Kinematic patterns associated with accuracy of the drop punt kick in Australian Football

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Summary
Research into the kinematics of movement associated with the accuracy of the drop punt kick in Australian Football has been limited. The aim of this study was to examine pelvic and lower limb kinematics during the performance of a drop punt kick, in order to identify factors associated with accurate kicking performance. Ten professional Australian Football League (AFL) players performed 20 drop punt kicks towards a target situated 15 m away, using their preferred leg. A three-dimensional motion analysis system was used to record the kicking motion from heel contact of the support limb through to ball contact. The subjects were divided into an accurate group (≥50% accuracy; n = 5) and an inaccurate group (<50% accuracy; n = 5) based on target hit rate. Kinematic profiles for both kicking and support limbs were compared between the two groups. Results showed that the accurate group had significantly greater hip flexion in both limbs and greater knee flexion in the support limb throughout the kicking movement. The accurate group also had significantly greater anterior pelvic tilt at heel contact (accurate 20.8°; inaccurate 12.7°). These data show that kinematic differences in lower limb joint angles may be related to kicking accuracy.

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Introduction
Australian Football is considered by many to be a premier sport in Australia and is one of the largest contributors to the sport and recreation industry. It is the nation’s leading spectator sport and has the third-highest number of players of all levels of any Australian sport.1

In Australian Football, the drop punt kick is the standard kicking technique used for ball progression.2 The object of punt kicking is to project the ball accurately over a desired distance at a desired velocity.3 Considerable time and resources are spent on training and coaching players to improve their kicking accuracy as games can be won or lost from the outcome of a single kick. To date, two published studies2,3 have examined the drop punt kick in Australian Football. Orchard et al.2 described the kinematics of the drop punt kick and the role of the major lower limb muscles in powering the kick, in order to gain information to
help explain injury patterns. Cameron and Adams have examined kicking footedness and movement discrimination in elite Australian Football players. Research into the kinematics of movement associated with the accuracy of the drop punt kick in Australian Rules football has not been investigated.

The aim of this study was to examine pelvic and lower limb kinematics of the kicking and support limbs during the drop punt kick in order to better understand some of the factors associated with kicking accuracy.

**Method**

**Subjects**

Ten players from the training squad of an AFL team participated. Only players who were in full training at match fitness level were included, thereby excluding any players with injuries affecting their physical performance. The study was conducted during the pre-season. The age of the participants ranged from 20 to 29 years, with a mean age of 23.1 years (S.D. = 3.0). The mean weight of the participants was 85.8 kg (S.D. = 8.9) and the mean height was 186.5 cm (S.D. = 5.1).

The Human Research Ethics Committee at La Trobe University approved the study procedures. Participants were given an explanation of the procedure and signed an informed consent form. Each subject was required to attend one session of approximately 90 min duration.

**Equipment and procedures**

The kinematics of kicking were measured using a three-dimensional motion analysis system (Vicon-512, Oxford Metrics Ltd., UK). The system consisted of six infrared 50 Hz cameras, which were used to track movement trajectories of 25 mm spherical reflective markers attached to anatomical landmarks of the lower limbs. The system was calibrated according to the manufacturer’s instructions prior to each data collection session. A total of 21 markers were attached to the subject in the following locations: sacrum, anterior superior iliac spine, greater trochanter, lateral aspect of the thigh and leg, knee joint axis, lateral malleolus, heel, second metatarsophalangeal joint, base of the fifth metatarsal and the lower lateral border of the shoe inferior to the lateral malleolus. Bony landmarks of the feet were palpated through the shoes and the markers were attached to the shoe. The thigh and leg markers were attached to 4 cm long wands. The remaining markers were attached directly to the skin using double-sided adhesive tape.

Physical measurements required by the biomechanical modelling software (Plug-in-Gait, Vicon, Oxford Metrics) were also obtained in order to calculate the location of the hip, knee and ankle joints. These included height, weight, distance between the anterior superior iliac spines, distance between the greater trochanter and anterior superior iliac spines, leg length, knee and ankle width and tibial torsion (defined as the angle of difference between a line joining the malleoli and a line joining the knee epicondyles).

A static standing trial was recorded to obtain a reference point for the markers. For this trial, Knee Alignment Devices (KADs) were placed on the lateral and medial femoral condyles. The KAD enables the Vicon software to establish the knee joint centre and knee joint axis alignment. These were then replaced with knee joint axis markers for the dynamic trials. The marker on the second metatarsal was in position during the static trial but was removed for the kicking trials because of ball contact with the dorsum of the foot. The second metatarsophalangeal joint marker was reconstructed after data capture from the three foot markers worn during the trials. In addition, markers were attached to the top and bottom seams of the football to enable the system to track ball movement.

Participants were instructed to perform 20 drop punt kicks, using their preferred limb towards the target 15 m away, the minimum legal distance kick in Australian Football. To avoid practice effects, subjects were given a warm-up period prior to data collection. Although the task may be similar to that undertaken during AFL games, performing inside a laboratory was relatively novel and therefore athletes performed at least five kicks with each leg until their performance had stabilised. During recorded trials, subjects were instructed to kick with their preferred limb so that they were performing at their highest skill level. The number of kicks performed was selected so performance was not affected by fatigue. The right limb was the preferred kicking limb in nine of the 10 subjects. All trials were conducted with subjects wearing their indoor training shoes because of the floor surface in the laboratory.

**Kicking area**

The study was conducted in a two-storey indoor human movement laboratory. The ‘approach’ area consisted of a 10-m long section of linoleum located before a force platform. The force platform (Kistler,
Winterthur, Switzerland) measuring 60 cm × 40 cm was situated at the kicking end of the ‘approach’ area and was used to determine initial contact of the support foot with the floor by recording ground reaction force.

Target

The target consisted of a life-sized cardboard cut-out of an AFL player, placed immediately in front of the players and 15 m from the centre of the force platform. The subjects were instructed to aim towards the chest area of the cut-out, which was identified with a green circular marker measuring 24 cm in diameter. The target was chosen as it represented a life-size player towards which the subjects could kick. Short distance kicks are mostly used to kick the ball to another player rather than to score, so a life-sized player cut-out helped make the conditions similar to those in football training or matches. The cut-out measured 184 cm in height and 49 cm across from elbow to elbow. It was adhered to a moveable board, which allowed the accuracy of kicks that did not hit the target to be measured and recorded. The centre of the target was located 133 cm from the floor and 51 cm from the top of the head of the cut-out, to the centre of the marker.

Accuracy determination

Two researchers recorded kicking accuracy. Accurate kicks were defined as hitting the target in the upper body and the segments defined as L1 (left one) and R1 (right one) (Fig. 1). These segments were chosen because a player would be able to reach the ball and catch it if it was kicked to these areas. Trials that hit any other segments or missed the board completely were considered to be inaccurate. Results of the two recording sheets were compared and there were no discrepancies between kicks recorded as accurate and inaccurate by the two researchers.

Data analysis

Each subject was categorised as either an ‘accurate’ or ‘inaccurate’ kicker by obtaining a percentage of the accurate trials from the total trials. There were five participants with a kicking accuracy of 50% and above (range 50–75%) and they were allocated to the accurate kicking group. The five remaining subjects had a kicking accuracy of less than 50% (range 20–40%) and were allocated to the inaccurate group. There were no significant differences between the two groups for any anthropometric variable.

Vicon workstation software (Oxford Metrics, UK) was used to reconstruct the two-dimensional data from each camera into three-dimensional trajectories. The first 15 trials for each subject that could be successfully reconstructed were analysed. This number of trials allowed for the omission of any trials that were unable to be reconstructed due to marker occlusion. One subject performed only 10 trials and therefore all 10 were analysed for that subject.

The kicking stride from the frame of stance limb contact to the frame of ball contact was chosen as the period for analysis. Heel contact (HC) was defined as the instant where the support foot contacted the force platform, as initial contact for all subjects was made with the heel. Ball contact (BC) refers to the instant the kicking foot contacted the ball. This period was chosen because this is the period during which the velocity and trajectory of the kicking limb is established and the trajectory of the ball determined. Heel contact and ball contact are clearly defined events, which enable time-normalisation of data for comparison between individuals.

Given that kicking is a reasonably dynamic movement and involves shock loading, markers, particularly those mounted on wands, are likely to have experienced vibration. The raw data were smoothed to account for potential noise utilising Woltring’s μ-spline technique with a mean squared error setting of 20, incorporated in the VICON software package. The largest marker artefacts would have occurred as a result of the impact between the ball and the kicking leg after the phase of interest in the current analysis. Plug-in-Gait (Vicon, Oxford Metrics) biomechanical modelling software
was used to process and output the data as kinematic profiles. The timing of the kinematic patterns were normalised between HC and BC with HC = 0% and BC = 100%.

Sagittal plane angles (defined here as rotations around flexion-extension axes) for the pelvis, stance ankle, both knees and both hips at both HC and BC were compared between the accurate and inaccurate groups. Initial and final angles were analysed rather than peak angles. Inspection of the curves indicated that initial and final angles were indicative of differences between the groups over the whole time period. Moreover, since the trajectory of the ball is determined at the moment of BC, the position of the limbs at the time of BC was of primary interest.

Only sagittal plane movements were investigated as this is the plane in which most motion and power generation occurs. This is also the plane in which observers are most likely to observe kicking technique. Movements in the frontal and transverse planes are relatively small and are therefore less reliably observed. Ankle, knee, hip and pelvic angles were initially derived for individuals based on an average of the 15 kicks, and then means taken for the five subjects. The dependent variables were pelvic, hip, knee and ankle angles at both HC and BC. The length of the approach step (distance between heel contact of the kicking limb and heel contact of the stance limb) was also calculated as a percentage of leg length. For each dependent variable, independent t-tests were used to compare between the accurate and inaccurate groups. The Mann–Whitney U-test was used for data not normally distributed. Normality was assessed using the Shapiro– Wilks statistic. An alpha level of \( p < 0.05 \) was used for each test.

**Results**

**Ankle**

Ankle data could only be reconstructed for the support limb. For both groups the ankle movement began with a small degree of dorsiflexion, moved into plantarflexion and then ended at BC in either neutral or slight plantarflexion (Figure 2). Ankle kinematics values are shown in Table 1 and were not significantly different between the accurate and inaccurate groups either at HC (\( t(8) = 0.16, p = 0.05 \)) or BC (\( t(8) = 1.10, p = 0.05 \)).

**Knee**

The averaged kinematic graphs indicate that the accurate group had greater knee flexion throughout the kicking movement (Fig. 3B). For the kicking limb, the accurate group had greater knee flexion compared to the inaccurate group (Fig. 3A). For the support limb, the difference between the groups was significant at HC (\( t(8) = 2.959, p < 0.05 \)) and BC (\( U(8) = 2.2, p < 0.05 \)). The Mann–Whitney U-test was used for data not normally distributed. Normality was assessed using the Shapiro–Wilks statistic. An alpha level of \( p = 0.05 \) was used for each test.

**Figure 2** Ensemble averages (±1 S.D.) of stance limb ankle dorsiflexion and plantarflexion for the accurate (black line) and inaccurate (grey line) groups. HC occurred at 0% and BC at 100%.

**Hip**

The kinematic patterns of the hip for both limbs showed that the accurate group had greater hip flexion throughout the kicking movement (Fig. 3B). For the kicking limb, the accurate group began with hip in a slightly flexed position (2.6°) whereas the inaccurate group began with hip in an extended position (−12.1°). The between-group difference was a significant 14.8° (\( t(8) = 5.877, p < 0.01 \)). The results at BC, where hip flexion was maximal, also showed a significant difference (\( t(8) = 2.440, p < 0.05 \)) between the accurate and inaccurate groups (Table 1). For the support limb, the hip began in flexion and decreased to nearly neutral at BC in both groups. Again, the accurate group had significantly greater hip flexion at HC (\( t(8) = 3.638, p < 0.05 \)) and BC (\( t(8) = 2.780, p < 0.05 \)).
Table 1 Mean (S.D.) angular joint kinematics at heel contact and ball contact in the sagittal plane

<table>
<thead>
<tr>
<th>Joint</th>
<th>Heel contact</th>
<th>Ball contact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accurate</td>
<td>Inaccurate</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support limb</td>
<td>11.4 (3.9)</td>
<td>10.9 (4.6)</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>28.3 (15.4)</td>
<td>11.6 (6.9)</td>
</tr>
<tr>
<td>Support limb</td>
<td>9.5 (3.1)</td>
<td>4.2 (2.5)</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>2.6 (2.6)*</td>
<td>−12.1 (5)</td>
</tr>
<tr>
<td>Support limb</td>
<td>48.4 (1.4)</td>
<td>39.3 (5.4)</td>
</tr>
<tr>
<td>Pelvic tilt</td>
<td>20.8 (0.7)</td>
<td>12.7 (4.2)</td>
</tr>
</tbody>
</table>

Note: *p < 0.05 accurate vs. Inaccurate group. All angles are in degrees.

Figure 3 Ensemble averages (±1 S.D.) of the flexion-extension angles of the knee (A) and hip (B) of the kicking and support limbs for the accurate (black line) and inaccurate (grey line) groups. HC occurred at 0% and BC at 100%.
Pelvis
The kinematic patterns of pelvic movement showed that the pelvis moved through neutral and into posterior tilt during the last half of the movement (Fig. 4). There was a significant difference in the degree of anterior pelvic tilt at HC between the accurate and inaccurate groups ($t(8)=4.250$, $p < 0.05$). The accurate group had a mean anterior tilt angle of $20.8^\circ$ (S.D. = 0.7) at HC and the inaccurate group had a mean of $12.7^\circ$ (S.D. = 4.2) (Table 1). However, at BC the difference was not significant ($t(8)=1.122$, $p > 0.05$).

The angle of anterior pelvic tilt in static trials was calculated for each subject and group to determine if the accurate group had increased anterior tilt during normal standing posture. A significant difference ($U(8) = 2.9$, $p < 0.01$) existed between the groups with the mean angle of anterior pelvic tilt in the accurate group of $13.8^\circ$ (S.D. = 0.3) compared to the inaccurate group average of $8.8^\circ$ (S.D. = 0.2). The change in anterior pelvic tilt from standing to HC was significant for the accurate group ($t(4)=20.3$, $p < 0.001$) but not the inaccurate group ($t(4)=2.2$, $p > 0.05$).

Approach step length
No difference between the approach step length was found between the accurate and inaccurate group (113% versus 104%, $t(8) = 0.97$, $p > 0.05$). Both groups used a similar approach step.

Discussion
This study showed that there were differences in the kinematic patterns between the participants who were classified as “accurate kickers” and those who were classified as “inaccurate kickers”. The differences involved multiple joints in the lower limbs, but particularly the support limb where, at HC, the accurate group showed greater pelvic tilt, and hip and knee flexion.

Support limb knee flexion was substantially greater in the accurate group throughout the movement. Knee flexion is an important limb length adjustment mechanism which lowers the centre of gravity during stance phase in walking. During the kicking movements analysed here, increased support limb knee flexion would have lowered the centre of gravity somewhat throughout the movement. Lowering the centre of gravity is one way of increasing the stability of the body, a principle which is emphasised in many textbooks on sports biomechanics [see Ref. 4 and Hay 6, p. 145]. It may be that the slightly lower centre of gravity and increased stability in this group contributed to their increased kicking accuracy. It may also be that the increased flexion of the kicking limb apparent in Fig. 3a in the accurate group was an adaptation necessary to ensure toe clearance of the kicking limb. It should be noted that, although these differences appeared substantial in the kinematic graphs (Fig. 3a), they were not statistically significant. This may have been a result of the small sample size and insufficient power to detect differences.

The two groups were different in terms of standing pelvic alignment with the accurate group demonstrating about five degrees greater anterior tilt. This raises the possibility that physical differences between players may also contribute to varying accuracy between the two groups. Such an association would have implications for the potential gains that could be expected from coaching. The difference in pelvic tilt may account for much of the difference observed between groups during the kicking movement ($8.1^\circ$ at HC, $3.3^\circ$ at BC).

Previous studies investigating the biomechanics of kicking have focussed on the kicking limb possibly because it moves through a much greater range of movement than the support limb. In the present study, although there were differences in hip flexion at HC between the groups, these were probably a reflection of the posture adopted by the support limb at HC. There were no significant differences in knee flexion in the kicking limbs, further emphasising the key role of the support limb.
A limitation of the present study was the small number of subjects, although this is not atypical of similar studies in the area. The findings require further investigation in larger samples and in non-elite players. In addition, only a short distance from subject to target was used. Whether or not these data can be extrapolated to kicking over a longer distance, such as kicking for goal, remains to be determined. This experiment found that the accurate and inaccurate group had different pelvic alignment during standing. In future studies it would be of interest to normalise joint angles to standing posture, in order to control for this variable. Finally, it would be useful for future studies to compare joint kinematics of an individual subject for trials that were accurate versus those that were inaccurate. This would enable each subject to act as their own control.

Conclusion
This study has explored lower limb kinematics in relation to kicking accuracy in Australian Football. Small but significant differences in lower limb joint angles between the accurate and inaccurate groups may be related to differences in kicking accuracy. The biomechanical relationships between the kinematic variables observed and kicking accuracy is unclear but may be related to the stability of the body over the stance limb.

Practical implications
The differences identified in this study suggest that the kicking action may well be set up in the support limb. This information may provide an additional strategy for coaches when trying to improve a player’s kicking technique.

Acknowledgement
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References