Biomechanics in a football instep kick

Introduction

An instep kick is one of the most fundamental technical skills in football. The skill allows teams to maintain possession, helping to create attacking opportunities and enabling tactical play. This is because, the instep pass is widely used due to its ability to produce controlled ball speed and accuracy over short and long distances. An effective execution of an instep pass requires coordinated sequencing of lower-limb segments, stabilisation of the support leg, and precise foot-ball impact mechanics (Lees et al., 2010). Given the importance of passing accuracy for performance at all levels (from premier league to Sunday league), understanding the biomechanics of the instep pass is essential for identifying factors that influence successful execution.

Biomechanically, the instep kicking actions involve a combination of hip flexion, knee extension and ankle plantarflexion during the forward swing, with segmental velocity transferred along the kinetic chain to maximise foot speed at impact (Lees et al., 2010). Critical variables in previous research include backswing knee angle, front swing angular velocities, support leg knee flexion, pelvic rotation and the orientation of the support foot at ground contact.

Kicking research consistently highlights the role of hip flexion as the primary driver of forward swing velocity. During the instep kicking action, the hip moves from a hyperextended backswing to into rapid flexion before ball contact, contributing substantially to the acceleration of the thigh segment (Nugroho and Doewes, 2023). This proximal to distal sequencing is crucial for generating high foot velocity and ensuring the transfer of mechanical energy down the leg.

The knee joint plays an equally important role. This is as a large backswing knee flexion angle increases the range of motion for the subsequent extension, contributing to a faster shank angular velocity during the forward swing. Studies have shown that knee extension velocity is strongly associated with ball speed, and that players who demonstrate greater knee flexion in the preparation phase often produce more effective kicks (Nugroho and Doewes, 2023). Additionally, the timing of the transition from knee flexion to rapid extension is a key performance variable that differentiates skilled and less skilled kickers.

The ankle angle at impact is also a crucial determinant of pass accuracy and ball flight characteristics. Effective instep kicking typically requires the ankle to be held in a firm, plantarflexed position so that the foot behaves as a rigid lever at impact (Lees et al., 2010). Poor ankle stability or excessive dorsiflexion reduces force transfer and can alter ball trajectory. Ankle angle can also influence the contact surface of the foot, which affects accuracy and consistency in passing.

Previous research comparing kicking techniques has shown significant differences in hip, knee, and ankle joint angles between various kick types and between successful and unsuccessful attempts (Nugroho and Doewes, 2023). However, much less attention has been given to bilateral differences within an individual performer, despite the common presence of limb dominance in football as players often say they have a ‘stronger’ and ‘weaker’ foot when it comes to performing skills such as passing and shooting.

Therefore, the aim of this project is to quantitively compare hip flexion, knee flexion-extension and ankle angle between dominant and non-dominant foot instep passes, identifying how these kinematic variables differ between each limb and how they relate to established performance characteristics. These variables were selected due to their strong association with ball speed, accuracy, and technical efficiency.

Methods

The analysis is based on a 19-year-old male who has consented to performing an instep pass on both the left side (dominant foot) and the right side (non-dominant foot), specifically analysing hip, knee and ankle kinematic movements. The recording took place in the ulster university biomechanics lab using an iPhone 16 set at 60Hz and 30fps, set 11.76 feet away from the participant and a height set at 4.11 feet on the tripod. The iPhone was set at the same height throughout the videoing on a tripod. The video was then screenshotted at the main stages of the kick and zoomed in for a closer view of the movement.

The participant then kicked the size 5 football from a marked spot to keep a consistent approach distance with the left more dominant foot first to the net in front, repeated 3 times, then changed over to the right and placed the tripod on the opposite side at the same distance and repeated the kick 3 times. The participant was instructed to take a natural stance on the same spot every time and approach the ball to kick at a controlled intensity, so it is repeatable and reliable.

To ensure an accurate 2D analysis, the camera lens was aligned perpendicular at the point where the participant is kicking the ball. The distance between the camera and kick was chosen to ensure a wide view and reduce distortion. The room we used had good lighting, which allowed for clear visibility of the markers and ball movement in the photos (Stampfl et al 2023). Small markers were made from white tape on the key joints for the movement, such as the hip, knee and ankle on both sides to improve the identification of them.

The video was then downloaded onto a Windows 11 computer and analysed using the Kinovea software, which is a reliable software used to measure angles and distance in biomechanics (Elwardany et al, 2015). Using this software, we measured the angles of the hip and knee flexing and extending and the skank angle on both the right and left side during the kick. The hip, knee and ankle were all measured at the beginning and at the end of the kick.

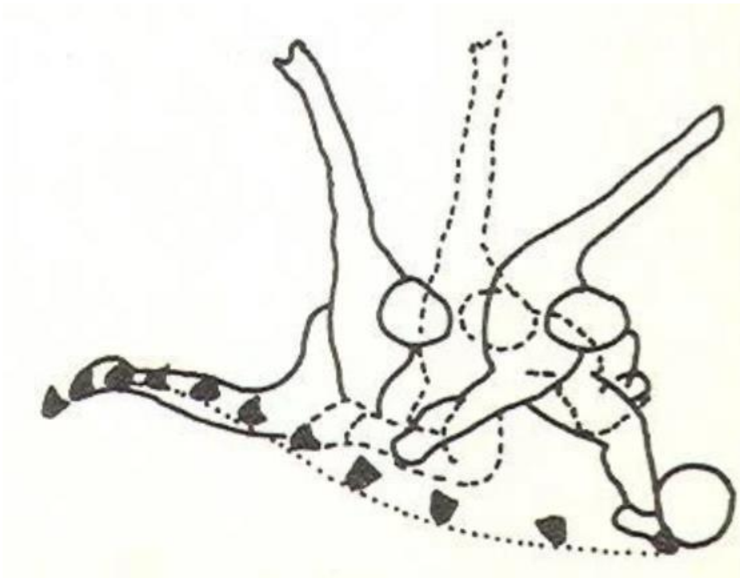

Figure 1: Top view of the kicking foot movement during a maximal instep kick (Shan and Zhang, 2011)

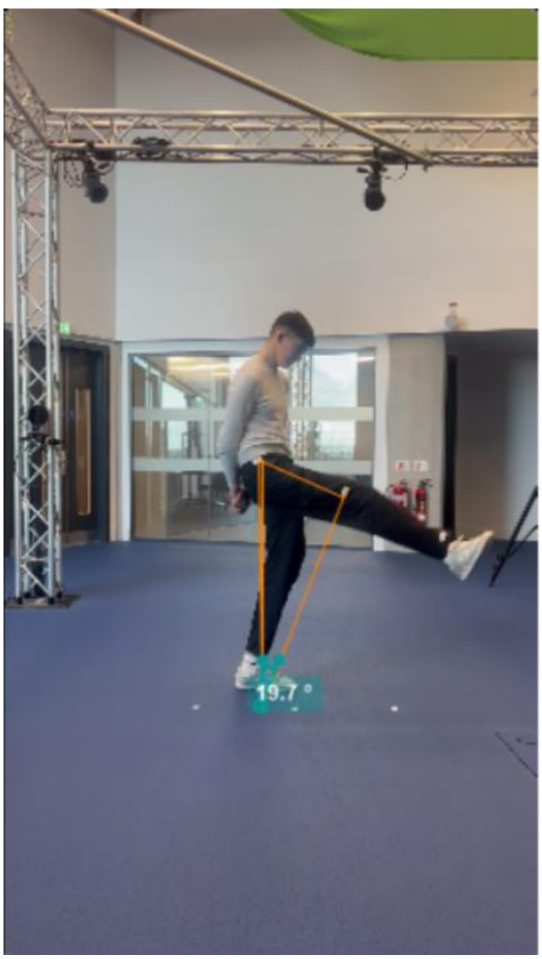

Figure 2: Hip flexion angle of right leg

Figure 3: Hip flexion, knee flexion and shank angles at ball contact of left leg

Figure 4: Peak knee backswing angle of left leg

Results

	Kick 1	Kick 2	Kick 3	Average	SD
Left (dominant)	42.9	44.0	41.5	42.8	±1.0
Right (non-dominant)	42.3	40.2	43.1	41.9	±1.2

Table 1: Hip flexion for each trial on both dominant and non-dominant sides including average and SD

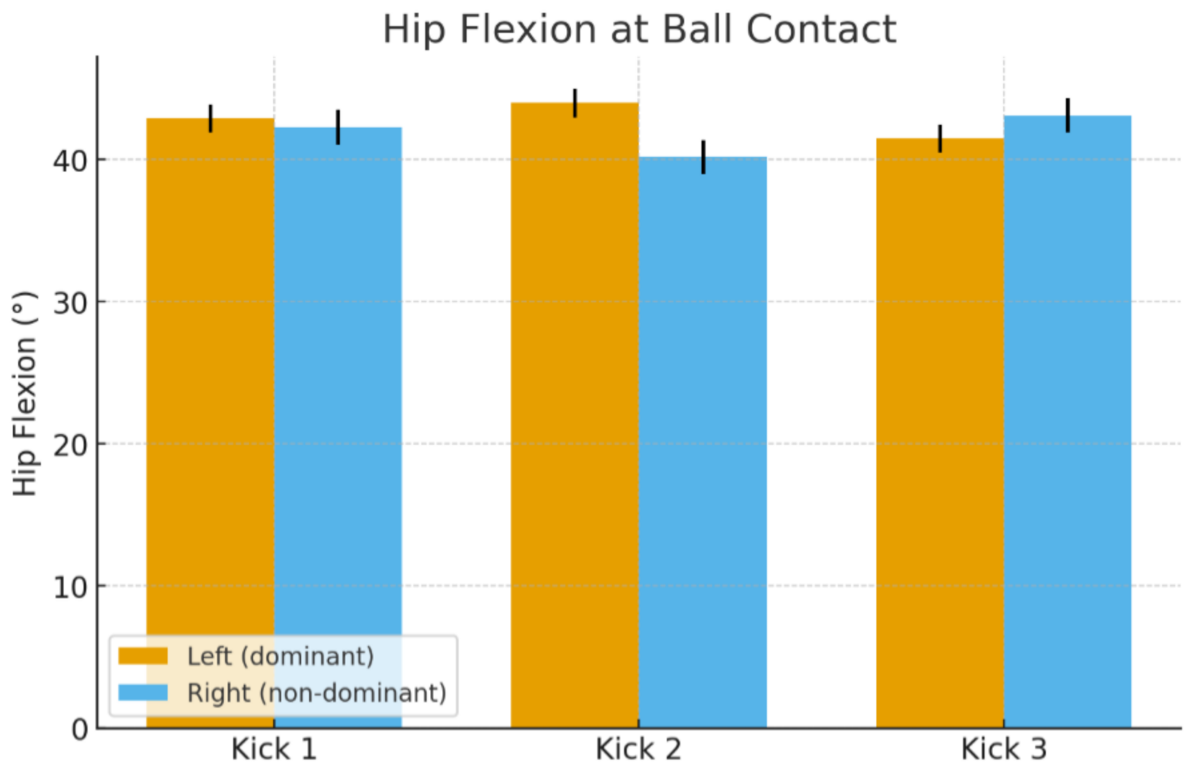

Figure 5: Hip flexion for each trial on both dominant (left) and non-dominant (right) sides

	Kick 1	Kick 2	Kick 3	Average	SD
Left (dominant)	156.0	158.2	154.5	156.2	±1.5
Right (non-dominant)	178.9	176.4	177.8	177.7	±1.0

Table 2: Knee flexion for each trial on both dominant and non-dominant sides including average and SD

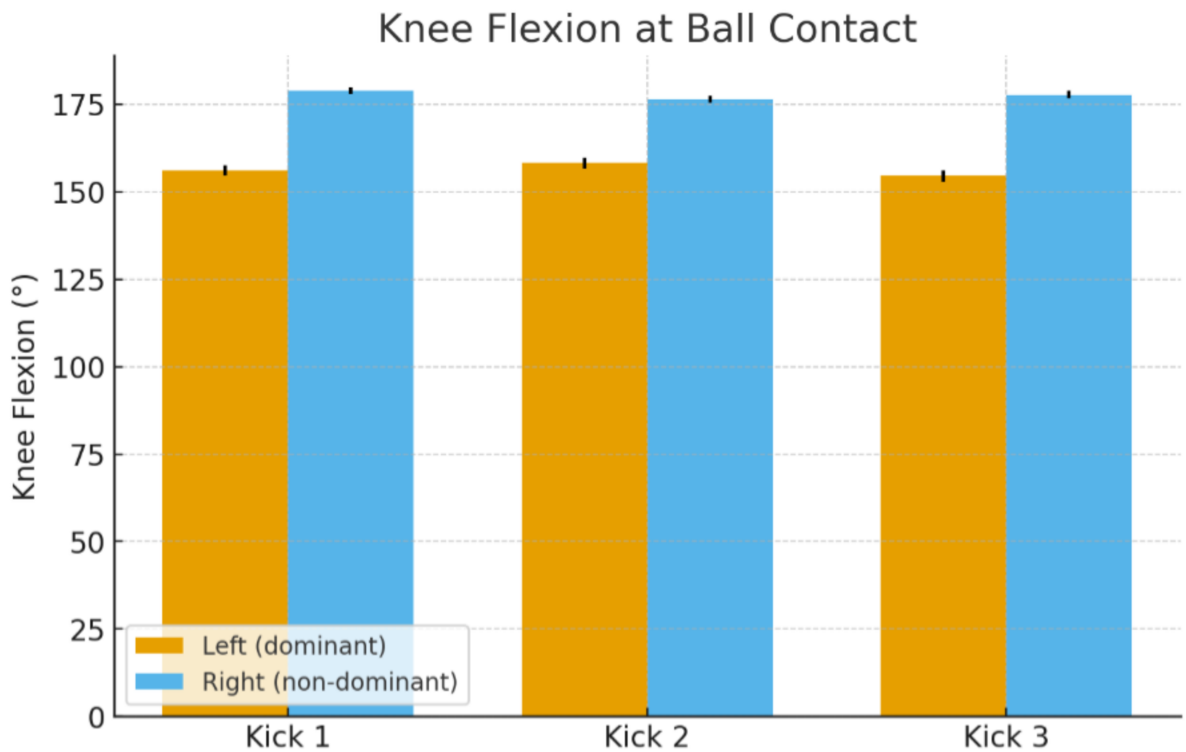

Figure 6: Knee flexion for each trial on both dominant (left) and non-dominant (right) sides

	Kick 1	Kick 2	Kick 3	Average	SD
Left (dominant)	26.6	28.1	27.3	27.3	±0.6
Right (non-dominant)	19.7	21.0	20.3	20.3	±0.5

Table 3: Shank angle for each trial on both dominant and non-dominant sides including average and SD

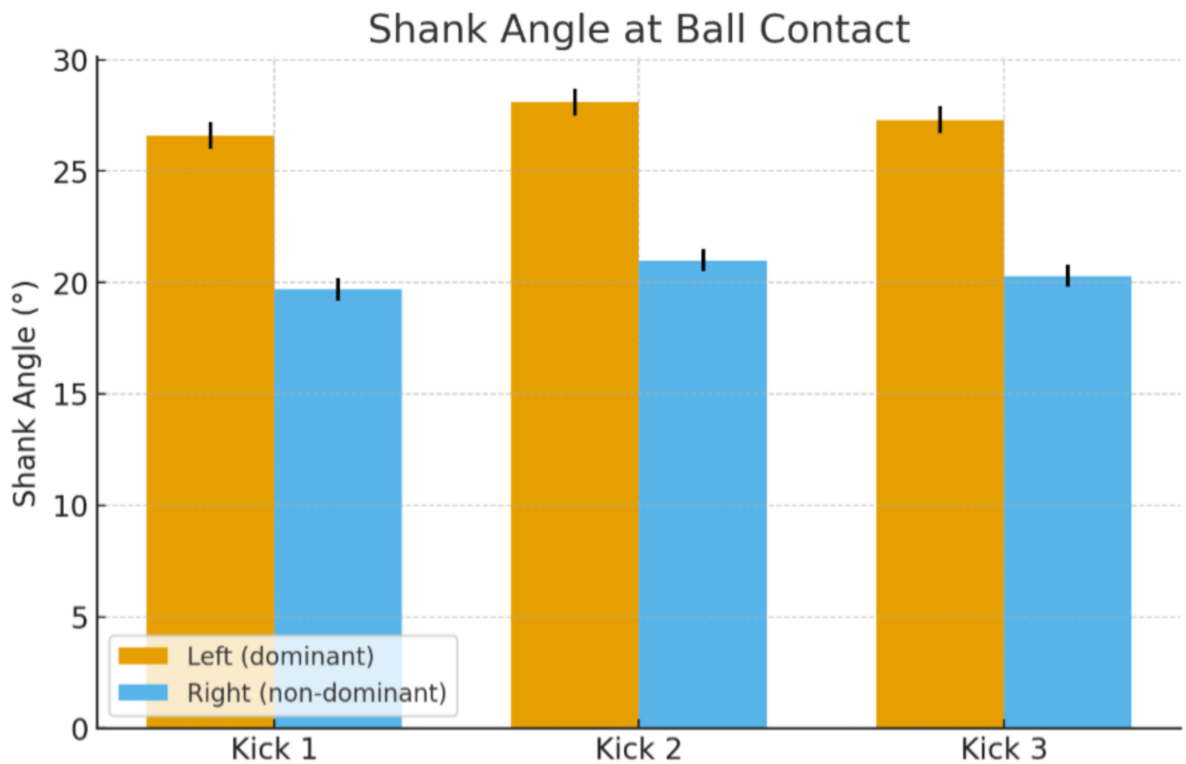

Figure 7: Shank angle at ball contact for each trial on both dominant (left) and non-dominant (right) sides

	Kick 1	Kick 2	Kick 3	Average	SD
Left (dominant)	113.5	115.0	111.2	113.2	±1.6
Right (non-dominant)	106.3	108.1	105.4	106.6	±1.1

Table 4: Peak knee flexion during backswing for each trial on both dominant and non-dominant sides including average and SD

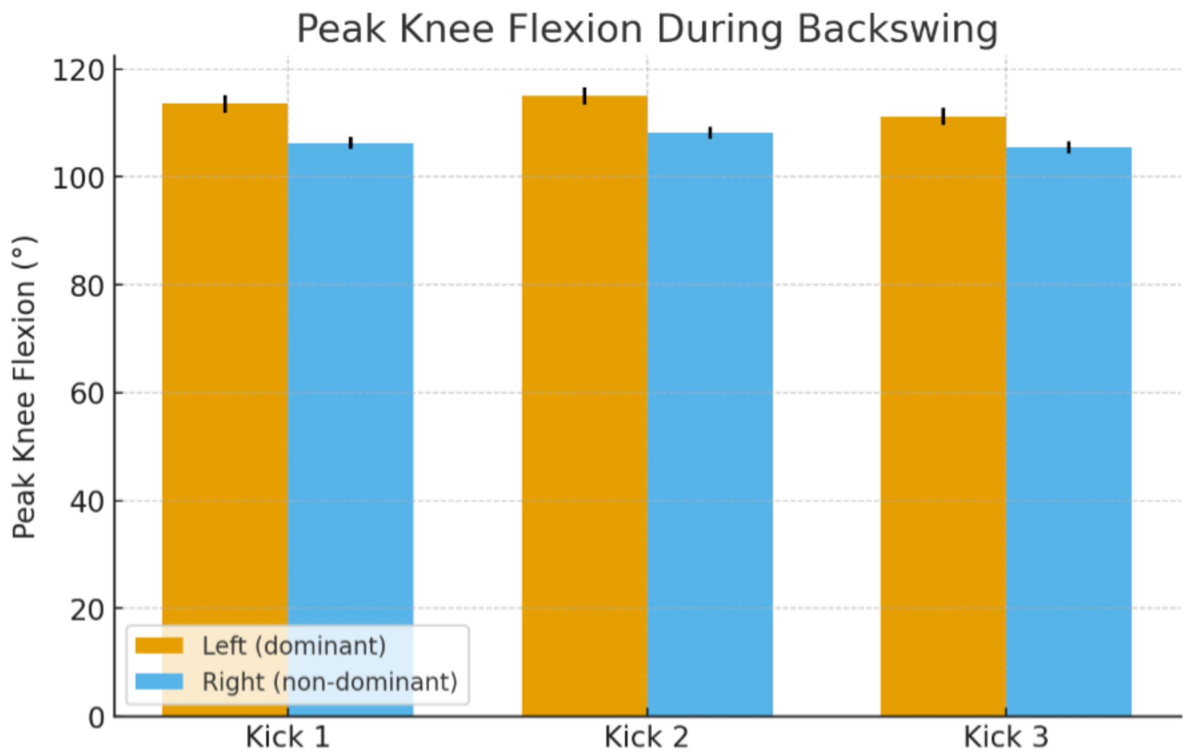

Figure 8: Peak knee flexion during backswing at ball contact for each trial on both dominant (left) and non-dominant (right) sides

Discussion

The report aimed to quantitively compare hip flexion, knee flexion-extension, and ankle angle between dominant and non-dominant foot instep passes and to identify how these kinematic variables differ between each limb as well as how they relate to established performance characteristics. By analysing the kick, across three limbs, the results indicated that the participants hip flexion had a very small difference between the dominant and non-dominant foot. This suggests the symmetrical capability in producing hip flexion since the hip is a large proximal segment with relatively similar strength bilaterally. However, hip flexion alone doesn't determine kick quality, the critical factor is timing within the kinetic chain (Lees, et al., 2010). As segments differed greatly between limbs, the similar hip angles do not imply similar kicking performance. The knee flexion showed a far greater difference in the results between the dominant and non-dominant foot, the non-dominant leg contacted the ball with far greater knee extension at 178 degrees compared to the dominanat leg at 156 degrees, this indicates that a controlled slightly flexed knee at impact allows for smoother proximal to distal energy transfer, greater angular velocity and better stability, whereas an overextended knee causes a rigid pattern associated with inexperienced players, reduced ball control and potential injury increase. This knee flexion analysis aligns with Nugroho's et al (2023), which indicates that knee extension velocity and timing differentiate skilled vs less skilled kicks. During the knee backswing phase of the kick, the dominant leg had a larger backswing at 113.2 degrees compared to the non-dominant foot at 106.6 degrees. This proves that the dominant foot has a greater range of motion, allowing for the larger backswing flexion, more time for shank acceleration and greater knee velocity, meaning that knee flexion during the back swing phase links to higher leg and ball speed. The large differences in knee angles match evidence in Lees et al (2010) when reflecting on proximal to distal energy flow. The shank angle on the more dominant leg produced a greater shank angle at impact, which suggests a greater angular velocity, better transfer of energy along the leg, more effective segmental sequening and cleaner contact with the ball's centre. This indicates the participant's dominant foot has a good kicking technique. The non-dominant shank angle was much smaller, which corresponds to lower foot velocity. The results in our report support Shan & Zhang, (2011), who emphasised that higher shank inclination and angular velocity are hallmarks of the dominant or more skilled kicking side. Overall, the results showed that the dominant limb equals a coordinated proximal to distal sequencing, whereas the non-dominant limb equals a stiffer, less coordinated pattern. This match established research showing limb dominance strongly affects kicking skill mechanics (Lees et al 2010). The differences between the dominant and non-dominant leg mainly come down to experience and neuromuscular control. The dominant leg is used far more often for kicking, so it develops better timing. It also develops coordination and range of motion. This explains why the dominant limb showed a larger knee backswing, better shank angle and more controlled knee flexion at impact. The non-dominant leg showed stiffer movement, less backswing and an overextended knee, which are typical signs of less practiced technique. These findings match what previous research has shown about how limb dominance affects kicking mechanics and overall performance (Lees et al., 2010; Shan & Westerhoff, 2005).

There are a few limitations that may have influenced the results. First, the sample size was small, so it is hard to make the findings to relevant all players. Only sagittal-plane motion was analysed even though kicking is a 3D movement, meaning important factors like hip rotation or foot orientation were not included. Only three kicks per leg was collected, and this may not represent the player's usual performance because kicking can vary from attempt to attempt. The controlled lab environment also does not replicate match conditions, which could change technique. These limitations might explain some of the variability in joint angles and may reduce how confidently the results can be applied to real game situations.

The results suggest several things a coach could use in training. Since the non-dominant leg showed weaker technique, practising bilateral kicking would help balance coordination and improve overall performance. Coaches could focus on drills that increase the non-dominant leg's backswing range, improve knee control at impact and develop smoother timing. Using video feedback would also help players see differences between legs and understand how to correct them. Training both legs equally could help with passing in pressured situations and may also reduce injury risk by improving movement coordination.

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