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A musculoskeletal modelling approach of the assessment of the risk of hamstring injuries in professional soccer players: A pilot study

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1. Introduction

Hamstring injuries are the most common non-contact injuries in football and negatively affect team performance and club finances (Buckthorpe *et al.* 2019). Despite an abundant literature, the evaluation of the risk of hamstring injuries remains complex as it lacks evidence-based recommendations and reliable field-testing. The aetiology is commonly acknowledged as “multifactorial” and numerous potential risk factors have been proposed in the literature including muscle weakness, decreased flexibility, posture, fatigue, etc. (Gabbe *et al.* 2006). It most commonly occurs in the Biceps Femoris long head (BFLh) and a previous history (in the last 12 months) is considered the main predictor of subsequent hamstring injury. Previous experimental research showed that kinematic analysis provides a global external insight but fails to apprehend musculoskeletal solicitations (Thelen *et al.* 2006). On the contrary, analysis of musculoskeletal parameters (e.g. muscle length or strain rate) appears more relevant but direct measurement on the field is impossible, and only quantifiable through musculoskeletal modelling (Delp *et al.* 2007). The aim of this study was to investigate the risk of hamstring injury using a musculoskeletal approach during a functional test designed for this purpose.

2. Methods

2.1 Participants

Twelve professional elite footballers (age: 24 ± 4 years, height: 183 ± 12 cm, weight: 85 ± 12 kg) volunteered to participate in the study. Players were distributed in two groups, whether they sustained a hamstring history injury in the previous year (“Injured”; $N = 5$) or with no history of hamstring injury (“Control”; $N = 7$).

Players were informed of study protocol prior to inclusion and that they could withdraw at any time without penalty. All components of the study were designed according to the principles of the Declaration of Helsinki and were approved by the Sports Science and Medical Department of the Stade Rennais Football Club (#2018-005-SRFC), and all trials were supervised by a medical doctor.

2.2 Protocol

After a 15-min standardised warm-up, participants performed a reactive agility task consisting in reaching

one of four ground targets from a jumping start based on a visual cue displayed on a large screen whilst players were jumping. Players were instructed to reach a given target using the heel of their ipsilateral foot with leg stretched out, toes raised, and ipsilateral hand as close as possible to the target. Targets were located on the ground in front of them, oriented at 15° and 50° on right and left sides, and trial order was randomised. The test was considered complete when four successful trials on each target were recorded (Figure 1).



Figure 1: Overview of the experimental setup

2.3 Musculoskeletal modelling

Three-dimensional kinematics were obtained from a 24-camera motion analysis system (Vicon, Oxford, UK). Marker data served as input of a full musculoskeletal model, developed by Lai *et al.* (2017) to estimate lumbar and lower limb joint angles from the recommended OpenSim calculation steps (Delp *et al.* 2007). The model was scaled to match participant's anthropometry and joint angles were calculated through a global optimisation-based inverse kinematics procedure. Maximal BFLh muscle length was estimated and normalised relative to resting length.

Dependent variables used for group comparisons were normalised maximal BFLh length, BFLh stretch time from resting length to maximum length, and stretch rate calculated as the ratio between the first two dependent variables. Lower limb joint angles were estimated and compared between groups at the peak of BFLh.

2.4 Statistical analysis

Wilcoxon sum-rank test was conducted for all dependant variables. Significance level was set at $p < 0.05$.

3. Results and discussion

All participants performed the test. Four invalid trials were removed out of the 172 trials. We observed no significant difference between conditions (15° and 50°, $p = 0.65$). Maximal BFlh length and time to stretch were significantly greater in the control group. Stretch rate was not significantly different across groups (Table 1).

Variables	Injured	Control	p
Normalised maximal BFlh length	1.47 ± 0.09	1.54 ± 0.04	< 0.01
BFlh stretch time (s)	0.39 ± 0.10	0.48 ± 0.10	< 0.01
Stretch rate	1.30 ± 0.27	1.27 ± 0.25	0.45

Table 1 Comparison of dependant variables between groups (mean of all conditions and all participants).

Kinematics associated with these muscle parameters revealed that participants of the control group had greater maximal hip flexion and pelvis anterior tilt, and a smaller knee flexion than injured players (Table 2).

Joint angles	Injured	Control	p
Pelvis anterior tilt	-24.5 ± 19.0	-38.2 ± 9.2	< 0.01
Pelvis list	3.0 ± 4.2	1.4 ± 5.0	0.63
Pelvis rotation	2.8 ± 6.5	0.5 ± 6.6	0.65
Hip flexion	91.1 ± 20.5	106.5 ± 6.8	< 0.01
Hip abduction	-18.9 ± 6.3	-19.6 ± 7.4	0.81
Hip internal rotation	13.7 ± 10.8	20.1 ± 10.2	0.07
Knee flexion	-41.4 ± 4.1	-35.9 ± 11.5	< 0.01

Table 2 Comparison of all joint angles estimated for each groups (mean of all conditions and all participants).

This approach permitted to uncover different muscle kinematics between previously injured and non-injured players, where the decrease of BFlh stretching capacity was linked to a different strategy or a difficulty to stretch posterior muscle chain during this field test. This means that limitations in range of motion were greater and met more rapidly in previously pathological injured players compared to control players.

Although parameters in the sagittal plane were relatively constant within groups, both groups were characterised by great inter-individual variability in other planes, especially in hip internal rotation.

4. Conclusions

The main finding of this study is that musculoskeletal modelling allowed to analyse musculoskeletal function in greater detail than with a kinematics assessment alone. A longitudinal investigation was in progress to confirm those findings. The association between a specific field test and a musculoskeletal approach developed in this pilot study gives new preliminary insights on the impact of a previous history of hamstring injury on lower limb kinematics and BFlh muscle length and can help assisting medical practitioners, coaches, sport physicians and physiotherapists to prevent hamstring injuries.

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