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The *Presenting Author* commits himself to attend the conference. The *Presenting Author* will be Mr Shane Gore

TITLE	Stiffness as an outcome measure of rehabilitation in athletic groin pain patients		
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Topic: Functional Assessment

Introduction: Athletic groin pain (AGP) is a chronic condition, prevalent in field sports including football. Current outcome measures following rehabilitation in AGP include radiological and clinical measures [1], however these provide little insight into potential propagative movements associate with AGP. A detailed biomechanical assessment may be used to identify other potential outcome measures in AGP. One biomechanical measure, which may be of particular importance for injury risk, is stiffness. Previous research has associated greater stiffness with for example stress fracture [2], and contrastingly lesser stiffness with achilles tendinopathy [3]. To date however, stiffness has not been examined in AGP. The purpose of this investigation was to examine if sagittal plane joint stiffness of the hip, knee and ankle are potential outcome measures of successful rehabilitation in AGP.

Methods: Sixty-five male patients presenting with AGP and fifty male controls were recruited to this study. Assessment included patient report outcome measures, adductor squeeze scores and a biomechanical examination of stiffness during a lateral hurdle hop test. Subjects with AGP were tested pre and post rehabilitation, while controls were tested once. The biomechanical assessment involved three trials of a lateral hurdle hop test. Reflective markers (14mm diameter) were placed at bony landmarks on the lower limbs, pelvis and trunk as per the Vicon Plug in Gait model (Vicon, Oxford, UK). Eight infrared cameras (200Hz; Vicon, Bonita B10, UK), synchronized with two force platforms (1000Hz, AMTI, BP400600, USA) collected marker motion and force data respectively. Marker and force data were filtered using a fourth order low pass Butterworth filter at 15 Hz to avoid impact artifacts. The data was subsequently exported to Matlab 2013b (Mathworks, USA), where stiffness was calculated and the statistical analysis conducted. Stiffness was examined during the eccentric phase of the hurdle hop action. During this phase, normalized joint stiffness was calculated as the ratio of change in joint moment to the change in joint angle (Eq. 1):

$$\text{Normalised joint stiffness (NJS)} = (\Delta M. kg^{-1}) / \Delta \theta$$

Where ΔM is the change in joint moment and $\Delta\theta$ is the range of motion of the joint. Given the observation of fluctuating joint moment signs (e.g. between eccentric and concentric hip extensor moments), a novel weighted mean stiffness calculation was proposed to adequately represent the mean stiffness of a joint. The mean weighted net joint stiffness was calculated from the net joint stiffness of each phase i where the joint was acting eccentrically (Eq. 2):

$$\text{Mean weighted net joint stiffness} = \left[\sum_{i=1}^{i_{max}} (N)S_i + \Delta\theta_i \right] / \sum_{i=1}^{i_{max}} \Delta\theta_i$$

All results are presented as mean \pm SD. Cohen's effect size was reported as small (0.2 – 0.5), medium (0.5 – 0.8), and large (> 0.8).

Results: Using the HAGOS questionnaire, adductor squeeze tests and return to pain free sport as outcome measures, sixty-five athletes presenting with AGP were returned to play in a median time of 9.1 weeks with no return of symptoms. Stiffness was significantly less in the AGP pre rehabilitation in comparison to the control group at the ankle and knee but not at the hip. From pre to post rehabilitation, neither ankle nor knee stiffness changed significantly (Table 1).

Table 1: Sagittal Plane Stiffness Results

Stiffness (k)	AGP Pre	AGP Post	Control	AGP Pre vs. Control	AGP Pre vs. AGP Post		
Variable	Mean \pm SD	Mean \pm SD	Mean \pm SD	D	Sig	D	Sig
Ankle plantarflexor	1.06 \pm 0.31	1.07 \pm 0.32	1.25 \pm 0.38	0.55	0.00	0.00	0.98
Knee extensor	3.14 \pm 1.65	2.93 \pm 1.44	4.05 \pm 3.32	0.36	0.05	0.13	0.35
Hip extensor	1.01 \pm 43.05	7.45 \pm 24.77	6.42 \pm 148.45	0.05	0.79	0.15	0.31

D = Cohen's D effect size, Sig = significance (p).

Conclusion:

Despite a successful return to pain-free participation in sport in 65 players with AGP after rehabilitation, none of the variables that differed significantly to the control group pre rehabilitation, changed significantly from pre to post rehabilitation. This would suggest, based on current return to play standards, that stiffness in general is not a sufficiently sensitive measure alone to determine rehabilitation success in patients with AGP. Future research should examine joint stiffness in AGP patients in all three planes of the lower limb.

References:

- 1 Falvey ÉC, King E, Kinsella S. Athletic groin pain (part 1): a prospective anatomical diagnosis of 382 patients — clinical findings , MRI findings and patient-reported outcome measures at baseline. 2015;;1-9.
- 2 Milner CE, Hamill J, Davis I. Are knee mechanics during early stance related to tibial stress fracture in runners? *Clin Biomech* 2007;**22**:697-703.
- 3 Maquirriain J. Leg Stiff ness Changes in Athletes with Achilles Tendinopathy. *Int J Sports Med* 2012;**33**:567-71.