APPLICATION OF BIOMECHANICAL KICKING RESEARCH

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The punt kick is an important skill in many sports including Australian football. This paper outlines two examples of research-driven changes to the kicking training programme in elite sport. Support leg kinematics and ground reaction forces were found to be associated with greater foot speed at ball contact and could separate more and less skilled kickers. Conditioning and technical drills were modified to attempt to enhance this component of the kick. Changes in kicking technique due to fatigue were evaluated using a short and long term fatigue protocol. For the short term protocol, players were able to maintain foot speed at ball contact but they did it using a different movement strategy. Hip moments and power were significantly larger post-fatigue. As a result, the positioning of kicking work in training was altered. Future work needs to evaluate the effect of these changes in training.

KEY WORDS: punt kick, Force plate, training implications.

INTRODUCTION: Kicking is an important skill in many sports. The punt kick, where the ball is released from the hand prior to the kick is the predominant kick in Australian and Gaelic football and is an important aspect of American football, the rugby codes and soccer goalkeeping. This paper summarises some of the kicking research programme at Victoria University and how the findings have been integrated into training at the elite level.

2. Support leg ground reaction forces and kinematics

Support leg mechanics and ground reaction forces (GRF) have been found to be important in soccer (Orloff et al., 2008) and American Football kicking (Kermond and Konz, 1978). Using a number of kicking tasks, we examined these factors in association with the Australian Football (AF) punt kick. Elite AF players performed accuracy kicks towards targets at 20 m and 45m, kicks for maximal distance and kicks using different approach speeds using both the preferred and non-preferred legs. GRF were recorded using an AMTI force plate (500 Hz) and Optotrak Certus (200 Hz) collected kinematic data during the stance phase of each kick.

Table 1 reports GRF and support leg knee angles during the stance phase of the kick as well as foot speed at ball contact for maximal kicks. There was no difference between the preferred and non-preferred legs for GRF or support leg mechanics. Braking forces were directed backwards only (i.e. no propulsive forces existed, Figure 1a) as for soccer kicks (Lees et al., 2010). Other findings showed that peak vertical forces were related to approach speed (the faster approach the larger the force) and compared to running at the same speed were 1.5-2 times larger (i.e. at a stride pace, GRF are approximately 3 times body weight, kicking at this pace resulted in GRF of approximately 4.5 times body weight).

The support knee exhibited a similar pattern for all players (example curve in figure 1b). At support leg foot strike, the knee was flexed to 24 degrees. The knee flexed further during the stance phase to approximately 50 degrees before extending through ball contact (41 – 42 degrees) and continuing to extend until the support leg left the ground during follow through. This patterning was evident in previous studies examining the support leg in both AF (Dicheria et al., 2006) and soccer (e.g. Lees et al., 2009). Lees et al. (2009) noted that the knee extended before ball contact in soccer, stabilizing the movement. A similar pattern was evident in AF kicking in this study and the same mechanism might be operating. However, 'lift' or the difference between maximum flexion angle and knee angle at ball contact was not related to foot speed so the usefulness of this extension might be related more to toe clearance of the kick leg rather than directly associated with development of foot speed.

Table 1 Mean GRF/support leg values and correlations for preferred (P) and non-preferred leg maximal kicks.

	Preferred		Non-preferred	
	M	SD	M	SD
Foot speed (m/s) *	22.4	0.7	19.1	1.0
COM speed at support leg foot strike(m/s)	3.38	0.18	3.23	0.15
Knee Angle at support leg foot strike (°)	22	3	22	4
Maximum knee flexion(°)	49	3	49	9
Knee angle at ball contact (°)	43	6	41	11
Stance time (s)	0.27	0.06	0.28	0.07
Fz max (BW)	3.0	0.3	3.1	0.4
Fy max braking (BW)	1.0	0.1	1.0	0.1
Fx max (BW)	0.3	0.1	0.6	0.2
Fx min (BW)	0.14	0.10	0.12	0.10

*P<0.05 Fx Max = GRF towards non-kick side, Fx Min = GRF towards kick side

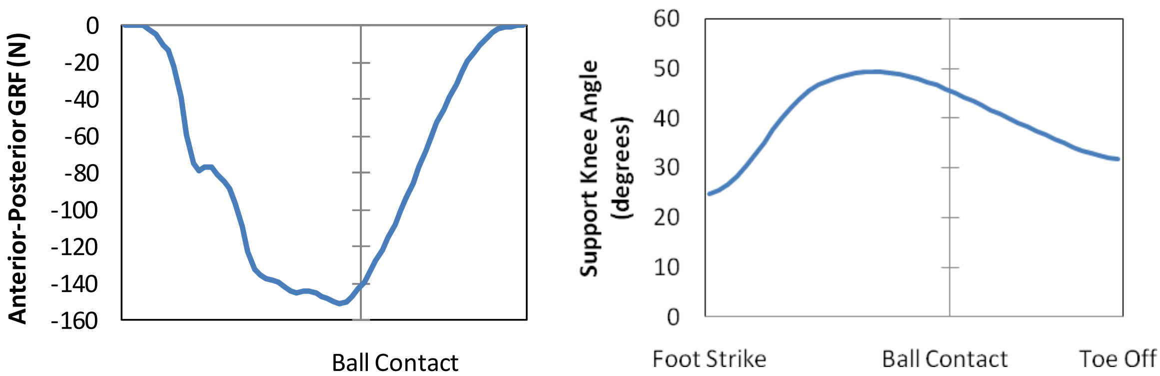

Figure 1: Example (a) Anterior-Posterior (Fy) forces and (b) support knee angle curves from support leg foot strike until toe off after ball contact.

Table 2 reports significant correlations between foot speed (which is the major technical factor associated with kick distance) and GRF and support leg parameters. A more extended knee at support foot landing and through the stance phase was associated with greater foot speeds. However, flexion during the stance phase did not correlate with foot speed indicating that it is the starting position of the knee at foot strike that is the important factor, after which players tend to produce a similar amount of flexion. For GRF, greater maximum vertical and braking forces were also linked to greater foot speed. Of note, when players were divided into better/poorer kickers based on coach ratings, the same results existed with better kickers exhibiting a more extended support knee and greater forces under the foot compared to poorer kickers.

Table 2: Significant correlations between foot speed and GRF and support leg parameters ($p < 0.05$).

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Knee Angle at support leg foot strike (°)	-0.73
Maximum knee flexion(°)	-0.71
Stance time (s)	-0.71
Fz max (BW)	0.69
Fy max braking (BW)	0.87

From these findings, a number of components were implemented into training. Being able to brake harder is likely to be related to the strength of the support leg and postural muscles so conditioning work was added to the programme. Given the knee flexes during the stance phase, single-joint quadriceps muscles are working eccentrically (confirmed by kinetic analyses) for the majority of the stance phase so more eccentric work was included into the programme. An important aspect of this phase of muscular work, however, was the rapidity of the movement (stance time 0.27-0.28 s) so specific conditioning tasks were included to mimic this timeframe centring on landing from run-ups and jumping. Technically, an overemphasis on the braking component to the kick was also implemented in some drills and identifying an individual's ability to brake was made part of the standard kicking biomechanical evaluation. Finally given the different forces experienced due to approach speeds, programme monitoring of kicking was expanded to ensure kicks of different approach speeds were included weekly for all players.

3. Effects of fatigue on kicking technique

Changes in technique have been identified in various sporting tasks (e.g. Jumping and landing, Coventry, 2006; soccer kicking, Apriantono et al., 2006) that can lead to reduction in performance and increased injury risk. Using a short and long term game-specific fatiguing protocol, we examined changes in punt kicking technique in senior and junior elite AF players.

For the short term protocol, 20 m sprint times significantly increased (Pre = 3.25 s, Post = 3.44 s, P = 0.002), but players were able to maintain a similar foot speed at ball contact. This seemed to be produced by a change in the movement strategy, with maximal hip moment increasing (Pre = 204 Nm, Post = 226 Nm, P = 0.016). Hip power at ball contact (Pre = -283 W, Post = 364 W, P = 0.077, effect size = 1.063) and maximal hip power (Pre = 940 W, Post = 1169 W, P = 0.138, effect size = 0.891) displayed large effect sizes, (Coventry et al., 2011). Of note, these effects became significant with further testing with larger player numbers and similar patterns existed for the long term fatigue protocol.

One of the important implications for the training programme at the time was the positioning of kicking work during the training structure. Kicking volume was a focus for this team and so 10-15 minutes were allocated to do kicking work immediately after warm up and before other drills such as match simulations. This meant that kicking volume was substantial in the non-fatigued state and given most kicks in the game will be performed under fatigue, this did not represent game-specific training. As a result, the kicking block was moved to mid/late training session so that kicking volume under fatigue was increased. Specific one-on-one kicking sessions were also modified to ensure technique work was performed under fatigue and the degree of change in technique for different individuals was made part of the biomechanical kicking test battery.

Summary

This paper has outlined two examples of research-driven training modifications. In the first, conditioning and technique work was modified to enhance the braking aspect of the punt kick. In the second, the timing of when kicking volume was performed in the training session was modified to increase kicking under fatigue. Future work needs to evaluate these changes to determine if they improve performance. This work not only requires the implementation of frequent biomechanical testing but also there is a need for novel measurement techniques to be developed to better assess kicking performance.

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