COORDINATION PATTERNS OF PREFERRED AND NON-PREFERRED KICKING OF THE DROP PUNT KICK: A KINEMATIC ANALYSIS OF THE PELVIS, HIP AND KNEE

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This study expanded on previous work investigating preferred (P) and non-preferred (NP) leg kicks in Australian football (AF), however this work included the kinematics of the pelvis and hip as well as the knee. Eight elite AF players performed drop punt kicks with their P and NP legs. Three dimensional kinematic data (Optotrak Certus, 250Hz) from kick foot toe off to ball contact was recorded for each kick. Significantly larger foot speed and knee angular velocities were produced by the P leg. Differences in coordination were found to be largely ROM and velocity based. Of note was the P leg produced greater ROM at the knee and pelvis but the NP leg produced greater ROM at the hip suggesting a different strategy might exist for the different legs. More work exploring the different involvement of the hip, knee and pelvis is warranted.

KEYWORDS: Coordination, kicking, preferred and non-preferred leg.

INTRODUCTION: Australian Football (AF) is a popular Australian team sport. The aim of the game is to progress the ball down a field and score as many goals and points as possible by kicking the ball between posts at the attacking end of the ground while at the same time, preventing your opponents from scoring. Ball progression can be achieved by kicking or handballing the ball to a teammate or to space and kicking is the only method of scoring goals. Due to the high pressured nature of the game, AF requires its players to kick with their preferred leg (P) and non-preferred leg (NP). Ball (2003) reported that 20% of kicks in AF are performed with the NP and this can be as high as 45% for some players. Players who can kick equally well on either leg are seen to have a tactical advantage as they can produce more rapid and successful ball disposals.

Only one study has examined the kinematic differences between P and NP kicking in AF although low N limited statistical analyses. Hancock and Ball (2008) found non-significant large effects for the difference in knee ROM between the two kicking legs at (P = 0.12, d = 0.9). The study also examined phase plane diagrams of knee angle-knee angular velocity and reported similar overall shapes of the curves but the non-preferred foot curve was smaller than that of the preferred foot curve. The authors concluded that differences between the P and NP were range of motion and angular velocity based and not coordination or timing for elite performers.

A limitation of the Hancock and Ball (2008) study was that it was limited to the knee. To more fully understand differences between the P and NP kicking, more joints and segments need to be examined. In particular, the hip joint and pelvis segment have been shown to be important in kicking and need to be included in this analysis. Dichiera et al. (2006) reported differences in pelvic motion and positions between accurate and inaccurate AF kickers and substantially larger joint moments have been reported at the hip (220Nm) compared to the knee (90 Nm) during the kick suggesting the hip is a principal area for force generation (Robertson and Mosher, 1985). As such, it is expedient to expand the exploration of coordination differences in the AF to include the hip and pelvis, a point that Hancock and Ball (2008) make.

The aim of this study was to determine if differences exist between preferred and non-preferred leg kicks for kinematic factors and coordination, and including evaluation of the hip and pelvis.

METHOD: Eight elite Australian Rules football players, currently playing in the Australian Football League (AFL) were recruited for this study. All players reported being right foot dominant and free of any lower limb injury. Details of participants are shown in Table 1.

Table 1. Participant Details

	Age (years)	Height (cm)	Mass (kg)	Years on AFL List
Participants	21.3 ± 0.9	1.87 ± 0.15	85 ± 5	3.6 ± 2.1

Participants performed 10 test kicks using new Sherrin AF footballs inflated within the specified pressure range of 62-76kPa (Australian Football League, 2003). Five kicks were performed using their P and five kicks were performed using their NP. Participants used their preferred run up and kicked into a net 5 m away (directly in front). Participants wore standard training apparel (football jumper, shorts) as well as their regular training shoes ('turf' training shoes).
During each kick, 250 Hz three dimensional data of the shank, thigh, knee, hip and pelvis were collected using Optotrak Certus System (Northern Digital Inc., Waterloo, Canada, root mean square error of 0.1mm in 2D and 0.15mm 3D). Three Optotrak cameras were placed approximately 5 m from the kick area in three different positions (behind the kick, to the left of the kick, to the right of the kick) directly facing the designated kicking zone. Clusters of infra-red light emitting diodes (LED) were placed on the pelvis, shank, thigh and foot of both legs of each participant. The thigh clusters were placed on the lateral side of the thigh midway between the greater trochanter and the lateral epicondyles of the femur. The shank markers were placed on the lateral side of the shank, midway between the lateral malleolous and the distal end of the calf muscle. The pelvis LEDs were positioned relative to the anatomical landmarks (AL's) of the posterior superior iliac spine and the sacrum. An additional single marker was placed on the shoe over the head of the fifth metatarsal. AL's were located and established at the pelvis (left/right iliac crests and posterior/ superior iliac spines), hip (left/right greater trochanter), knee (medial/lateral epicondyl) and ankle (medial/lateral malleolus) using a digitising probe (Northern Digital Inc., Canada).
The P and NP kicks were compared for coordination profiles and kinematic data identified as important in previous research. Coordination profiles were evaluated using angle-angle diagrams (knee-hip angle, hip-pelvis angle) and phase plane diagrams (knee angle-knee angular velocity). Kinematic data included foot speed, pelvis, hip, thigh, knee and shank angles, angular velocities and ranges of motion (all identified as important in AF kicking, Ball, 2008). T-tests were conducted for each mean value to determine the statistical significance of each value. Angles were 2D in the saggital plane as the AF kicking movement is planar. The alpha level was set at $p < 0.05$ for significance. Effect sizes were additionally calculated (Cohen's *d;* small *d* = 0.2, medium *d* = 0.5, large *d* = 0.8, Cohen, 1988).

RESULTS: Table 2 reports significant differences between preferred and non-preferred legs.

Table 2. Significant differences between the preferred and non-preferred leg kicks.

	Foot Speed (m/s)		Knee Angular Velocity at Ball contact (°/s)	
	P	**NP**	**P**	**NP**
Mean	19.1	17.2	1302	1043
SD	1.5	1.5	216	176
P-Value	0.05		0.04	
Effect Size	1.3		1.3	
Effect Scale	Large		Large	

Non-significant large effect sizes also existed for knee range of motion (d = 1.24), hip angular velocity at ball contact (d = 0.71) and hip range of motion (d = 1.20). No significant differences or medium or large effects were found for timing parameters.

Figure 1 shows the mean hip-pelvis angle-angle cyclogram with a difference near BC noted (shaded area).

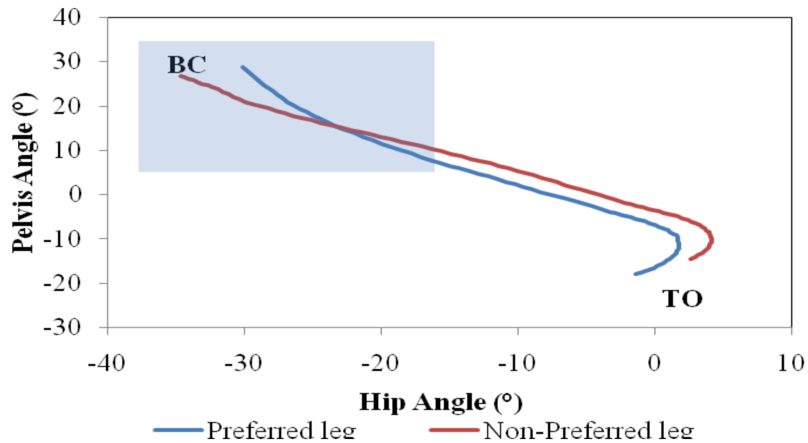

Figure 1. Mean Hip-Pelvis Angle-Angle Cyclogram for the Preferred and Non-Preferred Kicking Leg (TO= Toe Off, BC = Ball Contact)

DISCUSSION: The significant difference in foot speed between P and NP in the current study supported previous research. Hancock and Ball (2008) study found a large non-significant effect existed between the two kicking legs (P = 0.09, d = 1.5) and with the same N as this study, this would have been a significant result (note the larger effect size). Similar findings have been reported for soccer kicking with both Dorge *et al*., (2002) and Nunome *et al*., (2006) reporting significant differences in foot speed between the P and NP kicks. A large significant effect was found to exist for knee angular velocity at ball contact for the preferred kicking leg (P = 1302 °/s, NP = 1043°/s). The difference found in this study indicated that elite players can generate more foot speed and knee angular velocity with their preferred leg.

Angle-angle diagrams and non-significant findings for timing parameters indicated that differences between the P and NP were range of motion and velocity rather than coordination based. This supported the findings of Hancock and Ball (2008) but with the inclusion of more joints in this study. Based on these findings, coaching should focus on increasing range of motion and foot speed of the non-preferred leg to improve performance.

Although ROM values were not significant, an interesting pattern emerged that is worth noting for future studies. ROM was larger for the P at the knee and pelvis but was smaller at the hip (medium or large effects existed for each comparison). This might suggest a different strategy or difference in control of movement between the preferred and non-preferred legs might exist. Future work exploring this mechanism is warranted.

The pelvis-hip angle-angle diagram in figure 1 showed interesting results. The shaded area illustrates a subtle difference in the movement pattern just prior to ball contact. There are two possible explanations for this difference. The hip angular velocity of the P could have decreased more than the NP in preparation of ball contact. However, as the pelvis angle for both legs

reached similar values at ball contact it is more likely that the pelvis angular velocity of the P increased in order to generate more power for ball contact.
During performance of the NP, participants could have also placed constraints on the pelvis and knee ROM in order to simplify the control of the movement by limiting it to the hip joint. This explanation can be linked to Bernstein's (1967) theory of locking degrees of freedom. The hip for the non-preferred leg might be easier to control and therefore, the player locks down (or restricts at least) the surrounding joints to allow for more movement to be conducted at the selected joint or segment. Conversely, hip angular velocity of the preferred leg decreased (48°/s) toward the point of ball contact while the pelvis angular velocity continued to increase (124°/s). The pelvis could have been used to generate more of the power at ball contact. As such, rather than a larger hip extension, the larger last stride might be related to a greater pelvis ROM which in turn leads to a larger pelvis angular velocity at ball contact.

CONCLUSION: Differences existed between the preferred and non-preferred foot in AF kicking. Significantly larger foot speeds and knee angular velocities were produced by the preferred foot kicks. Observation of angle-angle diagrams indicated that differences were ROM rather than timing and coordination based. However some interesting differences existed with ROM being larger at the knee and pelvis but smaller at the hip for the preferred foot. Future work with large N is warranted to further explore this aspect of AF kicking.

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