FOOT-TO-BALL INTERACTION IN PREFERRED AND NON-PREFERRED LEG AUSTRALIAN RULES KICKING

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Kicking is an integral skill within Australian Rules Football (ARF) and the ability to kick with either foot is essential at the elite level. A principal technical factor in the kicking skill is the nature of impact between the kicking foot and ball (Ball, 2008a). This study compared characteristics of foot-to-ball interaction between preferred and non-preferred kicking legs in Australian Rules football (ARF). Eighteen elite ARF players performed a maximum distance kick on their preferred and non-preferred legs. From high-speed video (6000Hz), two-dimensional digitised data of seven points (five on the kick leg, two on the ball) were used to quantify parameters near and during impact. The preferred foot produced significantly larger foot speed, ball speed, work done on the ball, ball displacement while in contact with the foot and change in shank angle during the ball contact phase.

KEYWORDS: Football, Kicking, Ball impact

INTRODUCTION: Australian Rules football (ARF) is one of the most popular sports in Australia. As the only form of disposal allowed for goal-scoring in ARF is kicking, the ability to kick accurately and effectively is integral to ARF players. In addition, as approximately 20% of kicks in Australian Football League (AFL) games are performed with the non-preferred foot, and this percentage can be as high as 45% for some individuals (Ball, 2003), the ability to kick effectively with either leg is an essential attribute for a player. This ability provides a player with greater disposal options and makes it more difficult for the opposition to defend.
The nature of foot-ball impact is a technical factor that is important to the kicking skill (Tsaousidis and Zatsiorsky, 1996; Dorge et al., 2002; Nunome et al., 2006a; Ball, 2008a). For ARF kicking, Ball (2008a) found that foot speed before impact, ball speed after impact, time in contact between foot and ball and ball displacement during contact were important parameters during foot-ball impact. From the results, Ball (2008a) argued that work was done on the ball during foot-ball impact which is important for the nature of foot-ball impact as momentum equations would be inappropriate for describing the foot-ball impact. Tsaousidis and Zatsiorsky (1996) found similar results for soccer kicking.
In spite of the importance of preferred and non-preferred leg kicking in ARF, there have been few studies examining these kicks and no studies focussing on the important aspect of nature of impact. The aim of this study was to compare ball to foot characteristics for preferred and non-preferred foot kicking in ARF.

METHODS: Eighteen Australian Football League (AFL) players (Age: 22.8 ± 4.2 years) kicked a Sherrin Australian Rules football (used in AFL competition, pressure range of 67-75 psi) with the preferred and non-preferred leg. Reflective markers were placed on the kicking leg prior to kicking. Players performed their preferred run-up approach and kicked for maximum distance through marker cones placed 40 metres from a line indicated by two markers. All players kicked until a 'good' kick (defined as a kick that went between the cones and was considered by the player and kicking coach to be a good maximal kick) was executed. All kicks were videoed at 6000 Hz using a Photron Fastcam APX-RS high speed camera (Photron Ltd, San Diego) placed perpendicular to the line of the kick with one good kick for each participant and each leg stored to disk.
Data Analysis: From the video for each kick, ten frames immediately prior to the initial contact between foot and ball (initial impact) and ten frames immediately after the end of contact between foot and ball (release) were identified for analysis. For each frame, seven points (head of fibula, lateral malleolus, heel of boot, head of the 5th metatarsal, toe of boot, top point of ball, bottom point of ball) were digitised using Silicon Coach Analysis tools

(Silicon Coach Ltd, NZ). The digitised XY coordinates were transferred to Microsoft Excel to enable the calculation and analysis of seven parameters identified as important during foot-ball impact (Table 1).

Table 1. Definition and calculation of measured parameters.

Parameter	Definition
Foot speed (ms^{-1})	Foot speed was defined as the average speed of the centre of the foot prior to initial foot-ball impact. X and Y coordinates of four points on the kick leg (ankle, heel, head of 5^{th} metatarsal, toe of boot) were averaged to approximate the centre of the foot. Foot speed was calculated in the X and Y-directions between each frame, then averaged across all the digitised frames prior to initial foot-ball impact. The resultant foot speed was then calculated using quadrature summation.
Ball speed (ms^{-1})	Ball speed was defined as the average speed of the centre of the ball across all ten digitised frames after release. X and Y coordinates of two points (bottom of ball, top of ball) used to approximate the centre of the ball. Ball speed was calculated in the X and Y-directions between each frame, then averaged across all the digitised frames after foot-ball release. The resultant ball speed was then calculated using quadrature summation.
Ball:foot speed ratio	Ball:foot speed ratio was defined as the average ball speed at release divided by average foot speed at initial impact.
Time in contact (ms^{-1})	Period of contact between foot and ball from initial impact to release. Time in contact was calculated using the timer function supplied by Silicon Coach. The timer function was used to determine the number of frames in which the foot was in contact with the ball. Once the number of frames was determined, this was then divided by the frame rate (6000 Hz) to give time in contact between foot and ball.
Ball displacement (m)	Ball displacement defined as the change in displacement between the centre of the ball at initial impact and the centre of ball at release. The X and Y co-ordinates of the two points on the ball (top of ball, bottom of ball) were averaged to determine the position of the centre of the ball. Ball displacement was then calculated by subtracting the coordinates of the centre of the ball at impact from the coordinates of the centre of the ball at release.
Change in shank angle (°)	Difference in shank angle (angle between the horizontal axis and line between the head of fibula and ankle of the kick leg) between initial impact and release. The horizontal angle function supplied by Silicon Coach was used to find the shank angle by digitising the head of the fibula and ankle. Shank angle at impact was then subtracted from the shank angle at release to determine change in shank angle.
Work done on the ball (J)	Calculated using the formula, Work = mass x acceleration x displacement. Approximated using the mass of the ball (450g), ball acceleration during foot-ball impact (calculated from change in ball speed during foot-ball impact divided by time in contact) and ball displacement. Change in ball speed (used in ball acceleration) was defined as the difference between average ball speed before impact and average ball speed after release.

Statistical Analysis: Paired t-tests were conducted for each kicking parameter. Statistical significance was set at $p < 0.007$ after Bonferroni adjustment. Effect sizes (large: $d > 0.8$, medium: $d > 0.5$, small: $d > 0.2$) as defined by Cohen (1988) were also conducted.

RESULTS: Table 2 reports the mean and standard deviation values for the measured parameters as well as the results of statistical tests comparing preferred and non-preferred leg kicks.

Table 2. Mean and standard deviation of measured parameters for preferred and non-preferred kicking legs.

		Preferred Leg	Non-preferred Leg	t-test (*p*-value)	Effect size (*d*)
Foot speed (ms^{-1})	Mean	26.5	22.6	<0.001*	1.77
	SD	2.5	1.7		Large
Ball speed (ms^{-1})	Mean	32.6	27.0	<0.001*	1.32
	SD	4.4	3.8		Large
Ball:foot speed ratio	Mean	1.23	1.20	0.055	0.25
	SD	0.11	0.13		Medium
Time in contact (ms^{-1})	Mean	11.53	12.05	0.01	0.37
	SD	1.25	1.48		Medium
Ball displacement (m)	Mean	0.22	0.19	<0.001*	1.50
	SD	0.02	0.02		Large
Change in shank angle (°)	Mean	13	12	<0.001*	1.38
	SD	1	1		Large
Work done on the ball (J)	Mean	225.0	156.2	<0.001*	1.53
	SD	45.0	42.3		Large

* Significant difference (p<0.007) after Bonferroni adjustment.

Preferred and non-preferred legs differed significantly for five of the seven parameters analysed. In all cases, preferred leg kicks produced the greater values with a large effect size. No significant difference existed between kicking legs for ball:foot speed ratio and time in contact although for both, a small effect existed.

DISCUSSION: Foot speed recorded for the preferred leg in this study (26.5 ms^{-1}) was similar to values reported for elite ARF players (26.4 ms^{-1}, Ball, 2008b). No foot speed data exists for ARF kicking on the non-preferred leg, though the values in this study (22.6 ms^{-1}) were comparable to those found for soccer kicking (20.6 ms^{-1}, Nunome et al., 2006b). Ball speeds for preferred (32.6 ms^{-1}) and non-preferred (27.0 ms^{-1}) legs were similar to those reported by Nunome et al. (2006b) for soccer players (preferred: 32.1 ms^{-1}; non-preferred: 27.1 ms^{-1}). The values for ball:foot speed ratio, both preferred (1.23) and non-preferred leg (1.20), recorded in this study were within the range of values found for soccer kicking (Preferred leg: 1.06, Asami and Nolte, 1983; 1.35, Nunome et al., 2006b; Non-preferred leg: 1.19, Dorge et al., 2002). The mean time in contact for the preferred leg (11.53 ms^{-1}) was longer than the values reported by Ball (2008a) for ARF kicks (30 m kick: 9.8 ms^{-1}; 50 m kick: 10 ms^{-1}). However, the value in this study lay between values reported for soccer kicking (9.1 ms, Nunome et al., 2006a: 16 ms, Tsaousidis and Zatsiorsky, 1996). Preferred leg ball displacement (0.22 m) lay within the range of values reported by Ball (2008b) for elite ARF players (0.19-0.24 m).

Differences existed between preferred and non-preferred legs at foot-ball impact. Values for preferred leg kicking were significantly greater for foot speed, ball speed, ball displacement, change in shank angle and work done on the ball. No difference was found for ball:foot speed ratio and time in contact between preferred and non-preferred leg kicking.

Ball and foot speeds were greater for the preferred leg compared to the non-preferred leg, while no difference was found for ball:foot speed ratio. This may indicate that foot speed is the influential factor for ball speed. Strong correlations between foot and ball speed (Preferred leg, r = 0.79, p < 0.001; non-preferred leg, r = 0.64, p = 0.005) support foot speed being the influencing parameter for ball speed. However, the testing in this study limited kicks to 'good' kicks and the nature of impact between foot and ball might be more influential for

'mis-kicks' where the ball is not struck with an optimal orientation and/or position on the foot. This is an important useful future direction.

Change in shank angle was greater for the preferred leg, indicating that the shank moved through a greater range for the preferred leg compared to the non-preferred leg. More work was done on the ball for the preferred leg kick. In addition, a large significant effect existed for ball displacement, with the preferred leg moving the ball further than the non-preferred leg. However, no significant difference existed between kicking legs for time in contact. This indicates that greater power existed for the preferred leg, as may be expected.

Work was done to the ball during contact with the foot for both the preferred and non-preferred legs. Players produced significantly higher values for work done to the ball when kicking with the preferred leg compared due to both a greater average force being applied to the ball and greater displacement over which the force was applied. While the values for ball:foot speed ratio in this study may suggest that foot speed is the main influencing factor for ball speed, work done on the ball may also influence ball speed due to force being applied to the ball during foot-ball impact. Ball (2008a) suggested that muscular force generated at the hip and/or knee can be applied to the ball during foot-ball contact due to large values for change in shank angle, work done on the ball and ball displacement during foot-ball impact. The values in this study suggest a similar finding. As the values for work done on the ball, change of shank angle and ball displacement were all greater when kicking with the preferred leg, this indicates that the preferred leg was able to apply greater muscular force during foot-ball impact.

CONCLUSION: Differences exist in the nature of ball-foot impact between preferred and non-preferred foot kicks in ARF. Preferred foot kicks produced greater foot and ball speed, ball displacement, change in shank angle and work done to the ball. The greater amount of work being done to the ball during preferred leg kicking was due to both a greater average force being applied to the ball and greater displacement over which force was applied. Further research should focus on examining the source of work done to the ball. Suggestions that muscular force is responsible for the work done on the ball (Tsaousidis and Zatsiorsky, 1996; Ball, 2008a) are still to be determined, yet may provide important scientific information for coaching and strength and conditioning techniques of ARF players.

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