# BIOMECHANICS OF GOAL-KICKING ACCURACY IN AUSTRALIAN FOOTBALL USING AN INERTIAL MEASUREMENT SYSTEM

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Accurate goal-kicking is important to a team's success in Australian Football (AF). However, it remains a largely unexplored area in sport biomechanics. This study examined technical aspects of goal-kicking accuracy using an inertial measurement system (IMS). Two junior AF players performed 15x20m goal-kicks in the field. Kinematics were measured using the Xsens MVN link IMS (240Hz). Results showed that both players had greater support leg ($p<0.04$; $d>1.0$) and kick leg ($d>1.0$) knee flexion during accurate goal-kicks. Individual differences were reported for footspeed and shank angular velocities for accurate goal-kicks. These individual differences highlight the need to conduct an individual-based analysis in goal-kicking research.

**KEY WORDS:** Kicking, accuracy, inertial measurement system, Australian Football.

**INTRODUCTION:** A player's goal-kicking ability can have a major bearing on a team's success in Australian Football (AF), with accurate goal-kicks identified as the most influential performance indicator in AF match outcome (Robertson *et al*., 2015). In spite of the importance of accurate goal-kicking, it remains a largely unexplored area in sport biomechanics. In the only biomechanical analysis of goal-kicking in AF, Ball et al. (2002) used an in-field notational analysis to examine goal-kicking accuracy in eight elite AF players. Accurate kickers were reported to keep the ball straight in approach, drop the ball in line with the kicking thigh and finish with the leg pointing towards goal. Notational analysis identified important technical errors associated with goal-kicking performance, however it only permitted a two-dimensional analysis.

Goal-kicking accuracy has also received limited attention across the football codes. Research has been predominantly focused on kicking velocity (Baktash *et al*., 2009; Padulo *et al*., 2013; Zhang *et al*., 2012), with only two studies evaluating goal-kicking accuracy in the rugby codes. Ball et al., (2013) investigated technical aspects of accurate goal-kicking in four elite rugby league players. Accurate kickers were found to adopt an upright trunk position and were not square to the target. Individual differences were also reported between players in accurate kicks. Bezodis et al., (2007) investigated upper body motion in goal-kicking in five rugby union players. The authors highlighted the importance of the non-kicking side arm to kicking accuracy and the need for three-dimensional (3D) analysis when investigating goal-kicking technique in the rugby codes.

Research is warranted to extend these limited findings, through exploring the 3D characteristics of goal-kicking accuracy in AF. However, the major reason for the limited biomechanical research investigating goal-kicking accuracy, is due to the inherent limitations within traditional biomechanical analysis techniques. Investigations are often confined to laboratory settings with limited capture volumes or restricted to one location per system in field environments, making it difficult to analyse goal-kicking accuracy under 'real-world' contexts, such as kicking in-front of goal.

The use of wearable inertial measurement systems (IMS), to capture full-body motion has emerged in biomechanical research (Reenalada *et al*., 2016; Rotenberg *et al.,* 2013). IMS permit an unrestricted, 3D analysis of performance and have been used as an alternative method to camera-based motion analysis systems, to quantify sport-specific movements such as, snowboarding (Krüger & Edelmann-Nusser, 2009), swimming (Fong & Chan, 2010) and marathon running (Reenalada *et al*., 2016), in their natural environment. Research has reported IMS to have acceptable levels of concurrent validity when measuring kicking

kinematics (CV%=<4.0%; r=>0.91) in AF, when compared to a motion analysis system (Blair *et al*., 2016), advocating the use of IMS to measure goal-kicking kinematics in AF.
IMS present the opportunity examine the 3D characteristics of goal-kicking accuracy across a range of contexts. This work is needed to establish an evidence base to define the technical elements that are associated with accurate goal-kicking in AF, to provide specific kinematic information to assist with the coaching of the skill. Therefore, the aim of this study was to examine technical aspects of goal-kicking accuracy in Australian Football using an inertial measurement system.

**METHODS:** Two junior AF players (age:12±0yrs; height:166±1cm; mass:56±1kg; playing experience:8±0yrs) volunteered and provided written informed consent to participate in this study. Ethical approval was granted from the University's Human Ethics Committee.
The IMS used in this study was the Xsens MVN link system (Xsens Technologies B.V., Enschede, the Netherlands), which is composed of 17 inertial measurement sensors built into a compression suit. Each sensor integrates a tri-axial accelerometer (±160m.s$^2$), gyroscope (±2000deg.s) and magnetometer (±1.9Gauss), internally sampling at 1000Hz. Prior to data collection, anthropometric measures were collected from participants and a calibration was performed to determine the sensor to segment orientation in MVN Biomech Studio (Xsens software, v4.3, Enschede, the Netherlands).
Following a warm-up, players were instructed to perform 15x20m goal-kicks using their preferred foot, from three different positions on an AF pitch; the centre, 45° to the left and 45° to the right of goals. Five kicks were performed at each position and the order of kicks was randomised. Positions were selected based on Australian Football League champion data of typical goal-kicking positions (official match statistics from the 2015 season). Players were instructed to perform kicks under match-like conditions and a Sherrin Football (size 4, sherrin, Australia) was used. During each kick, 3D kinematic data was collected at 240Hz. Accuracy was assessed using a performance criterion: hit vs miss. This accuracy measure corresponds to how kicks are assessed as accurate or inaccurate in competition.
Sensor data was fused using the Xsens proprietary algorithms (Xsens Kalman Filter) and filtered using a light smoothing in MVN Biomech Studio, as recommended by the manufacturer. Data was then transferred to Visual 3D (c-motion, Inc. Germantown, USA) where all kicks were analysed from kick foot toe-off until the instance before ball contact (BC) (Ball, 2008). The Xsens 3D model, which consists of 23 segments and 22 joints, was assigned to motion files and joint angle trajectories where calculated following a YXZ cardan sequence (c-motion, 2016). Kinematic data included; footspeed, knee, hip, pelvis angles and shank angular velocity (all identified important in AF punt kicking literature: Ball, 2008; Dicheria *et al*., 2006). Kicks were separated into hit vs miss comparisons for each player. To determine if differences exist between accurate and inaccurate kicks, descriptive statistics (Mean±standard deviations), paired t-tests (P<0.05) and effect size (Cohen *d*, (1988); small: *d*>0.2, medium: *d*>0.5, large: *d*>0.8) were calculated in excel for each player.

**RESULTS:** Table 1 reports accurate (hit) and inaccurate (miss) goal-kicks for both players.

**Table 1: Comparison of hit vs miss goal-kicks for both players.**

| | Player 1 | | | | Player 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Hit (n=10) | Miss(n=5) | *d* | Effect size | Hit (n=7) | Miss(n=8) | *d* | Effect size |
| Foot speed at BC(m.s-1) | 13.2±2.5 | 14.2±2.6 | 0.4 | Small | 12.5±1.4 | 10.5±1.1 | 1.2+ | Large |
| Kick leg minimum knee flexion(°) | 129±5 | 125±3 | 1.1 | Large | 122±4 | 119±6 | 1.0+ | Large |
| Support leg knee flexion at HC(°) | 28±3 | 24±1 | 1.0+ | Large | 24±4 | 16±4 | 1.5+ | Large |
| Maximum hip extension(°) | 35±2 | 35±4 | 0.1 | None | 30±1 | 29±2 | 0.2 | None |
| Shank angular velocity at BC(°/s) | 1497±295 | 1658±241 | 0.6 | Medium | 1444±347 | 1202±140 | 0.9 | Large |
| Pelvic angle at HC(°) | 15±2 | 14±1 | 0.4 | Small | 14.0±2.8 | 13.5±2.1 | 0.2 | None |

**+** denotes statistical significance (P<0.05); **BC**= Ball Contact**; HC**=Support leg heel contact.

**DISCUSSION:** The aim of this study was to examine technical aspects of goal-kicking accuracy in AF using an IMS. Foot speeds reported in this study (14.2m/s) were lower compared to values reported for juniors in AF literature (Ball *et al*., 2010: 21.3m/s). Higher foot speeds have been associated with kicking distance (Ball, 2008), therefore lower foot speeds would be expected in this study, as players were kicking over a shorter distance. Shank angular velocities, knee flexion, hip extension and pelvis kinematics lay within the ranges for punt kicking reported in AF literature (Dicheria et al. 2006; Ball, 2008).

Support and kick leg knee kinematics were found to be associated with goal-kicking accuracy in both players. Accurate goal-kicks had greater support knee flexion at HC ($p<0.04$; $d>1.0$), with increased knee flexion during the swing phase in the kick-leg ($d>1.0$) compared to inaccurate kicks. This supports Dicheria et al. (2006) findings in punt kicking accuracy. This strategy is suggested to lower the players centre of gravity during the goal-kick, helping to stabilise and balance the player throughout the kick. With the lower kicking position, increased kick-leg knee flexion is required to ensure the foot does not strike the ground during the goal-kick. This finding suggests conditioning the support leg to maintain a more flexed position during goal-kicking may contribute to kicking accuracy. However, these findings are in contrast to Ball (2013), who reported a more extended support leg knee was correlated to larger foot speeds (N=14; r=073, p=0.004) for kicking distance. These inconsistencies may be indicative of different strategies adopted by players when kicking for accuracy or distance in AF. This is an important direction for future work, to address these inconsistencies and examine the relationship between accuracy and distance goal-kicks.

Individual differences were evident for foot speed and shank angular velocity for accurate kicks. Player one demonstrated slower foot speeds and shank angular velocities during accurate goal-kicks, representative of a speed-accuracy trade-off (or Fitt's law, 1954). A reduction in movement velocity has previously been identified (Peacock *et al.,* 2017; slower foot speeds: -4.4 $m.s^{-1}$, $p<0.05$) as a mechanism adopted by players to regulate and control the intersegmental movement of the kick-leg to optimise foot position during impact, helping to control the ball flight trajectory in an accuracy task. Although this was not evident in player 2, with accurate kicks demonstrating higher foot speeds ($p=0.01$, $d=1.2$) and shank angular velocities ($d=0.9$). Future work is warranted to explore this aspect of goal-kicking, to identify if individual-specific strategies exist in goal-kicking in AF.

Previous AF literature in punt kicking, identified that accurate kickers had greater pelvic tilt and hip flexion (Dicheria *et al*., 2006). However minimal differences were reported in hip and pelvis kinematics between accurate and inaccurate kicks in this study for both players. Whilst these differences are possibly due the differences in biomechanical modelling procedures between studies, future research is needed to explore the contribution of the hip and pelvis to kicking accuracy and address this inconsistency in the literature.

Future work with a larger N is needed to determine if the findings are significant. However, the individual differences reported also highlight the need for future goal-kicking research to conduct an individual-based analysis, as well as a group-based analysis, supporting previous work in rugby goal-kicking (Ball *et al.,* 2010). This is important as coaching recommendations may need to be tailored to the individual rather than applying a theoretical model of 'good' technique. Further, due to insufficient numbers of hit vs miss kicks at each position, comparisons between positions were not made in this study. Future work should examine if differences exist for kicks taken at different positions, to determine if results can be generalised across positions or whether technical adjustments are made dependent on where the goal-kick occurs in the field. In addition, accuracy was graded on a performance criterion (hit vs miss), however this could potentially mask important technical information as accurate kicks are classified over a wide margin (6.4m). Assessing accuracy over smaller margins may further elucidate mechanisms of goal-kicking accuracy in AF.

**CONCLUSION:** This study provided technical data for accurate 20m goal-kicks, using an inertial measurement system. Findings demonstrated increased support leg knee flexion at heel content and increased kick-leg knee flexion during swing phase may contribute goal-kicking accuracy. Individual differences were reported for footspeed and shank angular velocities during accurate goal-kicks, suggesting the speed of the movement in an accuracy task may be specific to the individual. These individual differences highlight the need to conduct an individual-based analysis in goal-kicking research.

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