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BALL IMPACT DYNAMICS IN THE PUNT KICK

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Impact is an important component of kicking. However, while soccer studies have examined foot to ball interaction through impact, studies examining the punt kick in other football codes have been limited to determining average parameters for impact based on pre and post-contact data. The aim of this study was to analyse foot to ball interaction through impact for the punt kick. High speed video (4000 Hz) of maximal kicks performed by four elite rugby league players were digitised from 5 frames before contact until after the ball had left the foot. Impact could be divided into four phases similar to the soccer kick. Maximal forces of 2062 N were substantially larger than average force of 1045 N for impact indicating. Findings have implications for performance enhancement and injury prevention.

KEY WORDS: High speed video, rugby league

INTRODUCTION: Understanding the characteristics of impact during kicking is important for enhancing performance and reducing injury. A number of studies have evaluated impact characteristics in soccer (Tsaousidis and Zatsiorsky, 1996; Andersen et al., 1999; Nunome et al., 2006) and the punt kick (Ball, 2008; Ball, 2010; Smith et al., 2010). Contact times of 9-14 ms and ball displacements of 0.14-0.26 m have been reported for these studies, which have included soccer, Australian football (AF) and rugby league kicks.

Studies examining the punt kick have used pre and post contact data to evaluate average impact characteristics. Ball (2008) examined 30 m and 50 m punt kicks using 1000 Hz video to evaluate contact time and kinetic and kinematic parameters during the foot to ball contact phase by digitising the foot and ball in the final 0.01 s before impact and 001 s after the ball had left the foot. From these data, foot and ball speed, contact time, ball displacement, average force, work done on the ball was quantified. Ball (2008) reported finding larger forces, ball displacements and work done on the ball for the longer kicks. Using a similar methodology, differences were found between preferred and non-preferred leg kicks (Smith et al., 2010), between different kick types in rugby league (Ball, 2010) and between junior and senior kickers (Ball et al., 2011).

While these studies have found important and useful information, they have not examined the foot to ball contact phase itself. Nunome and colleagues have evaluated the soccer kick in more detail using novel methods to enable illustration of forces through the impact phase while avoiding the issue of smoothing a high-frequency event evident in kicking. Shinkai et al. (2009) found peak forces of approximately 3000N, which are substantially larger than the average forces reported for soccer kicking. This is an important direction for punt kicking evaluation as the same underestimation might exist for these kicks.

The aims of this study were to describe foot to ball motion during the impact phase and to evaluate the peak forces in the punt kick.

METHOD: Data Collection: Four elite rugby league players kicked a rugby league ball (Steeden, Cheltenham, Australia; used in rugby league competition games) for maximum distance. Players wore training apparel and boots used in games. Prior to warm up and kicks, reflective markers were placed on the kick foot boot at the heel, head of the fifth metatarsal and the ankle. Four half-dome reflective markers were also placed on the ball. Three were spaced on one side of the ball such that they could be seen from side-on to the kick while the fourth was placed on the opposite side of the ball. High-speed video (Photron SA3, Photron Ltd, San Diego USA) footage was obtained for each kick at 4000 Hz while VICON (Vicon Motion Systems, Oxford, UK) collected three-dimensional data of the kick at 250 Hz. The high-speed video field of view was positioned directly side-on to the line of kick and on the kick leg side to enable foot markers and the three ball markers to be seen and was optimised for analysis by zooming into the kick area. Markers were tracked from before initial ball contact until the ball went out of view of the video image after release using ProAnalyst software (xcitex, Cambridge MA, USA). Data were digitised using a fourth order Butterworth digital filter (cut-off 350 Hz as used in previous impact research, Shinkai et al., 2009) then transferred to Microsoft Excel for further processing. Eight parameters were calculated from this data (Table 1) while contact time was determined visually from video footage. The centre of the foot was defined as the midpoint between the three markers placed on the boot. The centre of the ball required more detailed analysis. Due to the ball drop component of the skill, the markers on the ball were not always directly side on to the camera view. To account for this, the centre of mass of the ball was obtained from the VICON data at the instant before ball contact. This represented the true centre of the ball. Then using the saggital plane coordinates of this centre, the relationship between the three visible markers on the high-speed video analysis could be evaluated. This relationship was then, used to approximate the centre of the ball. This was necessary for each kick individually. From this centre of foot and ball data, velocity and ball reaction force were calculated.

RESULTS AND DISCUSSION:

Table 1 reports mean values for each parameter. Foot and ball velocities were similar to those reported by Ball (2010) for elite league players (foot velocity 20.0 - 21.8 m/s; ball velocity 25.8 - 26.9 m/s; ratio 1.22 – 1.30). However, distance travelled and contact times differed (distance 0.20 - 0.23 m; contact time 6.8 – 7.2 ms) with shorter distances and longer contact times evident in this study. The contact time in this study was more similar to other studies in soccer and Australian football (AF: 9.8-10 ms, Ball, 2008; 11.5ms, Smith et al., 2009; soccer: 9ms, Asai et al., 2002; 16ms, Tsaousidis and Zatsiorsky 1996; 11.1 ms, Nunome et al., 2006). Some of the difference between this and the Ball (2010) study might be explained by the different kicks with maximal kicks performed in this study compared to a 45 m kick, a drop kick and a bomb in the Ball (2010) study. However, the magnitude of the difference in time in particular (approximately 30%) warrants further work to explore this factor.

Table 1 – Selected parameters related to the foot and ball

	Mean	SD
Distance ball travelled while in contact with foot (m)	0.18	0.04
Contact time (ms)	10.9	0.6
Foot velocity before ball contact (m/s)	21.3	3.1
Foot velocity after ball contact (m/s)	15.3	0.4
Foot velocity reduction rate	27%	8%
Ball velocity after ball contact (m/s)	27.8	3.0
Ball-foot velocity ratio	1.31	0.04
Ball reaction force peak (N)	2062	219
Ball reaction force average (N)	1045	94

Figure 1 shows foot and ball velocity from before ball contact (BC) until the point at which the ball has left the foot for each player. Overall similar patterns existed for each player. Similar to Shinkai et al (2009) for soccer kicking, the punt kick impact phase can be divided into four phases. The first lasted for approximately 2 ms and was indicated by the ball centre as defined by the markers remaining at the same velocity before BC. During this phase, foot speed also remained the same as pre-BC values. Observing video footage, this phase was associated with ball deformation at the point of contact. In the second phase, the ball centre accelerated rapidly until it became larger than the foot velocity. During this phase, the foot slowed by 3-5 m/s and ball deformation rate reduced to the point at which the foot and ball were moving at the same speed, indicating no further deformation was occurring. The third phase saw a continuation of this acceleration of the ball while the foot continued to slow. During this phase the ball began to reform. The final phase exhibited a flattening of the ball velocity curve, indicating the acceleration phase had completed and velocity was maintained. At the point of release the ball had completely reformed.

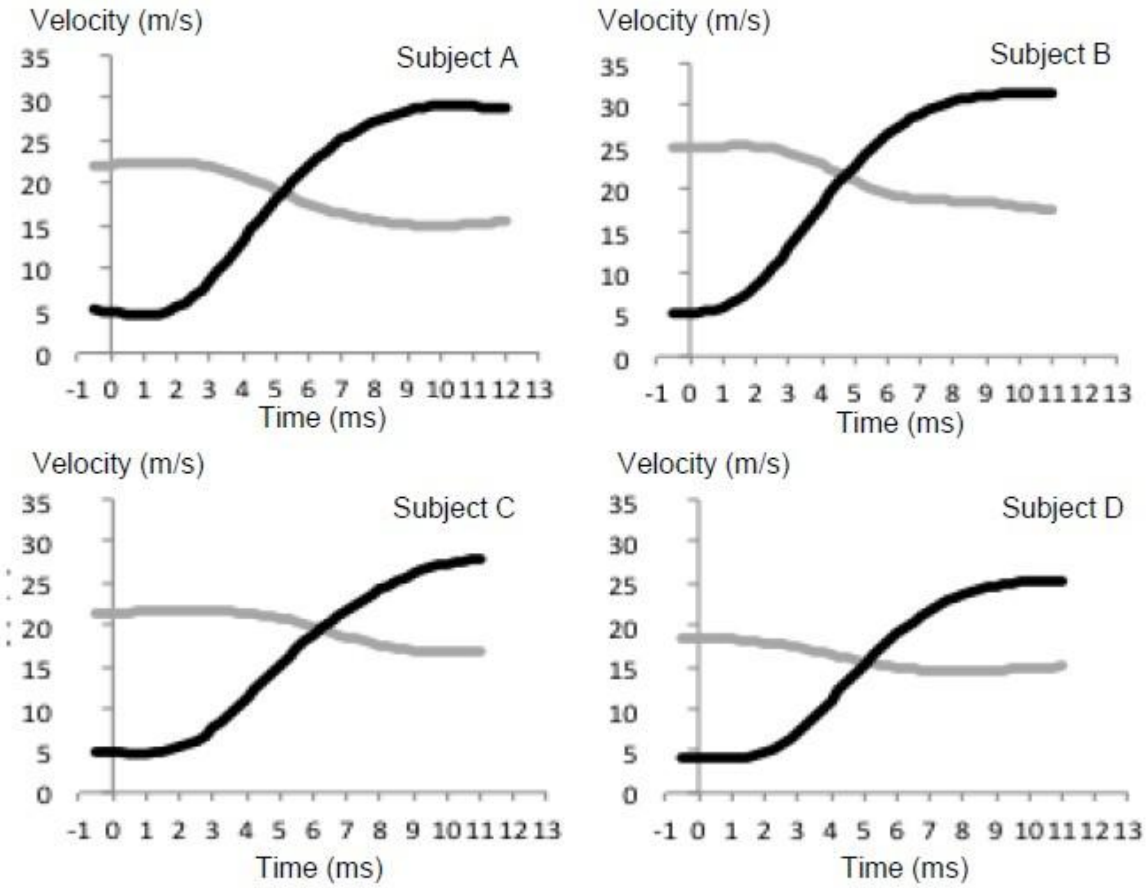

Figure 1: Foot and ball velocity changes from the instant before ball contact to the point at which the ball leaves the foot (dark line = ball, light line = foot).

Peak forces were two times larger than the average force calculated for rugby league punt kicks. This substantially larger force has implications for both performance enhancement and injury potential. From a performance perspective, increasing the ability to apply force to the ball would seem to be important in kicking for distance. Although limited with only N=4, correlations between peak force and both foot and ball velocity ($r > 0.99$) were stronger than that between average force and foot and ball velocity ($r = 0.9$ for both) suggesting that peak force is a more influential parameter. From an injury perspective, Tol et al. (2002) suggested that repeated force due to kicking might be related to ankle impingement syndrome. With these very larger forces, this is certainly a possible mechanism. The larger forces might also have implications for other injuries common in punt kicking sports such as osteitis pubis and hip related disorders.

A methodological limitation of this study was the use of the centre of the ball as defined when the ball was un-deformed. Shinkai et al. (2009) showed that ball velocity curves differed between models using this method and the one developed by those authors to define the centre of mass (CM) of the ball. The CM of the ball started to increase in velocity immediately at BC compared to not until 2 ms when using the un-deformed ball centre. While this was considered for this study, it represents a more complex mathematical task due to the ovoid shape of the ball and the task constraint of dropping the ball prior to the kick. The drop meant that the ball was not consistently directly side-on. Soccer kicking studies have used markers on the leading hemisphere of the ball (the edge on the opposite side of the kick foot and deformation) but as the ball rotated slightly for some kicks, this could not be employed for the punt kick. Further, the impact area between the foot and the ball included the point of the ball, so the leading edge of the ball could not fully be determined for all frames. Future work needs to address this issue via the use of 'shape' digitising, where the whole ball might be digitised as a single shape and the geometrical centre be determined, or using 3D analysis.

CONCLUSION: This study has described the foot to ball interaction during the contact phase in the punt kick. Patterns were similar to those reported for soccer kicking where the ball initially deforms then rapidly accelerates during which the ball velocity exceeds foot velocity and finishes with a stabilizing of velocity before separating from the foot. Peak forces were substantial, exceeding 2000 N, and represented values that were approximately twice the average force. These findings have implications for performance and injury prevention.

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