WHEN DO KINETIC CHANGES PLACE GREATEST RISK FOR NON-CONTACT ACL INJURY DURING THE STANCE PHASE OF FOOTBALL CUTTING MANEUVERS IN MATCH PLAY CONDITIONS?

Rajiv Kaila[1], Gareth Irwin[2]

[1]The Royal National Orthopaedic Hospital, Stanmore, London. UK;
[2]Cardiff Metropolitan University, Cardiff. UK

This research aimed to determine when kinetic changes place greatest risk for non-contact ACL (anterior cruciate ligament) injury during football cutting in match play. Fourteen professional football players undertook three trials of a straight line run and sidestep cutting at 30° and 60° with standardised velocity on an approved football surface. Two types of standardised studded football boots were utilised. Using inverse dynamics analyses, an eight camera gait analysis system synchronised with a force platform, determination of knee joint moments, joint forces and flexion angles were undertaken. Magnitudes and timings were compared with critical limits for ACL injury. 33-50% of stance during cutting was associated with increased risk of ACL injury with peak valgus and internal rotational moments and anterior joint forces. Knee flexion above 30° at 22%-77% of stance appears protective. By ensuring knee control by training techniques, ACL injury risk could be reduced.

KEYWORDS: football; cutting; kinetic; timing; ACL; injury

INTRODUCTION:

The majority of all ACL (anterior cruciate ligament) tears in sports are non-contact in origin (Arendt and Dick, 1995). The shoe-surface interface has been shown to play a significant role in sports injuries (Torg and Quedenfeld, 1974). In soccer match play conditions it is unclear from a biomechanical perspective when the ACL is at greatest risk of injury during cutting maneuvers. This research assessed changes in knee joint kinetics and kinematics to better understand when, during the stance phase of cutting, the ACL is placed at most risk of non-contact ACL injury. The aim of this research was to gain a better understanding of these biomechanical changes so as to aid directing injury prevention by training altered techniques.

METHODS:

Participants: 14 injury-free professional male outfield male football players. All were free from any injury for at least two consecutive seasons and had no history of injury requiring hospital admission. All were right foot dominant. Data Collection: Using 3D inverse dynamics analyses based on an eight camera gait analysis system (120Hz VICON 612, Vicon Motion Systems Limited, Oxford, U.K) synchronised with a force platform (Kistler 9287BA, 960Hz, Kistler, Alton, U.K), absolute knee internal/external rotational moments (Mz), valgus/varus moments (My), anterior/posterior joint forces (IJFx) and knee flexion angles were determined throughout the stance phase of randomly cued straight ahead and sidestep cutting maneuvers at 30° and 60° using the dominant lower limb. The participants undertook the maneuvers using standardised studded boots on a FIFA (Federation of the International Football Association) approved surface (FieldTurf FTS01, FieldTurf, Montréal, Canada) at 5.5-6.0 m•s^{-1}. Each undertook three trials of a straight line run (0°) and sidestep cuts at 30° and 60° using their dominant side. Each subject was tested using 2 studded standardised football boots (Copa Mundial; Adidas, Germany and Air Zoom Total 90 v3 FG; Nike, USA). The subjects were required to rest at least 2 minutes between each trial to prevent effects of fatigue. Testing was completed for each player in a single session without any changes to the protocol or equipment. Approach velocity was measured using two pairs of infrared velocity timing gates (Elekio Sport, AB, Sweden), placed immediately in front of the force platform and 2 m in front. Data Analysis: All trials were interpolated using a cubic spline to 100 data points to facilitate presentation as a percentage of the stance phase. A non-parametric ANOVA followed by Friedman’s tests were employed to quantify differences between the variables as a function of cutting angle. A significant difference was determined by $p < 0.001$. Magnitudes and timings were compared with critical limits for ACL injury from robotic/in-vivo and cadaveric research. These indicate valgus My above 125Nm, internal Mz above 35Nm (Piziali et al., 1980), anterior IJFx above 2000N (Woo et al., 1991) and knee flexion 20-30° (Li et al., 2004; Markolf et al., 1995) place the ACL at risk of rupture.

RESULTS:

For each maneuver there were no significant differences in each variable when comparing the 2 studded football boots. Knee flexion 20-30° occurred during cutting between 0-22% stance and 73-94% stance, respectively. Cutting maneuvers increased the risk of ACL injury by significantly increasing valgus My and internal Mz ($p < 0.001$). The timing of the peak valgus My sufficient for ACL rupture occurred between 23% - 60% of stance phase when knee flexion was 30°-52°. The range varied between 177.8 N·m to 231.6 N·m (Nike Air Zoom Total 90 v3 FG boot). Peaks of internal Mz occurred between 33% to 58% of the stance phase for 30º and 60º cutting manoeuvres and were sufficient for ACL rupture. Between 8% to 82% of stance values were sufficient for ACL rupture. The peak range varied between 332 N·m (Nike Air Zoom Total 90 v3 FG) to 353 N·m (Adidas Copa Mundial boot). The peak anterior IJFx for 60 degree cutting maneuvers were 1344 N and 1212N for the Nike Air Zoom Total 90 v3 FG and Adidas Copa Mundial boots, respectively. Although these forces were insufficient for ACL rupture on their own, the values increased for greater cutting angles from the straight line run, although not significantly. Anterior IJF forces were greater than 1000N during 22% - 50% of stance.

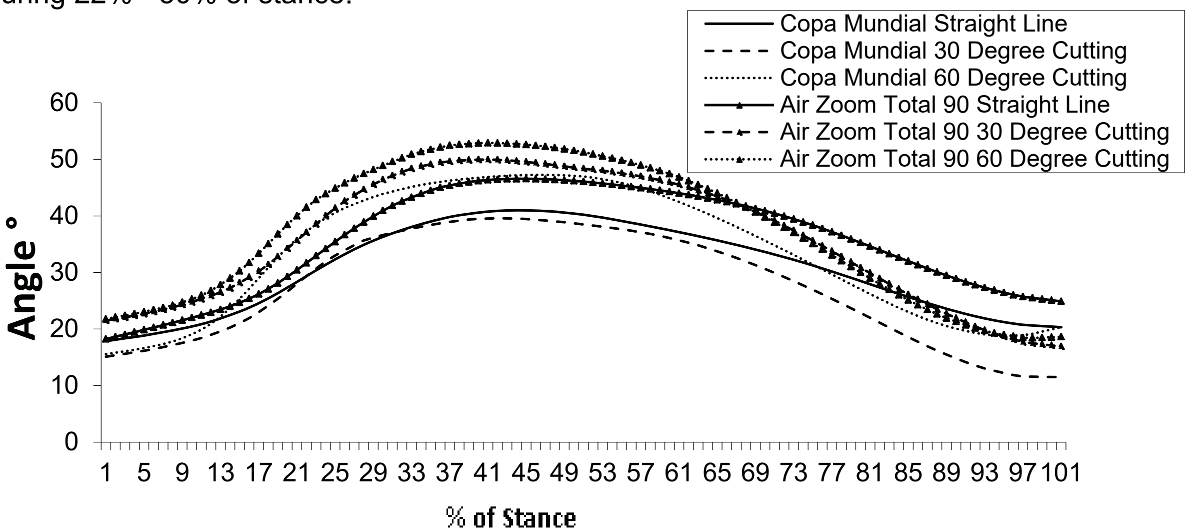

Figure 1 Adidas Copa Mundial & Nike Air Zoom Total 90 v3 FG mean knee flexion/extension angles

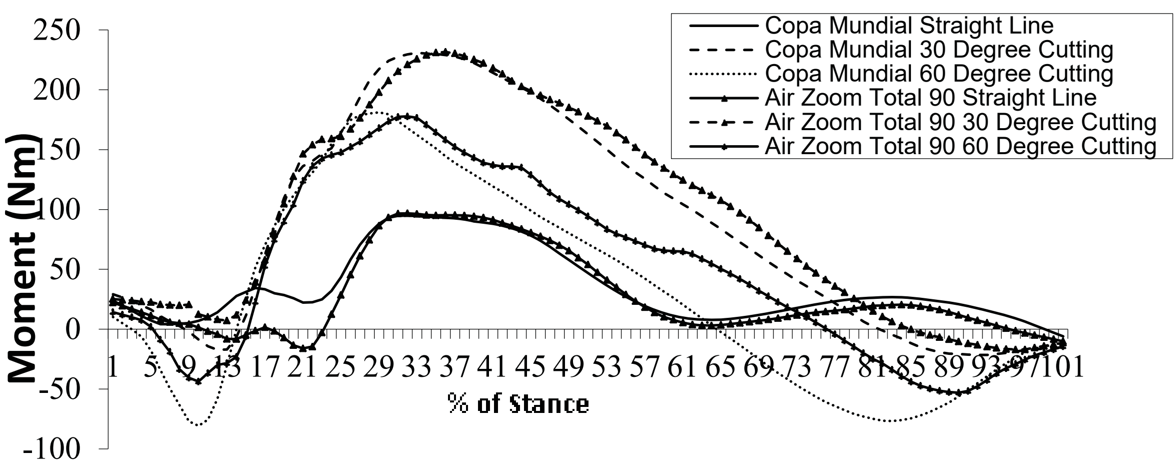

Figure 2 Adidas Copa Mundial & Nike Air Zoom Total 90 v3 FG mean knee valgus/varus moments

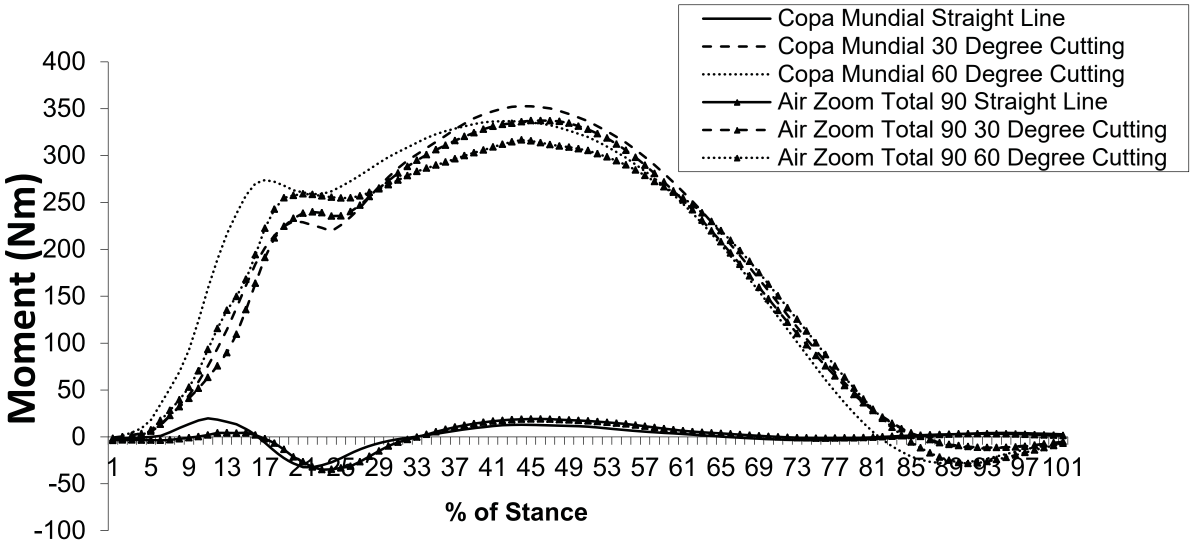

Figure 3 Adidas Copa Mundial & Nike Air Zoom Total 90 v3 FG mean knee internal/external rotation moments

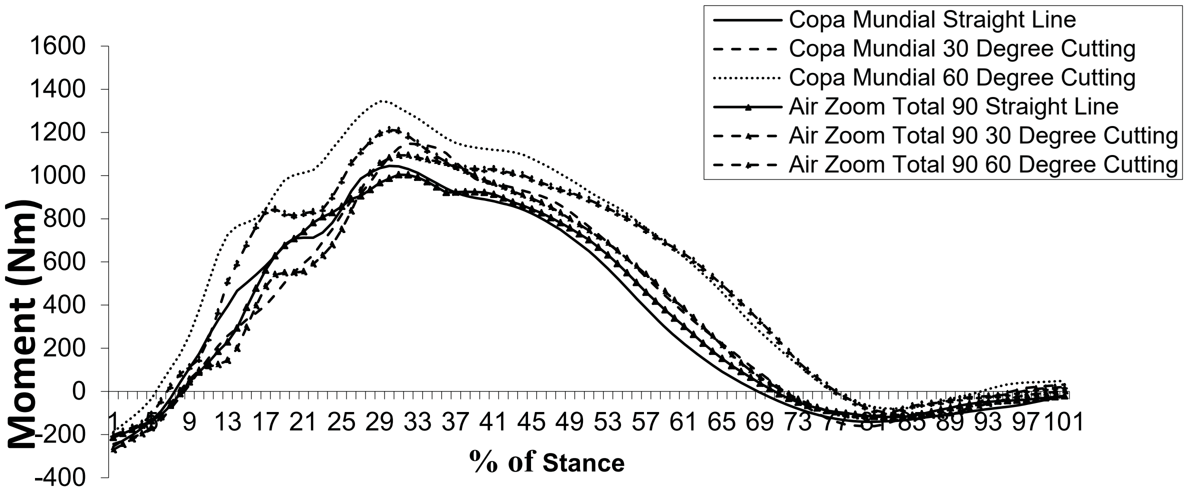

Figure 4 Adidas Copa Mundial & Nike Air Zoom Total 90 v3 FG mean knee anterior/posterior internal joint forces

DISCUSSION:

ACL injury risk was greatest with the coincidence of valgus moments (My) and internal rotational moments (Mz) between 33-58% of stance. Between 33% and 50% of stance at peak pushoff when the anterior internal joint force also peaked may be the most crucial timing for ACL injury. The increasing knee flexion above 30° from 22%-77% of the stance phase onwards with these associated kinetic alterations appears protective against potential ACL injury.

Previous research has indicated that internal Mz is likely more important than valgus My in causing ACL injury. Internal Mz is associated with straining the ACL (Markolf et al., 1995). Video analyses have indicated internal tibial rotation and valgus knee angle positioning as causative for ACL injury (Olsen et al., 2004). My strains the medial collateral ligament (MCL) by placing a valgus moment. If the MCL ruptures first the ACL is placed at greater risk as peak anterior IJFx coincide. Previous work has shown that in this situation a lower anterior IJFx value would result in ACL rupture. The peak anterior IJFx values in this research were not great enough on their own to cause ACL rupture but with a MCL ligament rupturing first they may be sufficient to progress to damage the ACL. Mazzocca et al. (2003) identified if the MCL is ruptured this results in a significantly reduced anterior tibial force required for ACL rupture, from 2110N +/- 50N down to 1250N +/- 90N. ACL injury is frequently associated with MCL damage and if this occurs first then resultant forces on the ACL required to cause rupture may require reduced rotational moments, valgus moments, and certainly anterior tibial forces. Measured internal Mz and valgus My peak values during cutting maneuvers were sufficient for ACL rupture and their timings coincided between 33-58% of stance. If a MCL injury was present, the anterior IJFx forces measured using both boots in 60 degree cutting maneuvers would have been sufficient for ACL injury. It is acknowledged that the previous measures of critical limits for ACL injury from robotic/in-vivo and cadaveric research are limited by testing techniques and the quality of the cadaveric specimens. However, this work provides a sound basis to better understand the risk of ACL injury. Although it is likely that neuromuscular control also plays an important role in preventing injury, each of the kinetic changes measured may be crucial for ACL injury and explain the high incidence of concomitant MCL and ACL injuries.

CONCLUSION:

The period of the stance phase 33-50% during cutting appears to be associated with increased risk of ACL injury. Peaks of knee valgus and internal rotational moments and anterior joint forces occur at this timeframe. A concomitant increasing knee flexion above 30° at 22%-77% of stance appears protective. Reduced control and reduced knee flexion may increase the risk of ACL injury at these times. Utilising this knowledge, by ensuring good control of knee biomechanics during cutting maneuvers, especially at this timeframe, by training techniques, could aid reduction of ACL injury risk.

REFERENCES:

Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med*. 1995;23:694-701.

Li G, Zayontz S, Most E, DeFrate LE, Suggs JF, Rubash HE. In situ forces of the anterior and posterior cruciate ligaments in high knee flexion: an in vitro investigation. *J Orthop Res*. 2004;22:293-297.

Markolf KL, Burchfield DM, Shapiro MM, Shepard MF, Finerman GA, Slauterbeck JL. Combined knee loading states that generate high anterior cruciate ligament forces. *J Orthop Res*. 1995;13:930-935.

Mazzocca AD, Nissen CW, Geary M, Adams DJ. Valgus medial collateral ligament rupture causes concomitant loading and damage of the anterior cruciate ligament. *J Knee Surgery.* 2003; 16(3):148-51.

Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med*. 2004;32:1002-1012.

Piziali RL, Rastegar J, Nagel DA, Schurman DJ. The contribution of the cruciate ligaments to the load-displacement characteristics of the human knee joint. *J Biomech Eng*. 1980;102:277-283.

Torg, J.S. and Quedenfeld T. (1974). The shoe-surface interface and its relationship to football knee injuries. *J Sports Med*, **2**(5), 261-269.

Woo SL, Hollis JM, Adams DJ, Lyon RM, Takai S. Tensile properties of the human femur–anterior cruciate ligament–tibia complex: the effects of specimen age and orientation. *Am J Sports Med*. 1991;19:217-225.