BIOMECHANICAL ANALYSIS OF ELITE FEMALE RUGBY PLACE KICKERS

Alexandra C. Atack[1], Jack Lineham[1] & Neil E. Bezodis[2]

[1] Faculty of Sport, Allied Health and Performance Sciences, St Mary's University, Twickenham, UK.

[2] Applied Sports, Technology, Exercise and Medicine, Swansea University, UK

The purpose of this study was to investigate rugby place kicking technique of elite female players. Five International-level female place kickers took at least five maximum range place kicks, and their technique was analysed using 3D motion capture. In comparison to successful male kickers, females achieved slower kicking foot and ball velocities and shorter maximum kicking distances. Reduced extension of the support leg hip and knee joints, combined with slower centre of mass deceleration, meant that females appeared to transfer less momentum from their approach to the ball, thus, requiring them to perform more positive work at their kicking hip. A faster approach to the ball and more pronounced support leg extension may enable females to achieve greater place kicking distances.

KEYWORDS: kick, kinematics, kinetics, support, women.

INTRODUCTION: Participation in women's rugby has seen rapid growth in recent years. In 2019 there were ~2.7 million female players globally, which was a 28% increase from 2017 (World Rugby, 2020). Interest in the women's game has seen similar rises, with a record 42,579 in attendance at the World Cup Final in 2022 compared with 17,115 in 2017 (Rugby World Cup, 2023). To support this development, World Rugby released their Women's Plan 2021-2025 seeking equity for women, in terms of rugby participation, welfare and high-performance. Accompanying the increased popularity of the sport, research has sought to understand the profiles and demands of these athletes to provide an evidence base for applied practice (see Heyward et al., 2022 for a review). Currently the majority of these studies have focused on injury (39%), physical performance (26%) and match characteristics (21%) but there has been no consideration of the technical performance of key skills, such as passing and kicking.
An analysis of the knock-out matches at the last Women's Rugby World Cup reveals only 59% of all place kicks taken were successful (Rugby Pass, 2023), and with both a semi-final and the final decided by 3 points or less, improved place kicking success may affect the match outcome. Research has examined place kicking technique within male populations (e.g. Atack et al., 2019b; Hébert-Losier et al., 2020; Jones et al., 2022), however, given previously identified differences in physical performance capacities (across speed, power and change of direction tasks; Freitas et al., 2019) and training experience (Heyward et al., 2020) between males and females as well as technique differences in other kicking skills (e.g. soccer instep kicking; Katis et al., 2015), specific investigation of place kicking by female players is warranted. The purpose of this study was to investigate place kicking technique of elite female players, and to compare these against similar data collected previously from male kickers, with a view to inform training practices.

METHODS: Five International-level female rugby place kickers (24 ± 4 years, 1.74 ± 0.05 m, 73.8 ± 5.0 kg) provided consent to participate in this study which was approved by the host University's ethics committee. Following a self-selected warm-up and familiarisation kicks, participants performed at least five maximum range place kicks towards a target suspended in a net (representative of the centre of the goalposts) approximately 2 m in front of their kicking tee, with their support leg landing on a force platform embedded in the floor (Kistler 9287BA, 1000 Hz). Artificial turf was laid throughout the kicking area and all kickers wore their moulded boots. Kinematic data were collected using fourteen Vicon Vantage 5 cameras (250 Hz) throughout the kicking area. Eighty markers were used to define a 14 segment full-body model

(Atack et al., 2019b), whilst six reflective markers tracked the motion of the ball. Participants also performed three maximal countermovement and squat jumps on the force platform.

Marker trajectories were reconstructed in Vicon Nexus (v. 2.2) before the .c3d files were exported for further processing in Visual 3D (v. 2021.11.3). All movement trials were cropped to the frame prior to ball contact (indicated by the toe marker reaching peak anterior velocity). Marker trajectories were filtered at 18 Hz (determined by residual analysis) and gaps (<10 frames) interpolated using a cubic spline. Segmental kinematics were reconstructed using Inverse Kinematics, with 3D rotations, but no translations, permitted at all joints. Kicking and support leg joint angles were calculated using the XYZ Cardan rotation sequence and angular velocities determined. Joint kinetics of both legs were also calculated through an inverse dynamic analysis (using ground reaction forces filtered at 18 Hz and inertia data from de Leva, 1996) and normalised using the equations of Hof (1996). The raw ground reaction forces were then re-filtered at 125 Hz and the net impulse was calculated through integration (trapezium rule) to calculate total horizontal centre of mass deceleration from support foot contact to ball contact. All kicking leg joint mechanics were time-normalised to 101 points from the top of the backswing (highest vertical position of the foot) to ball contact, whilst all support leg data were normalised from support foot contact.

Initial linear and angular ball velocities were recorded, and kick performance was determined as the predicted maximum distance of each kick (Atack et al., 2019a). The mean of all the kicks taken by each kicker was calculated for all variables. These were compared to previously published values from successful male kickers (n = 18, Atack et al., 2019b), using independent t-tests for discrete variables and 1D SPM (Pataky, 2012) for time histories ($p < 0.05$) or the non-parametric equivalent tests if the data was not found to be normally distributed.

RESULTS: The female kickers achieved significantly slower resultant kicking foot and ball velocities and a significantly shorter predicted maximum distance than the male kickers (Table 1). The females also demonstrated a significantly slower lateral kicking foot velocity at ball contact, but there was no difference in the longitudinal spin imparted to the ball (Table 1).

Table 1: Kick performance characteristics for female and male kickers (mean ± SD, * *p* < 0.05)

	Female	Male
Resultant foot velocity at ball contact (m/s)	18.7 ± 1.1	20.3 ± 1.0*
Lateral foot velocity at ball contact (m/s)	6.7 ± 0.9	8.8 ± 1.5*
Resultant ball velocity (m/s)	23.4 ± 0.8	27.6 ± 1.7*
Longitudinal ball spin (revs/s)	1.1 ± 0.6	0.8 ± 0.6
Predicted maximum distance (m)	21.4 ± 4.0	39.3 ± 4.9*

The female kickers produced significantly greater kicking leg knee moments both during the initial downswing (extensor) and just prior to ball contact (flexor) than the male kickers (Figure 1b) but there was no difference in the knee extension velocities achieved (Figure 1a) nor the total positive knee extensor work done (0.01 ± 0.01 for both kicker groups). The female kickers produced a significantly greater hip flexor moment for over 90% of the downswing (Figure 1d) which became extensor dominant prior to ball contact. Although there was no difference in the hip flexion velocities achieved (Figure 1c), the female kickers did significantly more positive hip flexor work during the downswing (0.12 ± 0.02) than the males (0.09 ± 0.02).

Females exhibited significantly slower support leg knee flexion velocities (Figure 2a), accompanied by a reduced knee flexor moment following support foot contact, and reduced knee extensor moment up to ball contact than the males (Figure 2b). There was no difference in the total positive or negative knee joint work done by the two groups (0.01 ± 0.01 and -0.02 ± 0.01 for both). The females also demonstrated significantly slower support leg hip extension for the final 63% of support foot contact (Figure 2c), and this was reflected in them performing significantly less positive hip extensor work (0.02 ± 0.01) than the males (0.05 ± 0.02). Additionally, female kickers slowed their horizontal centre of mass velocity significantly less (-1.10 ± 0.12 m/s) than the males (-1.64 ± 0.30 m/s).

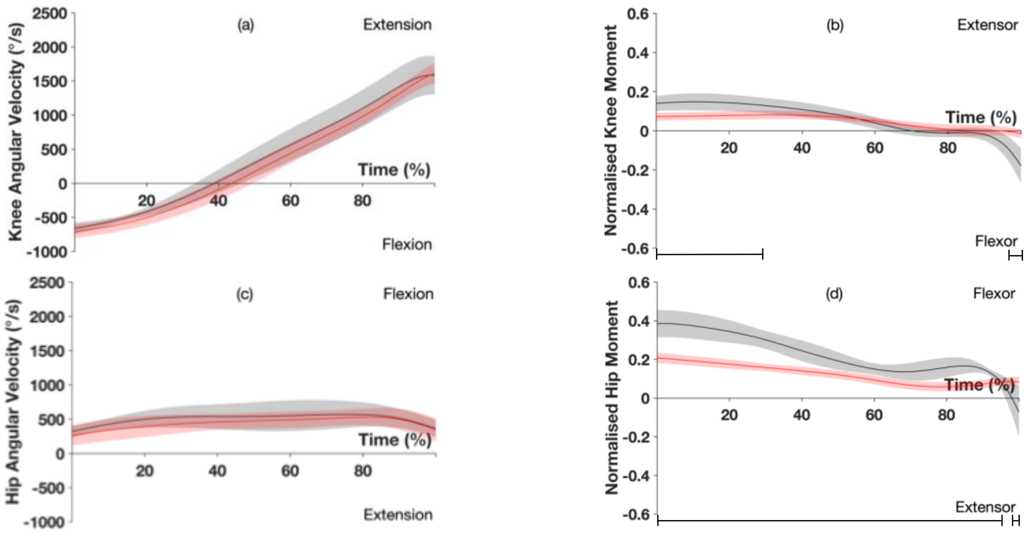

Figure 1: Kicking leg knee (a,b) and hip (c,d) joint mechanical time histories from top of the backswing (0%) to ball contact (100%) for female (black) and male (red) kickers. Bars under each figure indicate regions where there were significant differences (*p* < 0.05).

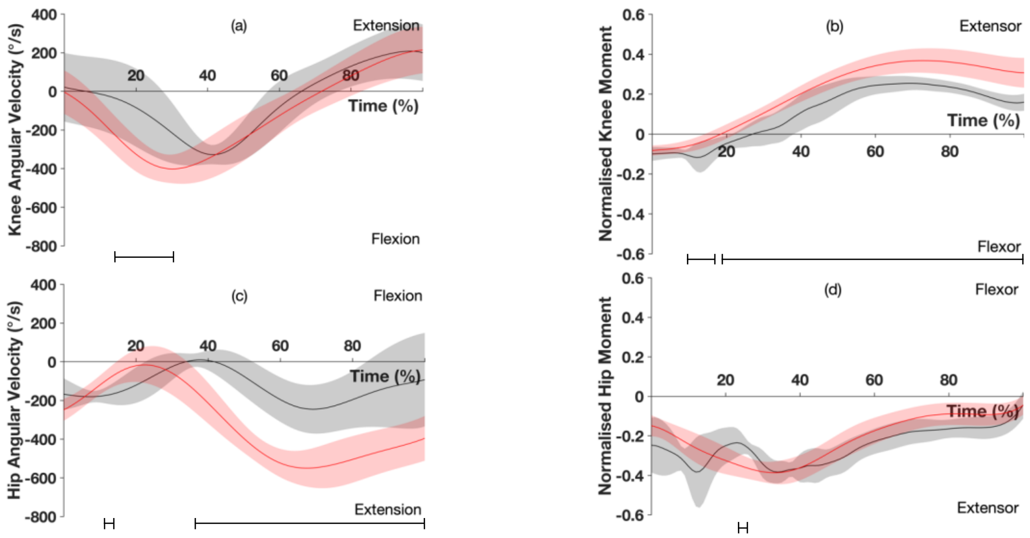

Figure 2: Support leg knee (a,b) and hip (c,d) joint mechanical time histories from support foot contact (0%) to ball contact (100%) for female (black) and male kickers (red). Bars under each indicate regions where there were significant differences (*p* < 0.05).

DISCUSSION: The aim of this study was to quantify the techniques of elite female rugby place kickers and compare them to previously collected data from successful male kickers. In terms of kicking performance, females achieved significantly shorter predicted maximum distances and slower ball and kicking foot velocities (as seen in kicking in other football codes, e.g. Katis et al., 2015). Although the female kickers were typically unsuccessful from greater distances due to a lack of accuracy (the ball would have passed outside of the left-hand upright), this was not due to greater longitudinal ball spin (which was comparable to the males). Thus, it may be concluded that the slower kicking foot and ball velocities were more important.

The female kickers performed significantly greater positive kicking hip flexor joint work and demonstrated larger kicking knee extensor moments during the downswing compared with the successful male kickers. Previously, greater positive hip flexor work has been associated with faster kicking foot and ball velocities in male kickers (Atack et al., 2019b), however, this was not the case for the female kickers in this study which may be explained by the reduced support leg action that was observed.

Research within soccer instep kicking has identified the importance of both a fast support leg extension (Augustus et al., 2017) and centre of mass deceleration (Potthast et al., 2010) for transferring momentum to the kicking leg. Female kickers presented a significantly smaller support leg knee extensor moment following support foot contact and significantly slower support hip extension velocities for the same period. Accompanied by their significantly reduced centre of mass deceleration prior to ball contact, this indicates that the females were less effective at transferring momentum from the approach to their kicking leg. As countermovement jump height was comparable between the two groups (0.40 ± 0.04 m for the females and 0.39 ± 0.08 m for the males) this does not appear to be a deficit in the capacity of the hip or knee extensors, although analysis of other jump types (e.g. single leg or drop jumps) may more accurately reflect the demands placed on the support leg. Instead, it is proposed that this is a difference in technique, with female kickers approaching the ball slower (with less “intent”) and instead relying on generating velocity through forceful contraction of the kicking leg hip flexors and knee extensors. However, without adequate transfer of momentum, this action alone does not enable sufficient kicking foot velocities to be achieved for longer place kicks. Furthermore, as previously demonstrated, reliance on generating velocity through hip flexor dominance has been associated with less accurate place kicking (Atack et al., 2019b) as it may prevent the multi-articular hip joint from playing a role in controlling the direction of the kicking foot. Although analysis of the female kickers’ approach to the ball and the path of their kicking foot is warranted, it is suggested that they may benefit from approaching the ball faster, bracing their support leg following support foot contact before extending the hip and knee joints, to transfer momentum to their kicking leg and achieve comparable foot velocities.

CONCLUSION: Elite female place kickers achieved shorter predicted maximum kicking distances than successful male kickers. Their ball and kicking foot velocities were slower, and this was likely due to reduced support leg action halting their forward motion and transferring momentum to the kicking leg. Although female kickers performed greater kicking leg joint work, this was not sufficient to achieve comparable kicking foot velocities and was likely at a detriment to their accuracy. Further research should consider female kickers’ approach to the ball and interventions seeking to promote greater support leg action as an alternative strategy to generate sufficient velocity and achieve greater kicking distances.

REFERENCES

Atack, A., Trewartha, G., & Bezodis, N.E. (2019a). Assessing rugby place kick performance from initial ball flight kinematics: development, validation and application of a new measure. *Sports Biomechanics*, 18(5), 457-469.

Atack, A.C., Trewartha, G., & Bezodis, N.E. (2019b). A joint kinetic analysis of rugby place kicking technique to understand why kickers achieve different performance outcomes. *Journal of Biomechanics*, 87, 114-119.

Augustus, S., Mundy, P., & Smith, N. (2017). Support leg action can contribute to maximal instep soccer kick performance: an intervention study. *Journal of Sports Sciences,* 35(1), 89-98.

Freitas, T.T. et al. (2019). Differences in change of direction speed and deficit between male and female National rugby sevens players. *Journal of Strength and Conditioning Research,* 35(11), 3170-3176.

Hébert-Losier, K., Lamb, P., & Beaven, C.M. (2020). Biomechanical determinants of placekicking success in professional Rugby Union players. *Sports Biomechanics,* 27(7), 861-876.

Heyward, O., Nicholson, B., Emmonds, S., Roe, G., & Jones, B. (2020). Rugby preparation in female rugby codes: an investigation of current practices. *Frontiers in Sports and Active Living,* 2, 583194.

Heyward, O., Emmonds, S., Roe, G., & Scantlebury, S., Stokes, K., & Jones, B. (2022). Applied sport science and sports medicine in women’s rugby: a systematic scoping review and Delphi study to establish future research priorities. *BMJ Open Sport and Exercise Medicine,* 8, e001287.

Jones S., Nunome, H., Augustus, S., Peacock, J.C.A., Ball, K., & Bezodis, N.E. (2022). Understanding the effects of ball orientation in Rugby Union place kicking: the preferences of international kickers and the kinematics of the foot-ball impact. *Sports Biomechanics.*

Katis, A., Kellis, E., & Lees, A. (2015). Age and gender differences in kinematics of powerful instep kicks in soccer. *Sports Biomechanics,* 14(3), 287-299.

Potthast, W., Heinrich, K., Schneider, J., & Brüggemann, G.-P. (2010). The success of a soccer kick depends on run up deceleration. *International Society of Biomechanics in Sports Proceedings Archive*, 28(1), 121–123.