RELATIONSHIP OF SIMULTANEOUS HIP AND KNEE KINETIC & KINEMATIC MAGNITUDES AND TIMINGS ON POTENTIAL ACL INJURY RISK DURING FOOTBALL MATCH PLAY CUTTING MANEUVERS

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Fourteen professional male football players undertook straight line run and sidestep cutting at 30° and 60° with standardised approach velocity on an approved football surface using standardised studded football boots. The relationship of simultaneous hip and knee kinetic and kinematic magnitudes and timings on potential non-contact ACL (anterior cruciate ligament) injury using inverse dynamics analyses by an eight camera gait analysis system synchronised with a force platform were determined. Early peak cutting hip abduction and internal rotation moments at 13-32% of stance and high hip abduction angles are related to later peak knee valgus moments and internal rotation moment values at 30-46% that can influence ACL injury. Early stance large hip abduction angles and valgus moments early should be targeted in injury training prevention.

KEYWORDS: hip, knee; kinetic; kinematic; timing; ACL

INTRODUCTION:

Previous work has analysed the effect of boot type and changes in knee kinetics and kinematics during football cutting maneuvers (Kaila R, 2007). However, it is unclear in cutting maneuvers during football match play conditions how hip kinetic & kinematic magnitudes & timings alter in comparison to those at the knee and how they relate to potential ACL injury risk. A better understanding of the relationship between magnitudes and timings will help in understanding the impact of the normal process of cutting on these biomechanics variables and can aid identification why and when the ACL may be at greatest risk. This information can then be utilised in highlighting dangers during play, enhancing performance and in directing injury prevention training programmes. This study aimed to evaluate simultaneous hip and knee kinetic and kinematic changes throughout the stance phase of straight line running and cutting maneuvers in football match play conditions in this regard.

METHODS:

Participants: 14 injury-free professional outfield male football players undertook randomly cued straight ahead running (SA) and sidestep cutting maneuvers at 30° and 60° using the dominant lower limb. Each subject was tested using standardised Adidas Copa Mundial (Adidas, Germany) studded boots running on a FIFA (Federation of the International Football Association) approved surface at 5.5-6.0 m•s^{-1}. All were free from any injury for at least two consecutive seasons and had no history of injury requiring hospital admission and were right foot dominant. Each undertook three trials of a straight line run (0°) and sidestep cutting at 30° and 60° using their dominant right side. 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 internal/external rotational moments (Mz), knee valgus/varus (hip abduction/adduction) moments (My), flexion/extension moments (Mx) and anterior/posterior joint forces (IJFx), valgus/varus joint forces (IJFy), flexion/extension angles (Ax), knee valgus/varus (hip abduction/adduction) angles (Av) and internal/external rotation angles (Az) were determined throughout the stance phase. 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 quantified differences between the variables as a function of cutting angle. A significant difference was determined by $p < 0.001$.

RESULTS:

No significant difference in IJFx at the hip and knee were identified between cutting & SA maneuvers. Knee IJFx peaks occurred at 31%-34% of stance and reached 1345N. Knee IJFx were predominantly anterior whilst hip IJFx were predominantly posterior throughout stance. My & Mz & IJFy significantly increased in the hip and knee for cutting maneuvers compared to SA. During sidestep cutting maneuvers for the hip and knee Mx did not increase significantly compared to SA.

Av hip angles significantly increased for cutting maneuvers compared to SA. In contrast at the knee there was no significant difference.

In contrast, during SA hip angles were varus/adducted from 0-80% of stance and then valgus at the end of stance. During cutting only the hip Av was significantly valgus throughout the majority of stance, whereas the knee was always valgus regardless of maneuver.

The pattern of magnitudes of Ax flexion/extension angles at the hip were similar to that of the knee, although the hip Ax peaks were earlier in stance. The pattern of timings and magnitudes of Ax, Ay and Az at the knee were not significantly different for cutting or SA maneuvers. For the hip, although Ax and Ay pattern of timings and magnitudes were also similar, hip Ay were significantly greater in magnitude for cutting compared to SA maneuvers, although the peaks were later in stance. Throughout the stance phase of 30° & 60° cutting maneuvers the hip was abducted throughout between 6.5° and 17° whereas in SA the angles ran close to a neutral position between 2.6° abducted and 4.6° adducted.

For the hip, although Mx pattern of timings and magnitudes were similar for cutting and SA maneuvers, My and Mz were significantly 3-4 times greater in magnitude for cutting compared to SA maneuvers, although the timing patterns were similar. My peaks occurred at similar times between 27-32% of stance. At the knee My and Mz were significantly greater in magnitude for cutting compared to SA maneuvers although the timing patterns were similar, reflecting a similar pattern at the hip. My at the hip and knee for 30° cutting maneuvers were of higher peak magnitude than for 60° cutting maneuvers. The timings for peak My and Mz occurred significantly earlier in the stance phase for the hip compared to the knee.

Hip internal Mz graphs of timings and magnitudes mirror those at the knee by an initial greater internal Mz peak at 13-15% stance phase and 2nd smaller peak at 57% for cutting maneuvers. At the knee the 1st peak occurred at 17% stance and is an Internal Mz but smaller and the 2nd greater at 44% stance phase. Peak cutting hip My were 2.5 times greater than at the knee but Mz was approximately 3 times smaller.

Mz at the knee was 15-17 times greater during cutting v SA. My at the knee was 0.6-2.3 times greater during cutting v SA. The 1st Hip internal rotational moment peak at 16% of stance coincided with knee flexion 20°-30°. Knee peak cutting valgus My and internal Mz occur at 30-38% and 44-46% of stance, respectively. Knee flexion 20-30degrees occurred between 10-22% stance and 70-82% and coincided with the 1st Hip Mz peak at 16% of stance and the peak acceleration of My.

The following points identified appear particularly important:

i) My, Mz show similar patterns of timings and magnitudes at the hip & knee with significant difference for cutting v SA

Hip Ay were significantly more abducted throughout cutting maneuvers v SA whereas knee angles showed no significant difference for cutting v SA.

ii) Between13-32% of stance the earlier peak cutting hip My and Mz moments may impart or be related to the peak knee My and Mz that are seen later in stance between 30-46% of stance. In particular, this may be related to the hip always being significantly more abducted in its angle during these cutting maneuvers.

iii) Early in stance at 13-32% high hip abduction angles and My and Mz appear related to high knee My and Mz later in stance. Targeting early hip control at this timeframe appears important in reducing potential ACL injury. The magnitudes of hip My compared to Mz values were approximately 4 times greater throughout stance and are likely to influence high knee My and Mz moments which were sufficient for cadaveric ACL rupture. The knee was shown to flex beyond 30° from 22-70% of stance and would be protective against ACL injury at this time by reducing tension.

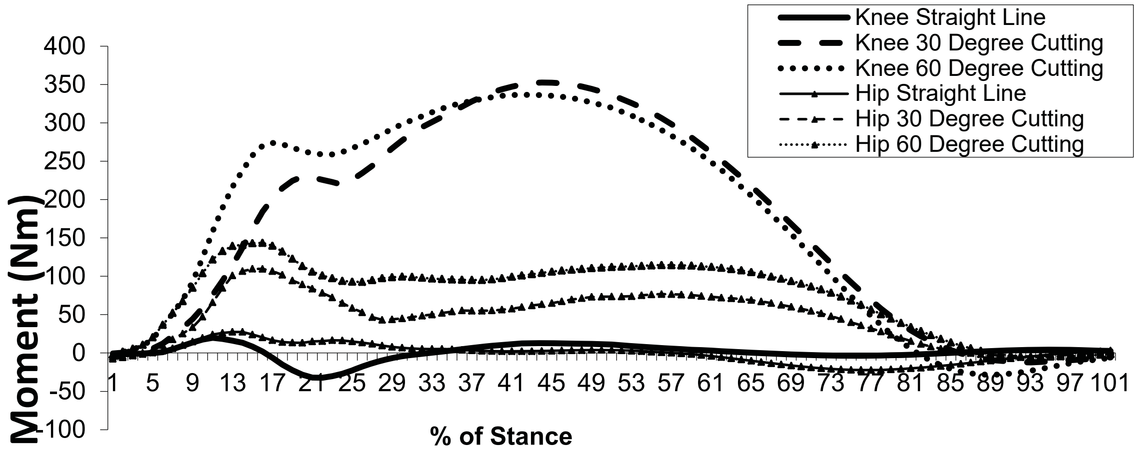

Figure 1 Mz Hip & Knee Internal/External rotation moments

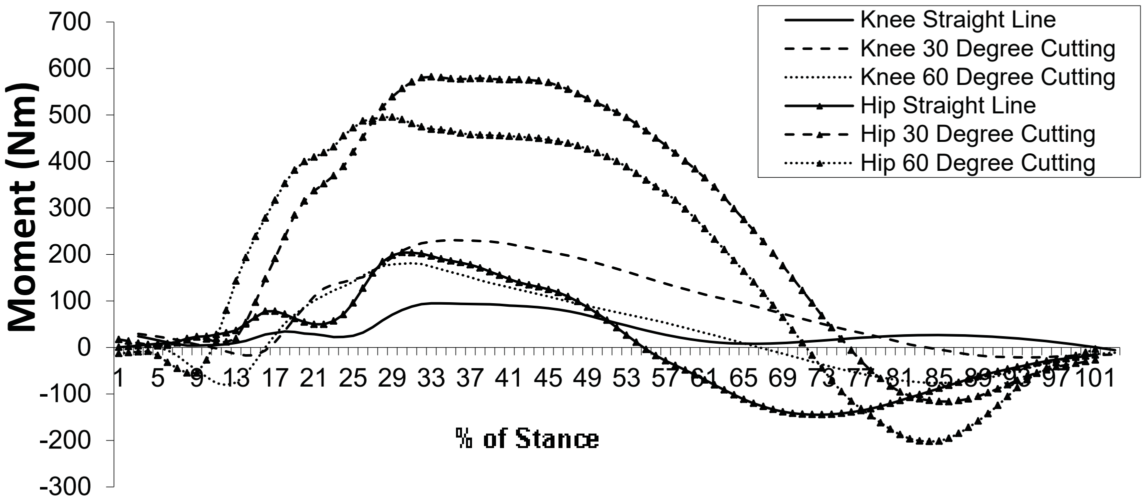

Figure 2 My Hip & Knee Valgus/Varus moments

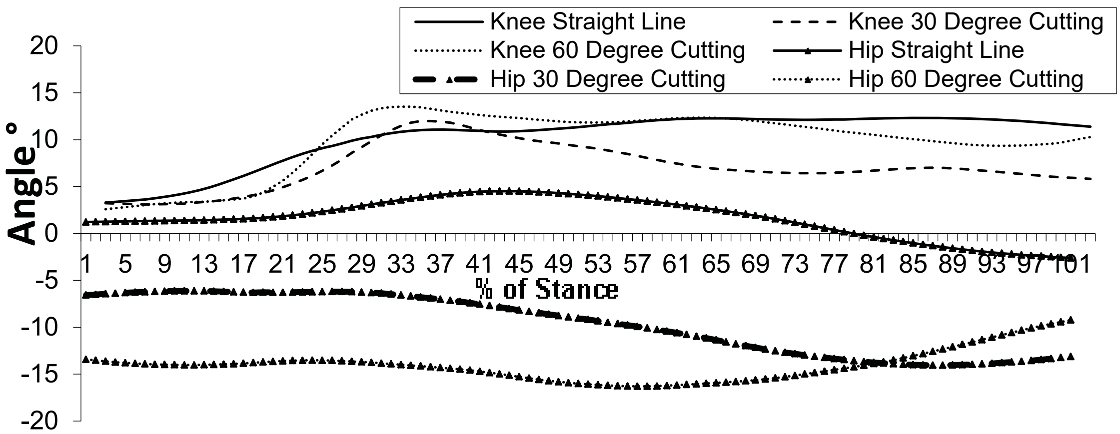

Figure 3 Ay Hip Abduction/Adduction Angles & Knee Valgus/Varus Angles

DISCUSSION:

Values and timings were compared with critical limits for ACL injury from robotic/in-vivo and cadaveric research. These indicate knee 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 increased risk of rupture. This study shows early in the stance phase of cutting that hip high internal Mz and valgus My peaks and valgus Av positioning coincide with knee flexion 20°-30° when the ACL is at risk of injury. The cutting tasks showed greater hip abduction My than at the knee. Cutting tasks required greater hip Av and was placed in a valgus position throughout stance.

Magnitudes of forces & moments associated with ACL rupture are limited by research methods utilised using non in-vivo/dynamic situations. Also cadaveric specimens used may have been affected by changes in tissue composition and strength by means of specimen preservation, freezing methods and by the age of specimens used. However, robotic systems and intact fresh-frozen human knee ACL specimens have shown similar values for simulated in-vivo situations (Woo et al., 1991). We recognise that neuromuscular factors will have a bearing on injury risk but by using inverse dynamics it is reasonable to assess the timings and magnitudes of kinetic & kinematic changes to evaluate injury risk in match play conditions.

It has been previously proposed that altering knee biomechanics through training and by specifically targeting knee valgus positioning and internal knee rotation moments (Olsen et al., 2004) could reduce ACL injury risk. However the effect of the hip joint and kinematic and kinetic timings during the gait cycle of most concern for ACL injury was not known. Identification of the above associations of early peak cutting hip abduction My and internal Mz moments at 13-32% of stance and high hip abduction Av and related later peak knee My and Mz values at 30-46% of stance has aided explaining the sequence of loading events at the lower limb joints and in understanding injury risk, mechanisms and injury intervention strategies. In performing cutting maneuvers it has to be understood that the hip is required to be placed at high abduction angles and this will be associated with high abduction My. However, ensuring that this is controlled and knee flexion increases above 30° and hip and knee Mz are kept to a minimum appears to be protective in reducing ACL injury risk.

CONCLUSION:

The early stance phase of cutting is associated with hip kinematic and kinetic changes that can influence potential ACL injury. This study has highlighted the kinematic and kinetic relationship of the hip and knee joints and given better insight how the ACL is put at risk for injury. In cutting maneuvers, early peak hip abduction My and internal Mz moments and high hip abduction Av are related to later peak knee My and Mz values. It appears that injury prevention training should target early stance phase hip abduction angles and valgus moments.

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