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Deviating running kinematics and hamstring injury susceptibility in male soccer players: Cause or consequence?

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ABSTRACT

Background: Although the vast majority of hamstring injuries in male soccer are sustained during high speed running, the association between sprinting kinematics and hamstring injury vulnerability has never been investigated prospectively in a cohort at risk.
Purpose: This study aimed to objectify the importance of lower limb and trunk kinematics during full sprint in hamstring injury susceptibility.
Study design: Cohort study; level of evidence, 2.
Methods: At the end of the 2013 soccer season, three-dimensional kinematic data of the lower limb and trunk were collected during sprinting in a cohort consisting of 30 soccer players with a recent history of hamstring injury and 30 matched controls. Subsequently, a 1.5 season follow up was conducted for (re)injury registry. Ultimately, joint and segment motion patterns were submitted to retro- and prospective statistical curve analyses for injury risk prediction.
Results: Statistical analysis revealed that index injury occurrence was associated with higher levels of anterior pelvic tilting and thoracic side bending throughout the airborne (swing) phases of sprinting, whereas no kinematic differences during running were found when comparing players with a recent hamstring injury history with their matched controls.
Conclusion: Deficient core stability, enabling excessive pelvis and trunk motion during swing, probably increases the primary injury risk. Although sprinting encompasses a relative risk of hamstring muscle failure in every athlete, running coordination demonstrated to be essential in hamstring injury prevention.

1. Introduction

Hamstring injuries are the single most frequent non-contact muscle injury in male soccer [1–3]. The vast majority of those occur during high speed running, where the muscle fails structurally or functionally [4], due to repetitive intense eccentric loading throughout the front- and (early) stance phases of the running cycle [5–9]. Because the mechanical and metabolic demands imposed upon the hamstring unit during running acceleration are even more intense than is the case for constant speed sprinting, this posterior thigh unit is at highest risk of injury during explosive acceleration towards full speed sprint. Sufficient acceleration capacity and adequate starting speed are key motor components in soccer performance, necessitating optimal hamstring function. In trying to identify intrinsic risk factors for adequate injury prevention, rehabilitation, and safe return to play, existing research tends to be restricted to the investigation of functional and structural regional neuromuscular characteristics in resting state conditions [2,3,8,10,11].

Among others, muscle strength and flexibility, morphologic and -metabolic features, as well as neuro-dynamics and stretch tolerance have been investigated in relation to hamstring injury vulnerability [1–3,10,12]. In addition, because of the functional integrity of lower limbs and the lumbopelvic complex, joint mobility of the spine and lower limb as well as multiple other factors responsible for functional lumbopelvic control (postural control, coordination, strength, etc.) are thought to be crucial in rehabilitation and prevention [1,13–19]. Nonetheless, these potential hamstring injury correlates have only rarely been scrutinized during explosive acceleration for full speed sprinting, during which the hamstring is at highest risk of injury [20,21]. High amounts of negative work and tensile strain are inherently present in acceleration and high speed running. Why some players manage to keep their hamstrings in optimal shape and others sustain (recurring) muscle injuries throughout those repeated sprint (-acceleration)s, is a capital question that needs to be resolved in order to adequately and sport specifically prevent these types of high speed running injuries. Besides, although lumbopelvic control training or 'core stability' training has proven to be highly valuable in

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rehabilitation outcome and secondary injury prevention [15,22–29], its exact role in the athlete's primary injury vulnerability and its influence on muscle mechanics during running and kicking, remains unclear.

After the example of Kibler et al., we define 'core stability' as 'the ability to control the position and motion of the trunk and the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities' [30]. This implies a fairly broad functional interpretation, in which both the kinematic and kinetic features that add up to a controlled and coordinated guidance of the body center of mass throughout integrated activities, as there is running, are embedded. Because (high speed) running particularly implies providing the body center of mass with acceleration and velocity to achieve a fast horizontal displacement through horizontal force production, the functional integrity of the core is especially important as regards the economy, sustainability and safety of running and sprinting performances. Bearing in mind the evidence behind the hamstring injury mechanism [8,9], it would seem merely logical that running technique and the associated biomechanical features, as there is sufficient functional control of proximal lumbopelvic unit (containing the body center of mass), within the (high speed) running cycle could be of substantial influence in the risk of sustaining a hamstring injury.

The biomechanics of running have been subject of study repeatedly. Strikingly however, high speed running kinematics have never been investigated in direct association with hamstring injury occurrence. Therefore, this study intended to investigate the association between lower limb and trunk kinematics throughout maximal acceleration towards full speed sprinting and hamstring injury susceptibility in a sample at risk (male soccer players). This association was explored both retro- and prospectively, to allow strict differentiation between possible kinematical causes and consequences of hamstring injury. Although both trunk and lower limb kinematics were taken into account, our focus was particularly directed towards trunk- and pelvis function to explore a possible association between running related hamstring injury risk and 'core stability'.

2. Materials and methods

2.1. Participants

Throughout the second half of the 2013 soccer season, 30 soccer players with a recent history (last injury sustained within the past season or the prior one (past 24 months)) and 30 matched controls, all active in the same amateur competition series (Oost-Vlaanderen, Belgium), were recruited. Players were excluded if they had

– a history of severe lower limb injury, which could have influenced kinematics
– a history of lower back complaints/lower back complaints at present, which could bias the intrinsic risk profile
– less than 5 years of competitive soccer experience, as this could induce selection bias

To exclude age related pathologies, soccer players aged beneath 18 or above 35 years were excluded from the study as well. All participants were completely free from injury and ready to play at the moment of testing.

A hamstring injury was defined as a soccer related injury in the hamstring muscle region, preventing the player from participating in training or competition for at least one entire week. The majority of respective hamstring injuries within the injury group was diagnosed clinically, with or without enclosed medical imaging (depending on the decision of the medical staff). Actual recruitment and inclusion of formerly injured participants was mainly based on self-report, as we were not able to get in touch with all physicians and physiotherapists involved in prior diagnosis and rehabilitation. At the time of testing, none of the players experienced any pain or discomfort in the hamstring region during soccer participation or during the running protocol in this study.

2.2. Testing procedure

All participants were informed about the content and the purpose of the testing procedure and signed the Informed Consent, after which they were familiarized with the running protocol and the course of the three-dimensional (3D) motion analysis. This information was consistently provided by the same qualified researcher (JS), who was in charge of the entire testing procedure (participant preparation, data assembly and -processing) as well, which minimized the risk of intertester bias. This study was approved by the Ethics Committee of the Ghent University Hospital (number of approval: EC/2013/118).

In order to get a valid impression of the participant's running coordination throughout acceleration towards full speed sprinting, without bias of fatigue or muscle soreness, subjects were instructed not to engage in intensive training or soccer competition 48 h prior to testing.

After testing, participants were informed about the online diary which was put together for the purpose of injury registration during follow up (http://www.hsi.ugent.be). This online survey contained questions about weekly exposure (match and training) and the incidence/presence of soccer related injuries and complaints. The participants were asked to complete this survey every Monday throughout the entire 2013–2014 season, as well as the first half of the 2014–2015 season, accounting for a follow up period of one entire and one half of a soccer season.

Follow up was terminated at the winter break of the 2014–2015 season, during which period all participants were contacted again for final injury inquiry.

2.3. Three-dimensional kinematic testing protocol

When indicating having understood the content and course of the testing procedure, participants were instructed to undress, wearing only a pair of tight shorts and indoor soccer shoes. Afterwards, 40 passive infrared reflective markers (12 mm lightweight markers, Qualisys AB, Sweden) were attached in accordance with the LJMU Lower limb and Trunk Model for motion analysis (Van Renterghem J., Liverpool John Moores University), representing respective bony landmarks and segment clusters (Fig. 1(a)). The kinematic analysis of the linear acceleration to full speed sprinting was conducted on a 40 m (m) running track, which was surrounded by 8 cameras for 3D motion capturing (Oqus, Qualisys AB, Göteborg, Sweden). These cameras were installed between meter 15 and 25 of the running track (resulting in a kinematic measuring volume of 10 m), as this is the average distance over which maximal acceleration is achieved in attempting to reach maximal running speed (Fig. 1(b)) [31]. All reflective markers were attached to the skin firmly by using double sided carpet tape, to prevent them from coming loose or falling off. The entire 3D data assembly of the

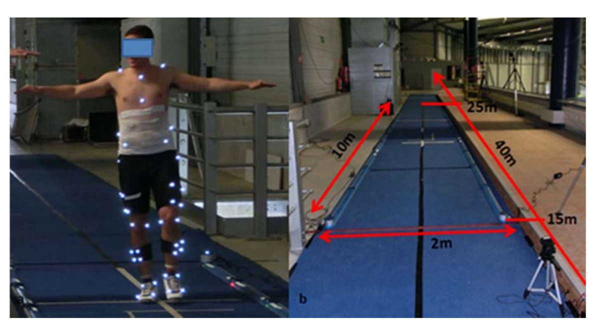

Fig. 1. (a) Static – and tracking marker placement; Functional joint capture protocol of the left knee; (b) 40 m sprinting track with [10*2]m 3D measuring volume in between the step detection bars of the Optogait system.

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