DO FIELD HOCKEY PLAYERS REQUIRE A SPORT-SPECIFIC BIOMECHANICAL ASSESSMENT TO CLASSIFY THEIR ANTERIOR CRUCIATE LIGAMENT INJURY RISK?

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The lower limb biomechanics of 13 elite female hockey players were compared between 1) a generic, and 2) a hockey-specific (i.e., flexed trunk and hockey stick present) ACL injury risk movement assessment. Our aim was to determine if an athlete's ACL injury risk classification differed as a function of their movement assessment. An increase in trunk, hip and knee flexion was observed during the hockey-specific movement assessment. No significant differences in key ACL injury risk factors (i.e., peak three dimensional knee moments) were observed. These results show that imposing hockey-specific requirements during a lab based movement assessment did not change an athlete's ACL injury risk classification when compared to a generic movement assessment.

KEY WORDS: postural constraints, ACL injury risk, movement assessment

INTRODUCTION: A rupture to the anterior cruciate ligament (ACL) is considered to be one of the most debilitating knee injuries an athlete can sustain in sport (Donnelly *et al.,* 2012a). As motion capture technologies, musculoskeletal models and non-linear analyses evolve, we now have the ability to move from static/quasi-static, to dynamic sport-specific movement assessments of an athlete's ACL injury classification in sport. *In-vivo/in-lab* research (Markolf *et al.,* 1995; Besier *et al.,* 2001b) and *in-silico* research (McLean *et al.,* 2004; Donnelly *et al.,* 2012b) have shown that a combination of peak extension, valgus, and internal rotation moments at the knee is associated with elevated ACL forces and injury risk in sport. Evidence also suggests a causal relationship between peak knee joint moments and an athlete's upper body postures during change of direction sporting tasks (Dempsey *et al.,* 2007; Donnelly *et al.,* 2012b).

Chaudhari *et al.* (2005) directly tested the influence of constraining an athlete's upper extremity movement in an attempt to replicate different sport-specific demands during planned sidestepping movements. Constraining the arms elevated peak knee valgus moments by 60% when compared with a baseline sidestep with no postural constraints (Chaudhari *et al.,* 2005). In landing tasks, Dempsey *et al.* (2012) also reported a relationship between whole body kinematics and knee moments, showing peak knee valgus moments increased when the upper-body was perturbed laterally during a single-leg landing task. These findings have direct implications for field hockey athletes, given the upper body constraints brought about through the use of a hockey stick during gameplay. The downstream impact of this sport-specific postural constraint on an athlete's injury risk in sport is currently unknown. Field hockey athletes may possibly be at greater risk of ACL injury, as the constrained upper body postures could generate a higher mechanical demand on their knee joint versus running with an unconstrained posture. Despite the distinct postural differences that a field hockey athlete adopts during gameplay, athletes are currently assessed using a well-published and accepted generic movement assessment (upright posture) when measuring an athlete's ACL injury risk in sport. This generic movement assessment has previously been used to measure field hockey athletes, as well as a wide variety of team sport athletes from an array of sporting codes (McLean *et al.,* 2005; Donnelly *et al.,* 2012a; Weir *et al.,* 2014).

The purpose of this study was to determine if an athlete's peak three dimensional (3D) knee moments and ACL injury risk classification changed when a generic movement assessment (GMA) or a revised hockey-specific movement assessment (HSMA) is used. We hypothesised that during a lab based HSMA, the flexed trunk postures associated with carrying a hockey stick will be accompanied by elevated peak valgus, internal rotation and extension knee moments when compared to the GMA (upright posture).

METHODS: Thirteen elite female hockey players (24.0 ± 3.0 yrs; 1.7 ± 0.7 m; 64.0 ± 6.9 kg) completed the GMA and HSMA in a block counterbalanced design. A random series of planned and unplanned change of direction (CoD) running tasks were completed in each assessment. The HSMA differed from the well-published GMA with the inclusion of a hockey-stick held low to the running surface, encouraging an increased flexed posture during each running task (Figure 1). 3D motion capture was used to record each sidestepping task, in accordance with previously published movement assessments (Besier *et al.,* 2001b; Dempsey *et al.,* 2009; Donnelly, *et al.,* 2012a). Kinematics and kinetics were recorded using a 22-camera Vicon MX/T40 system at 250Hz (Oxford Metrics, Oxford, UK) and force plate data at 2,000Hz (AMTI, Watertown, MA). Established kinetics (normalised to body weight (BW) and height (HT)) and kinematics variables associated with ACL injury risk (see Table 1) were analysed during the weight acceptance (WA) phase of three unplanned sidestepping tasks (Dempsey et al., 2007). A successful unplanned sidestep during testing was categorized as when the approach velocities fell between 4.5 $m \cdot s^{-1}$ and 5.5 $m \cdot s^{-1}$ and the sidestep CoD angle followed a 45º line marked on the running surface. Pre-contact velocities and mean change of direction (CoD) angles were collected to measure consistency between the GMA and HSMA. One-way repeated measures ANOVA (α=0.05) and Cohen's *d* for effect sizes were calculated to determine differences in dependent variables between the GMA and HSMA. Peak extension, internal rotation and valgus knee moments were used to determine an athlete's risk of ACL injury (Donnelly *et al.,* 2012a). Paired sampled t-tests on pre-contact velocities and CoD angles were calculated to assess differences in means between the HSMA and GMA.

Table 1: Discrete dependent variables measured during WA

Kinematics (°)	Kinetics (%BW x HT)
Peak trunk lateral flexion angle	Peak knee valgus moment
Mean trunk flexion angle	Peak knee internal rotation moment
Peak hip flexion angle	Peak knee extension moment
Peak hip abduction angle	Peak hip extension moment
Peak hip internal rotation angle	Peak ankle plantar flexion moment
Peak knee flexion angle	
Knee flexion angle at foot-strike	

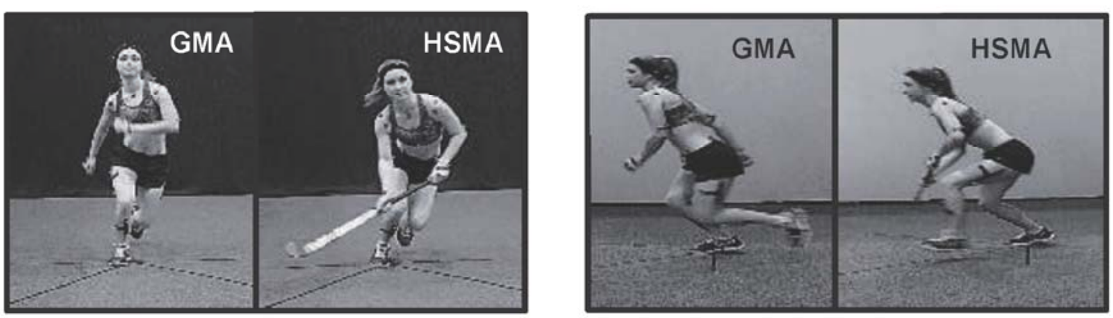

Figure 1: Frontal and sagittal views of the GMA and HSMA posture while completing a sidestepping running task.

RESULTS: No differences in approach velocities and CoD angles were observed between the HSMA and GMA. Mean trunk flexion in the HSMA was 15° higher than the GMA (F=33.04, *p*<0.001, d=1.62). This trend continued throughout the lower limb with the hip and knee (F=27.84, *p*<0.001, d=1.07) displaying significantly higher levels of peak flexion during WA in the HSMA compared with the GMA condition (see Table 2). Consistent with these findings, the HSMA was associated with increased peak hip extension moments relative to the GMA (F=10.04, *p*<0.01, d=0.79). Interestingly, this trend was not observed at the knee where no differences in peak extension moments were observed between the GMA and HSMA, despite the greater levels of knee flexion recorded at the knee for the HSMA. Importantly, in the context of ACL injury risk, there were no observed differences in peak valgus or internal rotation knee moments between the GMA and HSMA (Table 2).

Table 2: Mean peak ACL injury risk variables measured during the GMA and HSMA. Angles were measured in (°) and moments measured in (%BW x HT).

	Generic		Hockey-Specific		Effect	Observed
ACL Injury Risk Variables	Mean	(SD)	Mean	(SD)	Size	Power
Trunk						
Mean Trunk Flexion Angle	20.7	(6.60)	35.7	(11.9)**	1.62[a]	0.99
Lateral Flexion Angle	19.0	(6.20)	18.5	(6.00)	0.08[d]	0.07
Hip						
Flexion Angle	57.9	(7.30)	62.4	(8.20)**	0.59[b]	1.00
Abduction Angle	16.9	(7.70)	19.8	(6.50)	0.4[c]	0.50
Internal Rotation Angle	0.6	(7.50)	0.4	(7.30)	0.03[d]	0.05
Extension Moment	0.155	(0.030)	0.183	(0.040)*	0.79[b]	0.83
Knee						
Flexion Angle	52.4	(3.50)	56.0	(3.30)**	1.07[a]	1.00
Flexion at Foot-Strike Angle	18.9	(5.90)	21.2	(4.60)	0.44[c]	0.27
Extension Moment	0.234	(0.040)	0.222	(0.040)	0.28[c]	0.38
Valgus Moment	0.030	(0.020)	0.031	(0.020)	0.02[d]	0.05
Internal Rotation Moment	0.018	(0.010)	0.017	(0.010)	0.17[d]	0.18
Ankle						
Plantar Flexion Moment	0.061	(0.02)	0.060	(0.02)	0.09[d]	0.08

*Significant at $p<0.05$ **Significant at $p<0.001$
[a]Large effect size $d \geq 0.8$ [b]Medium effect size = 0.5
[c]Small effect size $d = 0.2$ [d]Minimal effect size ≤ 0.2

DISCUSSION: Contrary to our hypothesis, peak 3D knee joint moments were not influenced by the incorporation of a hockey stick during an ACL injury risk clinical movement assessment. Relative to the GMA, increases in trunk, hip and knee flexion angles during the HSMA were attributed to the imposition of a hockey stick and instructions to keep the stick low to the ground during testing. Similar peak knee moments during the HSMA may be explained by the adopted flexed posture, which effectively lowered the participant's whole body CoM during the sidestepping movement. With a lower CoM, an athlete would likely increase the dynamic control of their whole body CoM as described by Winter (1987). Increased dynamic control of the CoM is beneficial from a lower limb and more specifically an ACL injury risk perspective, as seen in previous studies (Dempsey *et al.,* 2007; Donnelly *et al.,* 2012b). We know perturbations of the upper-body caused by postural constraints in the frontal plane, increase moments at the knee (Chaudhari *et al.,* 2005; Dempsey *et al.,* 2012). However, in the current study, postural constraints only influenced sagittal plane kinematics as no significant differences in trunk lateral flexion were observed. Consequently, the flexed posture adopted in the HSMA did not appear to influence the non-sagittal joint moments at the knee, suggesting their ACL injury risk did not differ between the GMA and HSMA.

Increased hip extension moments during the HSMA are required to support the trunk while maintaining a flexed hip posture in order to prevent the CoM from falling to the ground. Previous research has found that decreased hip musculature strength, endurance and activation, predisposes athletes to various knee joint injuries (Kernozek *et al.,* 2008). Given that field hockey athletes must maintain increased levels of trunk flexion throughout an entire game, there is a possibility that the hip extension musculature, responsible for controlling trunk and hip extension, may be predisposed to fatigue (due to constant isometric and eccentric loading). Fatigue of the hip extension musculature over a game may reduce dynamic control of the knee during sidestep movements, placing athletes at risk of knee joint injuries. To further examine the role hip musculature plays while in hockey-specific postures, investigation into neuromuscular control and muscle activation during fatigued and unfatigued states is recommended.

CONCLUSION: An athlete's peak 3D knee moments during change of direction tasks were not different when their movement was assessed using the GMA when compared to the HSMA, despite displaying elevated trunk, hip and knee flexion angles during the HSMA. In an unfatigued testing environments, a GMA and HSMA will produce similar ACL injury risk classification recommendations.

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