HIP-KNEE COUPLING IN RUGBY PLACE KICKING AT THREE DIFFERENT DISTANCES

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The purpose of the study was to investigate hip-knee coupling in rugby place kickers, kicking at three different distances from the posts (40 m, 32 m, and 22 m). An optoelectronic motion capture system consisting of ten cameras was used for capturing total body kinematic data. Data collection took place outdoor, on a rugby field. During the forward swing a period of in-phase is reported as both the hip and the knee were flexing, creating a whip-like action. Even though absolute changes in joint angles of hip flexion and knee extension were seen, no changes were reported for the coordination patterns when kicking at different distances (22 m, 32 m, 40 m), indicating no change in movement strategy when kicking at different intensities.

KEYWORDS: vector coding, coupling angle, place kicking technique.

INTRODUCTION:

Successful place kicking can contribute significantly to a team's prospect of winning a match. An analysis of 582 international rugby matches showed that, if the place kicking performance was reversed, the outcome would be different in 14 per cent of the matches (Quarrie & Hopkins, 2015). Therefore, successful kicking could contribute significantly to winning a match. As rugby is becoming more professionalised, teams are turning to scientific, evidence-based research to provide them with the competitive edge.

The motion of the hip and knee has been identified as important in rugby kicking research. reporting that knee extension angular velocity of the kicking limb at ball contact was the only significant predictor of ball velocity (Sinclair et al., 2014). Supporting the importance of knee extension by means of comparisons, substantially more knee extension work is done by kickers achieving consistently greater distance compared to kickers achieving less than 32 m kicks (Atack, Trewartha, & Bezodis, 2017). Peak relative knee velocity, knee velocity, peak thigh segmental angular velocity, as well as foot centre of mass velocity were critical factors in creating high ball velocity. It was also reported that not only the events at impact are essential, but also events preceding ball contact, emphasising the importance of intersegmental coordination (De Witt & Hinrichs, 2012). The kicker is required to maximize the velocity at the distal end point of the extremity at ball contact (Anderson & Sideway, 1994). The need has been expressed for research investigating how changes in performance outcomes relate to changes in coordination patterns to accurately describe control of joints and segments interacting in goal-directed activity (Chow, Davids, Button, & Koh, 2007). The rugby place kick occurs from various positions on the field during a match and the ability of the kicker, to convert successfully from various distances is advantageous. The kicker, therefore, needs to coordinate their joints and segments to hit the ball with enough velocity and to achieve an optimal direction.

The aim of this study is to identify the coordination pattern used by kickers to achieve different kicking distances. The coupling angle is a time-continuous outcome measure that can be used to quantify coordination between two moving elements of the musculo-skeletal system and could be used to get more insight into different coordination strategies used under different task constraints.

METHODS:
Data collection took place outdoor, on a rugby field where nine male kickers performed five trials from three different distances (40 m, 32 m, and 22 m). A ten-camera motion capture system (Vicon ™ Vantage V5, Oxford Metrics Ltd., Oxford, UK) was used to collect kinematic data. Mobile posts were positioned on the field to simulate an actual kicking environment. The kicker was also allowed to do his own ball set-up and execute his preferred run up to ensure a natural kicking movement pattern. Spherical reflective markers were placed on anatomical landmarks of the kicker following the Plug-in-Gait model (Vicon, 2019) with the addition of a cluster of markers on the thigh and shank. Three-dimensional coordinates for the markers were reconstructed using Vicon Nexus software. Marker trajectories were smoothed using a fourth-order zero-phase Butterworth filter (18kHz). From the kicking leg initial toe-off to top of backswing the phase was defined as the backswing, while the forward swing phase was defined as top of backswing to ball contact.
Data reductions included normalisation of kicking phases, extracting discrete kinematic variables, joint angles, joint and segment coordination patterns (hip-knee, knee-ankle, and pelvis-torso), and coordination variability measures. Coordination patterns were determined by means of modified vector coding (Needham, Naemi, & Chockalingam, 2015), where coupling angles were calculated at each datapoint for the hip and knee angles. Kicking trials were grouped based on three kicking distances: 22m, 32m, and 40m. The mean of successful kicks was used to represent each participant at a specific distance; thereafter, group means were calculated. Statistical parametric mapping (SPM) was used to determine statistically significant differences in time-history data by means of a repeated measures ANOVA.

RESULTS:
The SPM results indicated for the knee angle the critical threshold of 6.261 (backswing) was not exceeded. The critical threshold of 6.003 (forward swing) was exceeded for the first 70% of the forward swing with a supra-threshold cluster probability of $p<0.005$, with larger knee flexion in the 40 m kicks. For the hip motion the critical threshold of 6.604 (forward swing) was not exceeded. The critical threshold of 6.536 (backswing) was exceeded at time point 15% to 70%with a supra-threshold cluster probability of $p<0.001$, with increased hip extension for the 40 m kicks. In the sagittal plane, during the backswing, the hip-knee coupling started in the anti-phase for 20 per cent of the time, then moved to the knee phase for the remaining 80 per cent of the backswing. The knee was the primary mover as it moved through a large ROM than the hip. Hip flexion occurred throughout the entire forward swing; however, knee flexion was still present for the initial part of the forward swing. Therefore, the in-phase was reported for the first 50 per cent of the forward swing, as both the joint flexion angles grow more positive. Peak knee flexion was then reached, and extension commenced. The anti-phase was present as the knee is extending and hip angle is flexing. The coupling angle moved from anti-phase to the knee phase for the final 20 per cent, indicating the final rapid knee extension before ball contact (see Figure 1). No difference was seen between groups.

DISCUSSION:
The purpose of this study was to investigate coordination characteristics of the hip-and knee and how these characteristics differ for different kicking distances. The increased hip extension and knee flexion angle for the 40 m kicks increase the distance through which the foot is moved during the forward swing, allowing more work as force can be applied over a greater distance (work = force x distance) resulting in greater foot velocity.
The distal- and in-phase present in the final part of the backswing and beginning of the forward swing may have contributed to the increased stretch of the knee extension muscles, aiding in the stretch-shortening cycle (Li, Alexander, Glazebrook, & Leiter, 2016; Shan & Westerhoff, 2005). Here, hip flexion and knee flexion takes place. During the forward swing, rapid knee extension occurs forming a whip-like motion of the kicking limb which is supported by the knee phase reported. The finding of the current study is consistent with previous research in segment coordination in soccer kicking (Li et al., 2016).

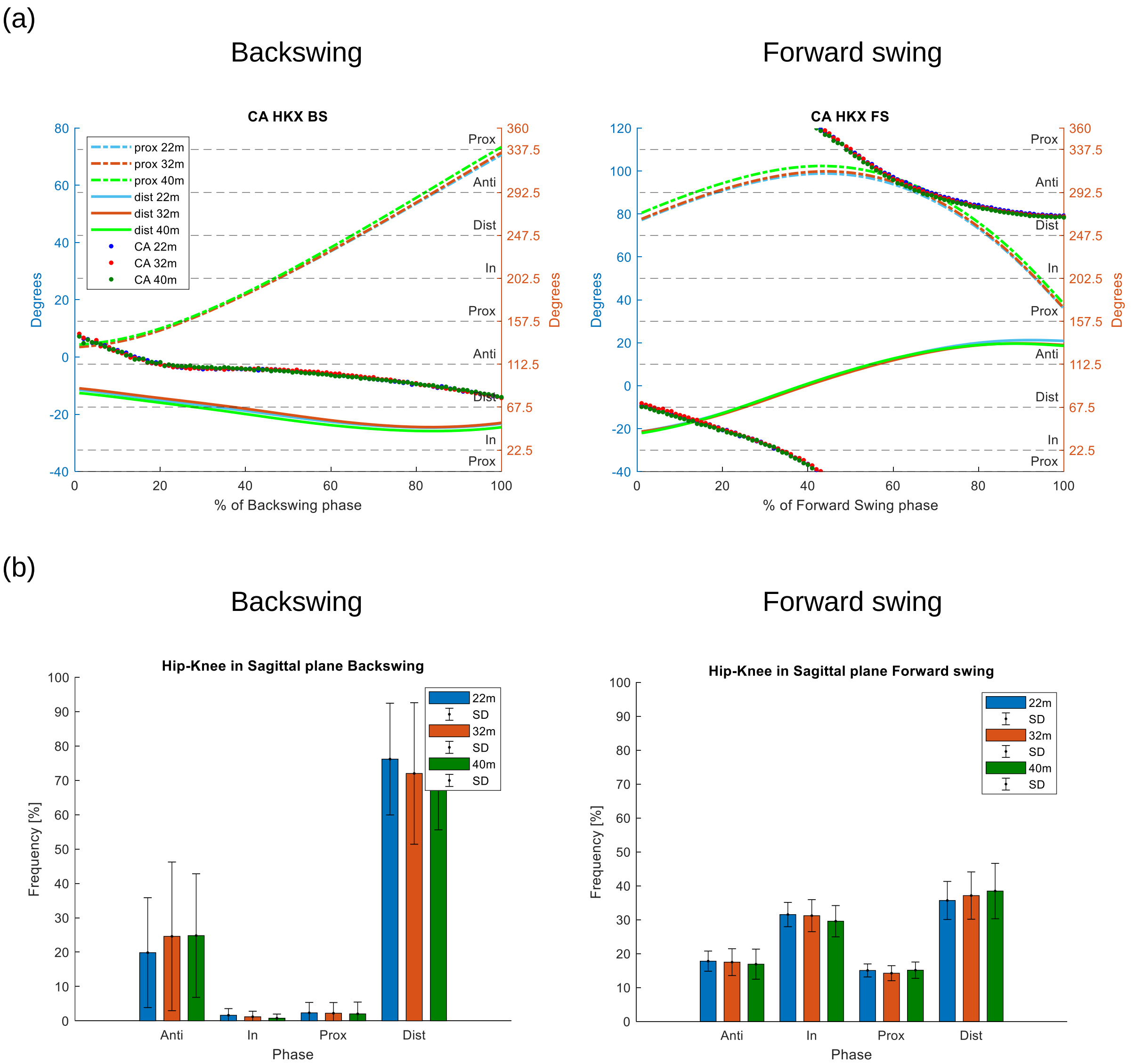

Figure 1: a) Mean coupling angle of hip-knee in sagittal plane for backswing and forward swing for 22 m, 32 m, and 40 m kicks. b) Histogram of time spent in each coupling phase for hip-knee in sagittal plane during the backswing and forward swing of the kicking movement.

It appears that coordination patterns do not change, as a kicker was asked to kick at maximal intensity; however, absolute angles might change. Joint couplings are, therefore, not influenced by absolute changes in the joint angles. It is thus speculated that timing and relative movement are vital to achieving successful kicks, while the motion of the hip and knee joint relative to each other should stay consistent.

CONCLUSION:

Based on the results of the current study, kickers should aim to keep the movement pattern, including timing of joints and segments relative to each other, consistent regardless of distance of kick. Coaches could use words like *rhythm* or *flow* for the kickers to concentrate on their coordination patterns. Hopefully, the methods used, and the conclusion made within the ambit of this research study can be used to build knowledge on coordination in kicking and spark interest in rugby research. Future studies should focus on investigating full body intersegmental and inter-joint coordination patterns in rugby place kicking.

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