THE DIFFERENCES IN RUGBY PLACE KICK TECHNIQUE BETWEEN SUCCESSFUL AND LESS SUCCESSFUL KICKERS

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This study aimed to understand the differences in technique between groups of rugby place kickers who achieve different performance outcomes. Thirty kickers were analysed using 3D motion capture and grouped as long (successful), wide-left or short (both less successful). The long kickers achieved a faster ball velocity than the short kickers by doing more positive hip flexor and knee extensor work. The long and wide-left kickers achieved comparable ball velocities, but used different strategies. The long kickers did more positive knee extensor work whereas the wide-left kickers did more positive hip flexor work, facilitated by a 'tension arc' achieved through pelvis-thorax rotation. Although the 'tension arc' may be beneficial for the generation of ball velocity magnitude, rugby place kicking coaches should be wary of its use due to its negative effect on accuracy.

KEY WORDS: accuracy, kicking, kinematics, kinetics, rugby union, torso.

INTRODUCTION: In an analysis of 582 international rugby matches between 2002 and 2011, 45% of all points scored came from place kicks, and the success percentage of each team's place kicker can determine the outcome of a match (Quarrie & Hopkins, 2015). Previous place kicking research identified peak knee extension velocity as the sole significant kinematic predictor of ball velocity (Sinclair et al., 2014). However, this only explained 48% of the observed variance in ball velocity magnitude, and no exploration of how these high joint angular velocities were achieved has been undertaken. Furthermore, there was no consideration of the direction of the ball velocity vector despite the inherent importance of accuracy in place kicking (the ball must pass between two vertical goalposts 5.6 m apart and over a horizontal crossbar 3.0 m above the ground). Determination of the kinematic and kinetic features of technique associated with long and accurate rugby place kicking would enable coaches to manipulate these features in kickers who are less successful because they either lack distance or accuracy in their performance. This study therefore aimed to identify differences in key kinematic and kinetic features of technique between groups of place kickers who achieve different performance outcomes, and to understand why these features are associated with varying levels of place kick success.

METHODS: Thirty-three male place kickers (mean ± SD: age = 22 ± 4 years, mass = 86.2 ± 8.8 kg, height = 1.82 ± 0.06 m) ranging from amateur to senior international playing level provided written informed consent to participate in this study, which was approved by the local research ethics committee. After a warm-up and familiarisation, participants performed at least five kicks, as if from their maximum range, towards a vertical target (representative of the centre of the goal posts) suspended in a net. Kinematic data were collected at 240 Hz in a laboratory using a Vicon© MX3 motion capture system. Eighty markers were used to define a 14-segment human-body model, and 54 of these markers (including rigidly-mounted clusters on the limb segments) tracked their motion during place kicks. Ground reaction forces (GRFs) underneath the support foot were synchronously recorded at 960 Hz using a Kistler 9287BA force platform. Six circular markers were also attached to the ball (Gilbert Virtuo, size 5) to track its motion.

Marker trajectories were labelled using Vicon© Nexus and the raw .c3d files were then exported for analysis in Visual 3D (v. 5.0, C-Motion©, USA). Ball contact was identified as the frame in which the kicking toe marker reached peak anterior velocity, and the start of ball flight as the frame where the anterior velocity of the ball first decreased after ball contact (Shinkai et al., 2009). Linear ball velocity was calculated from polynomial functions fitted to the first four frames of the displacement data (first order for both horizontal directions,

second order for vertical), and ball angular velocities were calculated as the first derivative of the ball orientations between the first and fourth frames of ball flight. These data were used as inputs to a model where they were combined with aerodynamic forces to estimate the maximum distance that each kick could be successful from (Atack et al., 2015). For each kicker, the kick with the greatest maximum distance was used for analysis of their technique.
Motion data were filtered at 18 Hz using a fourth order zero-lag Butterworth filter with endpoints padded (20 point reflection). Segmental kinematics were reconstructed using an Inverse Kinematics approach, permitting unconstrained 3D rotations at all joints but no translations. The GRF data were also filtered at 18 Hz and combined with the segmental kinematics and inertia data (de Leva, 1996) in an inverse dynamics analysis to determine the kicking hip and knee joint kinetics up to ball contact. Pelvis and thorax orientations about the global longitudinal axis were calculated, as was the rotation of the thorax relative to the pelvis. All variables measured in the medio-lateral direction and joint rotations about the longitudinal axis were inverted for left-footed kickers to allow direct comparison with right-footed kickers. Ball contact was defined as occurring at 0.0 s and the continuous data were time-normalised to 101 samples using an interpolating cubic spline from the top of the backswing to ball contact.
The kickers were grouped based on their performance outcome. Initially, kickers who achieved a maximum distance greater than 32 m (the average place kick distance in international matches; Quarrie & Hopkins, 2015) were identified and termed 'long' kickers (n = 18). Those kickers who achieved a maximum distance less than 32 m were sub-divided into short (n = 4), wide-left (n = 8) or wide-right (n = 1) kickers. Two kickers were excluded as they were within 4.0% (the accuracy of the ball flight model; Atack et al., 2015) of the 32 m threshold. The wide-right group was also removed from the analysis as only a single kicker was classified in this category. For each group, mean ± standard deviations were calculated for all variables. In order to understand successful place kicking, the technique of the long kickers was compared to that of the wide-left and short kickers. Effect sizes were calculated to compare discrete variables between the groups (Cohen, 1988), before 90% confidence intervals and magnitude-based inferences were derived with a smallest important effect determined as an effect size of 0.2 (Batterham & Hopkins, 2006). Time-histories were compared between the groups using a statistical parametric mapping two-tailed independent samples t-test with an α-level of 5%.

RESULTS: The long kickers' maximum distance was substantially greater than that of both the wide-left and short kickers but there was no clear difference in maximum distance between the wide-left and short kickers (Table 1). There was no clear difference in the resultant ball velocities achieved by the long and wide-left kickers but the long kickers' ball velocities were substantially faster than the short kickers (Table 1). The lateral direction of the ball velocity vector of the long kickers was substantially different from both the wide-left and short kickers, which were directed further towards the left and right-hand side, respectively. The long kickers achieved substantially less longitudinal ball spin (anticlockwise when viewed from above) than the wide-left kickers, but there was no clear difference in the longitudinal ball spin achieved by the long and short kickers (Table 1).

Table 1
Selected initial ball flight characteristics of the three groups (mean ± SD)

	Long	Wide-left	Short
Maximum distance (m)	39.3 ± 4.9	25.9 ± 3.2†	27.3 ± 3.8†
Resultant velocity (m/s)	27.6 ± 1.7	26.9 ± 1.6	20.8 ± 2.2†
Lateral direction (°)*	1 ± 3	-1 ± 2†	2 ± 3†
Longitudinal spin (°/s)	288 ± 206	746 ± 466†	473 ± 394

* A negative lateral direction indicates that the ball was initially travelling towards the left-hand-side of the goalposts, with a positive value directed towards the right-hand-side. † Denotes a substantial effect compared with the long kickers.

For joint kinetics, the long kickers did substantially more positive knee extensor work than the wide-left and short kickers (Figure 1a). Whilst the long kickers also did substantially more positive hip flexor work than the short kickers, they did substantially less positive hip flexor work than the wide-left kickers (Figure 1b).

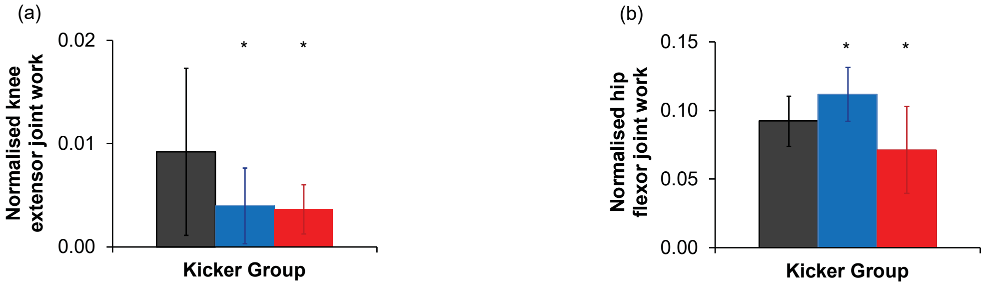

Figure 1. Mean ± SD positive (a) knee extensor and (b) hip flexor joint work for the long (black), wide-left (blue) and short (red) kickers. *indicates a substantial effect compared with the long kickers.

Both the pelvis and thorax segments were facing towards the right-hand-side of the goal (when viewed from above) for all groups from the top of the backswing to initial ball contact (Figure 2a,b). There was no significant difference in pelvis orientation between the long and wide-left kickers but the pelvis of the long kickers was facing significantly further towards the right-hand-side compared with the short kickers throughout the downswing (Figure 2a). The long kickers' thorax was facing significantly further towards the right-hand-side for the first 70% of the downswing compared with the wide-left kickers and for the complete downswing compared with the short kickers (Figure 2b). The difference in thorax orientations between the long and wide-left kickers from the top of the backswing meant that the wide-left kickers had a significantly larger relative pelvis-thorax angle throughout 80% of the downswing (Figure 2c).

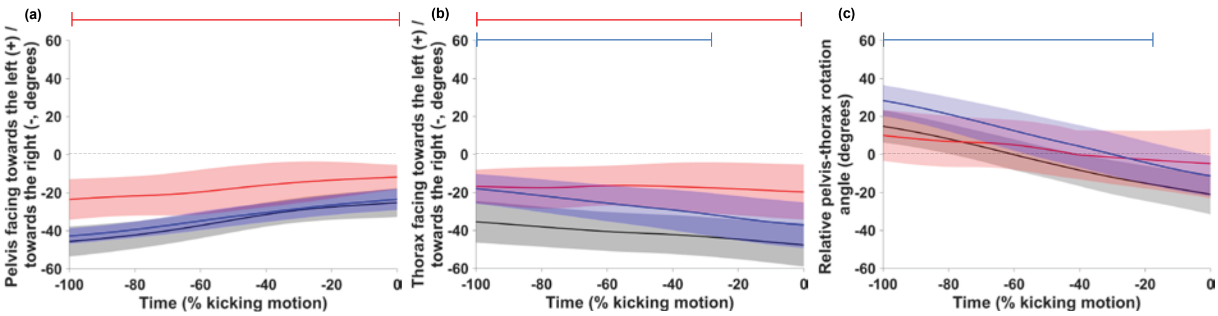

Figure 2. The (a) pelvis, (b) thorax, and (c) relative pelvis-thorax orientations about the longitudinal axis (mean ± SD cloud) from the top of the backswing (-100%) to initial ball contact (0%) for the long (black), wide-left (blue) and short (red) kickers. The horizontal bars indicate the times where the wide-left kickers (blue) and short kickers (red) were significantly different from the long kickers.

DISCUSSION: This study aimed to understand how the mechanics of successful (long) place kickers differed from those of less successful kickers who either miss wide or short. The substantially greater maximum kick distance of the long kickers was due to different performance factors when compared with each of the wide-left and short groups. The long kickers achieved a substantially faster resultant ball velocity than the short kickers, but a comparable velocity to that of the wide-left kickers. However, the wide-left kickers initially launched the ball to the left of the centre of the posts and with greater longitudinal spin causing it to curve further towards the left-hand-side during flight. Given the clear difference in the true performance outcome (maximum distance) between the long and wide-left kickers, these results highlight the importance of considering overall performance using a more complete measure than just ball velocity magnitude which would have inferred that the wide-left and long kickers were equally successful.
Given the strong positive relationship observed between foot and ball velocities in soccer kicking (Nunome et al., 2006) and the well-established proximal-to-distal transfer of energy down the kicking leg, the slower ball velocity of the short kickers is likely a function of the

reduced positive work done by the hip flexors and knee extensors compared with the other groups (Figure 1). Furthermore, the more 'front-on' pelvis of the short kickers throughout the downswing may also inhibit their performance as pelvic protraction is a known feature of high velocity kicking (Lees et al., 2009). Technical interventions may be employed by coaches focussing on altering the approach angle and therefore pelvis orientation of short kickers, or strength programmes could also be considered to develop their kicking leg hip flexor and knee extensor involvement and therefore their overall place kick performance.
The wide-left kickers' performance was limited by the initial direction of ball flight and greater longitudinal spin than the long kickers, but there was no difference in initial ball velocity magnitude (Table 1). The wide-left kickers performed substantially more positive hip flexor work but substantially less knee extensor work throughout the downswing than the long kickers (Figure 1). This strategy may be explained by the pelvis and thorax motion: both groups had a comparable pelvis orientation throughout (Figure 2a) but the wide-left kickers' thorax was facing more 'front-on' for the first 70% of the downswing (Figure 2b). This reflects the kinematics associated with the development of a 'tension arc' - a large relative angle between the pelvis and thorax segments at the top of the backswing which stretches certain muscles of the torso and is released during the downswing (Shan & Westerhoff, 2005). This could explain the wide-left kickers' greater positive hip flexor work compared with the long kickers (Figure 1b), as the initial stretch of the hip flexors would likely lead to greater force production during the subsequent contraction. However, although the use of a 'tension arc' has been related to faster ball velocities in soccer (Shan & Westerhoff, 2005) and may therefore have helped to contribute to the ball velocity of the wide-left kickers, it appears that its use may have detrimental effects on accuracy.

CONCLUSION: This study identified specific differences in the techniques of less successful rugby place kickers who miss short or left of the posts compared with successful kickers who can kick straight and over long distances. Short kickers are limited by reduced kicking leg joint work, and coaches could seek to address this through technical or strength programmes which encourage development of kicking hip flexor and knee extensor involvement. Coaches should also be encouraged to consider whether short kickers could approach the ball from a greater angle and therefore increase pelvis retraction on the kicking leg side at the top of the backswing. However, coaches should ensure that these kickers also adopt an open thorax at the top of the backswing to ensure that a 'tension arc' is not created across the torso. Although this may assist foot, and therefore ball, velocities it does not appear to be beneficial for overall rugby place kick performance where accuracy is of inherent importance.

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