CHANGES IN THE BIOMECHANICS OF A REACTIVE CUTTING MANOEUVRE IN AN ATHLETIC GROIN PAIN COHORT FOLLOWING A SUCCESSFUL REHABILITATION INTERVENTION

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Athletic groin pain (AGP) is prevalent in field sports that require rapid changes of direction. The purpose of this study was to investigate the kinetic and kinematic changes that occurred in an unplanned reactive cutting manoeuvre following a successful rehabilitation intervention. Kinematics and kinetics were analysed using statistical parametric mapping in 23 patients before and after an exercise intervention programme. Significant improvements were found in all subscales of the Copenhagen Hip and Groin Outcome Score and biomechanical changes were identified at the pelvis, knee and ankle. These findings provide insight into mechanical variables of potential importance in AGP as identified during a manoeuvre based on a common sporting task.

KEYWORDS: change of direction, unplanned, exercise, running, groin strain

INTRODUCTION: Athletic groin pain (AGP) is prevalent in field sports involving repetitive dynamic movements such as accelerations, kicks and rapid changes of direction: incidence in senior football has been reported at up to 2.1 per 1000 hours played (Waldén et al. 2015). While the aetiology of AGP is not well-understood, there is some evidence that dynamic tissue overload around the structures of the anterior pelvis caused by sub-optimal kinetics and kinematics during this type of activity may contribute to symptom development (Whittaker et al., 2015). Alterations to kinetics and kinematics in pre-planned laboratory exercise tasks have previously been identified in AGP patients following a successful exercise intervention programme (Gore et al., 2015). Unplanned reactive tasks, however, are commonly required during competitive field sport and are likely to present greater neuromuscular demands (Besier et al., 2001; Gabbett et al., 2008). Unplanned reactive tasks are accomplished using mechanics that are not necessarily correlated to those of pre-planned tasks and are likely to reflect better the movement patterns implemented during play (O'Connor et al., 2009). Investigating biomechanical adaptations in such tasks may hence be of use to understand and more-fully evaluate the effectiveness of AGP interventions.

The aim of this study was to investigate changes in kinematic and kinetic variables following a successful rehabilitation intervention in AGP patients performing an unplanned reactive change of direction manoeuvre (running cut). We hypothesised that multiple variables would change significantly following the intervention.

METHODS: Twenty-seven male recreational multi-directional field sport players diagnosed with AGP (mean ± SD: age 24.9 ± 5.8 years; height 180.6 ± 6.3 cm; mass 78.7 ± 8.6 kg; median, IQR: time with groin pain 36, 31 weeks) participated in this study. Informed written consent was obtained from all subjects.
Subjects completed a 90° maximum-effort reactive cutting task before (PRE) and after (POST) an exercise rehabilitation intervention. The task involved running towards a

stationary mannequin, responding to a visual signal to indicate the direction of the cutting manoeuvre (left or right), cutting in the indicated direction and finally passing through a timing gate located 2 m from the mannequin in the new direction of travel. The visual signal was given 4 m before reaching the mannequin. Total time for the manoeuvre from onset of visual signal to passing through the final timing gate was recorded (SMARTSPEED timing gates system, Fusion Sport, QLD, Australia) for each trial. A synchronised 10-camera optical motion capture (200Hz; Bonita B10, Vicon Motion Systems Ltd, Oxon, UK) and force plate (1000Hz; AMTI, MA, USA) system was used to record ground reaction forces and the positions of reflective markers placed on the body during the manoeuvre. Prior to testing all subjects completed a standardised warm-up routine involving jogging, squats and jumps.

The rehabilitation programme consisted of three levels: level one focused on intersegmental control and strength, level two on linear running mechanics and load tolerance and level three on sprinting and multidirectional mechanics. Competency was achieved at each level before progression to the next. Median time between PRE and POST testing sessions was 10.9 weeks (IQR 8.6 - 12.8 weeks). Subjects completed the Copenhagen Hip And Groin Outcome Score (HAGOS; Thorborg et al. 2011) at the time of each testing session.

Data were processed using the Vicon Plug-In Gait model to calculate joint and segment mechanics by applying standard inverse dynamics techniques (Winter, 2009). Force and marker position data were filtered using a fourth-order bidirectional Butterworth filter with a corner frequency of 15 Hz to eliminate impact artefacts. Stance phase contact time was identified by the start and end of the ground reaction force (>5 N) and kinematic and kinetic waveforms were then time-normalised to 101 data points. Paired Student's t tests were used to test the null hypotheses that total time to complete the manoeuvre and contact time during the change-of-direction stance phase did not differ PRE-POST. Statistical parametric mapping (SPM) was used to identify differences between PRE and POST biomechanical variables for the symptomatic side. Input variables were angle, moment, work, power and impulse in all three anatomical planes (flexion, adduction, internal rotation) of the hip, knee and ankle joints, and vertical displacement of the centre of body mass from the hip, knee and ankle joints. Cohen's d effect size was calculated in a point-by-point manner for differences (0.2-0.5 small; 0.5-0.8 moderate; >0.8 strong) and only significant differences with Cohen's d >0.5 were reported for SPM results.

RESULTS: All subscales of HAGOS (Pain, Symptoms, Function in Daily Living, Function in Sport and Recreation, Quality of Life and Participation in Physical Activities) improved significantly PRE to POST ($p<0.001$, Cohen's d 0.92-1.64). Neither total time to complete the manoeuvre nor contact time during the change-of-direction stance phase altered significantly following rehabilitation (Table 1). A trend towards a reduction in total time was observed but did not reach significance at $\alpha = 0.05$. Significant changes with moderate effect sizes (Cohen's d 0.51 - 0.63) were identified in kinematic and kinetic biomechanical variables. Rotation of the pelvis in the transverse plane towards the direction of intended travel increased throughout stance phase. Ankle dorsiflexion also increased and subjects demonstrated a greater ankle plantar flexor internal moment, power and impulse during the second half of stance phase. Vertical displacement of CoM relative to the knee joint increased (Table 2).

Table 1
PRE- and POST-intervention performance variables

Variable	PRE mean ± SD	POST mean ± SD	Mean % change PRE to POST	p	Effect size
Total time (s)	1.86 ± 0.12	1.83 ± 0.11	-2.1	0.06 NS	-
Contact time (s)	0.34 ± 0.05	0.34 ± 0.05	0	0.95 NS	-

Table 2
Significant differences between PRE- and POST-intervention biomechanical variables

Variable			Phase (%)	Mean ± SD change PRE to POST	Mean % change PRE to POST	p	Effect size
Pelvis	Angle (°)	Transverse	3-99	6.5 ± 2.6	n/a	<0.001	0.57
Ankle	Angle (°)	Sagittal	27-89	5.7 ± 2.9	n/a	<0.001	0.62
	Moment ($Nm.kg^{-1}$)	Sagittal	64-80	3.2 ± 1.7	10.9	<0.001	0.57
	Power ($W.kg^{-1}$)	Sagittal	79-88	0.03 ± 0.01	22.5	<0.001	0.63
	Impulse ($Nm.s.kg^{-1}$)	Sagittal	64-80	0.02 ± 0.01	10.9	<0.001	0.57
Knee	CoM-knee displacement (proportion of height)	Vertical	0-11	0.01 ± 0.00	4.6	0.032	0.51
			52-84	0.01 ± 0.01	5.4	0.002	0.51

DISCUSSION:
The observed changes suggest that subjects altered their kinetics and kinematics following a successful rehabilitation intervention for AGP. As little or no change was seen in performance variables describing time to complete the task, it is suggested that the biomechanical changes do not simply relate to an increase in overall running speed after rehabilitation but to modified movement strategies during the manoeuvre. The study design does not permit discrimination between AGP as a cause and AGP as a consequence of the biomechanics observed in the PRE group. Nevertheless, the results demonstrate that biomechanical changes following a successful intervention can be observed in the type of reactive manoeuvre applicable to a game situation.

Previous investigations of factors associated with groin and hip-related pain have typically focused on variables associated with the pelvis, hip and torso regions (reviewed in Whittaker et al., 2015). It is notable that the majority of PRE-POST changes in biomechanical variables identified here were located at the ankle joint. The ankle both modulates the transmission of ground reaction forces to more-proximal structures and is kinematically and kinetically influenced by the dynamics of the relatively high-mass proximal-limb and upper-body segments (Saha et al., 2008; Kluger et al., 2014). Franklyn-Miller et al. (2016) found that movement pattern clustering within an AGP cohort during a similar pre-planned change-of-direction task demonstrated significant differences in ankle kinematic variables between sub-groups, again suggesting that distal limb dynamics may be of relevance for the characterisation of differential movement strategies in an AGP population. Greater ankle plantar flexor moment and power, as observed in this study, have previously been shown to be positively related to cutting performance when changing direction through a more-acute angle than tested here (Marshall et al., 2014) and demonstrate an increased ability to generate explosive force around the ankle in the sagittal plane. The presence of separate sub-groups with distinct movement patterns in the task investigated here may have masked additional changes in outcome variables. Future studies should investigate whether this is the case.

CONCLUSION: Findings indicate that systematic biomechanical changes following an exercise-based rehabilitation programme in patients with AGP can be observed in an unplanned reactive cutting manoeuvre even without an associated change in the mean speed of travel. The localisation of kinetic changes to the ankle joint is notable and suggests that the role of altered distal limb mechanics as a cause or consequence of groin pain in an athletic population warrants further investigation. Such investigation may lead to further understanding of rehabilitation outcome measures for AGP.

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Acknowledgements

This work was supported by Sports Surgery Clinic, Santry, Dublin, Ireland.