DOES FORCEFUL EXTENSION OF THE SUPPORT LEG DURING THE KICKING STRIDE ENHANCE MAXIMAL INSTEP KICK PERFORMANCE IN A SKILLED SOCCER PLAYER?

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The purpose of this study was to apply a technique intervention to the maximum instep kick to increase performance. A carefully constructed intervention was based on evidence from motor learning studies. A single semi-professional player undertook a single subject design to investigate the effectiveness of the intervention, and analyse the mechanisms which underpin the technical improvements. Kinetic and kinematic data was collected pre and post intervention. Ball speed (26.9 ± 1.3m.s^{-1} to 29.2 ± SD 0.9m.s^{-1}) and knee extension velocity increased following the intervention. The mechanisms presented display a greater active contraction of support leg musculature led to increased energy transfer across the pelvis, and a greater subsequent passive energy transfer through the kicking limb.

KEY WORDS: power, pelvis, technique intervention.

INTRODUCTION: The maximal instep kick of a stationary ball is the most analysed soccer technique within current biomechanical literature (Lees, Steward, Rahnama & Barton, 2009). Previous research has highlighted a biomechanical understanding of the maximal instep kick is important as it is the most commonly used technique when attempting a direct shot at goal (Lees, Asai, Andersen, Nunome and Sterzing, 2010; Inoue, Nunome, Sterzing, Shinkai and Ikegami, 2014) and there is large body of research that describes the kinematic, kinetic and electromyographic characteristics of the maximal instep kick (see Kellis & Katis (2007) or Lees *et al.* (2010) for a review). Subsequently, the independent motion of the kicking leg as a multi-segment open kinetic chain that rotates around the pelvis in a proximal-to-distal fashion to maximise shank angular and linear velocity at ball contact as described by Putnam (1991) is well established (Nunome, Ikegami, Kozakai, Apriantono and Sano, 2006).

Less attention has been paid to the function of the support leg during the kicking stride, despite evidence to suggest the proximal-to-distal sequencing of the kick emanates not from the kicking leg hip and thigh (Putnam 1991, 1993) but from support leg action (Lees *et al.,* 2009; Inoue *et al.,* 2014). Extension of the support leg during the kicking stride might serve to displace the support leg hip vertically; initiating an interactive moment which decelerates the pelvis and facilitates swing of the kicking leg through to ball impact. To date however, the highlighted research has been purely descriptive, with no recommendation of how these mechanisms might be altered to elicit an increase in performance. It is therefore proposed that manipulation of technique accordingly might enhance overall kicking performance (i.e. increased ball velocity) and inform how coaches might improve kicking technique. However, before this hypothesis can be reliably tested, it is necessary to effectively elicit the desired changes of technique within the kicker. The aim of this case study was therefore to assess the effectiveness of a technique adjustment intervention designed to produce forceful extension of the support leg and subsequent vertical displacement of the support leg hip during the kicking stride of the maximal instep kick.

METHODS: The single male participant (age 22 years, height 1.80m, weight 80.5kg) was a semi-professional, and right dominant.
Due to the exploratory aim and scope of the investigation, a single subject design case study was used. Data was collected over two separate sessions one week apart. A total of 20

kicking trials were collected; ten to establish a representative baseline of the participant's normal kicking technique (NORMAL) and ten to assess the immediate influence of the technique adjustment intervention (INTERVENTION). All kicks were performed with the right foot.
The intervention was designed using aspects of Carson and Collin's (2011) Five-A model for technical refinement in skilled performers. During the initial awareness phase, the aim was for the participant to call into consciousness the differences between current (NORMAL) versus desired new (INTERVENTION) techniques. The adjustment phase then aimed to modify the technique and internalise the change to the extent that it was no longer in conscious awareness.
All kicks were performed in a carpeted laboratory with the participant's preferred (right) foot using a ball of standard size and pressure. The only instruction given was to strike the ball as forcefully as possible into the centre of a catching net placed 4m away, so to allow the participant to approach the ball in the way most comfortable to them for the specific kick conditions. The ball was placed so that the support (left) foot landed on a Kistler 9281B force plate (Kistler Instruments, Hook, UK) which collected GRF data at 1000Hz during the kicking stride. The trials were also captured with a 10-camera motion analysis system (250Hz) (Vicon Nexus 1.7.1, Vicon Motion Systems, Oxford, UK) and a Casio Exilm EX-FH20 Digital camera (CASIO Computer Co. Ltd, Tokyo, Japan) (210Hz) that was used solely to provide qualitative feedback during the intervention process. The participant wore their usual Astroturf soccer shoes and compressive shirt, shorts and socks for all trials.
Prior to both data collection sessions, 22 passive reflective markers (14mm diameter) were attached to selected lower limb anatomical landmarks with double sided tape and a static trial captured to ascertain the relative positions of these markers. Marker clusters (consisting of three markers) were also attached to the left and right thigh and shank to determine the orientation of these segments relative to the anatomical markers during the kicking trials. Anatomical markers were removed following collection of the static trials; as was the right foot 2nd metatarsal marker so it did not influence foot to ball contact. Finally, one additional marker was cut into hemispheres and placed over opposing poles of the ball.
The raw marker displacements were filtered using a quintic spline (predicted mean square error 30, chosen as per residual analysis conducted on a similar data set and by visual inspection of the current data set) within the Vicon Nexus software and the synchronised force and 3D motion data were exported to the Visual 3D software package (V5, C-Motion, Rockville, USA) for further analysis.
The kicking motion was defined by four key events. Support foot touchdown (SFTD) was the instance the force plate begun to measure a signal above 10N during the kicking stride, left hip joint low (LHLOW) was the instance where the calculated left hip joint centre was lowest in the global Z (vertical) plane, support leg extension (EXT) was the instance that the support leg knee began to exhibit an extension angular velocity and ball contact (CONTACT) was the instance that the kicking foot first contacted the ball. Subsequently, three key phases were identified based on support leg action during the kicking stride. Absorption Phase occurred between SFTD and LHLOW, Reversal Phase between LHLOW and EXT and Extension Phase between EXT and CONTACT. To allow for direct comparison between conditions, trials were time normalised between the instances of SFTD (0%) and CONTACT (100%)..
The variables chosen to represent the kicking motions were the support and kicking leg knee and hip joint power scalar, net joint moment (flexion/extension), joint contact forces (compressive/tensile), angular velocities (flexion/ extension) and angles (flexion/ extension).

RESULTS AND DISCUSSION: Peak ball velocity was consistently greater (Mean 29.2 ± SD 0.9m.s^{-1}) during the INTERVENTION trials than the NORMAL (26.9 ± 1.3m.s^{-1}). These values are consistent with those found elsewhere in the literature (Nunome *et al.,* 2006; Lees *et al.,* 2009; Inoue *et al.,* 2014) and it is argued that kicking performance was enhanced during the INTERVENTION condition. Furthermore, kicking knee angular velocity (extension) at CONTACT increased from 1870 ± 78 deg.sec^{-1} in the representative NORMAL trial to 2036 ± 105 deg.sec^{-1} in the INTERVENTION trial.

The absorption phase lasted for 43% of the total kicking action in the NORMAL trial compared to only 36% in the INTERVENTION trial. During this phase the support leg hip and knee flex (as shown by flexion angular velocities and compressive joint contact forces) to absorb GRFs. However, for both techniques the support leg knee is generating power (extension) during this phase and is also counteracting this flexion action with an extension joint moment throughout the phase. When performing the INTERVENTION technique the participant exhibited larger extension moments and compressive joint forces to resist support leg flexion that in the NORMAL trials. It could be argued that the INTERVENTION technique allowed the participant to minimise knee flexion (flexion angular velocity is larger throughout this phase in the NORMAL trial), allowing the support leg to reverse these flexion actions sooner during the kicking stride and increase the potential for greater extension in the subsequent phases of the kicking action.

The INTERVENTION trial was characterised by a longer (36%) reversal phase compared to the NORMAL trial (27%). In the support leg, peak hip and knee flexion angular velocity occur in the as these joints slow and prepare for extension in the final phase of the kick. Peak flexion angular velocity in the INTERVENTION trials (224 deg.sec^{-1}) was less than half that of the NORMAL trials (515 deg.sec^{-1}), providing further support for the notion that the greater support knee extensor moment seen throughout the kicking action in the INTERVENTION trial served to limit knee flexion. Furthermore, support leg hip reaches peak compressive joint contact force during the reversal phase for both conditions and a greater compressive joint contact force is exhibited in the INTERVENTION trial (30.5N/Kg^{-1}) compared to the NORMAL trial (21.9N/Kg^{-1}).

During the extension phase the support leg knee was extending more rapidly during the INTERVENTION trials and extension angular velocity at CONTACT was 213.3 deg.sec^{-1} compared to 93.1 deg.sec^{-1} in the NORMAL trial, suggesting that the intervention had elicited the desired changes to the participant's kicking technique. The pronounced support leg hip and knee extension in the final Extension Phase of the kicking stride during the INTERVENTION condition may have served to lift the support leg hip vertically and promote the downward (extension) velocity of the shank towards the ball (Lees *et al.,* 2009; Inoue *et al.,* 2014).

CONCLUSION: The current data suggested that support leg extension contributed to proximal to distal movement pattern displayed by the participant by promoting the passive energy transfer from the support to the kicking leg. It can be argued that the mechanisms that caused this were enhanced when support leg extension was exacerbated using the INTERVENTION technique, leading to a greater transfer of energy across the pelvis segment, greater tensile joint forces in the kicking leg which increased passive energy transfer and resulted in consistently higher kicking knee extension velocity at CONTACT and a subsequent peak ball velocity. The 5 A model (Carson and Collins, 2011) intervention provided successful intervention in altering technique and increasing performance outcomes during maximum instep kicking in soccer.

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