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Lower limb kinematics of male and female soccer players during a self-selected cutting maneuver: Effects of prolonged activity

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ABSTRACT

Background: Despite the recent emphasis on injury prevention, anterior cruciate ligament (ACL) injury rates remain high. This study aimed to ascertain the effects of prolonged activity on lower limb kinematics during a self-selected cutting maneuver.
Methods: Angular kinematics were recorded during an agility test performed until the completion time was greater than the mean plus one SD of baseline trials. Cut type was identified and the hip and knee angles at 33 ms post heel strike were determined. A linear mixed effects model assessed the effects of cut type, gender, and activity status on the hip and knee angles.
Results: Males performed sidestep cuts more frequently than females. Females increased the incidence of sidestep cuts after prolonged activity. At the hip, a gender–cut type interaction existed for the transverse ($p = 0.001$) and sagittal ($p = 0.11$) planes. Females showed more internal rotation during sidestep and more external rotation and less flexion during crossover cuts. For the frontal plane, a gender–activity status interaction ($p = 0.032$) was due to no change within females but greater hip adduction during prolonged activity within males. With prolonged activity, both genders displayed less hip ($p = 0.29$) and knee ($p = 0.009$) flexion and more knee ($p = 0.001$) adduction. Females displayed less hip and knee flexion than men ($p = 0.001$).
Conclusions: Sidestep may be more risky than crossover cuts. Both genders place themselves in at-risk postures with prolonged activity due to less hip and knee flexion.
Level of evidence: Level 4

1. Introduction

Anterior cruciate ligament (ACL) injuries are common in sports such as soccer, and basketball, with female athletes being two to ten times more likely to sustain ACL injuries than their male counterparts [1]. More than 70% of these injuries are a result of non-contact mechanisms, where the force applied at the knee is not a result of an external factor [1–5]. Most ACL injuries require surgery and significant rehabilitation programs the lifetime cost of which has been estimated to range from $38,170 to $88,000 per injury [1–3, 6]. Although preventative programs have been shown to be effective, the risk of sustaining an ACL injury still remains high in both male and female athletes; in part, because of the complexity in their design. Therefore, a more complete understanding of the risk factors associated with non-contact ACL injuries continues to be of great importance for developing more targeted preventative strategies.

Improper joint alignment, decreased strength and conditioning, muscular fatigue, and poor trunk and neuromuscular control are but a few of the risk factors that have been identified for sustaining non-contact ACL injuries, especially during cutting maneuvers. In athletic activities, the risk for sustaining a non-contact ACL injury increases with improper joint alignment [1, 4, 5, 7–9]. Specifically, at initial contact, the common joint postures associated with an increased risk for sustaining an ACL injury in athletes are an adducted hip and extended knee joint, externally rotated tibia, and laterally flexed trunk [10–14].

Certain differences exist between males and females in their at-risk lower extremity kinematics. Malinzak et al. reported that females tend to place their knee in a more valgus alignment during athletic cutting tasks than males [15]. Landry et al. determined that joint angle differences between elite male and female soccer players were most

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prominent at the hip [16]. Females demonstrated significantly less hip flexion than males during the stance phase of side-step cutting maneuvers [16]. In addition, McLean et al. found that females had less hip and knee flexion, internal rotation, and increased knee valgus angles compared to men during side-step cutting maneuvers to evade a defender [27].

Although studies have reported unique gender differences in the kinematics of the lower extremity that are associated with an increased risk for sustaining an ACL tear, several common flaws still remain. Most studies have been done using an experimental paradigm that is not truly representative of the environment in which an athlete gets hurt. Missing in the current literature is the effect of a “game-like experience”, and its role in placing athletes in at-risk lower extremity postures. In addition, many study protocols only included a specific cut type (i.e. side-cut or cross-over-cut) that does not truly represent game like events. During game conditions, two types of cuts are commonly identified: crossover and sidestep cuts. Depending on the task related demand, in game-like situations athletes are able to self-select cut-type in order to improve performance or reduce risk of injury. Recent research suggests, that a sidestep cut may place an athlete in a more at-risk position for a non-contact ACL injury [11, 17]. However, to date, the differences between how men and women perform different cutting maneuvers has not been fully explored. More importantly, the use of these types of cuts during game-like situations has largely been ignored in the literature.

Performing a cutting maneuver later in games has been reported to increase the risk of lower extremity injury [18, 19]. Research suggests the prolonged activity results in decreased muscle control that affects the ability to safely perform a cut secondary to alterations in lower extremity mechanics [20]. In addition, prolonged activity can affect joint proprioception and neuromuscular responses further impairing the ability to safely perform a cutting maneuver [21]. In studies that have focused on biomechanics during prolonged activity, scenarios that mimic game-like environments have not been utilized [20–24]. Therefore, to appropriately create a testing protocol that simulates the true game environment, prolonged activity models should be utilized when performing game-like cutting maneuvers.

The purpose of the present study was to compare the lower limb kinematics of male and female soccer players during a self-selected cutting maneuver and to assess the effects of prolonged activity on the kinematics. We hypothesized that performing a self-selected cut after prolonged activity will result in significant lower extremity kinematic changes, which place the limb in more at-risk alignment as compared to baseline cutting maneuvers. These changes in kinematics due to prolonged activity will be seen at a greater extent in female athletes.

2. Materials and methods

2.1. Subjects

The Human Experimentation Committee of Quinnipiac University approved the methods and procedures utilized in this study. A convenience sample of 29 subjects between 18 and 22 years of age who were members of the men's (n = 10) and women's (n = 19) Quinnipiac University soccer teams were recruited for this descriptive study. To be included, subjects had to be members of the men's or women's soccer team, be free of injury at the time of enrollment, and be able to complete an agility test. Subjects were excluded if they did not meet the inclusion criteria. Select subject demographics are noted in Table 1.

Table 1
The mean (±SD) height, weight, and age of the male and female subjects.

	Male (n = 10)	Female (n = 19)
Height (cm)	164.3 ± 5.6	180.8 ± 4.8
Weight (kg)	62.2 ± 7.0	78.1 ± 9.3
Age (years)	19.4 ± 1.3	20.1 ± 1.2

2.2. Procedures

This study consisted of two data collections, approximately one week apart. At the initial data collection, after obtaining informed consent, subject demographics consisting of gender, age, height, weight, and leg dominance were recorded. Subjects were then instructed how to perform the agility test, had the test demonstrated to them, and were given several practice runs to allow them to become familiar with the test. At the second data collection, retro reflective markers were placed over specific boney landmarks on the subjects' trunk, pelvis, and upper and lower extremities bilaterally using double sided adhesive tape (Fig. 1). A five second static trial of video data was recorded using a 10 camera video system (Motion Analysis Corporation, Santa Barbara, CA) sampling at 240 Hz. The subjects then performed the agility test protocol while video data was recorded.

2.2.1. Agility protocol

The agility testing protocol consisted of having the subject complete a modified T-Test. The T-Test required the subject to run through a T-shaped obstacle course (Fig. 2) as fast as they could while the time for the subjects to complete the course was recorded using a timing gait device (Equine Electronics Timing System, Equine Electronics). The prolonged activity protocol was established using a timed based decrement in performance model. The first four trials were considered the non-prolonged activity trials and represented baseline. Subjects were afforded a 60 second rest period between each trial to allow for full recovery. The times for the four non-prolonged activity trials were averaged and the standard deviation calculated. The subject then continued to perform the agility test alternating from making a run with all left turns and all right turns beginning every 30 s. The subject continued the test until they failed to have two consecutive runs within one standard deviation of the average non-prolonged activity trials. The subject was then asked to perform two more runs, one from each side, during which video data was recorded. These last two trials were considered the prolonged activity trials.

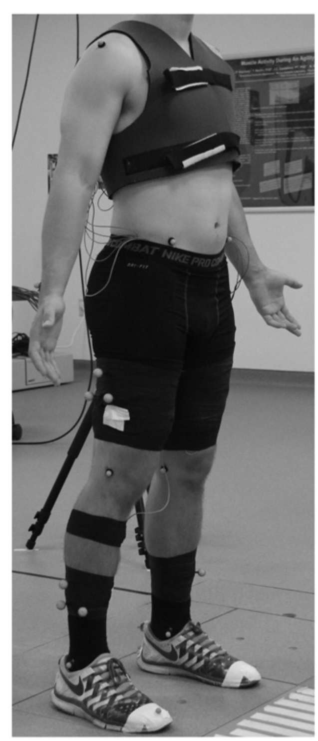

Fig. 1. Anterolateral view of a representative subject with marker set in place.