GENDER DIFFERENCES IN THE BIOMECHANICS OF RUNNING AND CUTTING MANEUVERS RELATIVE TO NON-CONTACT ACL INJURY

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Introduction
The anterior cruciate ligament (ACL) is the most commonly injured ligament of the knee. There is a substantial incidence of non-contact injury to the ACL. However, mechanisms of non-contact injury are not well understood. Non-contact injuries are most frequently reported during the deceleration phase of landing after a jump or in preparation for a cutting maneuver. In addition, the knee is in a position near full extension and there is typically a valgus or varus collapse of the knee associated with the landing mechanism. The biomechanics and limb loading during these maneuvers has not been well described. Further, there is minimal information available on the functional differences that may be related to gender during these types of activities, even though the non-contact injury rate for women can be more than five times greater than that of men in the same sport. The purpose of this study was to test the hypothesis that gender differences can be associated with the biomechanics of running and cutting and running and stopping maneuvers. Further, the study focused on the initial period following landing in a run to cut and a run to stop maneuver.

Materials and Methods
Ten female (26.5±6.7years, 1.6±0.6m, 66±119N) and ten male (25.9±7.4years, 1.8±0.7m, 84±110N) subjects were tested during running, running and cutting, and running and stopping maneuvers after IRB approval and informed consent. Subjects selected for this study had no previous history of musculoskeletal injury that would influence function. The studies were performed in a Biomotion Laboratory using a three dimensional optoelectronic system for motion capture and a multi component force plate for a measurement of ground reaction force. Joint kinematics and kinetics were calculated using a previously described link model of the lower extremity. The analysis focused on the lower extremity position and inter-segmental forces and moments during the landing phase of run to stop and run to side step cut maneuver.

The run to stop and run to cut maneuvers were achieved by first asking the subject to achieve a steady state running speed and running to a specific location on the force platform. For the cutting maneuver the subject was asked to perform a 90 degree sidestep cut perpendicular to the direction of progression and away from the planted foot. For the stopping maneuver, the subject was asked to stop on a single limb. The analysis was conducted during the initial phase of the maneuver following landing on the force platform. Forces were expressed as a percent of body weight (%bw) and moments were expressed as a percent of the product of body weight and height (%bw*ht). While both right and left limbs were observed for this study, a single limb was randomly selected from each subject for analysis. Group comparisons were made using a Student's t-tests with a correction for multiple comparisons at a significance level of P < .05.

Results
Two patterns (Figure 1.) of limb loading were identified during the landing phase (foot strike to 200ms) of the run to cut maneuver. Pattern 1 was characterized when the peak component of the inter-segmental force vector at the knee (along the axis of the tibia) took place during the landing phase. Pattern 2 was characterized when the peak force did not take place during the landing phase, but instead later on in the stance phase. 9 of the 10 male subjects generated the largest axial force (Pattern 1) at the knee during landing, while 5 of 10 of the female subjects had the Pattern 1 landing forces. The magnitude of the landing force was also significantly (p<.05) different between the male (273±64%bw) and female group (221±43%bw). This increase in the axial force along the tibia was coupled with an increase in the landing phase hip abduction moment in the male (3.63±2.1 %bw*ht) compared to the female (1.49±0.9 %bw*ht) population. While similar trends were observed for the run to stop maneuver, the differences were not significant during the landing phase.

Discussion
The larger axial component of the inter-segmental force at the knee in Pattern 1 suggest the lower limb is more closely aligned (relative to Pattern 2) with the direction of the resultant landing force. The large abduction moment at the hip would suggest that the Pattern 1 landing was produced by a rapid shift in the upper body over the support limb prior to the limb sustaining full load. This process might protect the limb from buckling since the main thrust of the limb is along the axis of the tibia.

The results of this study suggest a potential injury mechanism associated with the biomechanics of landing in preparation for a run to stop or run to cut maneuver. Nine of ten male subjects in this population tended to land in a manner that produced a greater magnitude of the force component along the axis of the tibia. The results of this study suggest a potential injury mechanism associated with the biomechanics of landing in preparation for a run to stop or run to cut maneuver. Nine of ten male subjects in this population tended to land in a manner that produced a greater magnitude of the force component along the axis of the tibia. These findings provide new information that can be applied towards understanding gender difference patterns in non-contact ACL injuries.

Figure 0. The landing phase portion of the run to cut maneuver was used to classify differences in the landing mechanics.

Figure 2. Pattern 1 placed the land force along the tibial axis during landing.


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