**KINEMATIC DIFFERENCES DURING INSIDE-OF-THE-FOOT SOCCER PASS WITH DOMINANT AND NON-DOMINANT LEG: A LABORATORY-BASED 3D MOTION STUDY**

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The inside-of-the-foot pass is one of the most common and important techniques in soccer, which plays a key role in ball control and teamwork. This study analyzed lower limb joint movements during inside-of-the-foot passes in a lab setting. Trials were performed by a healthy male subjects with his dominant and non-dominant leg, recorded by a marker-based motion capture system. Knee and ankle joint kinematics were analyzed. The dominant leg showed smoother and more consistent motion and reached slightly greater peak knee flexion. The non-dominant leg showed more variability, suggesting lower control and coordination. The results highlight noticeable movement asymmetries that may reflect training habits and leg usage in daily soccer practice.

**KEYWORDS**: soccer, 3D motion analysis, joint angles, technique analysis

**INTRODUCTION:** The inside-of-the-foot kick, also known as the pass kick, is considered as the fundamental soccer technique that integrates both tactical decision making and technical execution at the individual level. The ball is struck using the medial part (inside) of the foot, which allows for greater precision and accuracy in passing, making it one of the most commonly utilized motor skills during competitive match play(Nunome et al., 2006).Along with dribbling, it significantly contributes to effective game execution. Due to its precision and reliability, this technique forms the foundation of coordinated team actions and is crucial for sustaining ball possession in dynamic match situations(O'Reilly & Wong, 2012). Numerous studies have explored kicking techniques in soccer, providing detailed insights into the three-dimensional kinetics and kinematics involved. However, most of the literature has predominantly focused on the in-step (full) kick, with comparatively less attention on inside-of-the-foot kick. Only one study focused on comparing the inside-of-the-foot pass with the instep kick(Levanon & Dapena, 1998).Researchers agree that in both kicking techniques, the kicking leg functions as a three-segment kinetic chain consisting of the thigh, shank and the foot. The approach run phase ends when the heel of the support leg makes contact with the ground (heel strike). In the backswing phase, the hip extends, moves slightly inward (adduction), and rotates outward (external rotation); the knee bends and rotates inward, while the ankle points downward (plantar flexion) and moves slightly outward (abduction). During the forward swing, pelvis rotates around the support leg, the hip starts to bend (flex), and move outward (abduct), while still being externally rotated. At the same time, the ankle remains plantar flexed, the knee extends rapidly. At the moment of impact, the hip is flexed, abducted, and externally rotated, and the ankle is still plantar flexed but now moves slightly inward (adducted).(Zago et al., 2014) This study aims to analyze and compare the lower limb joint kinematics (knee and ankle) in the space during side-foot passes using the dominant and non-dominant leg in a laboratory setting.

**METHODS:** One healthy male participant (age: 25 years), with no recent history of musculoskeletal injuries or lower limb dysfunctions, volunteered for this study. The participant’s dominant leg was defined as the right leg, which he consistently used as the kicking leg during soccer training. The experiment was conducted in a biomechanics laboratory equipped with 16 high-speed infrared cameras (Qualysis), recording at a frequency of 200 Hz. Two Kistler force plates with dimensions of 900×600mm were applied along the movement path of the subject to keep track of the ground reaction force at a frequency of 1000Hz. For data collection, both static and dynamic calibration procedures were performed to ensure the accuracy of the 3D capture volume.

Reflective markers were placed on anatomical landmarks of the pelvis, thigh, knee, shank, ankle and foot. Pelvis markers were positioned on the anterior and posterior superior iliac spines (ASIS and PSIS). four markers were placed on the lateral surface of each thigh, two proximally and two distally. Knee markers were placed on the medial and lateral femoral epicondyles. For each shank, four markers were positioned proximally and distally on lateral sides. Foot markers included the big toe tip, 1st and 5th metatarsophalangeal joints (MTP), calcaneus tip, and the medial and lateral processes of calcaneal tuberosity. Ankle markers involved the medial and lateral malleoli. (Davis et al., 1991; Wu et al., 2002).

The participant was instructed to perform side-foot passes (using the inside of the foot) in a natural and self-selected manner, trying to drive the ball straight forward and maintain movement consistency across trials. Five trials were completed using each leg. Sufficient rest time was allowed between trials to minimize fatigue and ensure movement consistency.

Marker labeling and initial trajectory reconstruction were performed using Qualisys Track Manager (QTM) software. Automatic segmentation was applied to each trial using Visual3D, with ground reaction force of 20N as the cut-off threshold to circumvent the influence of zero shift and noise, so that the analysis time window was set to start from 0.2s before until 1.0s after the ground reaction force reached the threshold. The labeled and segmented 3D kinematic data were then exported and analyzed using MATLAB. Joint reference points were defined with the markers to calculate joint angles, so that hip joint was the midpoint of ASIS and PSIS, knee joint was the midpoint of medial and lateral femoral epicondyles, ankle joint was the midpoint of medial and lateral malleoli, and MTP was the midpoint of 1st and 5th MTP. Joint angles of the knee (defined as the angle formed by hip and ankle joints with respect to knee joint) and ankle (defined as the angle formed by knee joint and MTP with respect to ankle joint) in the space were extracted. Key variables included:

* Peak joint angles during the swing and contact phases
* Range of motion (ROM)

Comparative analysis between dominant and non-dominant leg performance was conducted descriptively, given the single-subject design.

**RESULTS:** The 3D motion analysis revealed distinct differences in lower limb joint kinematics between the dominant (right) and non-dominant (left) leg during the inside-of-the-foot soccer pass. Figure 1 shows the original time courses of knee angle of left and right leg in each trial, and Figure 2 shows the original time courses of ankle angle of left and right leg in each trial, respectively.

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**Figure 1: Left Leg Original Knee Angle (Left) and Right Leg Original Knee Angle (Right)**

A graph showing the different colors of the same color

AI-generated content may be incorrect.**A graph showing the same color line

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**Figure 2: Left Leg Original Ankle Angle (Left) and Right Leg Original Ankle Angle (Right)**

The dominant leg displayed a smoother and more consistent motion pattern throughout the passing movement, with less variability in the joint angles. Notably, the average peak knee joint angle was higher in the dominant leg, indicating stronger and more controlled plantarflexion and dorsiflexion. In contrast, the non-dominant leg showed greater variability, particularly during the follow-through phase, suggesting less refined motor control and neuromuscular coordination.

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**Figure 3: Right and Left Side Knee (Left) and Ankle (Right) Angle Dynamics**

In addition, both legs demonstrated similar movement patterns for ankle joint at the start of the pass. However, the dominant leg achieved a slightly higher average peak ankle angle (127°) compared to the non-dominant leg (123°). Post-contact, the non-dominant leg exhibited increased variability in ankle kinematics, indicating reduced consistency and control during the latter stages of the kicking motion.

These kinematic asymmetries suggest that the dominant leg benefits from enhanced neuromuscular training and usage, potentially resulting in improved balance, power transfer, and accuracy during passing.

**DISCUSSION:** This study showed clear differences in how the dominant and non-dominant legs moved during an inside-of-the-foot soccer pass. The dominant leg had a smoother and more stable motion, especially at the ankle. This is probably because it’s the leg the participant uses more often in training and games, which helps improve coordination and control(Al Attar et al., 2022). On the other hand, the non-dominant leg showed more variability, especially after the ball was kicked. This could mean that it’s less trained and less stable, which may affect both performance and control.

These kinds of movement differences between the two legs are not only important for technique but also for indicating injury risk. When one leg is used more than the other, it can cause strength and control imbalances. Studies have shown that such imbalances can increase the chance of injuries, especially in sports like soccer where players move fast and often change direction(Vigneswaran et al., 2025).

To reduce this risk, training can focus on both legs equally. Doing strength exercises with each leg separately, balance training, and practicing passes with the non-dominant leg can help create more symmetry and reduce injury risk. Some research also suggests that players who follow these kinds of programs not only perform better but also get injured less often(Al Attar et al., 2022; Drozd et al., 2024).

Limitations of this study are multifaceted. The single-subject design was very limited and the results and conclusions can not be generalized to a larger population. Inclusion of more subjects, ideally with diversified demographic and training background, is desired. Kinetic analysis can be included to provide deeper insight into neuromuscular mechanisms underlying the observed kinematic asymmetry. Lack of performance-related measures, e.g. passing accuracy, excludes the possibility to relate kinematic asymmetry to more meaningful outcomes in the game.

**CONCLUSION:** Despite the relatively simple single-subject design, the results offer useful insights. In the future, more research with a larger number of players could help confirm these findings and give coaches better tools to prevent injuries and improve performance.

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