CENTRE OF MASS MOTION DURING THE PUNT KICK

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Centre of mass (COM) motion has been linked to performance in kicking and cricket bowling. The aim of this study was to examine COM motion during the punt kick. Five elite Australia Footballers performed maximal and sub-maximal punt kicks. Optotrak Certus (200Hz) collected kinematic data and COM and foot speed were calculated. Greater COM deceleration was linked to faster foot speeds. Large effects existed between maximal and sub-maximal kicks for change in COM velocity and average impulse as well as for correlations between these parameters and foot speed within the maximal kick. Approach speed was significantly larger for maximal kicks but the relationship was unclear with a negative correlation with foot speed existing within maximal kicks. More work with larger N examining COM deceleration is recommended.

KEYWORDS:. Rugby, Australian Football, stance phase, deceleration.

INTRODUCTION: The punt kick is an important component of Australian Football (AF), American football and the rugby codes. Of particular advantage in punt kicking sports is the ability to kick the ball further. In the rugby codes, this allows for kicks gaining greater distance from defense or the ability to kick the ball higher allowing more time for attackers to run to the landing zone. In Australian football, greater kick distances allow for more passing options and for goalshots to be taken further from goals (Ball, 2008). Ball (2008) found a number of factors associated with distance kicking in AF with foot speed at ball contact being the most influential factor. Other aspects included shank angular velocity at ball contact, the length of the last stride and ball position relative to the body at the point of foot to ball contact.
A factor that has not been examined but might hold useful information is the motion of the centre of mass in the last step of the kicking motion. Greater reduction in COM speed in the last step has been linked to greater ball speeds in both soccer kicking (Potthast et al., 2010) and cricket bowling (Ferdinands et al., 2010). Both studies suggested this was due to a better transfer of momentum from full body motion of the approach into the more distal segments of the thigh in the case of soccer (Potthast et al., 2010) and the upper body and arm in the case of cricket bowing (Ferdinands et al., 2010).
Approach speed and direct contribution of whole body motion have been linked with performance in AF, soccer and cricket bowling. Both MacMillan (1976) and Ball (2008) found linear kick leg hip velocity was associated with greater foot speeds in AF kicking. In soccer, Opavsky (1988) reported greater ball speeds of 30.8 m/s when a run-up was used compared to 23.5 m/s for a stationary kick. Approach speed, as well as direct contribution of COM velocity at ball release (i.e. the COM is moving towards the target with the ball in hand therefore will contribute to ball speed in the direction of the delivery at release), have also been linked to faster bowling in cricket although Ferdinands et al. (2010) noted these studies have been somewhat conflicting and suffered from methodological issues. This is another area that has not been explored in the punt kick and is worth examination.
The aim of this study was to examine COM motion in the punt kick and to determine if approach speed and deceleration during the stance phase of the kick was associated with performance.

METHOD: Five elite AF players (age 19.8 +/- 0.9 years) contracted to an Australian Football League (AFL) club at the time of testing performed kicks using a Sherrin AF football (used in AFL competition). Players performed a standard warm up then were instructed to perform three drop punts typical of a 45m pass (sub-maximal) and three maximum distance kicks using their preferred leg, kicking into a net towards a target. Players were very familiar with both kicks, performing them frequently in training.

Prior to warm up and kicking, players were fitted with clusters of light emitting diodes (LED) on the trunk, pelvis, upper arms, forearms, hands, thighs and shanks as well as a single LED on the fifth metatarsal of the kick foot (set-up used in previous kicking research, e.g. Falloon et al., 2010). Anatomical landmarks were located and established using a digitising probe (Northern Digital Inc., Canada) to define joint centres at the wrist, elbow, shoulder, hip, knee and ankle. The pelvis was defined by the left/right iliac crests and posterior/ superior iliac spines. A three tower Optotrak Certus system collected three dimensional coordinates during the kick (200Hz). Displacement data was smoothed using a Butterworth digital filter with a 12 Hz cut off (determined by visual inspection of velocity curves and previous research identifying 12 Hz as appropriate e.g. Ball, 2008). From this data, centre of mass (COM) displacement and velocity as well as foot speed at ball contact was determined for each kick within Visual 3D software (Hanavan, 1964, data used for COM calculations). COM velocity was quantified at the instant before support foot landing and at ball contact. Average impulse was also calculated (body mass times change in velocity from stance leg landing until ball contact as used by Pottast et al., 2010). The mean value for each kick/leg condition for each player was used in further analysis.
COM motion was compared between preferred and non-preferred legs using t-tests. The relationship between performance as indicated by foot speed at ball contact, and COM variables was assessed with correlations. For both analyses, significance was set at $p < 0.05$ but due to the low N, particular emphasis was placed on effect sizes. COM curves from support foot landing until support foot toe off were examined qualitatively.

RESULTS: Table 1 reports mean values for foot speed at ball contact and COM velocity at approach and ball contact as well as the difference between these values.

Table 1
Mean COM velocity values (m/s) and average impulse (kg.m/s) for the 45m and maximal punt kick (X = medio-lateral, Y = anterior-posterior, Z = vertical, R = resultant)

Event	COM axis	45 m M	45 m SD	Maximum M	Maximum SD
Approach	X	0.0	0.3	0.2	0.3
	Y*^	3.3	0.3	3.7	0.1
	Z^	-0.9	0.1	-0.9	0.2
	R*^	3.4	0.2	3.8	0.0
Ball Contact	X	0.0	0.2	0.1	0.1
	Y	2.0	0.3	2.1	0.2
	Z	0.9	0.2	1.0	0.3
	R^	2.2	0.2	2.4	0.1
Change in COM Velocity	X	0.0	0.2	-0.2	0.3
	Y^	-1.2	0.4	-1.5	0.2
	Z	1.7	0.4	1.8	0.2
	R	-1.1	0.3	-1.4	0.1
Average Impulse	X	-3	17	-14	21
	Y^	-94	33	-124	14
	Z	136	35	147	15
	R^	-87	26	-116	3
Foot Speed*		18.8	0.9	21.1	0.2

*p<0.05, ^ d>0.8, large effect

Foot speed and approach speed (y-axis and resultant) differed significantly with very large effects (Cohen's d > 1.5) with maximal kicks producing larger values. Large non-significant

effects were also evident for resultant COM velocity at ball contact (d = 1.2), the change in COM velocity in the y direction (d = 0.95) as well as change in resultant COM velocity (d = 1.3) and average impulse in the y-axis (d = 1.2) and resultant (d = 1.5).
For the maximal kick, at approach, resultant COM speed was significantly correlated with foot speed (r = -0.95) and large non-significant effects were evident for both Y (r = -0.83) and Z (r = -0.81) axes. Large non-significant effects were also evident for the change in COM velocity in the y-axis (r = 0.77) and average braking impulse in the y-axis (r = 0.71). There were no significant relationships for the 45 m kick, nor were any large effects evident.

DISCUSSION: The link between the ability to decelerate COM during the stance phase of the kick and greater performance in the punt kick was supported in this study. The maximal kicks exhibited a larger reduction in COM velocity (1.5 compared with 1.2 m/s) and average impulse (124 compared to 94 kg.m/s) in the direction of the kick. Further, while absolute values ranged quite widely between kickers (evident in some of the standard deviation values which affected group comparison statistics), all five exhibited greater decelerations and larger average impulses for the maximal kick. Finally, large effects were evident from correlation analysis for these factors within the maximal kick with a larger change in velocity and average impulse associated with larger foot speeds. This finding is similar to the relationship found by Potthast et al. (2010) for soccer kicking and by Ferdinands et al. (2010) for cricket bowling. While these results need further work with more subjects to gain statistical significance, the size of the effects, the fact that all individuals exhibited the same within-player patterns and the similar findings in other kicking research support this relationship existing.
The link between approach speed and performance was unclear. A greater approach speed was evident for maximal compared to sub-maximal kicks, indicating that a faster approach might be advantageous for kicking the ball further. However, within-kick correlation analysis for the maximal kick indicated that a lower approach speed was associated with higher foot speeds. This was in contrast to the finding of Ball (2008) who found maximal linear hip speed explained 40% of the variance in foot speed in AF kicking. This difference might in part be explained by the use of the hip rather than COM with Ball (2008) noting that long axis rotation of the trunk and pelvis occurred. This would mean linear hip velocity will be higher than COM velocity and that it is more directly related to foot speed as it is part of the same leg rather than the whole body that COM represents. Given the low N for correlation analysis in this study it cannot be considered a robust finding without further work but it does suggest the possibility that optimising rather than maximising approach speed might be important. Certainly it would seem logical that a faster approach speed might be beneficial but there would come a point at which the gains did not continue to increase and aspects such as stability and balance during the kick were adversely affected. This is an important future direction for this work. Also of note in approach speed, the difference in COM velocity at ball contact between kicks (0.2 m/s) was considerably smaller than the difference in foot speed (2.3 m/s) so linear velocity of the whole body would seem to contribute only a small amount to foot speed at ball contact.
Examining COM curves qualitatively, COM motion was similar for all players (see figure 1 for example). In the direction of the kick (y-axis), COM slowed during the stance phase for all kicks. Differences between resultant COM velocity at the instant before stance foot landing of 3.4 m/s to 2.2m/s for the 45 m kick and 3.8 m/s to 2.4 m/s were both statistically significant ($p < 0.001$). It is possible this is due to the kicker improving the stability of the body in preparation for the kick, or of transferring momentum developed from the approach onto the kick leg as discussed previously. It also indicates braking forces only and no propulsive forces are acting on the body during this phase with a relatively consistent decrease in COM Y velocity and a clear change in curve direction only evident after ball contact. Solely braking forces with no propulsive forces in the stance phase of soccer have been reported (Lees et al., 2010).Confirming this would also be a useful future direction in examining the punt kick.

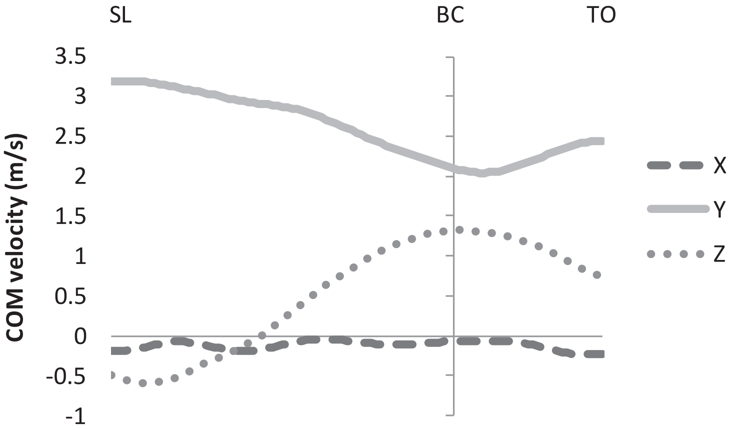

Figure 1: Example COM velocity curve from just before support foot landing (SL) until support foot toe off (TO) after ball contact (BC)

In the vertical direction, COM velocity of -0.9 m/s indicated a downward motion of COM prior to support leg landing (SL). After SL COM velocity continued to increase in the negative direction briefly as the support leg flexed before slowing its downward trajectory and moving upward. The upwards motion continued, peaking at or very near ball contact at approximately 1m/s then slowing to approximately 0.5-0.8 m/s at support leg toe off. Lateral motion differed slightly (although not significantly) between players and between the 45m kick and maximal kick. This seemed to largely depend on approach angle with players tending to adopt a slightly more angles approach for maximal distance kicks. However, values in the lateral direction were substantially lower than in the vertical and forwards direction.

CONCLUSION: The ability to produce greater foot speed in the punt kick seems to be linked to the ability to decelerate the COM in the stance phase of the kick, similar to soccer kicking and cricket bowling. Approach speed might also be linked but while maximal kicks exhibited greater approach speeds compared to sub-maximal kick, within-kick analysis indicated a negative relationship, so this relationship might be optimal rather than maximal. Future work with larger subject numbers is recommended.

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