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PROSPECTIVE COHORT STUDY

Gender-specific Lower Extremity Kinematic Differences in Collegiate Soccer Athletes during Three Kicking Tasks

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ABSTRACT

Introduction: The purpose of this study was to characterize gender differences in lower extremity kinematics during three different soccer kicking tasks.

Materials and methods: Twelve male and 13 female collegiate soccer athletes participated in this study. Seven trials of three soccer kicking tasks were collected: Maximal instep kick, crossing kick, side-foot pass. The three-dimensional lower extremity joint angles at ball contact and at their peak during the swing phase were obtained during each task.

Results: *Instep kick:* Males had significantly greater peak knee adduction ($p = 0.042$), and less peak knee internal rotation ($p = 0.046$) and peak hip extension ($p = 0.033$). *Side-foot pass:* At ball contact, males exhibited significantly greater knee flexion ($p = 0.025$), knee adduction ($p = 0.003$), knee external rotation ($p = 0.003$), and hip internal rotation ($p = 0.036$). Males exhibited significantly less peak knee extension ($p < 0.001$), peak knee internal rotation ($p < 0.001$), and peak hip external rotation ($p = 0.05$). *Crossing kick:* Males exhibited greater peak knee flexion ($p = 0.05$) and peak knee external rotation ($p = 0.023$), and less peak knee adduction ($p = 0.027$) and peak knee abduction ($p = 0.005$).

Conclusion: More gender-specific kinematic differences in the execution of the kicking tasks examined here were observed during both the side-foot pass and crossing kick than during the instep kick. Further characterization of gender differences in kick performance will aid in the development and evaluation of performance enhancement training programs and potentially identify gender-specific injury mechanisms related to kicking mechanics.

Keywords: Athletic performance, Crossing kick, Gender-specific differences, Instep kick, Lower extremity kinematics, Side-foot pass, Soccer.

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INTRODUCTION

Soccer is the most popular sport worldwide with over 265 million active participants.[1] Participation has shown steady growth over the past several decades with an increase of approximately 23 million participants between 2000 and 2006. The women's game has experienced rapid growth over the past several decades as well, with a total of approximately 26 million female participants in 2006.[1] In the United States, the number of women involved in collegiate soccer rose from approximately 7,500 participants in the 1991–1992 school year to >25,000 participants in the 2011–2012 school year—an increase of 337%.[2] Even with rapid growth of the women's game, a significant disparity still exists between biomechanical knowledge of the men and women's game.[3] With the marked increase in women playing elite-level soccer, an emphasis has been placed on understanding the differences between the men and women's game with respect to the impact of kicking mechanics and player performance.

Research on soccer-specific movements has targeted the lower extremity due to the primary focus of this body region during gameplay. The most frequently investigated aspect of the game is kicking, as it is the fundamental skill required for proficient gameplay.[4-6] The mechanics of kicking differ based on the type of kick employed by the player and the player's skill level.[5,7,8] A growing body of literature has sought to characterize the mechanics of these different kick types in both novice and elite athletes. Early studies, such as those by Phillips evaluated the kicking differences between elite and club-level athletes. Phillips provided a foundation for further investigation by showing that kicking was a highly conserved skill between both elite- and club-level athletes, although elite-level athletes were noted to complete kicking tasks with less variation in biomechanical measures.[9] Previous studies of the execution of the side-foot pass have focused on muscle activation in the lower limb and kinetic measures regarding the position of the thigh-shank plane and foot relative to the ball as they relate to foot velocity and ball speed.[8,10-12] Gender-specific differences in lower extremity alignment and muscle activation during the maximal instep kick and side-foot pass have also been reported.[3,12,13] Males were observed to employ a more hip dominant strategy via higher activation of the gluteus medius and gluteus maximus, while females were thought to employ a more quadriceps dominant strategy using decreased activation of the hip musculature compared with their male counterparts.[12] Similar gender-specific differences in control of the hip musculature have been observed in other athletic tasks including a single-leg squat[14] and single-leg agility maneuver.[15] In both the single-leg squat and single-leg agility maneuver, females performed the task with greater hip adduction than males.

The purpose of this study was to characterize the differences in lower extremity kinematics of three common soccer kicking tasks (instep kick, side-foot pass, and crossing kick) between male and female collegiate soccer athletes. Although gender-specific differences in soccer kicking has been previously reported, no direct comparison of lower extremity kinematics during different soccer kicking tasks has been reported. Current literature on measures indicative of soccer performance has focused on tasks which are not specific to sport.[16-18] Therefore, we performed a study aimed at examining a task critical to soccer gameplay. We hypothesized that differences in hip adduction, hip internal rotation, hip and knee flexion, and knee abduction angles would exist between men and women during these three different soccer kicking tasks. Further characterizing these gender-specific differences in kicking mechanics will help develop and evaluate training regimens aimed at improving performance and durability in both the men's and women's game.

MATERIALS AND METHODS

Participants

Twenty-five NCAA Division I soccer athletes (12 male and 13 female) volunteered to take part in this study. Each subject signed written informed consent approved by the institutional review board at the participating institution prior to inclusion. All participants had no history of lower extremity injury in the past 6 months, no history of ACL reconstruction in the past 3 years, and were currently active at least three times per week for 30 minutes.

Motion Capture

Before testing, each subject was given adequate time to warm up in a manner of his or her choice, including treadmill running and practice kicking trials. Each subject wore spandex shorts and Nike Air Pegasus shoes (Nike Inc, Beaverton, Oregon, USA) provided by the lab. An official size 5 Nike Geo soccer ball was used for all testing. A piece of retro-reflective tape was placed on top of the ball to aide in identification of ball contact during data collection. Prior to testing, 31 retro-reflective markers were placed on anatomic landmarks of each subject as outlined by Charnock et al.[19] An eight-camera motion capture system (Motion Analysis, Santa Rosa, California, USA) collected the kinematic data at 240 Hz by recording the trajectories of the retro-reflective markers.

First, a static calibration trial was conducted to identify the joint centers for the hip, knee, and ankle that would be used during data processing. Following static calibration, the medial knee and ankle markers were removed. Participants were then asked to perform seven acceptable trials of each of the three soccer kicking tasks: Side-foot pass, maximal instep shot, and crossing kick. The kicking task order was randomized in order to avoid any potential fatigue effects. An acceptable trial was defined as a kick in which the subject made appropriate contact with the ball and data were able to be collected throughout the entirety of the trial. Data were collected for each kick beginning with approach through the end of follow-through. Each kick was performed in the lab, with the ball being directed into a net approximately 2 m from the ball. The ball remained stationary prior to each kicking trial. Each subject was asked to use his/her dominant leg, which in all cases was the subject's right leg. The instep kick is the most fully characterized kicking task, and is traditionally described as contact of the ball by the dorsum of a plantar flexed foot with maximum velocity in the direction of the target at impact.[4,8,11-13,19,20] During the maximum instep, kick participants were asked to perform a direct kick with maximum power into the net directly in front of them. The side-foot pass is traditionally described as contact of the medial midfoot with the ball while the foot is in a neutral or slightly dorsiflexed position.[5,11,21] During the side-foot pass, the subject was asked to kick the ball with the inside of the foot into the net directly in front of them with enough power to enter the goal. The crossing kick is described as a kick that imparts spin to the ball at impact via a wide angle of approach, a leg swing oriented across the target in the transverse plane, with a more upward facing, abducted foot than that of the instep kick.[20] During the crossing kick, participants were asked to kick the ball with maximum power into the top left corner of the net.

Data were processed using Visual 3D (C-Motion, Bethesda, Maryland, USA). A recursive fourth-order Butterworth low-pass filter with a cut-off frequency of 12 Hz was used to process and smooth the marker trajectory data. The joint angles were calculated as Cardan angles between adjacent segments with an order of rotation of flexion–extension, abduction–adduction, and internal rotation–external rotation. The swing phase of the soccer kicks was each normalized from toe-off of the kicking foot until ball contact of the kicking foot. The normalized swing phase data were used when examining the peak hip, knee, and ankle angles during the swing phase as well as the angles at ball contact. The three-dimensional hip, knee, and ankle joint angles at ball contact and at their peak values during the swing phase were obtained during each of the three kicking tasks. These variables were assessed independently during the instep kick, side-foot pass, and crossing kick. The first three acceptable trials of the seven collected were averaged for each subject during each kicking task and used for analysis.

Statistical Analysis

Each dependent variable was compared between men and women using an independent samples t-test. Type I error was set at 0.05 for significance. Effect size correlation for each variable exhibiting significant differences between genders was calculated using the means and standard deviations (SD) for each group. The statistical analyses were completed using Statistical Package for the Social Sciences version 19.0 (SPSS Inc., IBM Company, Chicago, Illinois, USA).

RESULTS

Demographics

Male and female participants did not differ significantly in age (p = 0.407, males (M): 20.5 ± 1.57 years, females (F): 21.2 ± 2.59 years). Significant differences existed between genders in height (p = 0.002, M: 1.79 ± 0.07 m, F: 1.68 ± 0.07 m) and weight (p = 0.005, M: 74.6 ± 7.62 kg, F: 64.7 ± 8.2 kg) as expected.

Instep Kick

The instep kick demonstrated significant kinematic differences between genders in peak knee adduction, peak knee internal rotation, and peak hip extension (Table 1). Males had greater peak knee adduction [p = 0.042, effect size index (ESI): 0.399, M: 7.2 ± 2.9°, F: 3.8 ± 4.6°] than females. Males had lower peak knee internal rotation (p = 0.046, ESI: –0.392, M: 5.4 ± 5.1° F: 10.8 ± 7.5°) and lower peak hip extension (p = 0.033, ESI: –0.411, M: 23.7 ± 8.4° F: 30.1 ± 5.5°) when compared with females. No statistically significant differences between men and women were observed at ball contact.

Side-foot Pass

At ball contact, male and female participants demonstrated differences in knee flexion, knee adduction, knee external rotation, and hip internal rotation (Table 1). The average knee flexion angle for males was greater (p = 0.025, ESI: 0.439, M: 48.8 ± 3.1°, F: 42.6 ± 8.5°) than that of females at ball contact. Knee adduction (p = 0.003, ESI: 0.554, M: 7.6 ± 3.8°, F: 1.9 ± 4.6°), knee external rotation (p = 0.003, ESI: 0.554, M: 18.1 ± 4.4°, F: 11.4 ± 5.5°), and hip internal rotation (p = 0.036, ESI: 0.410, M: 4.0 ± 5.1°, F: –2.2 ± 8.4°) were greater for males at ball contact. In addition to differences at ball contact, men reported a lower peak knee extension angle (p < 0.001, ESI: –0.656, M: –14.1 ± 6.2°, F: –3.5 ± 6.0°), peak knee internal rotation (p < 0.001, ESI; –0.641, M: 1.0 ± 4.5°, F: 10.1 ± 6.3°), and peak hip external rotation (p = 0.05, ESI: –0.387, M: 9.0 ± 6.2°, F: 14.6 ± 7.1°) than did females.

Crossing Kick

Males and females exhibited differences in their execution of the crossing kick based on the differences in peak joint angles during the swing phase (Table 1). Males exhibited greater peak knee flexion (p = 0.05, ESI: –0.378, M: 87.6 ± 8.8°, F: 95.2 ± 9.8°), peak knee adduction (p = 0.027, ESI:

Table 1: Kinematic differences during three soccer kick types in elite male and female athletes (mean ± SD)

	Males	*Females*	*ESI*
Instep kick			
Peak knee adduction*	7.2 ± 2.9°	3.8 ± 4.6°	0.399
Peak knee internal rotation*	5.4 ± 5.1°	10.9 ± 7.5°	–0.392
Peak hip extension*	23.7 ± 8.4°	30.1 ± 5.5°	–0.411
Side-foot pass			
Knee flexion at ball contact*	48.8 ± 3.1°	42.6 ± 8.5°	0.439
Knee adduction at ball contact**	7.6 ± 3.8°	1.9 ± 4.6°	0.554
Knee external rotation at ball contact**	18.1 ± 4.4°	11.4 ± 5.6°	0.554
Peak knee extension*	–14.1 ± 6.2°	–3.5 ± 6.0°	–0.656
Peak knee internal rotation***	1.0 ± 4.5°	10.2 ± 6.3°	–0.641
Peak hip external rotation*	9.0 ± 6.2°	14.6 ± 7.1°	–0.387
Crossing kick			
Peak knee flexion*	87.6 ± 8.8°	95.2 ± 9.8°	–0.378°
Peak knee external rotation*	–15.7 ± 4.4°	–10.6 ± 5.9°	–0.441
Peak knee adduction*	7.4 ± 3.5°	3.5 ± 4.7°	0.429
Peak knee abduction**	–2.7 ± 6.2°	–10.1 ± 5.8°	0.525

*p < 0.05; **p < 0.01; *** p < 0.001

–0.441, M: 7.4 ± 3.5°, F: 3.5 ± 4.7°) and peak knee external rotation ($p = 0.023$, ESI: 0.429, M: 15.7 ± 4.4°, F: 10.6 ± 5.9°) than did females. In addition, males exhibited lower peak knee abduction ($p = 0.005$, ESI: 0.525, M: 2.7 ± 6.2°, F: 10.1 ± 5.8°) than did females.

DISCUSSION

To our knowledge, this study is the first description of gender-specific differences among elite-level soccer athletes in three prominent soccer kicking tasks—the instep kick, side-foot pass, and crossing kick. The results of this study indicate that male and female elite-level soccer players exhibit kinematic differences in their approach to these three kicking tasks. It is widely accepted that men and women differ in their approach to other athletic tasks, such as running, cutting, and jumping, but independent tasks, such as kicking techniques have been less thoroughly investigated.[15,22-25] Previous investigations of gender differences in soccer kick performance have focused primarily on muscle activation, with no direct comparison of kinematic differences for each individual kick type.[3,12]

We found that the instep kick had the fewest gender-specific differences, with only three dependent variables being different between groups. This degree of similarity between men and women with regard to instep kick kinematics has been reported previously in comparisons of limb segment velocities prior to and at ball contact,[13] but this study did not comment on gender-specific differences in joint angles. Males demonstrated greater peak knee adduction than females, and a global kinematic profile similar to that observed previously in the instep kick of elite male soccer players.[4,10] These results differ somewhat from those observed by Katis et al[26] in their review of amateur players performing a powerful instep kick. Katis et al also observed that, compared with amateur adult females, males exhibited significantly increased flexion of the hip prior to impact. However, in contrast to the results reported here, they observed no difference in knee internal rotation or adduction. The kinematic profile of the hip in sagittal plane observed here are also similar to those reported by Smith and Gilleard[27] in their cohort of 13 amateur male and female soccer athletes. The similarities between strategies employed by males and females in completing the instep kick may be an indication that the development of this motor program may be pivotal in the progression of athletes of both genders to the elite level.

The kinematic profile of the side-foot pass was more dissimilar between genders than that of the instep kick. Men employed greater knee flexion, knee adduction, knee external rotation, and hip internal rotation at ball contact compared with females. Females exhibited significantly greater peak knee internal rotation, peak knee extension, and peak hip external rotation than did males. This variability in execution of the side-foot pass suggests that males are employing a strategy that focuses primarily on externally rotating the knee in order to bring the mid-foot into the appropriate alignment for their desired ball striking position. Our results suggest that females accomplish this same task of orienting the lower extremity in the desired ball striking position via changes in their hip mechanics. Previous investigation of gender differences in side-foot kick alignment focused primarily on frontal plane mechanics,[12] and therefore, would not have detected the observed differences in the sagittal plane. This is of particular importance given that the observed sagittal plane mechanics may impact side-foot pass performance independent of gender.

The crossing kick is the least studied of the three kicking tasks examined in this study. Similar to the results observed in the side-foot pass, men and women show a high level of kinematic variability in executing a crossing kick. Men exhibited greater peak knee extension, peak knee adduction, peak knee flexion, and peak knee external rotation while women exhibited greater knee internal rotation and knee abduction. Of note, men and women showed no significant differences in any kinematic measures at ball contact. One variable that was not recorded in these trials that could offer some explanation as to why men and women exhibited differences in the crossing kick task is angle of approach. Women have been shown to employ a wider angle of approach and angle their body more to the right (for right-foot dominant players) of their target than do men in completing a crossing kick when compared with the instep kick.[20] Knowing this, our data suggest that by employing this wider approach angle and rightward facing body position, females are able to execute a crossing kick with significantly less knee external rotation and abduction than males. What is not clear based on this investigation is whether or not the observed kinematic differences translate to appreciable gender differences in maximum ball velocity or accuracy in executing the crossing kick.

The current study has furthered the understanding of the kinematics of male and female elite-level soccer players and given rise to many avenues of further investigation. The continued growth of soccer at both the amateur and elite levels should compel investigators to further characterize the changes in kinematics players undergo as they elevate their level of play. Understanding the details of skill acquisition and maturation will allow for the development of more effective training programs aimed at performance enhancement for athletes of different skill levels. Studies have examined the effects of gender and maturation on athletic tasks, such as cutting, landing, and instep kick mechanics in soccer, but to date, the effects of maturation on kicking kinematics in the three fundamental tasks employed in this study have not been characterized.[6,28,29]

Limitations of this study include the relatively small sample size and incorporation of only elite-level athletes. Further studies should incorporate athletes of different skill levels in the evaluation of these same kicking tasks to investigate the effects of maturation and training on execution of each type of kick. This study was also conducted in a laboratory setting with participants wearing running shoes, which may lead to potential differences in kinematics compared with what might be observed in participants in soccer cleats in a match play setting.

CONCLUSION

In conclusion, this is the first study to evaluate the kinematic differences in three common kicking tasks—the instep kick, side-foot pass, and crossing kick—in elite male and female soccer athletes. Instep kick mechanics are the most similar between genders when examining these three types of soccer kicks, suggesting that acquisition of proficiency in this skill is critical to elite-level gameplay in both the men and women's game. Men and women exhibited significant kinematic differences in execution of both the side-foot pass and crossing kick. The significant differences observed in these two kicking tasks suggest that men and women develop different motor programs aimed at producing the desired ball flight of each kick type.

CLINICAL SIGNIFICANCE

Future investigation should focus on characterizing the progression of kinematic changes in these kicking tasks from amateur to elite-level play in an effort to develop individualized training programs aimed at performance enhancement and durability in both the men's and women's game. The data generated here may also be useful in designing injury prediction models, examining how divergence from the trends observed here correlates with injury rates among male and female athletes over the course of their careers.

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