# AN ASSESSMENT OF THE COORDINATION AND COORDINATION VARIABILITY BETWEEN THE THORAX AND PELVIS DURING A MAXIMAL INSTEP KICK

**Jamie A Gosling, Robert A Needham and Nachiappan Chockalingam**

**Staffordshire University, Stoke-on-Trent, United Kingdom**
**Corresponding author email: r.needham@staffs.ac.uk**

The purpose of study was to assess coordination and coordination variability between the pelvis and thorax during a maximal instep kick (MIK) with the use of a modified vector coding technique. Nine university football players participated in this study. An opto-electronic motion capture system collected kinematic data on the dominant (DOM) and non-dominant (ND) side. The output from the vector coding technique was assigned to a coordination pattern classification that details the phase relationship between two segments, quantifies segmental dominancy, and provides information on segmental angle rotations. The results of this study and the reported coordination patterns of a MIK expands on current understanding of the tension arc (TA). Coordination variability was greater for the ND trials compared to the DOM trials. Overall, pelvis-thorax coordination and trunk angle kinematics are extremely influential when producing a high quality MIK.

**KEY WORDS:** Vector coding, coordination, variability, tension arc, football.

**INTRODUCTION:** In association football, the most common and important action is the maximal instep kick (MIK), used when passing, shooting at goal and taking set pieces (Lees & Nolan, 2002). The power generated during a MIK is associated with the formation and fast release of a 'tension arc' (TA) (Shan & Westerhoff, 2005), which is an expression of the stretch-shortening cycle (Lees, Asai, Andersen, Nunome & Sterzing, 2010). The active creation of the TA is formed via maximal hip extension (MHE) of the kicking leg and rotation of the thorax towards the non-kicking side. While the release phase of the TA involves a 'quasi-whip-like' action of the kicking leg and thorax rotation towards the kicking side (Shan & Westerhoff, 2005). The pelvis displays a similar movement pattern to the thorax during the MIK, retracting before MHE and protracting through to ball contact (Lees et. al., 2010). These observations suggest a strategy for coordination between the pelvis and thorax, with both segments rotating in the same direction (in-phase) during the TA formation, followed by rotation in opposite directions (anti-phase) during the TA release.

Kinematic differences have been noted between the DOM and ND kicking legs while performing a MIK (Sinclair et. al., 2014; Zago et. al., 2014). However, there is little research into how trunk kinematics contributes to these differences. Additionally, a football player's ability to use both feet with similar degrees of coordination during a football kick has been suggested as an indicator of ability level (Zago et. al., 2014). Bartlett, Wheat and Robins (2007) suggested that conventionally variability in movement performance has been seen by cognitive motor control theorists as associated with a lower level of skill. This could then be expected to be more prominent in ND footed football kicks.

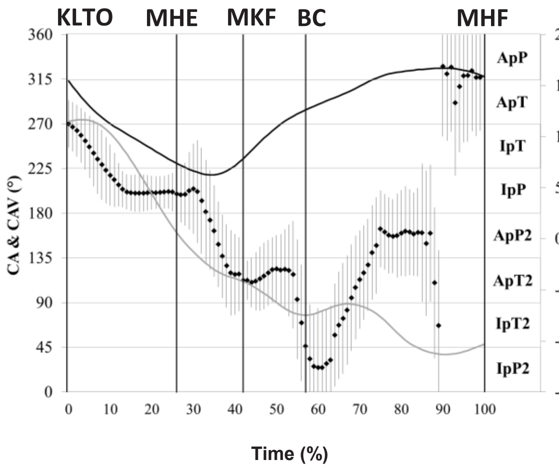
Whilst previous investigations have used angle-angle diagrams to assess coordination patterns, Vector Coding (VC) can be used to quantify coordination and variability on these angle-angle diagrams (Needham, Naemi & Chockalingam, 2014). Although numerous studies have examined the kinematics and kinetics of the MIK (Katis & Kellis, 2010; Kawamoto et. al., 2007). there is little evidence on the coordination between body segments. Recently Li, Alexander, Glazebrook and Leiter (2016) studied segmental coordination of MIKs. However, this study only focused on lower limbs in the sagittal plane and used 2D video analysis. The application of a coordination pattern classification by Needham et. al. (2015) allows for interpretation of a CA's segmental dominancy and segments in-phase or anti-phase movements.

The purpose of this study was to assess coordination and coordination variability of the pelvis and thorax using 3D analysis of a MIK with the use of vector coding on players DOM and ND kicking sides.

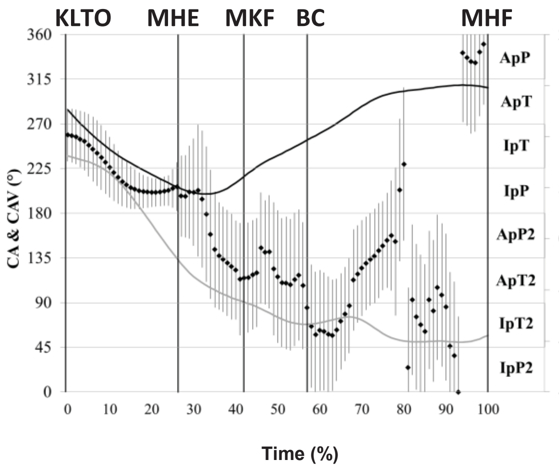
**METHODS:** Nine male university football players participated in this study (mean +/- SD age: 21.5 +/- 5 years, height: 181.38 +/- 23.2 cm, mass: 74.54 +/- 19.01 kg). Ethical approval was sought and received from the University Research Ethics Committee.
An 18-camera motion capture system (VICON, Oxford, UK) set at 200Hz was used to collect pelvis and thorax kinematic data (Needham et. al., 2015) in accordance with Leardini et al. (2011). Ten trials were collected on the DOM and ND sides. Data was normalised for time from kicking leg toe off (KLTO) to maximal hip flexion (MHF) of the kicking leg.
Further information on the CA and averaging calculations along with the details on the interpretation of the new coordination pattern classification is reported elsewhere (Needham et al., 2014; Needham et al., 2015).

**RESULTS:** There is a consistent anti-phase coordination pattern of rotation between the pelvis and thorax. This occurs soon after maximal hip extension (MHE) and continues through to ball contact (BC) within all three planes. This stage of the kick is during the release of the TA (figures 1A-1F).
In all three planes, the CA variability (CAV), as shown in figures 1A-1F, is noticeably greater for the ND trials compared to the DOM trials. This is particularly evident between the MHE and BC. Although the mean CAs in all three planes remains consistent for DOM and ND trials.
Figures 1A and 1B display greater mean thorax and pelvis segmental angles in the frontal plane during the DOM trials. Again, this is particularly prominent before BC. Likewise, in the sagittal plane (figures 1C and 1D) the thorax covers a greater ROM in the DOM trials (max 36° - min 5°) when compared to ND (max 27° - min 4°). Yet the transverse plane data (figures 1E & 1F) presents very similar angular kinematics between DOM and ND trials.
Vertical lines on figures 1A–1F highlight events during the MIK time frame: KLTO (0%), MHE (26%), kicking leg max knee flexion (MKF - 42%), BC (57%) and MHF (100%).

A.




B.



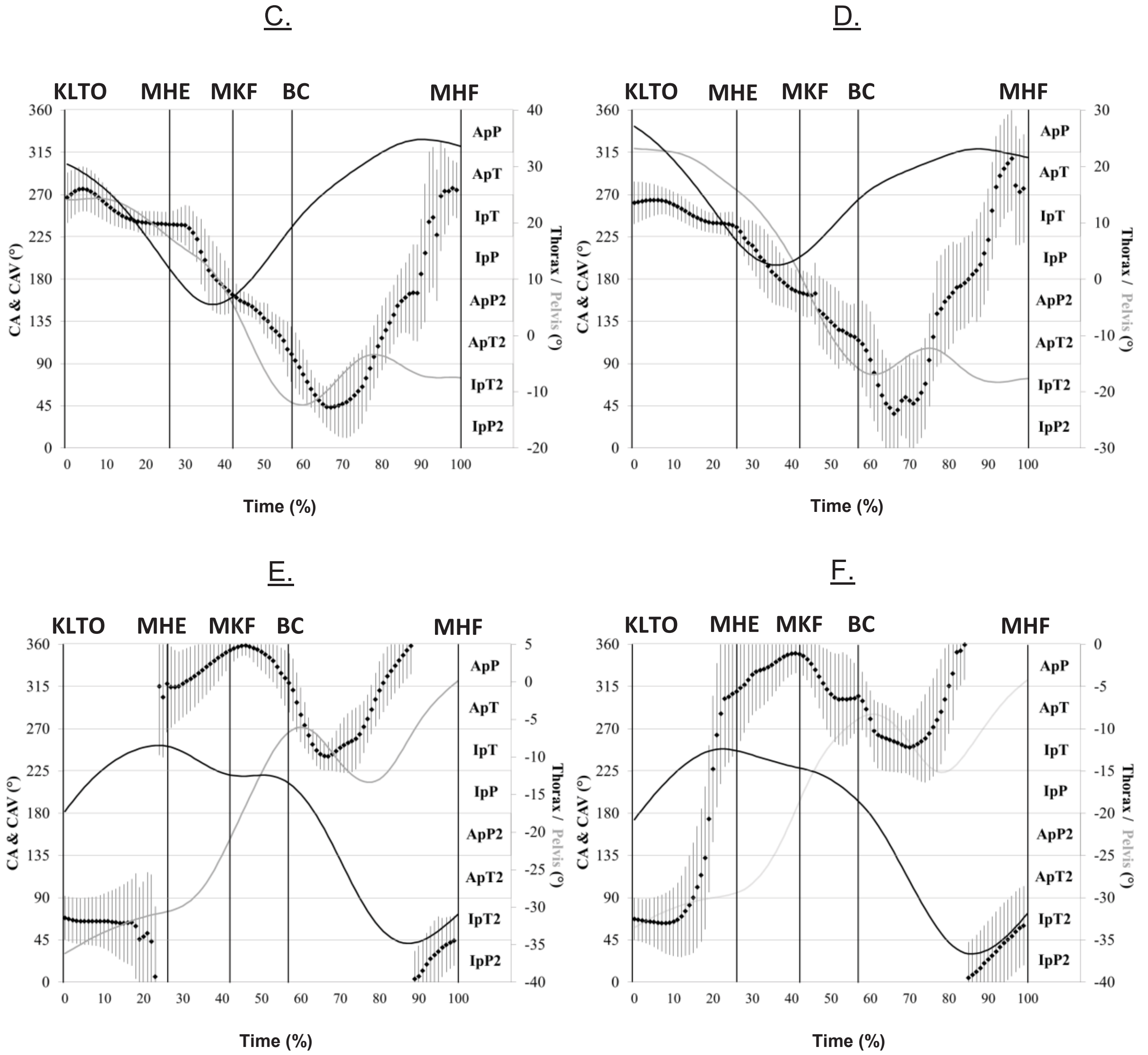



**Figure 1: Mean segmental angle (solid lines - right vertical axis) and CA ± variability (dots - left vertical axis) data in the frontal (A & B), sagittal (C & D) and transverse (E & F) planes of all 9 participants DOM (A, C & E) & ND (B, D & F) trials with segmental phase dominancy. Normalised to 100 data points to show time as a % (horizontal axis).**

**DISCUSSION:** In figures 1E and 1F between KLTO and MHE (during the initial formation of the TA) there is a clear in-phase coordination with distal dominancy (IpT2). This observation suggests that the thorax is the more influential of the two segments in formation of the TA. Anti-phase coordination is then displayed between MHE and BC (1E and 1F), which coincides with the release of the TA (Shan & Westerhoff, 2005). However, during the initial period of the TA release the mean CA reveals a transition to pelvis dominancy, although angular deviation data suggests that some of the participants demonstrated thorax dominancy. The impact of pelvis or thorax dominancy on MIK performance measures warrnts further investigation. Interestingly, pelvis dominancy also occured in the sagittal and frontal plane during the TA release phase, which supports the dynamics of the kicking leg (Lees et. al., 2010).

The larger CAV presented in the ND trials coincides with the earlier suggestions of Bartlett et. al. (2007) about higher variability being related to lower ability, as kicking with a ND limb will be of a lower quality. This may also relate to the adaptation and development of a new coordination strategy. The high CAV is particularly noticeable between MHE and BC, where the release of the TA transpires (Shan & Westerhoff, 2005). As there is a greater CAV in the

ND trials compared to the DOM trials, the data suggests that the coordination of the pelvis and thorax may influence MIK performance measures (kick accuracy, ball velocity etc). From MKF to BC, all three planes show anti-phase coordination between the pelvis and thorax. This is the release of the TA where the pelvis lifts/rotates to the non-kicking side and the trunk twists towards the kicking side in a counter-rotation (Lees et. al., 2010). The high CAV in the ND trials described during this phase of the kick could be due to inconsistent timings of the counter-rotation form the participants due to a lower capability/familiarity to kicking with a ND leg.

In concurrence with Lees and Nolan (2002) and Spinks et. al. (2002)'s findings, the results within the present study showed a sagittal plane mean thorax tilt angle of 19° at BC during DOM footed trials. On the other hand, the ND mean thorax angle was 14° at BC, outside of previous literatures desirable range of 18.8 - 27.9°. As it is likely the ND trials are a lower kick quality this could mean that ROM and tilt angle of the trunk during a MIK also has an effect on kick quality by reducing the power created in the release of the TA. Understanding of this desirable kinematic movement could assist in optimizing players training processes and improving mechanical effectiveness during performance (Kapidžić et. al., 2014).

**CONCLUSION:** The results of this study suggests the pelvis-thorax coordination and trunk angle kinematics are extremely influential when aiming to produce a high quality MIK. In addition, we report that the greater thorax tilt angle and ROM is desirable, along with lower variability indicating kick quality. The differences in pelvis-trunk coordination variability between the DOM and ND side highlight the complexity of executing a MIK. Overall, this study highlights the importance of analysing thorax kinematics when assessing a MIK.

**REFERENCES:**

Bartlett, R., Wheat, J. and Robins, M. (2007). Is Movement Variability Important for Sports Biomechanists? *Sports Biomechanics*, 6, 2, 224–243.

Katis, A. & Kellis, E. (2010). Three-Dimensional Kinematics and Ground Reaction Forces during the Instep and Outstep Soccer Kicks in Pubertal Players. *Journal of Sports Science*, 28, 1233-1241.

Kawamoto, R., Miyagi, O., Oshashi, J. & Fukashiro, S. (2007). Kinetic Comparison of a Side-Foot Soccer Kick between Experienced and Inexperienced Players. *Journal of Sports Biomechanics*, 6, 187–198.

Leardini, A., Biagi, F., Merlo, A., Belvedere, C., & Benedetti, M.G. ( 2011). Multi-segment trunk kinematics during locomotion and elementary exercises. *Clinical Biomechanics,* 26, 562–571.

Lees, A. & Nolan, L. (2002). Three-Dimensional Kinematic Analysis of the Instep Kick under Speed and Accuracy Conditions, *Science and Football*.

Lees, A., Asai, T., Andersen, T. B., Nunome, H. & Sterzing, T. (2010). The Biomechanics of Kicking in Soccer: A Review. *Journal of Sports Sciences*, 28, 805–817.

Li, Y., Alexander, M., Glazebrook, C. & Leiter, J. (2016). Quantifying Inter-Segmental Coordination during the Instep Soccer Kicks. *International Journal of Exercise Science*, 9, 646-656.

Needham, R. A., Naemi, R. & Chockalingam, N. (2014). Quantifying Lumbar–Pelvis Coordination during Gait using a Modified Vector Coding Technique. *Journal of Biomechanics*. 47, 1020–1026.

Needham, R. A., Naemi, R. & Chockalingam, N. (2015). A New Coordination Pattern Classification to Assess Gait Kinematics when Utilising a Modified Vector Coding Technique. *Journal of Biomechanics*, 48, 12, 3506–3511.

Nunome, H., Lake, M., Georgakis, A. & Stergioulas, L. K. (2006). Impact Phase Kinematics of Instep Kicking in Soccer. *Journal of Sports Sciences*, 24, 11-22.

Sinclair, J., Fewtrell, D., Taylor, P. J., Atkins, S., Bottoms, L. & Hobbs, J. (2014). Three-Dimensional Kinematic Differences between the Preferred and Non-Preferred Limbs during Maximal Instep Soccer Kicking. *Journal of Sports Sciences*, 0, 1–10,

Spinks, W., Reilly, T. & Murphy, A. (2002). Biomechanics of Football. *Science and Football IV*.

Shan, G. & Westerhoff, P. (2005). Full-Body Kinematic Characteristics of the Maximal Instep Soccer Kick by Male Soccer Players and Parameters Related to Kick Quality. *Sports Biomechanics*, 4l, 59-72.

Zago, M., Motta, A. F., Mapelli, A., Annoni, I, Galvani, C. & Sforza, C. (2014). Effect of Leg Dominance on the Centre-of-Mass Kinematics during an Inside-of-the-Foot Kick in Amateur Soccer Players. *Journal of Human Kinetics*, 42, 51-61.