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GENDER DIFFERENCES OF TRUNK AND LOWER LIMB POSITIONS DURING THE CUTTING MANEUVER

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The purpose of this study was to analyze the gender differences in positions of the trunk and lower limb during the cutting maneuver. We captured the trunk and lower limb positions during shuttle-run cutting in 8 male and 7 female soccer players. The distance from the center of the trunk to the foot-plant point in the frontal and sagittal planes, knee flexion angle, knee valgus angle, femoral inclination angle, trunk forward-inclination angle, and trunk lateral-inclination angle were measured. Our results showed that female subjects demonstrated less femoral inclination, greater trunk lateral inclination away from the cutting limb, and smaller distance from the center of the trunk to the foot-plant point in the frontal plane than male subjects. The study results may reveal potential risks for ACL injury.

KEY WORDS: risk factor, injury mechanism, ACL injury, compensation

INTRODUCTION: Anterior cruciate ligament (ACL) injuries occur at a high rate in female athletes (Agel et al., 2005), and these injuries often occur in non-contact sports situations such as landing and cutting (Boden et al., 2000). Female athletes are at an increased risk for ACL injuries in sports requiring rapid deceleration during cutting, pivoting, landing, and change in direction, with an injury rate 3 to 5 times higher than that of male athletes (Agel et al., 2005). In recent years, the trunk and lower limb positions of female athletes at the time of ACL injury have been reported (Boden et al., 2009, Hewett et al., 2009, Sheehan et al., 2012). From the results of these studies, at the time of ACL injury, knee abduction (Boden et al., 2009, Hewett et al., 2009), increased hip flexion (Boden et al., 2009), increased trunk lateral motion (Hewett et al., 2009), decreased trunk forward inclination (Sheehan et al., 2012), and extreme posterior position of the center of mass relative to the base of support (Sheehan et al., 2012) were observed. Avoiding these positions is important for prevention of ACL injury.
Previous studies have revealed some typical characteristics of female athletes during cutting to clarify why ACL injury often occurs in female athletes. Compared with males, female athletes had a smaller knee flexion angle (McLean et al., 2004), greater knee abduction angle (McLean et al., 2007), smaller hip flexion angle (McLean et al., 2004), and smaller hip abduction angle (McLean et al., 2004) during the cutting maneuver. However, there have been insufficient studies to clarify trunk and lower limb positions during cutting, in which ACL injuries often occur, although trunk position plays a role in ACL injury. Analysis of the cutting maneuver, including trunk position, is essential to determine the relationship between the characteristics of female athletes during cutting and the occurrence of ACL injury. Therefore, the purpose of this study was to analyze gender differences in the positions of the trunk and lower limb during the cutting maneuver.

METHODS: Eight male and 7 female soccer players were recruited for the study. Measurements were taken during shuttle-run cutting at maximum speed. During this maneuver, the subject ran straight ahead for 5 m, planted the cutting foot perpendicular to the initial direction of motion, changed direction to 180 degrees from the initial direction of motion, and ran again for 5 m (Figure 1). If the subject was unable to plant the foot perpendicularly or slipped during the cutting maneuver, the trial was excluded. The time between the start and the goal of shuttle-run cutting was also measured. If the time was less than the fastest time by more than 0.2 s, the trial was also excluded. Measurements were recorded for 3 successful trials.

Two high-speed cameras (EX-FH20, Casio, Japan; 210 Hz) were used to record the trunk and lower limb movements. Cameras were placed on the frontal and sagittal planes at a distance of 3.5 m from the foot-plant point (Figure 1). Ten plastic tape markers (16 mm diameter) were secured on each subject. The markers were placed on the right anterior superior iliac spine (ASIS), left ASIS, right frontal surface of the acromion, left frontal surface of the acromion, right acromion, right midpoint of the patella, right midpoint of the medial and lateral malleoli on the shoe, right greater trochanter, right lateral knee joint, and right lateral malleolus. Additionally, a tri-axial accelerometer (LP-WS0902, LOGICAL PRODUCT CORP., Japan; 200 Hz), secured on the second thoracic spinous process, was used to measure the acceleration accompanying trunk movement.

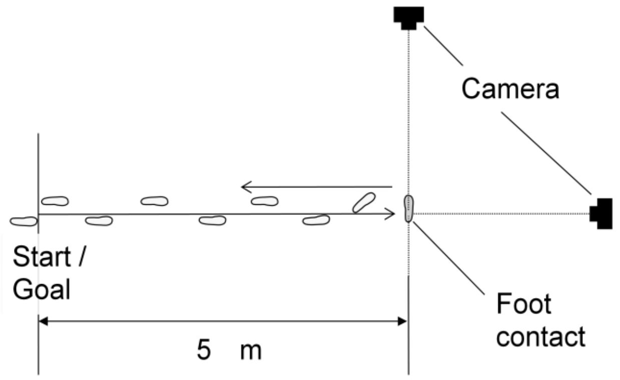

Figure 1: The shuttle-run cutting maneuver and camera positions

The captured images were imported to a digitizing software program (Pixel Runner G, PixelGate Ltd., Japan). From the digitized data, the distance from the center of the trunk to the foot-plant point in the frontal and sagittal planes was calculated. In the frontal plane, the center of the trunk was defined as the intersection point of the line joining the markers on the right frontal surface of the acromion and the left ASIS and the line joining the markers on the left frontal surface of the acromion and the right ASIS. In the sagittal plane, the center of the trunk was defined as the midpoint of the line between the markers on the right acromion and the right greater trochanter. The foot-plant point was defined as the point dissecting the line of contact between the shoe and the floor. The horizontal distance was also measured—in the lateral/medial direction in the frontal plane and in the anterior/posterior direction in the sagittal plane—and normalized by femur length. Additionally, knee flexion angle, knee valgus angle, femoral inclination angle, trunk forward-inclination angle, and trunk lateral-inclination angle (Figure 2) were measured. All variables were measured at the time points of foot contact and maximum knee flexion. A two-way analysis of variance (ANOVA) model (gender (2) x phase (2)) was used to examine the main effects of differences between the genders and interaction effects (gender/gender x phase). To determine each significant difference, Bonferroni multiple comparison tests were performed as post hoc tests. Significance was set at $p < 0.05$.

RESULTS: The results of ANOVA showed main gender differences with regard to the distance from the center of the trunk to the foot-plant point in the frontal plane, femoral inclination angle, and trunk lateral-inclination angle ($p < 0.01$, $p < 0.05$, $p < 0.05$, respectively). No significant differences were observed for interaction effect between all the variables. The results of the post hoc test (Table 1) indicated that the distance from the center of the trunk to the foot-plant point in the frontal plane at both the time of foot contact and maximum knee flexion was greater in male than female subjects ($p < 0.05$, $p < 0.01$, respectively). Femoral inclination angle at maximum knee flexion was greater in male than female subjects ($p < 0.05$).

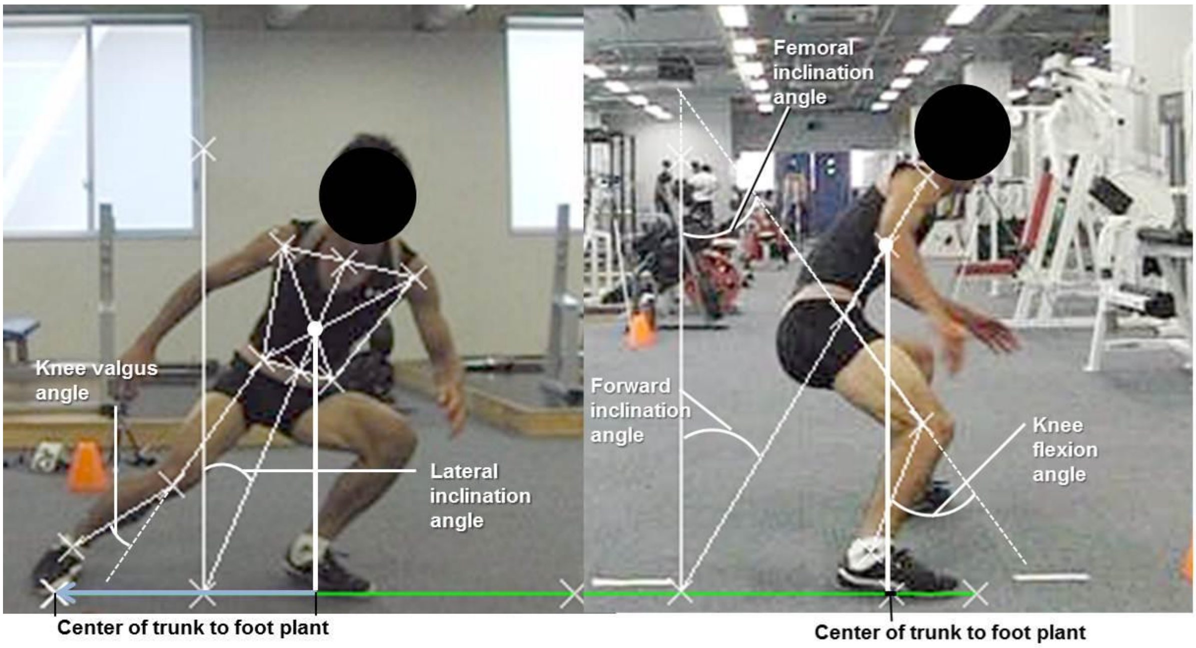

Figure 2: Illustration of trunk and knee motion during cutting

Table 1
Mean (SD) of the trunk and lower limb positions during cutting

	Foot contact				Maximum knee flexion			
	Male		Female		Male		Female	
COT to FP[a] sagittal plane	.26	(.20)	.20	(.30)	-.17	(.13)	-.25	(.24)
COT to FP[a] frontal plane	1.92	(.09)*	1.79	(.10)*	1.60	(.05)**	1.41	(.13)**
Knee flexion (deg)	30.5	(10.6)	28.4	(4.4)	64.8	(4.3)	59.1	(11.)
Knee valgus (deg)	13.1	(5.6)	20.6	(8.7)	27.6	(9.4)	35.5	(21.1)
Femoral inclination (deg)	19.9	(6.1)	16.2	(5.8)	33.1	(4.6)*	24.3	(10.8)*
Trunk forward inclination (deg)	23.7	(8.8)	17.7	(8.7)	34.3	(9.6)	28.5	(9.3)
Trunk lateral inclination (deg)	13.1	(3.0)	18.4	(6.9)	17.2	(1.7)	22.0	(9.5)

[a]: The distance from the center of the trunk to the foot–plant point

*: $p < 0.05$ **: $p < 0.01$

DISCUSSION: The results of this study showed gender differences for femoral inclination, with female athletes having less femoral inclination than male athletes. There was no significant difference in the distance from the center of the trunk to the foot-plant point in the sagittal plane and trunk forward-inclination angle. These results suggest that the trunk and lower limb positions in the sagittal plane demonstrated by female athletes during cutting were dissimilar from those associated with ACL injury, which are characterized by increased hip flexion (Boden et al., 2009), decreased trunk forward inclination (Sheehan et al., 2012), and extreme posterior position of the center of mass relative to the support base (Sheehan et al., 2012). Female athletes in the current study displayed reduced hip flexion. When the hip joint flexes with the same trunk inclination, the center of mass of the trunk segment moves away from the hip joint, which increases the external hip flexion moment. Female athletes have lower muscle activities of the hip extensors and, consequently, may not demonstrate the same trunk and lower limb positions as male athletes. If female athletes demonstrated the same trunk and lower limb positions as male athletes, they would maintain the position with quadriceps-dominant muscle activity. This would increase the ACL strain by the increased patellar tendon force (Withrow et al., 2006) and explain why ACL injury often occurs in female athletes.

The results of this study also showed differences between the genders in regard to trunk lateral inclination and the distance from the center of the trunk to the foot–plant point, with female athletes having greater trunk lateral inclination away from the cutting limb, and smaller distance from the center of the trunk to the foot–plant point, than male athletes. These results suggest that position of the trunk in the frontal plane demonstrated by female athletes during cutting was opposite that found in ACL injury, which is characterized by increased trunk lateral motion towards the cutting limb (Hewett et al., 2009). However, this trend does not decrease the risk of ACL injury, because it appears the same as a positive Trendelenburg sign caused by weakened hip abductors. To compensate for the Trendelenburg sign, the trunk inclines laterally towards the stance side. This compensation is similar to the position in ACL injury. It is beneficial to screen for the Trendelenburg sign during cutting, because female athletes demonstrating a positive Trendelenburg sign have increased risk of ACL injury.

CONCLUSION: The purpose of this study was to analyze the gender differences in trunk and lower limb positions during the cutting maneuver. Female subjects demonstrated less femoral inclination, greater trunk lateral inclination away from the cutting limb, and smaller distance from the center of the trunk to the foot-plant point in the frontal plane than male subjects. These characteristics of female athletes during cutting in the current study were dissimilar from those associated with ACL injury. Future studies must examine the potential risks during cutting associated with ACL injury for female athletes.

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