, including those in South America, where it exerts an extremely strong cultural influence (1,2). In recent decades, soccer has undergone significant technical, tactical and physical changes, demanding increasingly more from both professionals and amateurs (2–4). However, scientific knowledge of the sport has evolved to a lesser extent. The vast majority of soccer research is focused on improving motor movements, motor skill mechanics and understanding the forces exerted on joints, with a view to developing strategies that prevent injury (5,6). The motor movement that attracts the greatest interest in the literature is the kick, primarily in the leg performing the movement, due to its importance in soccer performance and results. However, few studies have been conducted on other important soccer movements, such as throw-ins, headers, jumps, goalkeeper movements, sprints, cutting maneuvers and support leg training in kicks (3,5,6). Cutting maneuvers and sudden stops are frequently executed in a soccer match, and should be investigated more in the literature, since they have consistently accounted for a large portion of injuries in the sport (5,7,8). With respect to the equipment used in soccer, recent decades have seen a considerable evolution in soccer shoe features, with increasingly bold and diversified designs, in addition to more modern materials (9,10). However, there is lack of scientific evidence about benefits or drawbacks of these technological advances, especially in terms of cleat shape.

Soccer shoes should provide comfort, good traction and stability, in addition to adequate sensitivity to execute movements during the match (11,12). In the course of their evolution, they have undergone several changes in materials. In the early 1900s, soccer shoes featured a leather upper and wooden sole and cleats, the latter soon replaced by the metal variety (9). The most modern materials currently used to make the upper and the sole have increased comfort, safety and possibly player performance. The two most widely used materials for soles and cleats are polyvinyl chloride (PVC) and thermoplastic polyurethane (TPU). The shoe outsole may change according with the design preference, such as length, width, diameter, shape, number and distance of studs (9). This different design of cleats, may increase safety of the players, with a better contact of the cleats to the ground during soccer movements, providing traction, which is an extremely important feature from performance and injury prevention standpoint (3,13,14). However, excess traction can be harmful to players, because their cleats may stick in the ground while executing cutting maneuvers or sudden stops, increasing the risk of non-contact leg injury (14–16). Non-contact injuries currently affect 78% of athletes, irrespective of sport (7,17). Most of these injuries, primarily in soccer, have occurred in the knee, around 48% affecting the anterior cruciate ligament (ACL) (7,17). Non-contact injuries are the most common in soccer players, and the use of inadequate shoes is an aggravating factor (1,18). A possible flaw in soccer shoes may be the arrangement and shape of the cleats, which could influence the magnitude of the moments and forces exerted on knee, ankle and hip joints (11,15,16). As such, the aim of this study was to compare the influence of three different cleat shapes on the knee joint moment during cutting maneuver and instep kick of soccer. Our hypothesis is that the different cleat designs will modify knee joint moments and the either cleat will exhibit a greater joint moment in the mid-stance phase than the round cleat, such as other authors (8,16). We further hypothesize that the cutting maneuver will produce different behavior in relation the instep kick.

METHODS

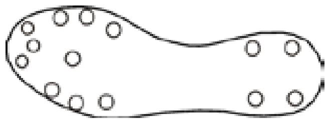
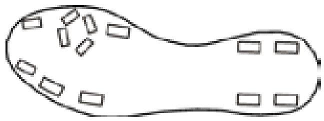
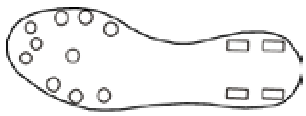
The sample consisted of 10 recreational players, weight 72.0±8 kg, height 1.70±0.7 m, BMI 24.8±3, shoe size 40 and age 29±6 years. The following inclusion criteria were adopted: at least two matches a week, a minimum of 3 years' experience, no injuries in the last 6 months and right leg dominance. This study was approved by the Research Ethics Committee of Vale do Rio dos Sinos University (UNISINOS) CEP UNISINOS - 007/2014. All participants gave their informed consent. Right leg dominance of the subjects was determined by the Waterloo questionnaire. The following equipment was used for anthropometric evaluation: stadiometer, metric tape measure and anthropometer. With respect to type of footwear worn, three soccer shoes with the same upper and different set of studs were compared (**Figure 1** and **Table I**).

The characteristic of the shoes selected, are detailed **Table I**. The three shoes used were made of PVC. This shoes was select because they are considered the most popular type of the cleats used in soccer. Furthermore, other study used this type of shoes for biomechanics analysis (1,11,12).

The following equipment was used to acquire dynamometric and kinematic data: a force platform (AMTIBP600600, Massachusetts, USA), six infrared cameras (VICON T-40, Oxford, UK), with a sampling rate of 200 Hz, and two video cameras, with a frequency of 100 Hz (BASLER, Ahrensburg, Denmark). Two photoelectric cells were used to monitor speed (SPEEDVIEW, TECSISTEL, Novo Hambur-

Figure 1. Soccer cleats used for evaluation: C1 - Circular cleats, C2 - Rectangular cleats, C3 – Mixed cleats.

Table I. Shoe outsole stud characteristics.

Soccer Shoes	Region	Number of studs (mm)	Length of studs (mm)	Diameter of studs (mm)	Width of studs (mm)	Distance of studs (mm)
	**Forefoot**	10	10	11	10,3	31
	Rearfoot	4	11	11	12	35
	**Forefoot**	10	10	0	9,5	32
	Rearfoot	4	15	0	10	39
	**Forefoot**	10	10	11	10,3	26
	Rearfoot	4	15	0	10	35

go, Brazil). REAL GAME monofilament artificial turf (PLACAR GROUP, São Paulo, Brazil), 52 mm high, 4 m long and 2.70 m wide, and an auxiliary 6 m x 1.70 m carpet were installed on a platform in the center of the laboratory (**Figure 2**). Only 1 to 3 mm-thick rubber granules were used for the installation. A total of 10 kg/m² of granules covered between 25 mm and 30 mm of the turf height, as proposed by El Kati (19). Ethylene vinyl acetate (EVA) sheets were placed throughout the laboratory in order to increase carpet adherence to the floor and subject safety during movements. The use of artificial grass for this study was because of difficulty methodological in installing a force plate on soccer field, but this no invalid the results, though exist a difference in impact forces between artificial turf and natural grass, this difference none with respect to type of shoe (1,11,14,23). Therefore the interest this study is the influence of soccer shoe on movement, and the grass not show interference in models tested. For data collection, participants wore only shorts, short barrel socks and soccer shoes (**Figure 2**). The first stage of the collection protocol consisted of anthropometric assessment, as follows: height, weight, leg length and bicondylar and bimalleolar diameters. After anthropometric evaluation, sixteen reflective markers were placed on the lower limb of the subject (two anterior superior iliac spines, two posterior superior iliac spines, two lateral epicondyles of the femur, two marker over the lower lateral 1/3 surface of the thighs, two lateral malleolus, two markers over the lower 1/3 of the shank, two second metatarsal heads, two posterior surface of calcaneous at the same hight above the plantar surface of the foot as the toes markers), in accordance with the Plug'n Gait marker model set (20) (**Figure 3**). The two marker of the foot, were fixed on the shoe, through of deep palpation of the bone prominences.

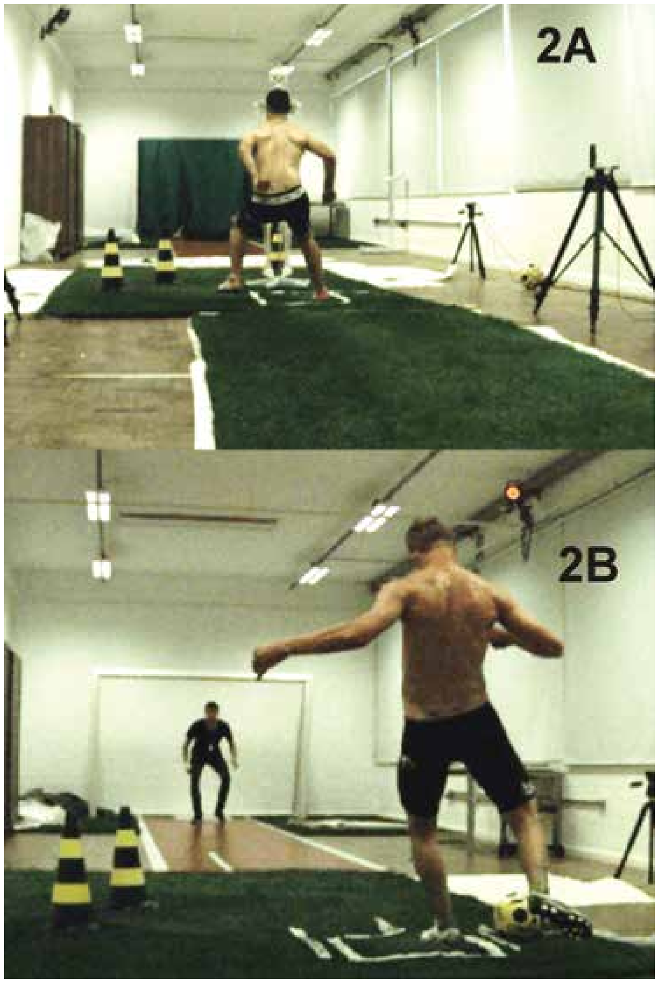


Figure 2. Set the lab during the Movements. (IIA) 45° Cutting Maneuver, (IIB) Instep Kick.

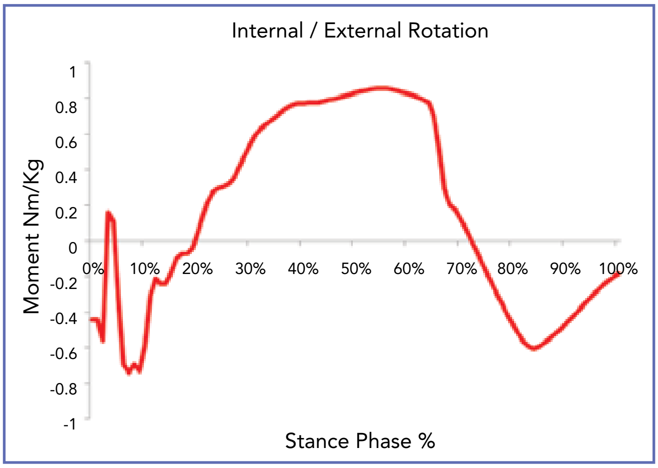


Figure 3. Process of dividing the data of the moment curve.

The order in which the soccer shoes were used was determined by random draw. Subjects were allowed 5 minutes to adapt to the proposed movements and collection environment. All the subjects made 10 trials under each condition, with a 30 to 60-second interval between movements.

Two movements were executed in random order, as follows:

45° cutting maneuver: Subjects stood 12 meters from the platform and at the signal, ran in a straight line towards the platform. Upon stepping onto the platform, they cut at an angle of approximately 45° and ran towards the marker located in front of them (21). The average speed was measured to all conditions of soccer cleats by two photoelectric cells positioned 2 meters before of the plate, with the aim of monitoring the approximation velocity of the subject (**Table II**).

Instep kick: Performed at a distance of 12 meters from a portable soccer goal (2.70 meters and 1.90 meters high), where the objective was to try with a maximal effort instep kicking, to score the goal. The trial, was considered valid when the player scored the goal, but there was not a visual target for player to hit. Subjects placed their support foot at a distance marked beside the ball, then kicked it with their instep. Neither kicking speed nor technique was controlled (**Figure 2B**).

In this study, the velocity of the ball was not measured, because the aim this analysis was the support leg, although it was asked for the subject to perform a instep kicking with maximum force. This guideline ensures that the athlete will perform with all conditions in the same manner.

Table II. Average of velocity during cutting movement.

C1(m/s)	C2(m/s)	C3(m/s)	P
2,95 ± 0,31	2,96 ± 0,21	2,96 ± 0,25	>0,05

The laboratory coordinate system was established at one corner of the one force plate, and all calculations were made with base this global coordinate system. The sample data for each segment was modeled as a rigid body with a local coordinate system that coincided with anatomical axes. The movements of translations and rotations were relative the neutral position established during a static standing trial. The software calculates the joint angle by means of a decomposition matrix based on Cardan sequences and six degrees of freedom model. The movements occur around 3 different axes, which describe two definition of movement each: flexion/extension, abduction/adduction and internal/external rotation. The moments of joint were calculate, via inverse dynamics method (Vicon Plug In Gait) which using of the values external forces applied to the inferior limb, the distribution of mass within the limb segments, the location of the joint center and the kinematic angle of the limb segments.

The data analysis was conducted using algorithms developed in the software (MATLAB® MATHWORK, Massachusetts, USA), which were used for to divide the movement into 10 phases during the foot stance, and flexion/extension, varus/valgus and internal/external rotation moments of the knee joint were calculated at every 10% of the stance phase (Figure 3), for each movement (8,22). For all data were extracted for the peak moments every 10% of the stance phase, in order to temporally identify the behavior of the respective knee joint moments during the movements performed, to identify the peak of joint moments in the anterior-posterior, medial-lateral and longitudinal axes in each (19).

Statistical analysis was carried out in SPSS software, version 20 (Chicago, USA). In one of the subjects, some attempts presented data outside normality, which ended up polluting the data, in an attempt not to lose a person from the sample, this was considered as an outlier, and removal of this data did not affect the analysis and the results of the study. After, the mean maximum and minimum peak of each subject were calculated at every 10% of the stance phase for each movement (8,22). Next, the Shapiro Wilk and Levene tests were applied to verify normality and homogeneity of variances. Repeated measures ANOVA and the Bonferroni post hoc test were used to determine the effect of different types of soccer cleats on the maximum and minimum peaks of knee joint moments during the movements assessed, at a significance level of $\alpha<0.05$.

RESULTS

Cutting movement: The cutting maneuver (**Figure 2A**) showed a difference between shoes only in the first 10% of the stance phase for the maximum peak of the external knee rotation moment (p=0.01). The C1 shoes (0.300 N·m/

kg) exhibited a higher external rotation moment magnitude when compared to their C2 (0.190 N·m/kg) and C3 counterparts (0.193 N·m/kg) (**Figure 4**).

For the minimum peak of the internal/external moment, there was no difference between shoes at any of the stance phase percentages (p>0.05). For sagittal plane moments, no

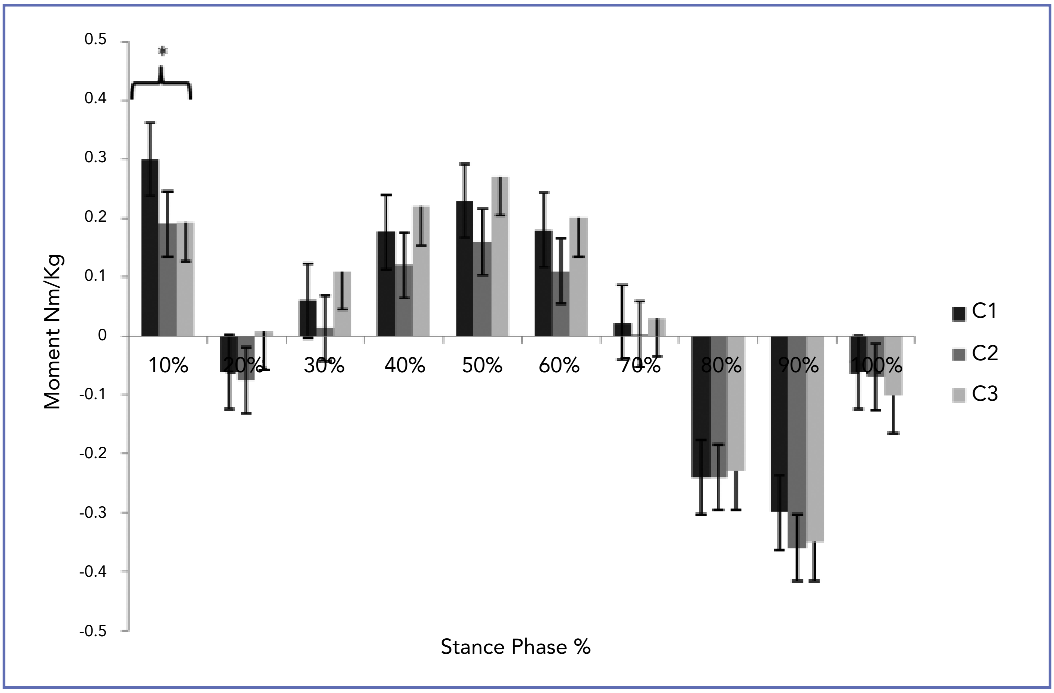


Figure 4. Comparative graph between the conditions with the maximum internal/external moment of the joint knee the each 10%of stance phase.
*Significant difference, p<0,05.

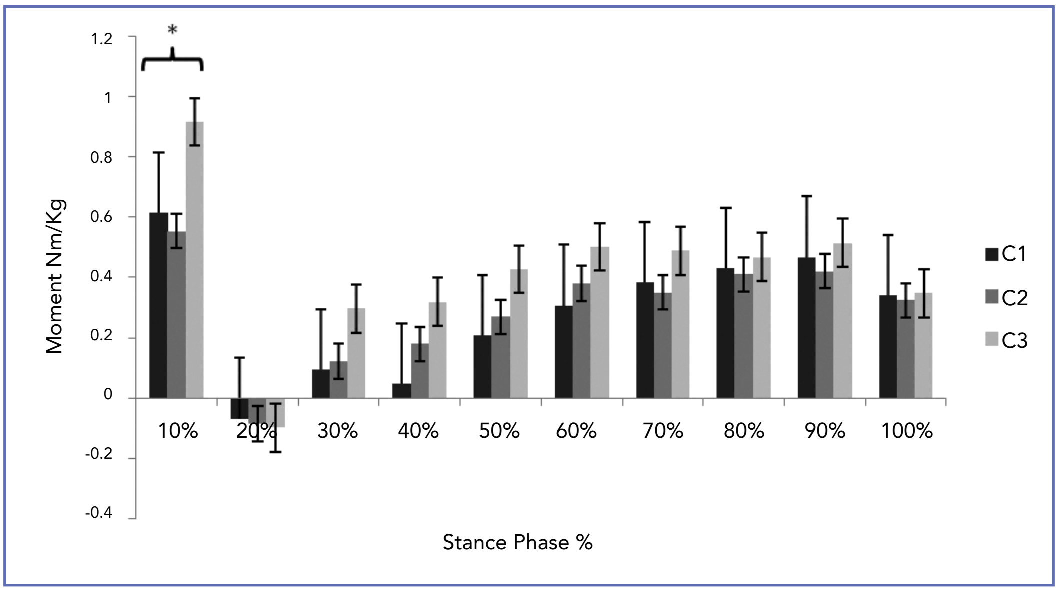


Figure 5. Comparative graph between the conditions with the maximum valgus/varus moment of the joint knee the each 10% of stance phase.

differences were observed at any of the stance percentages (p>0.05). With respect to the minimum and maximum peaks of knee joint moments in the sagittal plane, no differences were recorded at any of the stance phase percentages (p>0.05).

Kick: The kicking movement showed a difference in the frontal plane (**Figure 5**), in the first 10% of the stance phase for the maximum peak of the knee valgus moment (p=0.04). C3 shoes (0.915 N·m/kg) exhibited a higher knee valgus moment magnitude compared to C1 (0.614 N·m/kg) and C2 (0.553 N·m/kg).

A difference was found for the minimum peak of the internal knee rotation moment (p=0.04). C3 shoes (0.768 N·m/kg) obtained greater minimum peak magnitude compared to C2 (0.550 N·m/kg) at 60% of the stance phase.

No differences were observed for the maximum peak of the internal/external knee rotation moment at any of the stance phase percentages (p>0.05). In regard to flexion and extension joint moments in the sagittal plane, no differences were recorded for the minimum and maximum peaks of joint moments at any of the stance phase percentages (p>0.05).

DISCUSSION

The aim of this study was to determine the influence of different soccer shoe cleats on the knee joint moment. The results demonstrate that different cleat types influence the joint moment in the two movements under study, corroborating other investigations (3,11,18,21,22) and confirming our initial hypothesis that different cleat designs influence movement. The cutting maneuver showed a greater external rotation moment for circular cleat shoes (C1) in the first 10% of the stance phase when compared to the other cleat shapes used (**Figure 4**). The first 10% of the stance phase corresponds to the moment a player needs for neuromuscular pre-activation to help in absorbing body weight, since the body is not prepared for the initial foot-ground contact (23). Thus, in this phase cleat stability and traction are extremely important in helping athletes stabilize movement (1,5). The results show that the round cleat imposes a higher rotation load on the knee joint, suggesting that the use of this type of cleat may overload knee structures, thereby raising the risk of injury to the anterior cruciate ligament at initial foot-ground contact (1,5). The circular cleats provide less traction than the others, which may make the subject more vulnerable, increasing the external moments applied to lower limb joints and consequently requiring greater muscle activation to stabilize them, culminating in overload (1,5). In the present study, it is important to underscore that the either cleats tested exhibited a significantly lower rotation moment (**Figure 4**) than that of the other cleats at all the stance phases. Although this shape displayed better traction (8,13), it did not cause greater rotation moments when compared to the other cleat models. This result refutes our initial hypothesis that the either design would generate greater joint moments, particularly in the mid-stance phase, since no significant differences were observed between the cleats in this phase.

Higher rotation moments have been found in cutting maneuvers. A high rotation moment is one of the main factors causing knee injuries, primarily of the anterior cruciate ligament (3,8,19,21,22,24). Given that this common soccer maneuver exerts an overload 3 to 4 times the subject's body weight, it is believed that soccer shoes that decrease the overload applied to this joint would help prevent injury.

In the present study, no differences in knee joint moment were found between shoes during cutting maneuvers to the sagittal plane (flexion/extension moments). These results, as well as the moment values obtained, were similar to those of a number of literature studies (14,21). Likewise, frontal plane moments (valgus/varus moment) showed no differences at all stance phase percentages. This result corroborates those reported by (22), who also compared soccer shoes with different cleats during cutting maneuvers. Although either cleat shoes (C2) provided more traction, this trait did not result in greater overload in the mechanics of the movement, as occurs in higher knee joint moments. This demonstrates that biomechanical studies are necessary in order to develop soccer shoes that improve performance and prevent injury.

With respect to the kicking movement, no studies were found that compared the knee joint moment in the support leg, only the kicking limb. Corroborating our initial hypothesis, differences were observed between the kicking and cutting movements in the present study. For kicking, there were differences in the maximum peak of the valgus moment for mixed cleat soccer shoes (C3) in relation to the circular (C1) and rectangular (C2) shapes, in the first 10% of the stance phase (**Figure 5**). The highest valgus moment may cause greater overload on the medial collateral ligament (7,17). A higher internal rotation peak of the knee joint was also found in the support leg at 60% of the support phase of kicking for soccer shoes with mixed cleats when compared to their rectangular counterparts (**Table I**). These results may be associated with the different cleat heights, given that, despite the either shape on the heel of mixed cleat shoes, the lower cleat height resulted in a greater rotation moment in the knee joint at the onset of the stance phase. This suggests a lower cleat may contribute to faster foot transition after initial impact with the ground, causing greater impact on lower limb joints, due to the lower flexion angle of the knee at foot-ground contact, in addition to shorter response times in proprioception mechanisms. These aspects contribute to a greater valgus moment at the onset of the stance phase, raising the risk of knee injury, primarily to the anterior cruciate ligament, due to the combination of loads on the femur-tibia joint (18). Another factor that may have influenced the higher joint moment with mixed cleat soccer shoes is that their thinner cleats penetrate the ground more easily, thereby producing a greater rotation moment in leg joints (15). They also have irregular-shaped cleats, which may result in forces being exerted in different directions upon foot-ground contact, causing increased demand on skeletal muscles of the locomotor apparatus during the stance phase (25).

The present study demonstrated greater moments for circular cleat soccer shoes during the cutting maneuver and in mixed cleat shoes for the kicking movement, contrasting with the idea that a soccer shoe with greater traction generates more overload on the knee joint. The literature reports that shoes with higher traction are associated with greater moments and increased risk of injury, mainly to the LCA (13,18,21). In mechanical tests, the rectangular cleat shoes provided the best traction, which has prompted some authors to discourage the use of this type of cleat (13). However, we found greater knee joint moments for circular and mixed cleat shoes compared to those with rectangular cleats in the two movements studied. These results show that circular cleats do not cause lower joint moments.

The smaller effect of moments on knee joint structures may result in a safer movement, thereby reducing injuries. However, factors other than cleat shape may predispose players to injury, such as proper movement execution, which could play a role in protecting players, since it might improve muscle demand and movement control during the task.

The results obtained in the present study demonstrate that, irrespective of cleat shape, the highest moments normally occur at the onset of the stance phase. As such, developing a soccer shoe that provides greater stability and cushioning, protects players during initial contact with the ground and improves performance poses a challenge to the footwear industry.

One of the limitations of this study was assessing cleats designed for natural grass on artificial turf. Low and Dixon (23) found a difference in impact forces between artificial turf and natural grass, but none with respect to type of shoe. We underscore that this methodological limitation is also found in other articles, since there are technological difficulties in installing a force platform on soccer fields and in bringing natural grass into a laboratory (1,11,14,22). It is important to emphasize that the variable of interest is the influence of soccer shoe on movement, and that grass exhibits the same interference in all models. The other limitation for this study, was that we have not done the traction test or torsional test to measured the properties physical the sole. Smeets et al (2012) (25), showed that different cleats offer different values for mechanical traction and torsional torque. But, this study brought a realistic movement in soccer players, if compared the to mechanical models this is a important advance, because of more ecologically valid.

The primary effect of soccer cleats on knee joint moments occurred in the frontal and transverse planes. This is another limitation due to the high variability of knee moments in these planes. However, all the data analyzed displayed similar variability, after those exhibiting a significantly different pattern were excluded. Nevertheless, these findings should be interpreted with caution. We suggest that future studies with larger samples be conducted to confirm the biomechanical influence of the different types of cleats used here.

Table III. Mean and standard deviation of minimum peak of external/internal rotation of joint knee in movement of instep kick the each 10% of stance phase for the evaluate soccer shoes.

Perceptual of stance phase	C1(Nm/kg)	C2(Nm/kg)	C3(Nm/kg)
10%	-0,172 ± 0,11	-0,173 ± 0,13	-0,165 ± 0,08
20%	-0,201 ± 0,22	-0,20 ± 0,18	-0,322 ± 0,28
30%	-0,42 ± 0,50	-0,418 ± 0,42	-0,552 ± 0,43
40%	-0,57 ± 0,67	-0,52 ± 0,53	-0,696 ± 0,60
50%	-0,64 ± 0,75	-0,54 ± 0,56	-0,765 ± 0,67
60%	-0,66 ± 0,70	-0,55 ± 0,55	**-0,768*** ± 0,68
70%	-0,59 ± 0,60	-0,49 ± 0,52	-0,669 ± 0,63
80%	-0,334 ± 0,36	-0,36 ± 0,44	-0,049 ± 0,52
90%	0,014 ± 0,13	-0,015 ± 0,12	-0,055 ± 0,15
100%	0,022 ± 0,04	0,035 ± 0,04	0,034 ± 0,04

*Significant difference $p < 0{,}05$. Difference within C3 and C2.

CONCLUSION

The type of soccer shoe influenced both cutting and kicking movements. Circular cleat shoes produced a higher peak knee rotation moment at initial foot-ground contact. This demonstrates that rectangular cleats are not associated with greater knee joint moments.

Mixed cleat soccer shoes exhibited higher peak valgus moment at initial foot-ground contact as well as a greater minimum peak knee joint rotation moment in the mid-stance phase of the support leg for kicking.

As such, from an industrial standpoint, these results are important for the development of shoes that can lower the risk of knee injury in soccer players. New shoes that meeting requirement the athletes are fundamentals in future, in view of increased demand of sport performance. Thus is necessary that industry invest more attention for research in biomechanics of shoes.

Conflict of interest

The Authors has no financial or personal relationships with other people or organizations that could inappropriately influence their work (27).

Ethics approval

All procedures described in this study were approved by the Ethics Committee of our Institution. All subjects gave their informed consent in written form. Furthermore the manuscript follow the ethical to international standards according and as required by the MLTJ Journal.

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