Hip and groin pain in athletes
Tak, I.J.R.

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CHAPTER 4

Clinical biomechanics of the soccer instep kick related to groin pain; a review

Igor Tak
Adam Weir
Rob Langhout

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Abstract

The instep kick in football is a complex skill where high speed and precision are essential. Groin injury seriously affects performance level, is provoked by kicking and can be a career-ender. Biomechanical explanations on this injury are lacking. This article includes considerations of football biomechanics, force development, energy transfer, the role of total body range of motion (ROM), and the contrary findings with respect to hip range of motion in groin pain. This information may help to elucidate a relationship between range of motion and injury. Despite the non-conclusive studies relating ROM to groin injury, ROM is performance defining for kicking action in football code sports. The backswing component of kicking motion seems mostly important with respect to energy storage and production of the body. Lack of findings that relate function loss to groin injury might be due to classical function testing, which is usually performed in a non-functional flexed body position. Concomitant movements in total body extension during a kick are described. Future research aiming at these relations might take into account these findings and physical testing methods have to be developed.
Introduction

Three-dimensional movements in sports involving the kinetic chain are complex skills because a combination of precision and high speeds is needed\textsuperscript{127,212}. An instep kick is performed in 500 ms, stressing the required athletic performance\textsuperscript{37,57}. Information on biomechanics of instep kicking, obtained by modern techniques like motion capture and real time electromyography (EMG), allows better insight into kicking quality parameters. This could possibly help to target injury prevention, treatment and performance enhancement\textsuperscript{11,212,271,208}. The amount of biomechanical research in football does currently not match the worldwide immense popularity of the sport\textsuperscript{212,213}.

The instep kick is the most powerful kick in football and ball speeds are higher than those produced by outside and inside kicking\textsuperscript{212}. Clinically it is observed that kicking a ball and cutting, pivoting and sprinting, exacerbate groin pain in football players\textsuperscript{137,140,196}. Adductor-related injury is more frequently found to affect the kicking leg\textsuperscript{83}. As athletes report pain and loss of ability during instep kicking this current study focuses on this movement in relation to injury.

In this review the reader is offered a clinical perspective into biomechanics and the physical requirements of the instep kick. To study relations of range of motion and groin injury a clear description of functional ROM in football is needed and described. Relationships between groin injury and ROM are considered as well.

Methods

Search criteria

In the Pubmed database all available literature up to December 31\textsuperscript{st} 2012 was searched. Keywords used were “soccer”, “football”, “kick”, “kicking”, “instep”, “biomechanics”, “kinetics”, “kinematics”, “EMG”, “muscle”, “range”, “motion”, “adductor”, “groin” and “pain”, “injury” (see Figure 1).

Search results

The search resulted in 2165 titles that were checked for eligibility. Eligible studies were those describing motion behaviour (kinetics, biomechanics, kinematics) and/or muscle actions (EMG) of adult male sportsmen performing an instep kick. Studies into groin injury describing range of motion as risk factor or treatment variable were also selected. Electronic versions of journal articles ahead of publication on paper were included. Due to the paucity on literature strictly restricted to football players, team sports involving kicking actions as in other football codes like Australian Rules football, were included.
Review
Two authors (RL, IT) independently reviewed all titles and abstracts. If there was insufficient information in title or abstract, full text was obtained for evaluation. Disagreement was solved by consensus. This finally resulted in 84 titles of which abstracts were checked independently. The same criteria were used for cross-references. This resulted in 16 additional references. Readily available literature from books on sport biomechanics, kinetics, kinematics and functional anatomy was also used which resulted in 16 additional titles. A flow chart represents the selection process (see Figure 1).

Results
Phases of the instep kick
The instep kick in football can be characterised as a total body movement that comprises all degrees of freedom. In this study the five phases of Brophy et al.\textsuperscript{30} are used to present the instep kick (see Table 1 and Figures 2A-E). This presentation is more detailed than the three phases described by Naito et al.\textsuperscript{162} or four phases by Wickstrom\textsuperscript{259} and Masuda et al\textsuperscript{144}.
This clarifies more precisely the consecutive segmental movements and their positions.

**Phase 1: Preparation**

The main goal of the player in this phase is to generate forward speed and freedom of movement (Figure 2A) and is associated with planning of the kick.

**Phase 2: Back swing**

In this floating phase where there is no contact with the ground (Figure 2B), the main goal is to form a tension arc. This is the tensioning of the body along the diagonal including the kicking leg, trunk and arm at the non-kicking side. In this way the player will be able to generate a large motion dependent moment. The characteristics of the back swing phase are described in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Characteristics of the back swing phase.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kick side</strong></td>
</tr>
<tr>
<td>Pelvis rotates posteriorly 20° and anterior tilt 25°</td>
</tr>
<tr>
<td>Hip moves to 30° extension and 20° external rotation</td>
</tr>
<tr>
<td>Knee moves to 50° flexion</td>
</tr>
<tr>
<td>Ankle moves to submaximal plantar flexion</td>
</tr>
</tbody>
</table>

Table 1. Phases of the instep kick and their marked begin and end points.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparation</td>
<td>Heel strike kicking leg</td>
<td>Toe-off kicking leg</td>
</tr>
<tr>
<td>2. Back swing</td>
<td>Toe off kicking leg</td>
<td>Maximal hip extension</td>
</tr>
<tr>
<td>3. Leg cocking</td>
<td>Maximal hip extension</td>
<td>Maximal knee flexion</td>
</tr>
<tr>
<td>4. Acceleration</td>
<td>Maximal knee flexion</td>
<td>Ball impact</td>
</tr>
<tr>
<td>5. Follow through</td>
<td>Ball impact</td>
<td>Toe speed inflection</td>
</tr>
</tbody>
</table>

Figure 2. Consecutive phases of the kick. A: Preparation; B: Back swing; C: Leg cocking; D: Acceleration; E: Follow through.
**Phase 3: Leg cocking**

In this phase high hip flexion speed is generated. There is simultaneous hip and knee flexion with the trunk rotating to the kick side (Figure 2C). The characteristics of the leg cocking phase are described in Table 3.

**Table 3.** Characteristics of the leg cocking phase.

<table>
<thead>
<tr>
<th>Kick side</th>
<th>Non kick side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis towards anterior rotation</td>
<td>Arm moving in horizontal flexion towards adduction</td>
</tr>
<tr>
<td>Hip moves to 0° flexion and 25° abduction with decreasing external rotation</td>
<td>Shoulder moves to protraction</td>
</tr>
<tr>
<td>Knee moves to 110° flexion</td>
<td>Trunk moves to flexion and rotation of kick side</td>
</tr>
<tr>
<td>Ankle moves to submaximal plantar flexion</td>
<td>Support leg: Foot makes ground contact, hip and knee flexion occurs</td>
</tr>
</tbody>
</table>

**Phase 4: Acceleration**

The goal of this phase is to reach maximal acceleration of knee extension (Figure 2D) and its associated maximal foot speed. This guarantees maximal impact and energy transmission to the ball. The characteristics of the acceleration phase are described in Table 4.

**Table 4.** Characteristics of the acceleration phase.

<table>
<thead>
<tr>
<th>Kick side</th>
<th>Non kick side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis shows posterior tilt of 25° and 20° anterior rotation</td>
<td>Arm shows flexion and adduction</td>
</tr>
<tr>
<td>Hip moves to 20° flexion with decreasing abduction</td>
<td>Shoulder: moves to 20° protraction</td>
</tr>
<tr>
<td>Knee moves from 110° to 40° flexion</td>
<td>Trunk shows flexion and rotation</td>
</tr>
<tr>
<td>Ankle before ball contact slight dorsal flexion and at ball impact abduction, eversion and plantar flexion occurs</td>
<td>Support leg: flexion of hip and knee to 45° and extension just before ball impact</td>
</tr>
</tbody>
</table>

**Phase 5: Follow through**

After ball impact, that only lasts 10 ms, the player finishes the swing phase. With a maximal instep kick the supporting leg loses ground contact during follow through. The leg swings through in a combination of trunk flexion and rotation (Figure 2E). The characteristics of the follow through phase are described in Table 5.

**Table 5.** Characteristics of the follow through phase.

<table>
<thead>
<tr>
<th>Kick side</th>
<th>Non kick side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis protraction stops</td>
<td>Arm towards flexion and adduction</td>
</tr>
<tr>
<td>Hip moves from 20° to 90° flexion with adduction</td>
<td>Shoulder to maximal protraction</td>
</tr>
<tr>
<td>Knee is around 20° flexion</td>
<td>Trunk to maximal flexion and rotation</td>
</tr>
<tr>
<td>Ankle moves from submaximal plantar flexion to dorsal flexion</td>
<td>Support leg: extension to 0° at toe-off</td>
</tr>
</tbody>
</table>
Analysis of the instep kick

One measure of kicking quality is ball speed\[30,106,128,129\]. It is relevant to explore which forces contribute to an effective kick and, with respect to performance, injury prevention or treatment, to what degree muscle strength plays a role. In studies examining generation of ball speed it is accepted to use angular velocity of the kicking shank as the outcome measure\[49,117,262\]. During the football instep kick angular velocity is not only caused by a muscle moment (force x moment arm) generated over the knee joint but this moment is created by a sum of moments over all joints concerning the total kinetic chain. The effect of movements of body segments is much larger than the sum of the isolated parts\[101\]. Trunk rotation is an essential part of the instep kick\[212\]. Naito et al.\[162\] studied causal relations between three-dimensional movements of body segments and angular velocity of the lower leg. Distinction was made between motion dependent moment, muscle dependent moment and ground reaction dependent moment.

Motion dependent moment

The motion dependent moment was divided in centrifugal, Coriolis and gyroscopic moments\[162\]. Centrifugal forces were responsible for 49\% of the angular velocity of the lower leg. These are generated through hip flexion speed of the kicking leg. Coriolis forces of this leg were responsible for 17\%. The Coriolis effect can be described best as the concomitant movement of the leg as body rotation around the length axis occurs. This results in an abduction and external rotation movement. Furthermore the trunk rotation moment, formed by opposite thorax and pelvic rotation accounts for 34\% of angular velocity of the lower leg. Half there of is generated by a muscle dependent moment of trunk rotators (m. Obliquus Internus and Externus) and the other half by a gyroscopic related moment. Gyroscopic forces particularly occur in the rotational (transversal) plane.

Muscle dependent moment

It is important to note that velocity of knee extension is not only generated by muscle power. Conscious muscle input of the m. Quadriceps on ball impact negatively affects angular velocity of the knee\[42\]. This fits with the findings that high-level footballers do not show larger cross sectional area (CSA) than lower level players while ball speeds are much higher in the former group\[144\]. Additionally there is no difference in CSA for the dominant versus non-dominant sides. Muscle groups do show tonic muscle activity during instep kicking but there is a lack of peak activity before and during ball impact\[37\]. The m. Adductor Longus showed low activity throughout the kick with a relative peak just before maximal hip extension when also the quickest elongation of the m. Adductor Longus occurs. Before ball impact the m. Adductor Longus reaches its maximal length. At this moment there is also maximal hip abduction. The m. Adductor Longus is therefore functioning to control hip extension and abduction\[37\]. After the pre-stretch moment a
well-controlled hip flexion is initiated. The mm. Iliopsoas and Rectus Femoris are active throughout the downswing until ball impact \(^{18,55}\). A relative peak of the latter is shown in leg cocking\(^{18}\). On ball impact negative muscle moments were noted \(^{55,56,162}\).

**Ground reaction dependent moment**

Several authors Naito showed no significant relationship between ball speed and ground reaction forces\(^{112,162,177}\). It would seem that the balance of the support leg and not ground reaction moments is positively correlated to kicking accuracy\(^{38}\). An increased balance for the support leg compared with the kicking leg was suggested, but not found to be significantly different\(^{79}\).

**Ball speed**

Davids et al.\(^{59}\) suggested that coordination is a determining factor for talent in football. In experienced footballers it has been shown that the ball speed is up to 150 % of that of less trained players, respectively 87 and 61 km/hr\(^{212}\). Ball speed in elite players can reach 115 km/hr\(^{56,106}\). The dominant rather than the non-dominant leg produces higher ball speeds which has been related to a very high level of coordination development\(^{16}\). Skilled players however do also show high inter-segmental movement quality for their non-dominant sides\(^{14}\). This quality is reflected in the concept of kinematic sequence. Several authors stress the importance of technical skill (sequence) and physical flexibility in relation to optimal ball speed\(^{56,127,170,212,262}\).

**Flexibility**

Experienced footballers show significant more dynamic ROM of trunk rotation, hip extension and knee flexion than less experienced players \(^{212}\) which is associated to higher ball speeds\(^{212,213}\). Greater trunk extension and rotation of the non-dominant side helps to create a larger gyroscopic moment. This results in higher flexion rotation moment of the trunk in the kicking side direction\(^{162,212}\). An increase of hip extension results in a larger centrifugal moment of the kicking leg\(^{162}\). An identical positive relationship has been shown for the knee flexion angle and the acceleration of the lower leg towards extension\(^{57}\). Positive correlations were described for the relationship of ball speed and hip ROM in baseball pitchers\(^{239}\). This mutual relation between segments where ROM of all joints and muscles in the kinetic chain is important and has been called “dynamic coupling”\(^{271}\).

**Kinematic sequence**

A correct timing of body segment movements will enable the athlete to create high ball speed\(^{212}\). The instep kick resembles a whip-like movement in which a proximal-to-distal sequence of movement can be recognized\(^{56}\). This is achieved by deceleration of the proximal segment preceding acceleration of the distal one\(^{106,162,184,262}\). Juarez et al.\(^{106}\)
reported on this sequence with marker speeds on the pelvis first reaching its maximum linear velocity (5 m/s), consecutively followed by the knee marker (11 m/s), ankle marker (19 m/s), toe marker (25 m/s) and ball marker (30 m/s).

Recently the relationship between the initiation and flow of kinetic energy in a full body system and the related proximal-to-distal sequence was described\textsuperscript{162}. Energy redistribution enables the body to avoid extreme muscle work and may be advantageous in achieving safe and efficient kicking. Acceleration of the non-kicking side shoulder and arm starts at the beginning of leg cocking resulting in deceleration of the trunk. As the foot hits the ground, the supporting leg starts to decelerate resulting in the transfer of kinetic energy from the arm, trunk and supporting leg into the kicking leg.

In the acceleration phase, the action of the non-kicking side shoulder and arm continues to transfer energy from thigh to shank. In this phase, the centrifugal and Coriolis forces, due to the hip extension/flexion moment, decelerate the thigh and accelerate the shank. There is discussion on the cause of thigh deceleration as described by several authors\textsuperscript{162,170}. Contraction of hip extensors is most unlikely due to the negative moment of the thigh that has been observed\textsuperscript{170}. As the acceleration of the non-kicking side shoulder/arm transfers kinetic energy from thigh to shank, this could be a cause of thigh deceleration. The role of rapid posterior pelvic tilt, 50 ms before ball impact and the muscular moment of the trunk rotators are thought part of this same mechanism but need further clarification\textsuperscript{127,162}. As the centrifugal force depends on joint kinematics, energy transfer from thigh to shank is most optimal at 90 degrees of knee flexion\textsuperscript{161}.

Upper body control through acceleration of the non-kicking side arm, stabilization of the support leg and optimal kicking leg configuration are necessary parts of a well-coordinated kick. This may explain the high degree of body control to serve foot to ball coordination observed in the acceleration phase\textsuperscript{212}.

**Adductor-related groin pain in football**

Groin pain is usually worsened by kicking, sprinting or cutting and pivoting\textsuperscript{137}. Despite the findings of pathology in adductor tendons, abdominal muscles and bony structures in relation to groin injury there is no consensus on the exact pathological mechanism\textsuperscript{37,39,140,178,244}. Several studies have focused on the relationship between trunk and hip muscle function or hip joint ROM and injury\textsuperscript{14,27,47,48,59,60,100,174,241,263}. There is some evidence for decreased hip muscle strength, specifically hip abduction strength, being a risk factor\textsuperscript{174}. Evidence for ROM being a risk seems weak and findings are contradictory. To the authors knowledge no good quality studies have been performed on hip ROM as a target for therapeutic intervention in athletic groin injury. In daily practice however stretching is still widely advocated as part of rehabilitation programmes. Exercise therapy has been proven to perform well in athletes with groin injury and shows favourable outcome\textsuperscript{96}. 
Williams already described his findings of decreased hip ROM in groin injury in 1978 and hypothesized on the role of hip ROM in a possible pathological mechanism. Later Verrall et al. and Ibrahim et al. also found slight but significant rotational hip ROM loss to be a risk factor for the development of groin injury. This suited the findings of Delahaye et al. (2003) while other studies did not support these findings. Maffey and Emery stated in their systematic review that loss of hip ROM might be a risk factor. Stretching however seems of no benefit in the prevention of groin injury. The role of ROM loss is unclear.

Discussion

The literature available offers a detailed overview of the biomechanics of the instep kick. To answer the question what specific requirements a footballers body must meet to fulfil these criteria this knowledge is indispensable. In order to generate big momentum and thus a high end speed through multi segmental movement, a proximal-to-distal sequence is essential. In 2005 the use of 2D video analysis proved that like in golf and tennis this sequence is present in football as well. More recent studies using 3D techniques show that timing of trunk and arm are essential. The literature offers adequate information to clarify the role of muscular contribution to kicking.

Relationships were shown between ball speed and muscle and motion dependant moments of the trunk and kicking leg. Better footballers produce higher ball speeds and have larger ROM of trunk, arm, hip and knee throughout the back swing phase and higher knee flexion angles in leg cocking showing the importance of adequate inter segmental ROM with respect to ball speed. The studies that focused on hip ROM in relation to groin injury used traditional measurement methods to determine hip ROM. Range of motion in kicking seems to be important in the formation of a tension arc, which is a sport specific and total body function into extension direction.

Regarding the proximal-to-distal order of movement, it is likely that anterior pelvic rotation precedes hip flexion and knee extension, as in other sports such as golf. Juarez et al. showed this pelvic action recently. High muscle activity levels in the kicking leg are not found during ball impact. Active recruiting of trunk rotators is essential. Throughout the instep kick muscles show low-level activity. Higher peak muscle activity is obvious before the acceleration phase and functions for coordination of body segments. A larger ROM of the tension arc is likely to result in larger pre-stretch of trunk rotators, hip flexors and knee extensors that initiate leg cocking.

In experienced players larger knee flexion angles correlate positively with higher ball speeds. Larger ROM allows passive elastic structures to store potential energy and transfer this distally through the body as kinetic energy producing a high end speed.
Exaggerated muscle contractions may result in reduced coordination and precision\textsuperscript{105}. Less accurate kicks were shown to produce higher muscle activation levels of mm. Tibialis Anterior and Rectus Femoris\textsuperscript{112}.

When considering that the kinetic chain is formed by multiple segments anatomical studies have shown, that several anatomical structures like mm. Rectus Abdominus, Abdominus Obliquus Externus and Internus, Adductor Longus and the symphyseal joint are inextricably connected\textsuperscript{196}. Myers\textsuperscript{159} described several myofascial systems with mutual anatomic relations (Table 6). These systems are involved in the multi segmental movement modelling and some are stretched in the tension arc and leg cocking. Several muscles within these systems can initiate leg cocking after being stretched in the tension arc.

It is questionable to what degree the quality of the instep kick is affected by the loss of range of motion of local segments or joints in the kinetic chain. The athlete will generally not notice a loss of function until symptoms arise or performance drops. In the case of a lack of ROM there may be compensatory muscle power in an attempt to retain ball speed. This will place greater tensile stress on anatomical structures like the hip flexors and adductors. In several sports it is calculated that maximal stress is usually beneath the level at which damage would occur\textsuperscript{118}. Harris-Hayes et al.\textsuperscript{84} clarified that loss of function in the kinetic chain is related to compensatory lower back pain when the direction of function loss and mechanical load of the sport movement are rectified. It would be fascinating to study the effect of loss of ROM in the kinetic chain on injuries in the groin region and in performance in kicking. To perform such new reliable sport specific evaluation tools are needed.

Conclusion

The instep kick is the most powerful kick in football. Knowledge of the biomechanics of the instep kick is necessary to understand how ball speed is generated. Adequate ROM and coordination are essential. Groin injury in footballers could be related to function loss in the greater kinetic chain resulting in compensatory higher tissue loading of groin anatomical structures. This has not been evaluated as such. To evaluate this idea further tests are needed that enable to specify inter segmental ROM of the instep kick.