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**Research article**

# The effects of approach angle on penalty kicking accuracy and kick kinematics with recreational soccer players

**Joanna Scurr ✉ and Ben Hall**
Department of Sport and Exercise Science, University of Portsmouth, Portsmouth, UK

**Abstract**
Kicking accuracy is an important component of successful penalty kicks, which may be influenced by the approach angle. The purpose of this study was to examine the effects of approach angle on kicking accuracy and three-dimensional kinematics of penalty kicks. Seven male amateur recreational soccer players aged (mean ± s) 26 ± 3 years, body mass 74.0 ± 6.8 kg, stature 1.74 ± 0.06 m, who were right foot dominant, kicked penalties at a 0.6 x 0.6 m target in a full size goal from their self-selected approach angle, 30º, 45º and 60º (direction of the kick was 0º). Kicking accuracy and three-dimensional kinematics were recorded. Results revealed that there was no significant difference in kicking accuracy ($p = 0.27$) or ball velocity ($p = 0.59$) between the approach angles. Pelvic rotation was significantly greater under the 45º and the 60º approach angles than during the self-selected approach angle ($p < 0.05$). Thigh abduction of the kicking leg at impact using the 60º approach angle was significantly greater than during the self-selected approach ($p = 0.01$) and the 30º approach ($p = 0.04$). It was concluded that altering an individual's self-selected approach angle at recreational level did not improve kicking accuracy or ball velocity, despite altering aspects of underlying technique.

**Key words:** Biomechanics, three-dimensional, instep kick, football.

## Introduction

Soccer is the most popular sport in the world (Lees and Nolan, 1998). Biomechanics is often applied to soccer to define the characteristics of skills, to gain an understanding of their mechanical effectiveness and to identify factors essential for optimal performance (Lees and Nolan, 1998). The instep kick has been subject to the majority of biomechanical analysis and research (Barfield et al., 2002; Dorge et al., 2002; Lees and Nolan, 2002; Nunome et al., 2002; Shan and Westerhoff, 2005). Subjects are typically instructed to kick a stationary ball at a target from a distance of 8 to 12 m, corresponding to the penalty kick. The instep kick is often used when taking a penalty kick, as a combination of increased ball speed and shot accuracy can be maintained (Lees and Nolan, 1998).

Relatively limited scientific research has been undertaken on the technical aspects of soccer penalty kicks (Morya et al., 2003), despite their importance in competition. When taking penalties players may adopt the 'open loop' strategy by selecting one corner of the goal to shoot at, ignoring any actions the goalkeeper may take (Kuhn, 1988). Considering the kicking accuracy of modern professional soccer players, and the time required for a goalkeeper to reach the corners of the goal (Morris and Burwitz, 1989), it is surprising that 25% to 33% of penalty kicks in official competitions are missed (Kuhn, 1988). Therefore, there is a need to examine the factors underpinning penalty kick success.

Kicking accuracy is an important component of soccer performance, and can be defined as the ability to kick the ball at a specified area (Finnoff et al., 2002). Finnoff et al. (2002) suggested a valid and reliable method of measuring accuracy is to measure the distance of the ball from a specific target. This method provides information on the degree of accuracy as opposed to simply the ability to hit or miss the target.

When taking penalty kicks soccer players often approach the ball at an angle (Kellis et al., 2004). In general play, the approach angle is often dependent on the preference of the individual and the kick situation (Lees and Nolan, 1998). An angled approach is commonly used as it orientates the body to gain greater hip and knee flexion range of motion, and enables the kicking leg to be tilted in the frontal plane so that the foot can be placed further under the ball, thus enabling better ball contact (Lees and Nolan, 1998). Isokawa and Lees (1988) investigated the effects of approach angle on kick kinematics in trainer soccer players. Six male subjects took a one step run up to kick a stationary ball using approach angles of 0º, 15º, 30º, 45º, 60º and 90º. They found an approach angle of 30º to 45º to be optimal, with maximum velocity of the shank achieved with an approach angle of 30º and the maximum ball speed achieved with an approach of 45º. However, they did not investigate the relationship between the approach angle and accuracy, and it appears that no further investigation has been carried out focusing on different approach angles and kick accuracy of recreational soccer players.

The majority of kinematic data reported in the literature has been analysed using two-dimensional, sagittal plane methodologies (Lees and Nolan, 1998). Few three-dimensional studies have been conducted (Brown et al., 1993; Levanon and Dapena, 1998; Rodano and Tavana, 1993) but these have not reported movements occurring specifically in the transverse plane, such as pelvic rotation. Increases in pelvic rotation during kicking opens the hips, allowing the pelvis to move through a greater range of motion and prolonging ball contact time, which may have positive benefits for accuracy (Barfield, 1998). Lees and Nolan (2002) compared kinematics, including pelvic rotation, when kicking for speed or accuracy using a three-dimensional analysis, but they did not alter the approach angle. They found that the increase in ball speed,

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when kicking for power as opposed to accuracy, was associated with greater hip and knee range of motion.

It is clear that the instep kick, corresponding to the penalty kick, has been subject to the majority of biomechanical research in soccer kicking. However, there appears to be gaps in the literature, specifically relating to penalty kick accuracy, suggesting that the skill has not been fully described. The relationship between the approach angle, kinematics and the accuracy of the kick remains unclear. Therefore, the aim of this preliminary study was to examine the effects of approach angle on three-dimensional kinematics and accuracy of penalty kicks. Based on previous research it was hypothesised that an approach angle of 45° would significantly improve kicking accuracy and ball velocity, whilst altering kick kinematics, in particular increasing pelvic rotation.

## Methods

### Subjects

Seven male amateur recreational soccer players aged (mean ± s) 26 ± 3 years, body mass 74.0 ± 6.8 kg, stature 1.74 ± 0.06 m, volunteered to participate in this study. All subjects had a minimum of five years recreational playing experience, were right foot dominant (self-reported) and had experience of taking penalty kicks in training and match situations. Following institutional ethical approval all subjects provided written informed consent.

### Procedures

The study was conducted outdoors on an artificial soccer pitch and all subjects wore their own astro turf trainers. Following a warm up, stretching exercises and six familiarisation trials using each approach angle subjects were asked to kick penalties, with the emphasis on accuracy, using the instep portion of the foot at a speed they would usually take a penalty kick. Subjects kicked a total of twenty-four penalties, using a standard size 5 ball, at a 0.6 x 0.6 m plywood target positioned in the lower right corner of a full size goal (7.32 x 2.44 m). The centre of the target was marked with a cross. Four different approach angles were used; subjects' self-selected approach angle, 30º, 45º and 60º, with 0º perpendicular to the goal posts. The self-selected approach condition was used first, followed by the three experimental approach angles in a random order; these were marked clearly on the astro turf for subjects to follow. The length of the approach was self-selected by subjects to simulate the actual penalty kick situation; most subjects took between 3 and 5 strides. Within subject approach length was determined during the familarisation trials and remained consistent throughout testing. Six trials were recorded in each condition.

An eight-point calibration frame (volume 1.5 x 1.5 x 2.5 m) was used to calibrate the space in which subjects performed kicks (penalty spot). All kicks were visually recorded using two 50 Hz digital cameras (Sony, TRV 900E) at a shutter speed of 10 kHz. One camera was positioned in the left corner of the goal and the other at a 95º separate angle to the first camera, 5m to the right of the goal. For all kicks the target was filmed using a 25 Hz digital camera (JVC, GX N7S) to analyse accuracy. This camera was positioned at a distance of approximately 30 m directly inline with the target, capturing a field of view of approximately 3 m either side and above the target. Markers were attached to six anatomical landmarks on both sides of the body; greater tubercle of humerus, greater trochanter, anterior superior illiac spine, lateral femoral epicondyles, lateral malleolus and lateral aspect of fifth metatarsal.

### Data analysis

For all kicks in each condition, accuracy was recorded as the distance from the centre of the ball to the centre of the target in meters using SiliconCOACH Pro software (version 5.1.5.0, New Zealand). The accuracy measurement was taken 0.08 s before the ball hit the back of the net, the depth of the goal was 1.8 m, the mean ball velocity of 24.3 $m{\cdot}s^{-1}$ (± 2.4 $m{\cdot}s^{-1}$) meant that this measurement was taken 0.1 m before the goal line. Following kick accuracy analysis, the most accurate kick in each condition for each subject was selected for kinematic analysis. Kinematic analysis was undertaken using semi-automatic digitisation in Simi Motion 3D software (version 5.5, Simi Reality Motion Systems GmbH, Germany), the data were reconstructed and analysed in three-dimensions using direct linear transformation procedures. The cameras were synchronised using event synchronisation as the foot impacted with the ball. Camera frame rate was synchronised in the Simi software, by measuring the time offset between cameras in the DV signal arriving at the Firewire port (giving an accuracy of ± 0.01 s). The selected anatomical landmarks were digitised, along with the centre of the ball.

A variety of kinematic variables were chosen to identify key aspects of performance; maximum absolute ball velocity; shank abduction angle (projected onto the frontal plane), anterioposterior pelvic tilt (projected onto the sagittal plane), thigh abduction angle (projected onto the frontal plane), ankle dorsiflexion (projected onto the sagittal plane), hip flexion (projected onto the sagittal plane), knee flexion of the kicking and supporting leg (projected onto the sagittal plane); transverse pelvic rotation (about the vertical axis) and knee flexion range of motion from initiation of the kick to follow through. Supporting foot lateral and posterior displacement from the ball at impact were also measured from lateral aspect of the fifth metatarsal to the centre of the ball.

### Statistical analysis

Statistical analyses were undertaken using SPSS (v12.0.1). All data were checked for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests, where normality was assumed if $p > 0.05$). A non-parametric Friedman with a Post Hoc test (Mann-Whitney U) was used to compare differences in accuracy between the approach angles. Parametric differences in kick kinematics between the approach conditions were analysed using a repeated measures MANOVA (with approach angle as the independent variable and kick kinematics as the dependent variables). Shot accuracy and ball velocity variables demonstrated a statistical power of 0.8. An alpha level of $p < 0.05$ was established for all statistical tests.

**Table 1. Mean (±standard deviation) values for kicking accuracy and maximum ball velocity under each approach condition.**

| Approach Condition | Self-selected 30.3º (15.2º) | 30º | 45º | 60º |
|---|---|---|---|---|
| Accuracy (m) | .94 (.67) | 1.21 (.65) | 1.09 (.73) | 1.13 (.68) |
| Ball velocity ($m \cdot s^{-1}$) | 25.15 (2.07) | 24.23 (2.30) | 24.47 (2.12) | 23.51 (2.36) |

## Results

The self-selected approach angle was 30.3 ± 15.2º (mean ± *s*); range = 39º. Mean kicking accuracy values, representing the distance in meters from the centre of the target, under the four approach conditions (Table 1) were similar ($X^2 = 3.97_{,3}$, p = 0.26). The participants also displayed similar ball velocities for each approach angle ($F = 0.65_{,3,}$ p = 0.59).

The data in Table 2 represents the mean values of selected kinematic characteristics of the kick at the moment of impact. The participants' thigh abduction angle increased as the approach angle increased, enabling the thigh of the kicking leg to be more abducted at impact. The thigh abduction angle under the 60º approach was significantly greater than during the self-selected approach (p = 0.01) and the 30º approach (p = 0.04). There was no significant difference across approach angles for all of the other kinematic variables displayed in Table 2 (p > 0.05).

The data in Table 3 represents pelvic rotation and knee flexion range of motion from kick initiation until follow through. The participants displayed greater pelvic rotation when using a wider approach angle. The values under the 45º approach angle and the 60º approach angle were significantly greater than during the self-selected approach angle (p < 0.05). No significant differences were found in knee flexion range of motion between the approach angles ($F = 2.76_{,3,}$ p = 0.06).

## Discussion

The results of this preliminary study show that penalty kick accuracy was not improved by altering recreational players' approach angle (Table 1), which failed to support the first research hypothesis. As there is limited research regarding the effect of approach angle on kicking accuracy at skilled or amateur level, limited comparisons can be made. With skilled players Isokawa and Lees (1988) reported an approach angle of 30º to 45º to be optimal due to maximum shank and ball velocity, but they did not measure accuracy of the kick. The ability of the subjects may partially explain the fairly large accuracy measurements, and consequently the lack of improvement in performance. It has been suggested that kicking is enhanced with training and is a well-developed skill in experienced players, whereas amateur players demonstrate less consistency in coordination of movement (Davids et al., 2000; Lees and Nolan, 1998).

Ball velocity remained similar between the approach conditions (Table 1), which also failed to support the first research hypothesis. With the exception of Isokawa and Lees (1988) there is limited research regarding the effects of approach angle on ball velocity. Isokawa and Lees (1988) found that an approach angle of 45° was optimal for maximum ball speed in skilled players. In the present study altering recreational players' self-selected approach angle showed no improvement in ball velocity.

There is evidence that widening the approach angle altered aspects of underlying technique despite not improving the outcome of the kick. Pelvic rotation was significantly greater from the 45º and 60º approach angles compared to the self-selected approach angle (Table 3), which partially supports the second research hypothesis. The data for pelvic rotation also support Lees and Nolan (1998) description of movement that an angled approach of 45º opens the hips before contact, allowing the pelvis to move through a greater range of motion throughout the kick. Greater pelvic range of motion enables the performer to remain in contact with the ball for a longer period of time, increasing the possibility of a more accurate shot (Barfield, 1998). However, there is no evidence to suggest that these improvements in technique improved the outcome of the kick in recreational players.

The subjects' thigh abduction angle increased as the approach angle increased (Table 2) resulting in the thigh of the kicking leg being more abducted at impact. This supports Davids et al. (2000) description of movement that an angled approach of approximately 45º or greater tilts the body to one side, lifting the hip of the

**Table 2. Mean (±standard deviation) kinematic descriptors of the kick at impact under each approach condition.**

| Approach Condition | Self-selected 30.3º (15.2º) | 30º | 45º | 60º |
|---|---|---|---|---|
| **Angle (degrees)** | | | | |
| Ankle dorsiflexion | 130.2 (11) | 129.6 (11.1) | 132.3 (11.6) | 130.3 (13.3) |
| Shank abduction | 21.3 (8.4) | 20.6 (6.6) | 27.4 (8.5) | 28.9 (7.2) |
| Knee flexion | 156.2 (10.1) | 162.2 (8.8) | 160.5 (9.7) | 163.7 (9.8) |
| Supporting leg knee flexion | 135.3 (7.8) | 141.4 (10.9) | 136.7 (7.8) | 140.6 (7.5) |
| Hip flexion | 147.6 (5) | 148.5 (3.3) | 149.9 (5.4) | 153.1 (5.2) |
| Thigh abduction | 20 (9) * | 21.9 (7.5) * | 29.9 (8.3) | 33 (3.5) |
| Pelvic tilt | 7.4 (4.8) | 6.4 (4.2) | 9 (4.6) | 7.7 (2.7) |
| **Displacement (cm)** | | | | |
| Supporting foot lateral displacement from ball | 32.7 (7) | 31.1 (7.7) | 34.6 (6.1) | 41 (13.5) |
| Supporting foot posterior displacement from ball | 9.7 (8.1) | 10.6 (9.2) | 11.3 (9.1) | 11.7 (5.3) |

* Significantly different to the 60º approach (p < 0.05).

**Table 3. Mean (±standard deviation) range of motion in degrees during each approach condition.**

| Approach Condition | Self-selected 30.3º (15.2º) | 30º | 45º | 60º |
|---|---|---|---|---|
| Pelvic rotation | 26.6 (11.7) | 38.1 (17.5) | 54.2 (9.5) * | 55.9 (13.9) * |
| Knee flexion | 68.1 (18.6) | 71.9 (19.5) | 86.1 (13.1) | 89.4 (14.3) |

* Significantly different to the self-selected approach ($p < 0.05$).

kicking leg, enabling the thigh and shank to be tilted in the frontal plane. This enables the kicking foot to be placed further under the ball, which has been reported to improve ball contact (Lees and Nolan, 1998). It was evident from the present study that this improvement in technique did not enhance the outcome of the kick in recreational players.

Altering the approach angle showed no significant effect on the majority of the kinematics analysed in recreational players: ankle dorsiflexon, shank abduction, knee flexion of the kicking and supporting leg, hip flexion, pelvic tilt, supporting foot lateral and posterior displacement, and knee flexion range of motion were all similar for each approach angle ($p > 0.05$). Knee flexion of the supporting leg at impact (Table 2) was similar to that reported by Lees and Nolan (2002). Lees and Nolan (2002) found that increased knee flexion lowered the body enabling the kicking leg to be slightly flexed at impact, this enabled appropriate ball contact and improved kick velocity in skilled players, however, there is limited research regarding recreational players to compare these findings. The data for placement of the supporting foot (Table 2) under the self-selected and 30º approach angles were similar to that reported by McLean and Tumilty (1993) and Hay (1985), approximately 30 cm to the side and 10 cm behind the ball.

The positioning of the target in one corner of the goal provides more ecological validity to the methodology. Finnoff et al. (2002) placed a target in the middle of a replica goal to analyse kicking accuracy. However, in practice soccer players often aim for one corner when taking a penalty kick, due to the goalkeepers central positioning. The goalkeeper usually has limited success in saving the shot if it is kicked accurately into the corner with sufficient speed. For right-footed players, the use of an acute approach angle when shooting to the right corner of the goal may deceive the goalkeeper who could anticipate that the player is shooting for the left corner due to the direction of their approach.

It is interesting that the significant changes in kinematics from varying approach angles did not result in changes in kicking accuracy or ball velocity during penalty kicking with recreational players. This would suggest that these factors (kinematics and approach angles) are not important during accuracy training in recreational players, future research is needed to determine factors that might be useful to the training of accuracy for players of this level. The lack of significant findings in this study limit the practical recommendations for improving kicking accuracy among recreational players, however, it would be interesting to replicate this study with more experienced players. Future studies in this area may benefit from a larger sample size, however, for comparative purposes this study uses a similar sample size as Lees and Nolan (1998) and provides preliminary data in this novel area. The use of an artificial surface and astro turf trainers may have been a limitation, as few soccer matches are played under these conditions. Future research should utilise authentic playing surfaces and footwear. Finally, future studies in this area may benefit from an intervention period to allow subjects to adapt to the experimental conditions.

## Conclusion

For recreational soccer players it is concluded that altering an individual's self-selected approach angle does not improve kicking accuracy or ball velocity during a penalty kick. However, kicking from an approach angle of 45º and 60º may alter aspects of kick technique, such as enhancing pelvic rotation and thigh abduction of the kicking leg at impact, which have been reported to enable better ball contact (Barfield, 1998; Davids et al., 2000; Lees and Nolan, 1998). It is interesting to note these differences in technique in recreational players, further research is required to establish whether these alterations are apparent in skilled players, and as a result improve performance outcome of the kick.

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## Key points

- Penalty kicking accuracy and ball velocity were not improved by altering recreational soccer players' natural approach angle.
- However, widening the approach angle produced greater pelvic rotation and thigh abduction.
- Wider approach angles increased the range of motion of the pelvis, opening up the hips before ball contact, creating a greater arc of movement during the backswing and the follow-through.
- Wider approach angles also led to an increase in thigh abduction at impact, enabling the kicking foot to be placed further under the ball, which may improve ball contact.

## AUTHORS BIOGRAPHY

**Joanna SCURR**
**Employment**
Department of Sport and Exercise Science, Spinnaker Building, University of Portsmouth.
**Degree**
PhD
**Research interest**
Sports biomechanics, breast biomechanics and breast health.
**E-mail:** Joanna.scurr@port.ac.uk

**Ben HALL**
**Employment**
Department of Sport and Exercise Science, Spinnaker Building, University of Portsmouth.
**Degree**
MSc
**Research interest**
Sports biomechanics, soccer.

✉ **Dr. Joanna Scurr**
Department of Sport and Exercise Science, Spinnaker Building, University of Portsmouth, Cambridge Road, Portsmouth, PO1 2ER, UK.