LOWER LIMB MOVEMENT VARIABILITY DURING RUGBY UNION PLACE KICKING

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Place kicking accuracy has a significant impact rugby match outcomes. This project investigated the variability of the kicking leg kinematics and the consistency on the stance and kicking foot positions at ball contact in a group of seven highly proficiency kickers. Kinematic data were collected using a high speed motion capture system (500 Hz) during six simulated attempts on goal. Movement variability was assessed using Normalised Root Mean Square of the swing leg pelvis, hip and knee kinematics, and the standard deviation of the stance foot at opposite plant and kicking foot at ball contact (BC). Results suggest a strong relationship between stance foot placement, swing leg movement variability and the orientation of the kicking foot at BC. This pilot study highlighted the importance of movement variability in determining consistent foot placement at BC in place kicking.

KEY WORDS: football, coordination, kinematics, 3D motion analysis, consistency.

INTRODUCTION: Place kicking is a key aspect of point scoring in rugby union (rugby). Approximately 6% of all international level rugby matches hinge on the result of place kicks, with place kicking accounting for 45% of all points scored (Quarrie & Hopkins, 2015). However, despite the importance of place kicking to match outcome, place kicking success rates during the 2011 Rugby World Cup were only 69% for conversions and 59% for penalty goals (IRB, 2011). Accordingly, it is somewhat surprising that biomechanical literature on this crucial skill is extremely limited.

Previous research on place kicking has focused on swing leg kinematics (Atack, Trewartha, & Bezodis, 2014; Zhang, Liu, & Xie, 2012), descriptions of both kicking foot swing plane (Bezodis, Willmott, Atack, & Trewartha, 2014) and foot positions at impact (Baktash, Hy, Muir, Walton, & Zhang, 2009), and the contributions of the non-kicking arm (Bezodis, Trewartha, Wilson, & Irwin, 2007). The specific accuracy requirements of place kicking are likely to add to the complexity of the kicking action above that of other kicking tasks where ball velocity is the primary focus. For example, it is now well recognized that a person will rarely utilise the same movement strategy when performing successive trials under the same task constraints (Button, MacLeod, Sanders, & Coleman, 2003). Researchers in this field have suggested that this *functional variability* is a key aspect of performance in accuracy sports (Barris, Farrow, & Davids, 2014; Bartlett, Wheat, & Robins, 2007; Davids, Glazier, Araujo, & Bartlett, 2003). However, at the time of this report, the role of movement variability in place kicking has not been reported in the scientific literature. Accordingly, the aim of this pilot study was to examine the variability in lower limb kinematics in a group of experienced place kickers during a series of simulated shots on goal.

METHODS: Seven male semi-professional rugby players (age 23.86 ± 3.72 years; height 1.749 ± 0.092 m; mass 80.08 ± 11.84 kg) with at least 3 years of goal kicking experience at the semi-professional level of competition volunteered to participate in this project. All participants were free of injury at the time of testing and provided informed consent prior to commencing data collection. Ethics approval was granted by the institutional Human Research Ethics Committee.

All kicks were completed using standard size 5 match balls (Gilbert, Virtuo). Scaled “goals” were attached to the kicking net, with the bar height (0.34 m) and width of (0.64 m) designed to represent a kick from 30 m out in front (Linthorne & Stokes, 2014). Six successful kicks (i.e. struck the net between the “goal posts) were analysed for each participant.

Biomechanical data were collected using nine infra- red cameras (Qualisys AB, Gothenburg Sweden) sampling at 500 Hz. This system tracked the movements of 45 retro-reflective markers attached bilaterally to the acromion processes, lateral elbow epicondyles, styloid processes of both ulna and radius, the anterior and posterior superior iliac spines, greater trochanters, medial and lateral knee epicondyles, medial and lateral malleoli, and distal ends of 1st and 5th metatarsals. Additional markers were attached adjacent to the manubrium, xiphoid process, 3rd metatarsal of the kicking foot, spinous processes of C7 and T10, and to the tip and opposite sides of the ball. Four marker clusters were attached mid-segment on the lateral margins of both thighs and shanks.

Following data capture, marker trajectories were modelled in 3D using standard biomechanical software (Visual3D, C-Motion, Inc., USA) and then filtered using a fourth order zero-lag Butterworth filter (cut-off frequency 18 Hz). These data were then used to construct a 13 segment model of the trunk and upper and lower limbs. A global reference system (GRS) was established with positive Y-axis in the intended direction of ball travel, the X-axis perpendicular to the intended direction of travel (positive direction to the right) and the positive Z-axis pointing vertically. Lower limb kinematics were defined with reference to the orientation of the distal segment relative to the proximal, with hip and knee flexion/extension, adduction/abduction and external/internal rotations defined as rotations about the X, Y and Z-axis respectively. Pelvis kinematics were calculated relative to the GRS with sway, thrust and lift being defined as translation along each segment's respective X, Y and Z-axes. Anterior–posterior tilt, lateral tilt and axial rotations were defined using Euler angle calculations as angular rotation about each segment's X, Y and Z-axes. All joint orientations were normalised from the static trial as 0º.

The position of the stance foot at opposite plant (OP) and kicking foot at ball contact (BC) in relation to the ball were calculated as the vector resolutions of the respective lateral (along the X-axis) and horizontal distances (along the Y-axis) between the centre of masses of these segments and the centre of mass of the ball.

Consistency of stance foot placement at OP and kicking foot placement at BC were assessed based on the magnitude of the standard deviation (SD) across the six trails. Normalised Root Mean Square (NoRMS) were used to measure the variability between joint angles for the kicking leg (Knee to Hip angle/angle and Pelvis to Hip angle/angle) (Chow, Davids, Button, & Koh, 2008). NoRMS values where then compared to the SD of stance and kicking foot position at BC for each participant to quantify the relationship between intra-limb variability and kicking consistency. All descriptive data are presented as means ±1SD.

RESULTS: Results showed notable differences in consistency of the stance and kicking foot positions at ball impact between individuals (Table 1). Kicking leg movement variability also varied between participants although all demonstrated relatively consistent leg swing movement patterns. Sample sagittal plane angle-angle knee/hip and hip/pelvis graphs for the participants with the smallest and greatest swing leg movement variability (NoRMS) data presented in Figure 1.

Table 1
Mean (±1SD) stance foot positions at opposite foot plant (OP) and kicking foot positions at ball contact (BC) together with knee-hip and pelvis-hip angle/angle Normalised Root Mean Square (NoRMS) data for participants during six place kicking trials

Participant	Stance foot at OP (m)	Kicking foot at BC (m)	NoRMS Knee-Hip (deg)	NoRMS Pelvis-Hip (deg)
1	0.24 ± 0.01	0.19 ± 0.02	7.3	6.2
2	0.29 ± 0.02	0.24 ± 0.05	7.8	7.1
3	0.27 ± 0.04	0.19 ± 0.01	4.9	3.3
4	0.29 ± 0.01	0.20 ± 0.01	2.5	3.3
5	0.20 ± 0.01	0.18 ± 0.02	3.0	3.2
6	0.22 ± 0.03	0.19 ± 0.03	8.0	6.6
7	0.25 ± 0.02	0.20 ± 0.02	5.6	5.0

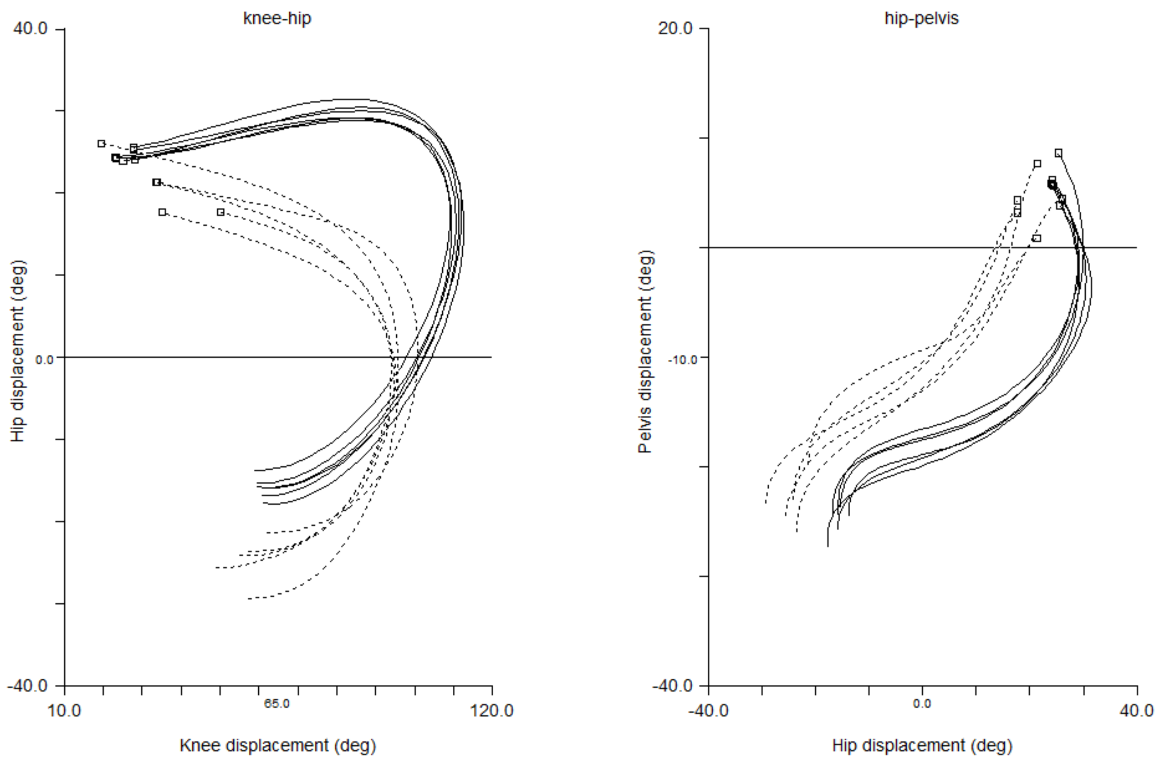

Figure 1: Knee/hip and hip/pelvis angle-angle graphs for participant 4 (smallest NoRMS – shown as solid lines) and participant 2 (largest NoRMS – shown as dotted lines). Data start at opposite foot plant and end at ball contact (signified by a small box).

DISCUSSION: This study explored how movement variability of the swing leg may compensate for variations in the orientation of the stance foot at OP to allow for consistent kicking foot placement at BC in rugby place kicking. Although kicking foot orientation at BC is acknowledged as an important part of place kicking performance (Baktash, et al., 2009), the role of functional movement variability of the kicking leg has not been reported previously in the scientific literature.

The accuracy requirements of place kicking suggest that it would be important to deliver the kicking foot consistently to the ball at BC (Kellis & Katis, 2007; Lees & Nolan, 2002). While it is common for some kicking coaches to focus on consistent stance foot placement relative to the ball, factors such as fatigue, surface conditions and playing environment mean that a certain degree of variability would be typical in normal match conditions (Bartlett, et al., 2007; Davids, et al., 2003).

The results of this pilot study suggest that inter-relationships exist between the consistency in placement of the stance foot at OP, swing leg kicking variability and the accuracy of kicking foot placement on the ball. For example, participant 4 displayed a high consistency in both his stance foot positioning at OP and kicking foot placement BC between each trail. This participant also displayed the most consistent swing leg movement patterns. It would appear that this participant's ability to land his stance foot in relatively the same place meant that there is little requirement for him to change his kicking leg movement patterns to deliver the foot to the ball consistently at BC. A direct contrast to this kicker is participant 3, a kicker who presented with the greatest variation in stance leg positioning at OP, but delivered the kicking foot consistently to the same position at BC. This participant appeared to demonstrate "adaptive" variability in his kicking leg kinematics, altering his movement patterns to compensate for his inconsistent placement of his stance foot. Conversely, participant 2 displayed poor kicking foot position consistency at BC, despite a fairly constant positioning of the stance foot at OP. It would appear that this participant's swing leg variability was "non-adaptive" with his kicking leg movement variability appearing to cause inconsistent foot placement at BC.

CONCLUSIONS: Results from this study suggest that minimal amounts of movement variability in the kicking leg may be beneficial if a player is able to land their stance foot consistently at OP. However, factors such as fatigue, surface conditions and playing environment mean that a certain degree of stance foot placement variability would be typical in normal match conditions. Accordingly, a place kicking technique that has a certain degree of adaptive movement pattern variability of the kicking leg would enable the kicking foot to be delivered consistently to the ball at BC to compensate for any inconsistency in the placement of the stance foot. However excessive amount of variability, or non-adaptive variability are detrimental to the success of the performance as it causes inconsistency of kicking foot placement at ball contact.

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