DIFFERENCES IN RUGBY PLACE KICKING TECHNIQUE AND PERFORMANCE BETWEEN YOUTH AND SENIOR PLAYERS

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The purpose of this study was to present normative place kicking data for youth players and compare them to senior players. Ten male players (seven youth, three senior) performed supra-maximal range place kicks on an outdoor, grass pitch. Ball trajectory was tracked to determine performance, and lower-body and torso kinematic data were analysed using XSens IMUs for each kicker's three longest attempts. Youth and senior kickers achieved comparable kick distances. No differences were seen in kicking leg kinematics between groups, however, youth kickers demonstrated greater stance knee extension and greater centre of mass deceleration (mean differences: 4.8° and 0.51 m/s respectively) between support foot contact and ball contact, allowing them to maximise the transfer of linear momentum from body to ball during the kicking phase.

KEYWORDS: field-based, inertial measurement unit, kinematic, XSens

INTRODUCTION: Place kicking has been identified as a key factor in determining rugby union match outcomes, contributing 45% of points scored in international matches (Quarrie & Hopkins, 2015). Given the influence of kicked points on match results, research has sought to understand biomechanical factors (including linear, segmental, and joint kinematics) that underpin successful kicking performance (e.g., Atack et al., 2019a, 2022; Hébert-Losier et al., 2020). Notably, all research to date has focussed on senior players, despite place kicks being performed in matches by players over the age of 14 (RFU rules and regulations, Rugby Football Union). In soccer, kick distance (Vera-Assaoka et al., 2020), ball velocity (Rodriquez-Lorenzo et al., 2019), kicking foot velocity (Palluci Vieira et al., 2021) and accuracy (Figueiredo et al., 2009) have all been shown to increase with age, likely due to the accrual of practice time, muscle mass and lower limb strength (Vera-Assaoka et al., 2020; Palluci Vieira et al., 2021). Research investigating place kicking performance has largely been constrained to the laboratory, with only Hébert-Losier et al. (2020) aiming to investigate 3D kicking kinematics in the field. Inertial measurement units (IMUs) have shown comparable kinematic outputs to optical motion capture during place kicking (Blair et al., 2018), and allow the capture of field-based data. Given the importance of place kicking on match outcomes, and previously reported differences in kicking performance with chronological age, there is a need for empirical research investigating the differences in place kicking performance and technique between youth and senior players, in an ecologically valid environment. The aims of this study are twofold – firstly, to present normative technique and performance data for youth players kicking outdoors, and secondly, to compare their technique and performance to senior players.

METHODS: Ten male place kickers volunteered to participate in the study; comprising seven youth (age = 15.1 ± 0.5 years, height = 1.79 ± 0.04 m, mass = 65.7 ± 5.9 kg) and three senior players (age = 22.1 ± 2.1 years, height = 1.82 ± 0.02 m, mass = 94.3 ± 10.6 kg). Kickers played at club, academy, or semi-professional level. All gave informed consent, including parental consent for participants < 18 years of age, before participating in the study, and ethical approval was granted by the local research ethics committee. All testing was performed outdoors on a grass rugby pitch. Wind speed was below 6 mph for all sessions.

Eight IMUs (Awinda, XSens) were attached to the kickers' foot, shank, thigh, pelvis, and sternum, and secured using adhesive tape (Tiger Tear, Tiger Tape). IMUs streamed data wirelessly at 100Hz to a laptop running MVN analyse software (MVN 2023.2). To ensure all kicks were maximal effort, the kicking tee was placed at a supra-maximal distance from the goalposts, calculated as the kickers' self-disclosed maximum range + 10%. All 10 kicks were taken from the supra-maximal distance, directly in front of the goalposts. Three-dimensional ball trajectory was calculated through manual digitisation (Tracker, v6.1.5) of the footage from two time synchronised cameras (HCV-180, Panasonic, 50Hz, 1080p) positioned behind the touch- and try-lines (Figure 1), with each kicker's longest three attempts selected for further analysis. Maximum kick distance was defined as the distance before the ball fell below the height of the crossbar (3m) or lateral deviation was greater than post width (± 2.6m) (Atack et al., 2019b).

Mean kick distance was calculated for each kicker's longest three attempts, and corresponding kinematic data was analysed. Segment pose data was HD-reprocessed within the MVN analyse software to minimise orientation error, before being exported to Visual-3D (v2020.02.3, C-motion). Two events were identified in the time histories, stance foot contact (SFC) and ball contact (BC), based on local maxima in the stance foot gyroscope and kicking foot accelerometer data, respectively. Joint angles and angular velocities in the sagittal, coronal, and transverse planes were calculated using a YXZ Cardan sequence, before being filtered using a low pass, 4^{th} order, recursive Butterworth filter at 18Hz, based on residual analyses. Data was cropped from SFC to BC and time normalised to 101 data points. Kinematic data was exported for further analysis in MATLAB (R2021b, Mathworks), where mean time histories were calculated for each participant. Discrete variables including linear horizontal pelvis velocity at both SFC and BC, and pelvis velocity change (SFC-BC) were calculated for each participant. Additionally, kicking and stance knee angles at SFC and BC as well as the change in angle from peak flexion to BC ($\theta_{BC} - \theta_{max}$) were calculated. Wilcoxon rank sum tests were performed to test for differences in maximum kicking range and discrete variables between groups, due to disparities in group sizes. Statistical parametric mapping was used to compare joint kinematic time histories between senior and youth players.

RESULTS: There were no significant differences in maximum kicking range, however, youth kickers exhibited a significantly slower linear pelvis velocity at BC and decelerated their pelvis to a greater extent from SFC to BC (Table 1). Differences were also observed in stance knee angle at BC and stance knee extension ROM, with youth kickers demonstrating greater extension of the stance knee at BC, and greater extension of the stance knee from max flexion to BC (Table 1, Figure 1d). No other differences were observed between groups (Figures 1 & 2).

Table 1: Maximum successful kicking range and pelvis linear kinematics and stance knee discrete joint angles of senior and youth kickers. (mean ± SD, * p < 0.05)

	Senior	Youth
Performance Data		
Max Kicking Range (m)	35.6 ± 3.8	32.6 ± 2.7
Linear Kinematics		
Pelvis Velocity at SFC (m/s)	3.56 ± 0.06	3.23 ± 0.37
Pelvis Velocity at BC (m/s)	1.91 ± 0.17	1.07 ± 0.36*
Pelvis Velocity Change (SFC-BC) (m/s)	-1.65 ± 0.20	-2.16 ± 0.17*
Joint Kinematics		
Stance Knee at SFC (°)	-22.3 ± 6.4	-24.9 ± 7.0
Stance Knee Peak Flexion (°)	-52.2 ± 4.7	-45.1 ± 4.9
Stance Knee at BC (°)	-51.1 ± 4.4	-39.3 ± 5.2*
Stance Knee Extension ROM (°)	1.0 ± 1.4	5.8 ± 3.4*
Kick Knee at SFC (°)	-99.6 ± 2.7	90.8 ± 15.3
Kick Knee Peak Flexion (°)	-116.9 ± 3.0	-109.3 ± 13.9
Kick Knee at BC (°)	-53.0 ± 14.8	-43.1 ± 7.8
Kick Knee Extension ROM (°)	63.0 ± 13.6	66.2 ± 13.3

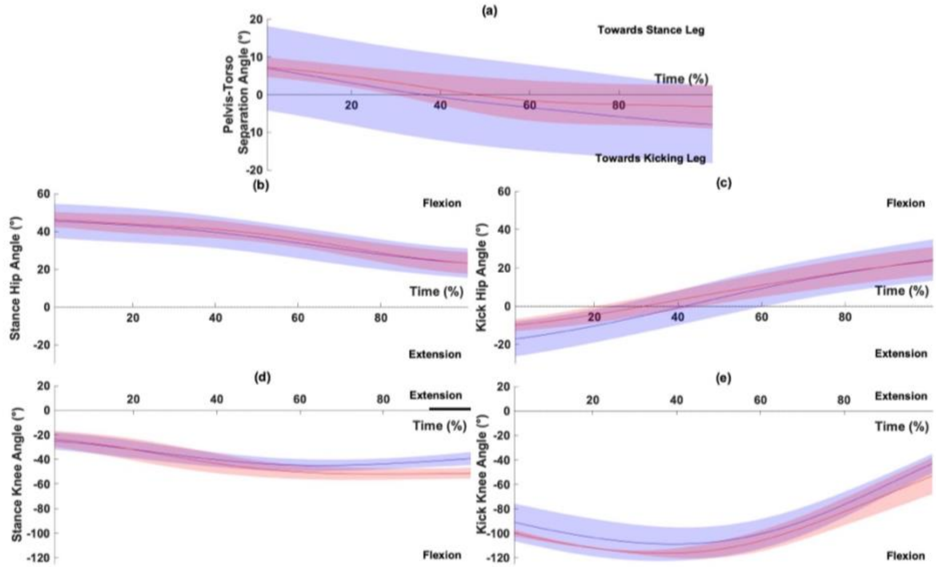

Figure 1: Joint angle time histories from stance foot contact (0%) to ball contact (100%) for youth (blue) and senior (red) kickers ± group sd (shaded clouds). Bars on x axis denote regions where significant differences were observed ($p < 0.05$).

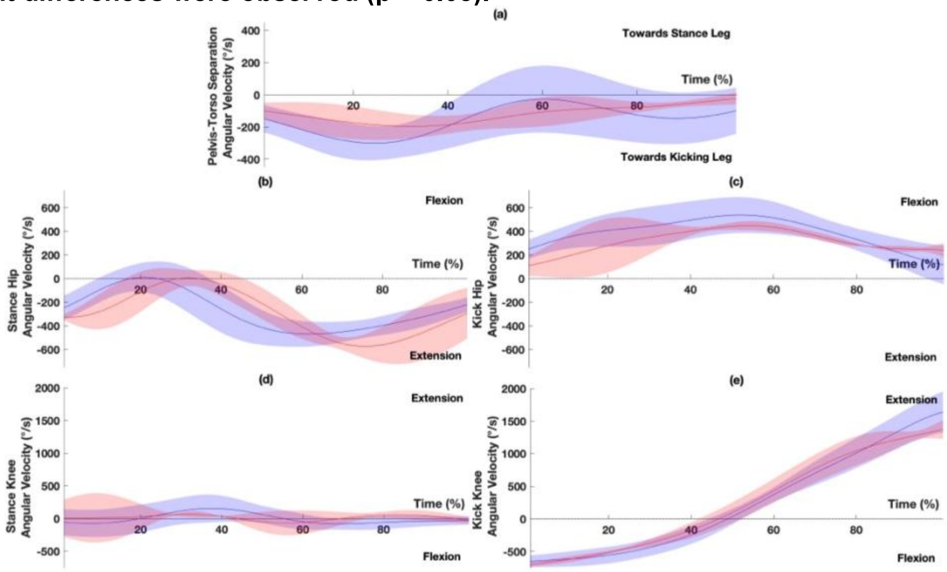

Figure 2: Joint angular velocity time histories from stance foot contact (0%) to ball contact (100%) for youth (blue) and senior (red) kickers ± group sd (shaded clouds).. Bars on x axis denote regions where significant differences were observed ($p < 0.05$).

DISCUSSION: This study aimed to present normative data for youth players kicking outdoors, with kinematics measured using IMUs, and to compare results with a group of senior players. When considering kicking performance, both groups achieved comparable kick distances - in neither group were the kickers' best three attempts limited by accuracy, rather, all kicks were limited by range. Both groups demonstrated kick distances greater than 32 m, a threshold used to classify more successful 'long' senior kickers (Atack et al., 2019). Youth kickers did, however, exhibit slower pelvis velocity at ball contact, in addition to greater deceleration of the pelvis from SFC to BC. Greater deceleration of the centre of mass (CoM) has previously been linked to superior performance of male vs female place kickers (Atack et al., 2023), however, no such link to performance was seen here. Given the youth kickers' body masses were notably less than that of the senior kickers (65.7 ± 5.9kg vs 94.3 ± 10.6kg), greater deceleration of the CoM may facilitate comparable transfer of linear momentum from the body to the ball during the kick. When considering kicking technique, joint angle, and angular velocity time histories were comparable to those previously reported for senior players, measured using optical motion capture (Atack, 2016). Significant differences were observed in stance knee angle at BC and stance knee extension ROM; with youth athletes tending to extend the stance knee, elevating the CoM prior to ball contact, and senior athletes maintaining stance knee angle following peak flexion. Increased elevation of the stance hip has previously been shown to positively impact kicking leg velocity, facilitating power flow across the pelvis and promoting passive acceleration of the lower leg (Augustus et al., 2017). Findings from the present study indicate youth kickers - who likely possess a deficit in lower body strength compared to senior players - adopted a whole-body compensatory strategy to achieve comparable kick distances, utilising passive strategies to accelerate the kicking limb. Whilst lower body strength was not assessed in the present study, this should constitute an area of further research to understand how youth kickers are able to achieve comparable kicking performance to their adult counterparts.

CONCLUSION: In this study, we presented novel, normative data for youth kickers using IMU technology on the pitch; both groups demonstrated similar techniques to those previously reported in laboratory-based studies. Youth place kickers achieved comparable maximum kicking distances to senior kickers. Notably, youth kickers decelerated their pelvis velocity and extended their stance knee to a greater extent prior to ball contact. We suggest these differences are related to body mass and strength disparities; for lighter kickers to transfer comparable linear momentum from body to ball, greater CoM deceleration must be attained. Findings indicate that youth kickers rely more on passive accelerative strategies, as opposed to actively accelerating the foot using the musculature of the kicking leg; Coaches should prioritise developing young athletes' kicking mechanics, focusing on the extension of the stance knee and controlling pelvis deceleration from SFC to BC.

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