PRINCIPAL COMPONENT ANALYSIS OF KICKING KINEMATICS IN MALE AND FEMALE SOCCER PLAYERS

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This paper aimed to compare the angular motion in the sagittal plane of the hip and knee in male and female soccer players during the entire kicking cycle through principal component analysis (PCA). Kicking kinematics were recorded for 43 soccer players with a motion capture system. The kicking cycle was defined from toe off to the end of follow through and time-normalised hip and knee joint angles data were used as input to PCA. Four PC were extracted for hip and knee joint angles. Multivariate tests suggested an overall significant difference in the PC scores between females and males for hip flexion data (p = 0.001) but not for knee flexion data (p = 0.060). The results suggest that the primary difference in joint angle patterns between females and males occur at the hip joint. More specifically, females tend to exhibit smaller hip extension motion than their male counter-pair during the backswing phase (during the first 20% of the kicking cycle).

KEY WORDS: football, biomechanics, hip, knee, LaLiga.

Introduction: Kicking is a coordinated, open chain movement of the lower limb which follows a sequential proximal to distal motion. The kicking motion is initiated by the hip, and linear velocities increase sequentially from the hip, knee, ankle and toe. In addition, the kicking action follows a whip-like pattern where deceleration of proximal segments leads to the acceleration of distal segments. Therefore, the motion patterns of the hip and knee play an important role in the kicking of a soccer ball.

Although the match activity demands in soccer differ between male and female soccer players (Taylor et al., 2017), the basic soccer training principles have remained the same for either. Previous studies have found differences in the kicking technique between male and female soccer players, with lower ball velocity (Katis et al., 2015) and lower joint velocities (Barfield et al., 2002) in females compared to males. However, to date there has been no study which compared the motion patterns of the hip and the knee during the entire kicking cycle between male and female soccer players. Hence, this paper aimed to compare the angular motion patterns of the hip and knee in the sagittal plane between male and female soccer players during the entire kicking cycle using principal component analysis.

Methods: The kicking motion was analyzed for twenty-four female (age = 22.15 ± 4.50 years, weight = 60.71 ± 9.48 kg) and nineteen male soccer players (age = 21.16 ± 2.00 years, weight = 71.46 ± 6.22 kg). Twenty-four retro-reflective markers (diameter = 14 mm) were attached to the anatomical landmarks of each participant's body, and 4 markers being attached to the ball (Navandar et al., 2018). A six camera Vicon Motion Capture System was used to collect data in laboratory conditions. Players kicked a stationary ball with both their limbs on FIFA approved artificial turf using the instep soccer kicking technique. Each player kicked the ball five times with either limb, and the trial containing the median value of ball velocity for each limb was selected for further analysis.

The kicking cycle was defined from toe off to the end of follow through, and seven segments were defined: the pelvis, and the thigh, the shank and the foot (for either limb) which were joined at the hip, knee and ankle joints respectively (Navandar et al., 2018). Intersegmental angles were determined at the joints using Euler angles (Navandar et al., 2018). Hip and knee flexion (+)/

extension (-) angles were extracted and normalised to 101 data points to represent the kicking cycle from 0 to 100% (Figure 1 – top row).
The time-normalised joint angle data were used as input to two separate PCA; one for the hip joint data and one for the knee joint data. In each case the input data represented an 85x101 data matrix (i.e., trials x normalized time). Within the PCA, each data from each trial was normalized with respect to its mean and standard deviation. Principal components (PC) were extracted with an eigenvector decomposition algorithm. The eigenvalue of each PC was used to calculate the variance accounted for (VAF) by each PC (Figure 1 – bottom row). PC scores were then calculated for each trial and used for all statistical analyses.

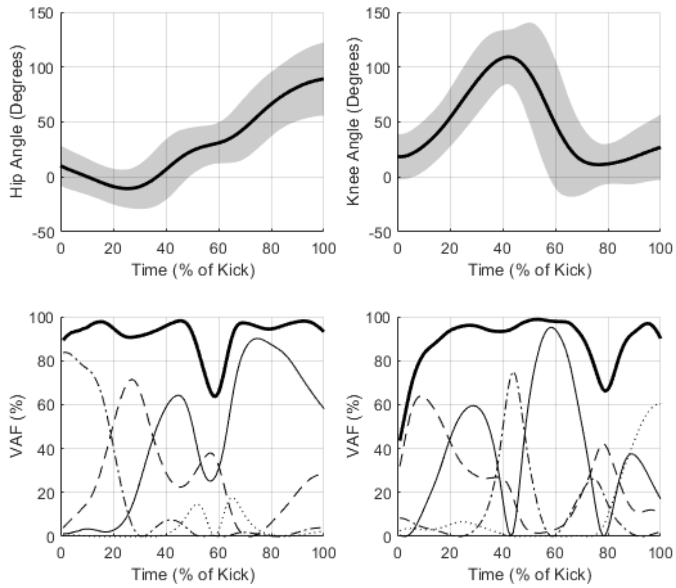

Figure 1. Top row. Ensemble average (mean±SD) hip (left) and knee (right) angles during the kicking cycle (toe off to end of follow through). Bottom row. Percent variance accounted for (VAF) by the four principal components (PC; PC1: thin black line, PC2: dashed black line, PC3: dash-dot black line, PC4: dotted black line) extracted from the hip (left) and knee (right) angle data.

The PC scores were used as input to two MANOVAs; one for the PC scores extracted from the hip angle data and one for the PC scores extracted from the knee angle data. Follow-up ANOVAs were performed to detect which PC scores differed between females and males. The level for statistical significance was set to an α-value of 0.05.

Results: The multivariate tests suggested an overall significant difference in the PC scores between females and males for hip flexion data (p-value = 0.001; η^2 = 0.277; power = 0.979) but not for knee flexion data (p-value = 0.060; η^2 = 0.106; power = 0.658). Follow-up tests suggested significant differences in PC3 scores between males and females (Table 1).

Table 1. Principal component (PC) scores from the hip and knee angle data for males and females.

			ANOVA		
	Females	Males	p-value	η^2	power
Hip					
PC1	-17.24 ± 98.43	21.32 ± 79.55	0.054	0.044	0.488
PC2	0.19 ± 59.16	-0.23 ± 56.74	0.973	0.001	0.050
PC3	-13.48 ± 31.86	16.67 ± 38.38	0.001	0.159	0.975
PC4	3.05 ± 21.13	-3.78 ± 22.13	0.151	0.025	0.300

Knee					
PC1	4.70 ± 131.79	-5.82 ± 118.28	0.703	0.002	0.067
PC2	1.79 ± 68.66	-2.21 ± 63.71	0.784	0.001	0.059
PC3	-16.27 ± 52.64	20.12 ± 55.77	0.003	0.103	0.862
PC4	0.23 ± 35.52	-0.28 ± 42.37	0.957	0.001	0.050

Four PC were extracted for hip and knee joint angles during the kicking cycle (Figures 2 & 3). For the hip joint (Figure 2), these patterns captured: 1) magnitude of hip motion from 20-100% of the kicking cycle, 2) range of hip motion, 3) magnitude of hip motion from 0-20% of the kicking cycle, and 4) the smoothness of hip flexion during 40-80% of the kicking cycle.
For the knee joint (Figure 3), these patterns captured: 1) a phase shift in knee motion between 30-50% of the kicking cycle, 2) overall magnitude of knee motion, 3) range of knee motion, and 4) magnitude of knee motion during the last 20% of the kicking cycle.

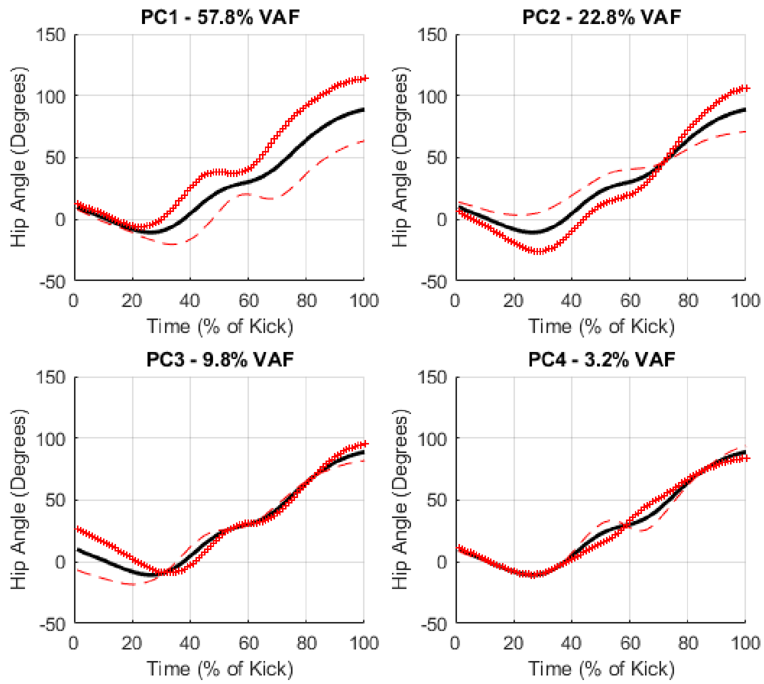

Figure 2. Variations in hip angle patterns captured by the four principal components (PC1 – PC4) during the kicking cycle. Ensemble average hip angle motion is given by the black line, whereas the effect of positive and negative PC scores on hip angle motion patterns are given by the + and – symbols, respectively. VAF – variance accounted for by the given PC.

Discussion: The results suggest that the primary difference in joint angle patterns between females and males occur at the hip joint. More specifically, females do not appear to extend the hip joint as much as the males during the first 20% of the kicking cycle (Figure 2 – PC3). The first 20% of the kick corresponds to the backswing phase (Navandar et al., 2018) when the hip extends, and is the first part of the proximal to distal sequence of motions of the lower limb. This phase is followed by the leg cocking, leg acceleration, and follow through phases, where the hip joint eventually flexes and decelerates. The PCA also indicated a small difference between male and female (p = 0.054, η^2 = 0.044) in this phase (Figure 2 – PC1), which could account for the previously reported differences between the kicking motion of males and females. This finding is also similar to other previous research, where a higher peak hip linear velocity (which occurs in the backswing phase) and higher hip flexion angle at the end of follow through was seen in the non-dominant limb kicks in male soccer players (Navandar et al., 2016).

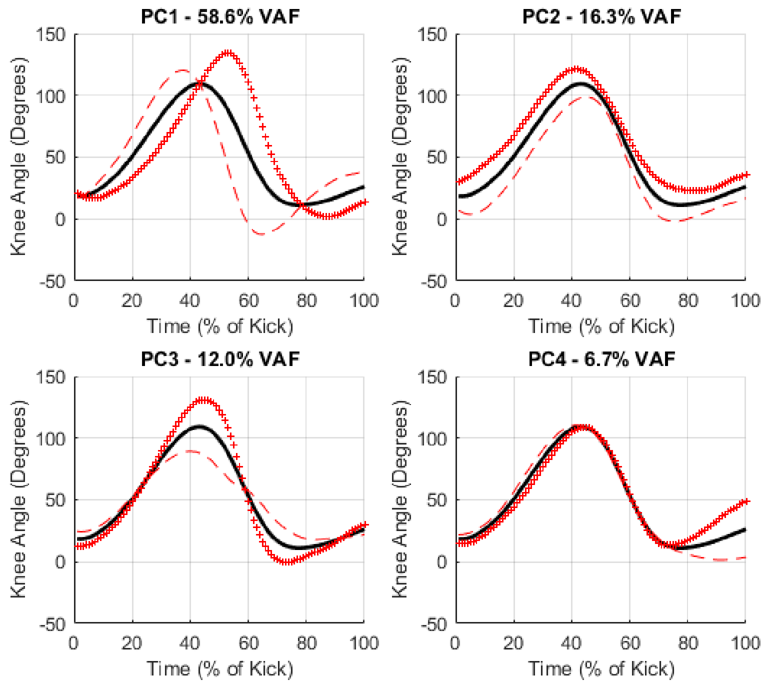

Figure 3. Variations in knee angle patterns captured by the four principal components (PC1 – PC4) during the kicking cycle. Ensemble average knee angle motion is given by the black line, whereas the effect of positive and negative PC scores on knee angle motion patterns are given by the + and – symbols, respectively. VAF – variance accounted for by the given PC.

The possibility that the differences in the hip motion are determinants of the differences in the velocities of the kicks is further corroborated by the fact that no differences were found in the PC scores for knee flexion, especially in the phase shift of knee motion (Figure 3 – PC1), which occurred in the leg cocking and the initial part of the leg acceleration phases and the overall magnitude of knee motion (Figure 3 – PC2).
However, small differences were found in the range of motion of the knee joint (Figure 3 – PC3), and this could be related to knee extension velocity in the leg acceleration phase. Further research on differences in joint angular velocities along with other kinematic variables such as ball could provide more insights into the biomechanical determinants of soccer kicks in male and female soccer players.
Conclusion: The findings of this study suggest that differences in kicking kinematics between females and males mainly existed in hip kinematics, especially in the hip extension during the backswing phase. Training drills focusing on simultaneous hip extension and knee flexion, could perhaps help improve kicking in female soccer players.

References

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