CHANGES IN HIP FORCE VECTOR AFTER ATHLETIC GROIN PAIN REHABILITATION DURING A RUNNING CUT

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The purpose of this study was to examine changes in hip force vectors after successful athletic groin pain rehabilitation. Forty athletes with athletic groin pain that underwent a rehabilitation intervention participated in this study. Hip force magnitude, direction and their combination were examined using a continuous waveform analysis. Hip posterior and medial force at the start and end of the movement decreased following rehabilitation, while superior forces increased (over most of the movement cycle). Findings suggest that athletes with groin pain benefit from a rehabilitation intervention that decreases posterior and medial hip joint forces.

KEY WORDS: Athletic groin pain, hip vector, intensity map.

INTRODUCTION: Athletic groin pain (groin pain) is a chronic injury in sports that involve dynamic movements (i.e. acceleration, deceleration, and sudden direction change) such as rugby union and soccer. In terms of time lost away from sport, it is behind only fracture and joint reconstruction (Ekstrand et al. 2001; Brooks et al., 2005). Although many differential diagnoses exist, it is generally agreed that all share an overload of bone or joint stabilizing muscles (Falvey et al. 2008). Possible rehabilitation approaches are surgical de-tensioning or repair of soft tissue. However, these interventions only target the symptoms rather than the cause of groin pain. Tissue overload and articular damage may be caused by poor movement strategies during unilateral high-speed activities (e.g. running cut) that require both strength and neuromuscular control. To date, no studies have examined hip forces during the running cut within groin pain patients. The analysis of hip joint forces might provide some indication if excessive forces within the joint, non-optimal force directions or a combination of both as possible drivers of groin pain. While hip forces can be examined by analyzing their magnitude or their direction, the separate analysis of forces and their direction has limitations as both factors interact with each other. Examining hip forces alone loses (to an extent) the information of force direction, while examining the force direction discards the magnitude of the force. Combining forces and their direction in one variable may reveal important information, which would be hidden otherwise, allowing a better understanding of the underlying factors of groin pain. The aim of this study was to examine the changes in hip force vector (magnitude, direction and their combination) in groin pain patients that underwent a successful rehabilitation. We hypothesized a change in hip force vector following the rehabilitation program.

Methods: Forty recreational field sports players diagnosed with chronic groin pain (mean ± *SD*: age, 24.6 ± 5.1 years; height, 181.1 ± 5.4 cm; mass, 81.9 ± 9.1 kg; time with groin pain, 63.5 ± 10.6 weeks) were recruited. Subjects performed a 75-degree change-of-direction cut using their symptomatic side before and after a rehabilitation intervention. The rehabilitation program contained 4 phases:

1) hip and pelvis stabilizing and strengthening exercises,
2) lower limb rate of force development exercises and linear running drills,
3) multidirectional running mechanics drills and
4) return to training and competition.

The progression through the phases was dictated by achieving competency in the previous level. An eight-camera motion analysis system (200Hz, Vicon, UK), synchronized with two force platforms (1000Hz, AMTI, USA), were used to collect each participant's running cut before and after the rehabilitation intervention. A detailed description of the data capture (marker placement, etc.) and processing can be found in Marshall et al. (2014). Hip forces and the hip joint center were calculated/defined using Vicon's Plug-in-Gait Model. Hip force direction was calculated as described in Bergmann et al. (1995). Analysis of Characterizing Phases was used to identify phases of variance (key phases) for the hip force magnitude and their directions. Subject scores were calculated to describe a subject's behavior within the identified key phases as described in Richter et al. (2014). A dependent t-test was used to examine if differences exist between subject scores generated for the pre and post condition. The generated subject scores were tested for normal distribution and heterogeneity in variance. If the subject scores were found to be non-parametric, the non-parametric counterpart of the dependent t-test (Wilcoxon signed rank) was used to test if significant differences exist between the conditions. To examine the effect of the interaction between magnitude and direction of the hip force a 'hip vector intensity map' was generated. When creating a 4 section intensity map, all magnitudes with the direction of 0-90° would be summed into a section 1 measure, while all magnitudes with a direction of 91-180° would be summed into a section 2 measure and so on. This process preserves the information of both the magnitude and direction of the hip force, providing a measure of intensity over every defined section and allows a statistical analysis. This study calculated the intensity for every degree (1-2°, 2-3°, … and 359-360°) generating a waveform with an intensity measure for 1-360° around the joint center. Before statistical analysis (a point-by-point dependent t-test), the intensity waveform was smoothed using a Butterworth filter. Differences in the intensity waveforms were only accepted if they appeared in a clear block (block > 5°) and if there was a clear plateau in the Cohen's D effect size. This approach was implemented due to the high number of comparisons and the possibility of a type I error. The alpha level was set to $p = 0.05$. The Cohen's D was used to determine the effect of examined measures and classified as $d < .2$ = small, $d > .2$ = medium and $d > .8$ = large. Clinical relevant ($d > .4$) and statistical differences were reported. All data processing and analysis was performed in Matlab.

Results: Hip force vectors were altered by the intervention. The pre group was found to have significantly larger posterior forces in the beginning as well as larger posterior and medial forces at the end of the movement cycle. The post group demonstrated significant larger superior forces from 17-44% of the movement cycle (table 1).

Table 1: Significant differences in hip forces

		Phase	P value	Cohen's D
Posterior Force	Pre > Post	3-11 %	.036	.38
	Pre > Post	67-100%	.001	.67
Medial Force	Pre > Post	4-7%	.072	.41
	Pre > Post	93-100%	.022	.50
Superior Force	Post > Pre	17-44%	.032	-.46
	Post > Pre	60-67%	.069	-.44
Resultant Sagittal Force	Post > Pre	18-21%	.064	-.34
	Post > Pre	22-42%	.033	-.46
	Post > Pre	59-67%	.071	-.44
Resultant Transversal Force	Pre > Post	3-9%	.026	.46
	Pre > Post	68-95%	.000	.69

Additionally, noticeable but not significant differences were found at the start of the medial forces and the end of the superior forces. For the resultant transverse plane forces, the pre-intervention group was found to have significantly larger magnitudes at the start and the end. The post-intervention group was found to have higher resultant forces in the middle of the sagittal plane, while having the tendency towards larger forces at the start and end of the movement cycle. Forces in the frontal plane and the overall resultant force (all planes combined) did not differ significantly. However, the observed effect sizes indicated a medium effect of larger forces in the post group in the first half and larger forces for the pre group at the end of the movement cycle in the frontal plane and the overall resultant force. For the force direction, the pre- and post-intervention groups differed in the frontal and sagittal planes, but not in the transversal plane. The post-intervention group demonstrated significantly greater directional angles compared to the pre-intervention group in the frontal plane over most of the movement cycle (3-8%, d = -.36; 23-31%, d = -.41; 33-42%, d = -.41 and 61-97%, d = -.57) and smaller directional angles at the end of the movement cycle in the sagittal plane (95-100%, d = .57; figure 1). The intensity analysis indicated differences between both conditions for the resulting forces. The post group had larger section measures within the frontal plane (d = -.75; figure 2a), while the pre group demonstrated larger intensity measures over two sections in the transversal plane (d ~ .70; figure 2b). The reader should note that the hip vector has been inverted in the figure 1 and 2.

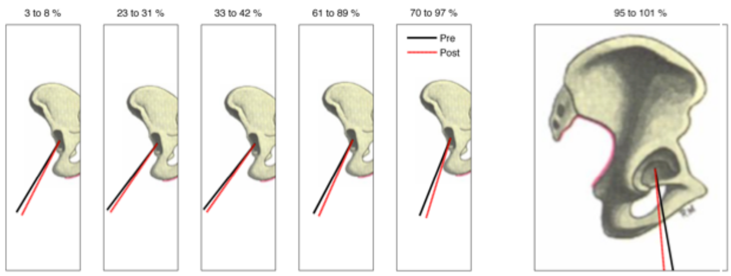
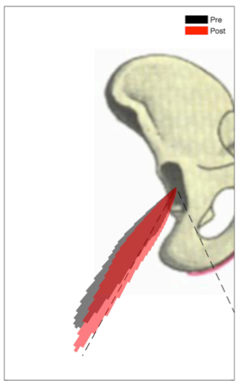


Figure 1: Illustration of the hip vector directional angle at significant different key-phases. The shown angle represents the mean angle of the presented key phase. The first five graphs (from the left) display differences in the frontal plane. The graph on the right hand side displays the sagittal plane.

Discussion: Findings of this study clearly show that the groin pain rehabilitation altered the hip forces during the running cut within the examined athletes, suggesting that joint tissues were loaded differently post rehabilitation. Findings demonstrated a decrease in posterior and medial forces at start and end of the movement with an increase of superior forces. It may be ***assumed*** that shear forces decreased (more compression towards the true joint center), which may contribute to the resolution of the symptoms of groin pain in the examined athletes. A decrease in shear forces does decrease the risk of potentially harmful joint loading pattern or an inappropriate loading of soft tissues because the hip joint is designed to absorb compression forces not shear forces. A decrease in shear forces along with an increase in compression force might have enhanced the joint health by altering the load to a more joint 'friendly' loading pattern. Additionally, such changes in the loading pattern might also be beneficial to the fibrocartilagenous ring of the hip, which is designed to tolerate compressive

a)



b)

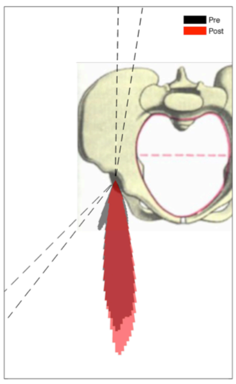


Figure 2: Illustration of the intensity map of the frontal plane (a) and transversal plane (b). Significant different areas are within the dashes black lines.

load much more efficiently than shear forces (Bian et al, 2011). Furthermore, reducing shear forces transfers the load away from hip flexors to more posterior chain structures.

The observed changes in loading pattern can be achieved by altering pelvis kinematics (change to neutral tilt and drop) as well as hip kinetics (increase of moment). Both factors have been found to enhance in a study of Gore et al. (2015), who examined kinematic and kinetic changes in a hurdle hop following the above-mentioned rehabilitation program. Overall, it can be hypothesized that improving hip stability not only provides preferential joint loading but also reduces the risk for articular damage and load on musculotendious structures. It seems that the groin pain rehabilitation improved hip stability, by dynamically stabilizing the hip through more efficient movement, and a reduction in the amount of shear forces around the hip that needed to be absorbed. However, a limitation of this study is that the hip force vector was generated using a generic model, which does not compute actual shear and compression forces acting on the hip joint, and that muscle forces that can change the hip force vector were not accounted for during the hip force calculation.

Findings of the intensity map confirmed the findings of the force magnitude and direction. In terms of the effect of changes, effect sizes highlight the importance of the interaction between the forces and directions within the planes on the joint system, as both the intensity and resultant force measures generated the highest effect sizes. Effect sizes in decreasing order are: frontal intensity measure, transversal intensity measure, the resultant transversal force, posterior force, frontal and sagittal force direction and the medial force with an absolute effect size d = .75, .70, .69, .66, .57 and .50, respectively.

CONCLUSION: Findings indicate that rehabilitation changed the hip force magnitude and its direction. Effect sizes indicated that factors that described a combination of magnitude and direction described the change best. Changes resulted in a decrease in posterior and medial and an increase in superior forces. Based on findings, athletes with groin pain should aim to decrease posterior and medial forces around the impact and toe-off phase in the hip joint.

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