# Biomechanical Characteristics of Elite Female Australian Rules Football Preferred and Non-preferred Drop Punt Kicks

Emily E. Cust[1,2,a], Kevin Ball[1], Alice J. Sweeting[1,2,b] and Sam Robertson[1,2,c]
[1]*Institute for Health and Sport (IHES), Victoria University, Footscray, 3011, Melbourne, Victoria, Australia*
[2]*Western Bulldogs Football Club, Whitten Oval, Footscray, 3011, Melbourne, Victoria, Australia*

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Abstract: While Australian Rules kick biomechanics has been researched considerably, there is yet to be focus specifically on women participants. Elite female Australian Rules football drop punt kick characteristics were collected from 15 elite female participants for both the preferred and non-preferred legs. All participants undertook a 20-kick protocol captured by a 3-dimensional motion analysis camera system. Preferred leg kicks produced faster foot velocities prior to foot-ball contact, 18.0 ± 1.2 $m.s^{-1}$ preferred, 16.2 ± 1.3 $m.s^{-1}$ non-preferred, and faster ball velocities post foot-ball contact, 24.7 ± 1.4 $m.s^{-1}$ preferred, 21.6 ± 2.0 $m.s^{-1}$ non-preferred. Differences in movement patterns of the hip and knee joint segments were shown between kick leg preferences; hip angular velocity 94.4 ± 75.9 °/s preferred and 126.2 ± 66.3 °/s non-preferred, knee angular velocity 1384.8 ± 415.2 °/s preferred and 1013.6 ± 230.2 °/s non-preferred. Research results identified the changes in elite women's drop punt kick mechanics in comparison to leg preference, which can be viewed against senior and junior men's Australian football kick analysis findings. The current research information could be of benefit to practitioners in linking targeted field coaching cues and conditioning programs tailored to identified kick skill and movement deficiencies.

## 1 INTRODUCTION

The National Women's Australian Rules Football competition (AFLW) is in its fourth year of operation, yet there has been no reported biomechanical analysis of women's kicking. In Australian Rules football (AF), efficient kick performance has been identified as a strong contributor towards team match success (Robertson, Gupta and McIntosh, 2016; Black et al., 2018).

In AF the drop punt is the most commonly performed kick due to the flight accuracy and ease of catching for the receiver (Ball, 2008). Across the six phases of a drop punt (Ball, 2008), several kinematic factors have been found to influence the success, efficiency, and accuracy of performance. Prominently, higher kick leg foot velocities prior to ball contact have a major influence on the kick distance (Ball, 2008; Ball et al., 2013; Peacock, Ball and Taylor, 2017) and ball velocities (Ball, 2008; Peacock and Balll, 2016; Peacock and Ball, 2017) achieved. The flight path accuracy of the ball is determined primarily by the combination of the flight characteristics imparted on the ball during the foot-to-ball contact phase (Peacock and Ball, 2018; Peacock et al., 2018). Differences in kick biomechanics have been found between the preferred and non-preferred leg in men's AF kicks (Smith, Ball and MacMahon, 2009; Ball, 2011) and soccer (Nunome et al., 2006). The ability to kick proficiently on both legs and over long distances in AF is a tactical advantage (Ball, 2008; 2011) in the dynamic unpredictable nature of match play. Biomechanical assessment may be an important information source for individual athlete skill profiling to identify areas of deficiencies for drop punts kicks.

The kick impact and technical components of men's kicking across several athlete levels has already been established allowing for quantified information to further develop kick skills on a team and individual basis. To address the lack of quantitative information in women's AF kick biomechanics, 3-dimensional optoelectronic motion

[a] http://orcid.org/0000-0001-6927-6329
[b] http://orcid.org/0000-0002-9185-6773
[c] http://orcid.org/0000-0002-8330-0011



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analysis was undertaken. Conducting this research is important for broadening the sport science support invested in the new AFLW competition, with the intention of improving athlete kick skill and therefore team match performances. The aim of this research was to analyse the biomechanical characteristics of elite female AF drop punts for both the preferred and non-preferred kick legs. The outcomes of this research can inform the technical aspects of distance kicking in women's AF to aid in athlete kick skill development, as well as links with strength and conditioning and injury.

# 2 METHODS

## 2.1 Participants

Fifteen elite female AF athletes provided written informed consent to participate in this research. Of the participants, twelve were contracted to an AFLW team and three were competing at a high standard in their respective State based competition. The University's Human Research Ethics Committee approved the study (application number 0000025654).

## 2.2 Research Procedures

Athletes undertook a drop punt kick protocol as part of a broader test battery. Ten drop punts were undertaken for maximum distance and intensity on each leg. Maximal kicks were performed into a net situated 30 m from the kick launch area. Prior to undertaking the protocol, each athlete completed a dynamic warmup including jogging, dynamic stretches and five 20 m submaximal kicks on each leg. All athletes wore their regular football boots and used official AFLW match balls (Sherrin, Scoresby, Australia). The testing was conducted in purpose built indoor football training facility on artificial turf.

Drop punt kicks were captured by a 10-camera optoelectronic motion analysis system (MAS) capturing at 100 Hz (T-40 series, Vicon Nexus v2, Oxford, UK). Previous assessment of sampling rates had found low maximum error ranges for kick parameters from 500 Hz to 100 Hz (Coventry et al., 2015). Cameras were set up as an arc around the testing area and mounted at varying heights in order to allow full capture of the kick and ball flight movements. 35 reflective markers (diameter: 14 mm) were taped to each athlete at anatomical landmarks as per previous kick research (Blair et al., 2018), shown in Figure 1. Four reflective makers were attached to the football (Figure 2) to create a coordinate system and establish the ball centre.

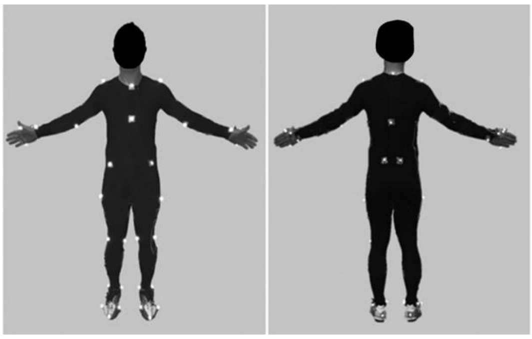

Figure 1: Athlete marker set-up.

Figure 2: Football reflective marker positions.

## 2.3 Data Analysis

Raw motion analysis data were digitised in Nexus (v.2.0, Vicon, Oxford, UK) and processed in Visual 3D (C-motion, Inc. Germantown, USA). Data were pre-processed through a polynomial interpolation (order: 3) and smoothed using a low-pass fourth-order Butterworth filter (cut-off frequency: 10 Hz) (Ball, 2008, 2011; frequent in-lab evauation of VICON data using spectral and residual analyses).

A total of 300 drop punts (150 preferred and 150 non-preferred kicks) were analysed for ball velocity values. The trials with the highest preferred and non-preferred ball velocities were selected for each athlete for full kinematic analysis in this study, as final ball velocities are the reflection of efficacy in impact characteristics applied to the ball (Peacock, et al., 2017; Peacock and Ball, 2018a). A total of nine drop punt kick parameters were analysed from the MAS data, see Table 1, based on previous technical parameters assessed in AF kick performance (Ball, 2008; Smith et al., 2009; Ball, Smith and MacMahon, 2010).

Table 1: Definitions of measured kick parameters.

| Parameter | Definition |
|---|---|
| Foot velocity prior to ball contact ($m.s^{-1}$) | Linear velocity of the foot segment measured from the head of the 5th metatarsal |
| Ball velocity post foot contact ($m.s^{-1}$) | Linear velocity of the ball segment |
| Ball: foot velocity ratio | Ball velocity at release divided by foot velocity at initial impact |
| Support leg knee flexion (°) | Degree of flexion of the support leg at ball contact |
| Knee angle at ball contact (°) | Angle between the thigh and shank of kick leg |
| Knee angular velocity (°/s) | Angular velocity of the knee joint of kick leg |
| Hip angle at ball contact (°) | Angle between the thigh and the trunk on the anterior aspect of the participant |
| Hip angular velocity (°/s) | Angular velocity of the hip segment |
| Pelvis linear velocity ($m.s^{-1}$) | Linear velocity of the pelvis segment |

Processed data for each parameter were exported to a custom Excel file and the group mean and standard deviation (SD) calculated for each preferred and non-preferred kick parameter. Paired t-tests were computed for each parameter with statistical significance set at $p < 0.05$. The effect size for each measure for between-group distances was calculated using Cohen's d statistic indicating a small or trivial (d = 0–0.2), moderate (d = 0.2–0.5), large (d = 0.5–0.8), and very large (d . 0.8) effect (Hopkins *et al.*, 2009).

## 3 RESULTS

Table 2 reports the mean data kinematic parameters of the foot, knee, hip, and ball segments. The preferred leg produced significantly greater foot velocity, ball velocity, knee angular velocity, and pelvis linear velocity, and a significantly smaller hip angle and hip angular velocity in comparison to the non-preferred leg. The maximum foot velocities achieved were 20.9 $m.s^{-1}$ and 17.7 $m.s^{-1}$ on the preferred and non-preferred legs, respectively. The maximum ball velocities achieved were 27.0 $m.s^{-1}$ and 25.5 $m.s^{-1}$ on the preferred and non-preferred legs, respectively.

## 4 DISCUSSION

The current research on women's elite Australian Rules football kick biomechanics reports the first analysis of its type to further the understandings of kick skill execution. Results showed that preferred leg kicks were characterised by faster foot velocities prior to ball contact, greater knee angular velocities, pelvis linear velocities, and smaller hip angular velocities. Linking information from biomechanical analysis with field coaching cues and conditioning programs may be beneficial for individualised athlete kick skill development.

Elite female AF athletes in this study produced higher foot and ball velocities on their preferred leg kicks. Foot and ball velocities for elite women were lower than the reported values for senior elite men (Ball, 2008; 2011; Smith et al., 2009) and junior elite men (Ball et al., 2010) AF athletes. Preferred leg drop punt kicks in elite senior men have shown foot velocities of 26.5 ± 2.5 $m.s^{-1}$ and ball velocities of 32.6 ± 4.4 $m.s^{-1}$ (Smith, Ball and MacMahon, 2009). Relation could also be drawn to kick distances achieved by women and men as foot velocity has shown strong correlation association with ball flight distance (Ball, 2008; Peacock, Ball and Taylor, 2017). Elite female soccer athletes have reported foot velocities of 17.70 ± 1.92 $m.s^{-1}$ (instep kicks) and 17.45 ± 1.59 $m.s^{-1}$ (curve kicks), and ball velocities of 22.62 ± 1.71 $m.s^{-1}$ (instep kicks) and 21.51 ± 1.33 $m.s^{1}$ (curve kicks) (Alcock et al., 2012).

The ball-to-foot velocity ratio is a measure of kick impact efficiency and is widely reported on in AF (Smith, Ball and MacMahon, 2009; Ball, Smith and MacMahon, 2010; Ball et al., 2013; Peacock and Ball, 2018b) and soccer research (Shinkai et al., 2009; Sakamoto and Asai, 2013; Nunome et al., 2018). The present study showed no difference for ball-to-foot ratio between the preferred (1.31) and non-preferred legs (1.33), which has previously been reported in male AF kick research (Smith et al., 2009). This may indicate that greater ball velocities on the preferred leg are the result of a faster leg swing as attributed by faster foot velocities and knee angular velocities in applying greater force onto the ball (Nunome et al., 2006; Smith et al., 2009) (Table 2). Differences in body mass have also been reported to affect the ball-to-foot ratio, which may confound comparisons between male, female, junior, and senior playing groups (Shinkai et al., 2013).

Differences in movement patterns were shown between kick leg preferences. Overall, the preferred leg achieved greater knee angular velocity and pelvis linear velocity, and smaller hip angle and hip angular velocity (Table 2). As the non-preferred leg produced larger hip angular velocities and hip angles, this may suggest that greater use of the thigh and hip segments were recruited. The change in movement pattern between the kick leg types may indicate the need for more stability via dominate hip control on non-preferred kicks. Another factor could also be related to the speed of run-up in approach towards the kick execution on each leg, although this was not measured in this study. Also, the result of less efficient use of sequential summation or transfer of momentum (Ball, 2011) as indicated by the lower knee angular velocity on non-preferred leg kicks. In comparison to senior AF male athletes (Ball, 2011), greater mean knee and hip angles, and knee angular velocities were achieved for both preferred and non-preferred kicks by elite women AF athletes. Although, lower hip angular velocities were produced in comparison to reported male AF athletes, 56 ± 65 °/s preferred leg and 138 ± 81 °/s non-preferred leg (Ball, 2011).

Technical differences in kick strategies have been demonstrated for thigh dominant or knee dominate kickers during maximal distance kicking (Ball, 2008) and further supported during goal kicking constraints tasks (Blair et al., 2018). Although kick performance indicators of foot velocity and kick distance were not significantly different between each approach suggesting similar kick performance outcomes can be achieved with either movement strategy (Ball, 2008). Looking into the thigh-knee angular velocity continuum, Ball (2008) sorted the participant data to provide indicative values for those athletes who use a thigh or knee dominant strategy for preferred leg distance kicking. In comparison, post-hoc evaluation of the current elite women's data was undertaken using the hip and knee angular velocities. Further analysis showed 14 out of the 15 athletes would be considered using a knee dominant strategy on their preferred leg. In contrast, on the non-preferred leg, the majority of the group would be classified hip dominant with data from 10 athletes of 15 indicating this. This trend is consistent with findings in the men's data where on preferred leg kicks there is increased contribution from the knee segment and lower hip or thigh involvement. The opposite shown on non-preferred leg kicks with greater hip segment contribution than the knee for force generation through the kick motion (Ball, 2011).

The support leg is important in maintaining stability through the kick motion and plays a role in the performance quality of a kick (Ball, 2013). A moderate non-significant effect of less knee flexion in the supporting leg at ball contact occurred on preferred leg kicks, 37 ± 11.3 ° to non-preferred kicks, 41 ± 8.3 °. This is in contrast to results found



Table 2: Impact characteristics for preferred and non-preferred drop punt distance kicks for elite women's AF. Data reported as mean and standard deviation (SD) values and results of statistical tests comparing preferred and non-preferred leg kicks.

| **Parameter** | **Preferred leg** | | **Non-preferred leg** | | ***p*** | **Effect Size (*d*)** |
|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | | |
| Foot velocity ($m.s^{-1}$) | 18.9 | 1.2 | 16.2 | 1.3 | <0.001* | 2.2 Very large |
| Ball velocity ($m.s^{-1}$) | 24.7 | 1.4 | 21.6 | 2.0 | <0.001* | 1.8 Very large |
| Ball: foot velocity ratio | 1.31 | 0.11 | 1.33 | 0.07 | 0.59 | 0.2 Small |
| Support leg knee flexion (°) | 37.0 | 11.3 | 41.0 | 8.3 | 0.25 | 0.4 Moderate |
| Knee angle at ball contact (°) | 50.7 | 12.2 | 57.7 | 13.5 | 0.13 | 0.5 Moderate |
| Knee angular velocity (°/s) | 13845 | 415 | 1014 | 230 | 0.02* | 1.1 Very large |
| Hip angle at ball contact (°) | 34.3 | 13.5 | 48.8 | 15.8 | 0.01* | 1.0 Very large |
| Hip angular velocity (°/s) | 94 | 76 | 126 | 66 | 0.04* | 0.7 Large |
| Pelvis linear velocity ($m.s^{-1}$) | 1.7 | 0.4 | 1.4 | 0.5 | 0.03* | 0.6 Large |

* Significant difference ($p < 0.05$)

in elite males across maximal kicks which showed greater support leg flexion on preferred leg kicks, 43 ± 6 °, than non-preferred leg kicks, 41 ± 11° (Ball, 2013). It has been suggested that greater support leg knee flexion leads to a lower centre of gravity and hence stability in the motion allowing for improved kick accuracy (Dichiera et al., 2006). Although the findings of Dichiera et al., (2006) are in contrast to Ball (2013), where results indicated that a more extended support leg knee on stance kick phase which was maintained to ball contact phase related to higher foot velocities and an improved drop punt distance achieved. During match play, athletes are repeatedly required to perform kicks with constraints against both distance and accuracy, most commonly in goal kicking (Blair et al., 2018). Kicking kinematics measured across changing distance on goal kicks showed that increased distances resulted in greater knee extension on the support leg during the stance phase (large effect size), and moderately higher foot velocities, shank, and knee angular velocities (Blair et al., 2018). The authors noted potential technical difference for tasks in the literature when both kick skill accuracy and distance constraints were combined. Suggesting this related to the research protocols used with accuracy tasks performed over shorter distances at lower speeds compared to research on maximal distance kicking causing athlete to adopt differing techniques to suit each task (Blair et al., 2018). For example, during maximal distance high impact kicks the athlete adopts a more upright position through the torso and consequently a higher hip position to generate the faster foot velocities required (Ball, 2013). Further work to assess how these variables influence elite women's kick performance considering the altered match play styles and therefore kick constraints compared to the men's game (Cust et al., 2019) would be of skill technique coaching benefit.

Practically, as foot velocity is strongly correlated to drop punt kick distance (Ball, 2008, 2011; Peacock and Ball, 2017) and used as a strategy to control the kick outcome (Peacock et al., 2017). A focus on improving an athlete's ability to generate high foot velocities on both legs would benefit overall kick skill and in-match tactical plays (Ball, 2008, 2011). Furthermore, if footballers dominantly kick on one leg, the increased repetition loading may create imbalances in hip and lower limb strength which could affect skill performance and increase asymmetry load related injury (Hart et al., 2013, 2014). As the current results show differences in the use of joint segments between the two legs, there is potential for muscle asymmetries to develop (Ball, 2011; Hart et al., 2014). Strategies such as training the non-preferred leg to recruit greater lower limb involvement through skilled coaching cues and targeted conditioning programs may again be of benefit to improving kick skill performance across both legs for tactical advantage in matches. Research has indicated that combined technical and strength-based interventions for AF athletes in training for the drop punk kick serves as a constructive approach to performance improvements (Ball, 2008; Hart et al., 2014).

Further research should progress assessment of the support leg mechanisms (Ball, 2013) and kinematic characteristics of the kick impact phase for elite women AF athletes in relation to kick accuracy (Peacock et at., 2017). Greater understandings into the underlying mechanisms for the differences between both preferred and non-preferred leg kicks for elite women, and between male and female kinematics during kick execution would be important to further quantify. As different movement approaches exist for kick execution, future research looking at the relationships between knee and thigh (or hip) strategies for distance kicks and kick accuracy would be of benefit to kick skill coaching and individual conditioning. Knowing individual athlete movement strategies would directly affect coaching and conditioning due to the different muscle recruitment processes for generating forces for each approach (Ball, 2008). In-depth information within this field could provide links to improve practices in women's AF kick skill coaching, individual athlete injury patterns related to repeated kick execution, and targeted strength and conditioning practices.

# 5 CONCLUSIONS

The biomechanical characteristics of elite female Australian Rules football drop punts kicks for both the preferred and non-preferred legs were quantified. Preferred leg kicks produced faster foot velocities prior to ball contact, greater knee angular velocities, pelvis linear velocities, and smaller hip angular velocities. Movement differences were found in hip and lower limb joint segments between both kick legs as greater knee angular velocity and pelvis linear velocity characterised preferred leg kicks, yet a higher hip angular velocity on non-preferred leg kicks. Improved understandings of women's AF kick skill via kinematic technical analysis could be of benefit in linking with targeted field coaching cues and conditioning programs tailored to identified kick skill and movement deficiencies.

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