DEFINING MOVEMENT STRATEGIES IN SOCCER INSTEP KICKING USING THE RELATIONSHIP BETWEEN PELVIS AND KICK LEG ROTATIONS

Simon Augustus, Penny Hudson and Neal Smith

Chichester Institute of Sport, Chichester, West Sussex, UK

The aim of this study was to examine the relationship between pelvis and kick leg rotation strategies during soccer instep kicking. Twenty semi-professional players performed kicks for maximal speed and accuracy. A strong relationship was shown between pelvis transverse rotation (i.e. speed of rotation of kick side hip towards the ball upon impact) and kick leg (i.e. thigh-knee angular velocity ratio upon impact) strategies ($r = 0.760$, $p < 0.001$). Knowledge of a kicker's preferred strategy can help inform technical and conditioning training recommendations for the individual. Pelvis maintainer-thigh dominant kickers might focus on developing the concentric capabilities of the hip flexors, whereas reverser-knee dominant kickers might benefit from developing the ability to decelerate the pelvis and thigh and induce motion-dependent angular acceleration of the lower leg towards the ball.

KEYWORDS: football, thigh, knee, training, 3D motion analysis.

INTRODUCTION: There is mounting evidence to support anecdotal observations that skilled footballers use distinct but equally functional movement strategies to perform ball kicking for maximal speed and accuracy (Atack et al., 2019; Augustus et al., 2021; Ball, 2008). For example, Ball (2008) observed a strong negative relationship ($r = -0.90$) between kick leg thigh and knee angular velocities at ball contact in 28 professional AFL punt kickers. He suggested a trade-off between these parameters, and that players lie on a continuum between 'thigh' (more thigh and relatively less knee angular velocity) and 'knee' (more knee and less thigh angular velocity) dominance. Importantly however, when he split the kickers into these two groups there was no discernible difference in ball distances and foot speeds. Atack et al. (2019) noted a similar phenomenon in 33 experienced rugby place kickers. Despite a negligible effect on ball speeds, those using a 'thigh' strategy performed more hip concentric hip flexor work, whereas those using a 'knee' strategy performed more concentric knee extensor work to accelerate the distal part of the kicking leg during the downswing. More recently, Augustus et al. (2021) identified a similar trade-off strategy in skilled soccer players. They noted a continuum between either 'reversing' or 'maintaining' pelvis transverse angular velocity in the final stages of the downswing. The former was characterised by a fast peak rotation of the kick side hip towards the ball (~300 °/s) that 'reversed' to ~ 0 °/s by ball contact, and the latter by a slower peak (~ 150 °/s) that was 'maintained' through to ball contact (Figure 1). Since pelvis transverse rotation about the support leg precedes proximal to distal sequencing of the kick leg, they tentatively concluded that 'maintainers' corresponded to a 'thigh' strategy (greater contributions from proximal segments), whereas 'reversers' exhibited a 'knee' strategy (greater contributions from distal segments). Unfortunately, they did not present kick leg kinematic or performance data (e.g. foot and ball speeds) from the two groups, so the relationship between thigh-knee and reverser-maintainer continuums remains unclear. If a robust relationship does exist between the two continuums, it may be possible for future research to: a) classify players based on their preferred strategy and b) prescribe tailored technical and conditioning recommendations for these different 'types' of kicker. Therefore, the aims of this study were twofold. The primary aim was to examine relationships between kick leg (thigh-knee) and pelvis rotation (reverser-maintainer) strategies in semi-professional soccer players. The secondary aim was to classify different 'types' of kicker based on these relationships.

METHODS: Following ethical approval, twenty male semi-professional soccer players (mean ± SD; mass 79.0 ± 7.5 kg, height 1.80 ± 0.10 m, age 23.8 ± 4.0 years, 10+ years playing experience) performed five instep kicks with their preferred foot towards a circular target (0.5 m radius) placed 3.6 m away. They were instructed to perform kicks 'as fast and accurately as possible' and trials that missed the target were discounted. Kicking motions were captured by 10-camera motion analysis (1000Hz, Vicon MX-40, UK) and marker trajectories exported to Visual 3D (V6, C-Motion, USA). Seven segments were incorporated into a six degrees of freedom lower-body model (Augustus et al., 2021). Following static calibration, segments were tracked using the CAST technique and hip and knee joint centres determined using functional methods. Kicking foot and shank markers were low-pass filtered using a time-frequency method to separate swing (Fc = 18 Hz) and impact phases (Fc = 150 – 300 Hz; Augustus et al., 2021). All other markers were low-pass filtered using a conventional fourth-order, dual-pass Butterworth filter (Fc = 18 Hz). Pelvis transverse angular velocity was the pelvis relative to the global vertical axis, thigh angular velocity (flexion/ extension) the thigh relative to the global medio-lateral axis, and knee angular velocity (flexion/ extension) the shank relative to the thigh. Thigh and knee angular velocities were used to replicate the thigh-knee angular velocities ratios (at ball contact) as described by Ball (2008). Foot and ball velocities were the resultant magnitude of foot and ball centre of mass velocities immediately before and after the ball contact phase, respectively. To explore pelvis strategies, participants were sorted by their percentage change between peak pelvis transverse angular velocity and the value at ball contact. The ten participants with the greatest percentage change were classified as 'reversers' and the ten with smallest percentage change as 'maintainers' (Augustus et al., 2021). Like Ball (2008), it is acknowledged these groupings are arbitrary and a continuum of strategies were likely to exist. Mean values from each participant's five kicks were used for further analyses as there was little within-participant variation (Augustus et al., 2021). Bonferroni adjusted independent t-tests assessed differences in discrete parameters between the two groups (No. of comparisons = 10, $\alpha = 0.005$, effect sizes (d) = small > 0.2, medium > 0.5 and large > 0.8; Cohen, 1988). Approach characteristics (angle, speed and kicking stride length) were included in these comparisons as known moderators of pelvic rotation strategy (Augustus et al., 2021). Similarly, statistical parametric mapping (SPM) compared time-series pelvis transverse angular velocities, thigh angular velocities and knee angular velocities from the two groups between kicking foot take off and start of ball contact (N = 3, $\alpha = 0.017$). Finally, Pearson's correlations explored relationships between pelvis and kick leg strategies (Table 2; N = 4, $\alpha = 0.013$, 0 - 0.2 = no correlation, 0.2 - 0.4 = weak, 0.4 - 0.7 = moderate, 0.7 - 1.0 = strong).

RESULTS: Kicking performance was not different between reversers and maintainers (ball velocity = 26.2 ± 2.1 vs 25.8 ± 1.3 m/s; foot velocity = 18.8 ± 1.2 vs 18.1 ± 0.8 m/s), but distinct pelvis and kick leg rotation strategies were adopted by the two groups (discrete results are summarised in Table 1). Approach angle (25.8 ± 6.1 vs 27.2 ± 4.7°, $p = 0.593$) approach velocity (3.4 ± 0.4 vs 3.4 ± 0.2 m/s, $p = 0.898$) and kicking stride length (1.5 ± 0.1 vs 1.5 ± 0.1 m, $p = 0.997$) were not different between the groups, with negligible effect sizes (d = 0 - 0.2). The SPM analyses showed maintainers were transversely rotating the pelvis faster than reversers (kick side hip towards the ball) between 94 -100% of the kicking motion ($p = 0.006$, Figure 1). The maintainers were flexing the thigh significantly faster than reversers between 95-100% of kicking motion ($p = 0.012$; Figure 1) and reversers extending the knee significantly faster than maintainers between 96 - 100% of the kicking motion ($p = 0.014$; Figure 1). Percentage change in transverse pelvis angular velocity showed a significant strong and positive correlation with knee extension velocities ($r = 0.704$, $p < 0.001$) and thigh to knee ratios ($r = 0.760$, $p <0.001$; Figure 2), and a significant strong negative correlation with thigh flexion velocities at ball contact ($r = -0.750$, $p < 0.001$). Thigh flexion velocities showed a significant strong negative correlation with knee extension velocities at ball contact ($r = -0.848$, $p < 0.001$).

Table 1. Mean ± SD values for reverser and maintainer groups. AV = angular velocity, BC = ball contact, EXT = extension. Greater thigh:knee ratio values indicate greater knee dominance.

	Reversers	Maintainers	p - Value	Effect Size (d)
% Change pelvis AV	93.5 ± 15.2	40.2 ± 17.7	< 0.001*	3.2 - large
Ball velocity (m/s)	26.2 ± 2.1	25.8 ± 1.3	0.600	0.2 - small
Foot velocity (m/s)	18.8 ± 1.2	18.1 ± 0.8	0.241	0.5 - medium
Pelvic AV BC (°/s)	-2.5 ± 44.9	148.3 ± 51.4	< 0.001*	3.1 - large
Thigh flex AV BC (°/s)	46.8 ± 84.0	186.0 ± 73.2	< 0.001*	1.8 - large
Knee ext AV BC (°/s)	1894.6 ± 77.4	1768.9 ± 87.4	0.003*	1.5 - large
Thigh: knee ratio BC	0.98 ± 0.04	0.91 ± 0.03	< 0.001*	1.8 - large

* indicates significantly different between groups ($p < 0.005$)

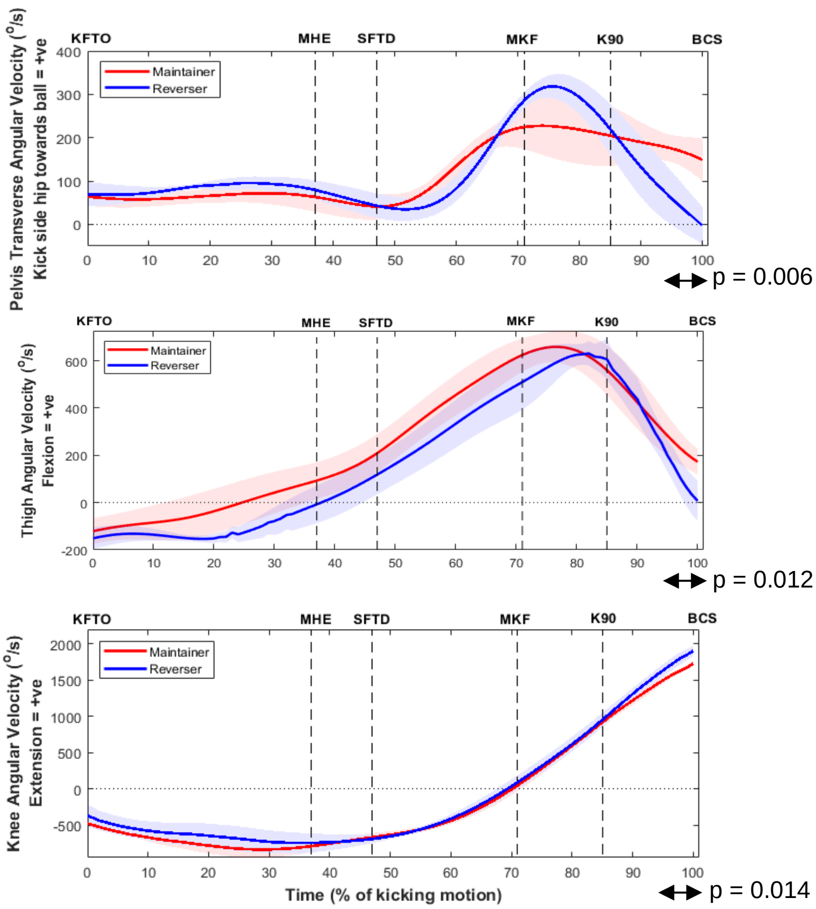

Figure 1. Mean ± SD pelvis transverse, thigh and knee angular velocities for maintainers and reversers. Arrows and p-values under each plot indicate location of SPM significant differences. KFTO = kicking foot take off, MHE = maximum hip flexion, MKF = maximum knee flexion, K90 = knee angle 90°, BCS = ball contact start.

DISCUSSION: The primary aim of this study was to examine relationships between kick leg (thigh-knee) and pelvis rotation (reverser-maintainer) strategies in semi-professional soccer players. In agreement with Ball (2008), the participants showed a strong negative relationship between kick leg thigh and knee angular velocity at ball contact. Although this relationship was weaker than Ball (2008) (r = - 0.900 vs -0.848), this suggests soccer players also perform on a continuum between thigh and knee dominance. However, Ball's (2008) AFL kickers did use faster thigh (313 ± 185 °/s) and slower knee angular velocities (1364 ± 253 °/s) at ball contact than the soccer players (Table 1). This could be indicative of greater propensity for thigh dominance in AFL punt kickers. Furthermore, strong relationships were shown between pelvis transverse rotation strategy and thigh-knee dominance in the soccer players. Greater changes in pelvis transverse angular velocity (i.e. angular deceleration) were associated with faster knee extension velocities (r = 0.704) and slower thigh flexion velocities (r = -0.750) at ball contact, suggesting it is appropriate to extends Ball's (2008) classifications to include pelvic reversers generally correspond to a knee strategy, and pelvic maintainers to a thigh strategy (Figure 2). This is also supported by the group comparisons. Despite obtaining similar foot and ball velocities, reversers showed slower pelvis and thigh rotations but faster knee extension in the latter phases of the downswing, whereas the opposite was evident for maintainers (Table 1; Figure 1). From a practical perspective, these findings support that pelvis maintainer-thigh dominant kickers might benefit from developing the concentric capabilities of the hip flexors and formation and release of a 'tension arc' between upper and lower body during a kick (Atack et al., 2019). Conversely, in addition to focussing on concentric knee extensor strength (Atack et al., 2019), the current results pelvic reverser-knee dominant kickers might also benefit from developing the ability decelerate forward rotation of the pelvis and thigh during the downswing and induce motion-dependent angular acceleration of the lower leg towards the ball.

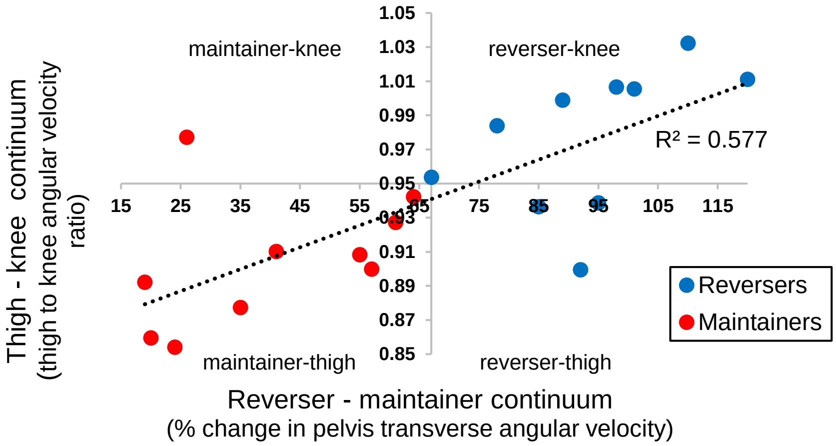

Figure 2. Quadrant model showing relationship between pelvis reverser-maintainer (x-axis) and kick leg thigh-knee strategy continuums (y-axis). Quadrants were arranged by placing the x and y intercepts at pooled mean values for percentage change in pelvis transverse angular velocity (x = 66.85%) and thigh to knee ratios (y = 0.94), respectively.

The secondary aim of this study was to classify different 'types' of kicker based on these relationships. Figure 2 indicates kickers could be classified by the quadrant they occupy on the scatterplot. The x and y axes indicate where a player lies on each reverser-maintainer and thigh-knee continuums, and the combination of these factors the quadrant they occupy. Given the strong relationship between pelvis and kick leg strategies, most participants were defined as either reverser-knee (top right quadrant), or maintainer-thigh dominant (bottom left quadrant) kickers, and training recommendations for these kickers could be prescribed as described in the previous paragraph. However, given only 58% of variance was accounted for, several participants fell within either reverser-thigh (N = 3; bottom right), or maintainer-knee (N = 2; top left) quadrants, and different training recommendations may be appropriate for these groups. While optimal training practices for these groups are currently unknown, researchers and practitioners could use the framework as a basis to first identify players comprising each group, then design and apply training practices that are tailored to those specific 'types' of kicker. It is acknowledged however; the model is currently specific to the 20 soccer players used in this study. Classifying kickers using these arbitrary quadrant boundaries should therefore be performed with caution and future work might determine more precise boundaries across different cohorts. For example, altered relationships might exist across different football codes (e.g. in AFL or rugby), in women and for different level of player (e.g. professional and amateur). Likewise, factors such as intra-individual variation and task complexity can influence a kicker's movement strategy. It is also plausible individual players could move between groups in different match-play situations and should be considered when designing training practices.

CONCLUSION: Semi-professional soccer players performed instep kicks on two continuums between thigh-knee and pelvic reverser-maintainer dominance, and knowledge of an individual's preferred strategy can help inform technical and conditioning training recommendations. Maintainer-thigh kickers might focus on developing the concentric capabilities of the hip flexors, whereas reverser-knee kickers might benefit from developing the ability to decelerate the pelvis and thigh and induce motion-dependent angular acceleration of the lower leg towards the ball.

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