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Short Term Outcomes of Hip Arthroscopy on Hip Joint Mechanics and Cartilage Health in Patients with Femoroacetabular Impingement Syndrome

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Abstract

Background: Femoroacetabular acetabular impingement syndrome (FAIS) consists of abnormal hip joint morphology resulting in painful hip joint impingement. Hip arthroscopy corrects the abnormal morphology and reduces clinical symptoms associated with FAIS yet the effects of hip arthroscopy on gait mechanics and cartilage health are not well understood.

Methods: Ten FAIS patients and 10 matched healthy controls were recruited and underwent gait analysis consisting of 3D hip joint kinematics and kinetics. FAIS patients underwent gait analysis and quantitative magnetic resonance imaging of the surgical hip joint before and seven months after surgery. Patient reported outcomes (PRO) were used to quantify hip joint pain, function and quality of life and were obtained from all study participants.

Findings: No significant differences were observed in hip joint kinematics or kinetics prior to surgery in the FAIS patients compared to healthy controls. After surgery, FAIS patients exhibited improved PRO, similar hip joint kinematic patterns, increased hip flexion moment impulse (HFMI) and decreased hip extension moment impulse within the surgical limb. FAIS patients that ambulated with increased HFMI after surgery demonstrated a decrease in posterior and anterior femoral $T1\rho$ and T2 values.

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Interpretation: FAIS patients exhibited improved PRO yet ambulated with altered sagittal plane hip joint loading after hip arthroscopy. Increased HFMI after surgery was associated with improved cartilage health within the surgical limb. These study findings suggest that sagittal plane hip joint loading at short-term follow-up after hip arthroscopy is associated with cartilage health and may be an important biomechanical parameter in post-operative rehabilitation programs.

Keywords

femoroacetabular impingement syndrome (FAIS); gait; hip joint; hip arthroscopy; impulse; magnetic resonance imaging (MRI)

1. Introduction

Femoroacetabular impingement syndrome (FAIS) consists of abnormal hip joint morphology along with clinical symptoms of impingement [1]. Abnormal contact between the femoral head and acetabulum in FAIS patients can cause altered function, and pain during activities of daily living [2]. Proper management or treatment of FAIS is important as FAIS may lead to degeneration of the hip joint cartilage and potentially result in hip joint osteoarthritis (OA) [2,3]. Hip arthroscopy is a surgical intervention used to correct the morphological abnormalities associated with FAIS [4] and is effective in improving hip joint symptoms [5,6]. Despite the improvements in hip joint symptoms, assessments of hip joint mechanics and cartilage health after hip arthroscopy are not well documented [5,7-9] and requires further study.

Previous studies have demonstrated lower hip joint sagittal [7,8,10], frontal [7,11] and transverse plane range of motion (RoM) [8] as well as lower peak hip extension [12] and abnormal hip joint loading [11-15] in pre-surgical FAIS patients when compared to healthy controls during walking. Assessment of discrete gait parameters such as peak joint moments may not be sensitive enough in detecting biomechanical differences as an effect of FAIS and therefore, may require a parameter such as the joint moment impulse [16-18] which may be more sensitive in detecting differences in joint loading in the FAIS population. Previous work has shown the external hip flexion moment impulse (HFMI) to be a sensitive measure in detecting differences in hip joint loading between the FAIS and healthy control populations [14].

Although hip arthroscopy is able to improve function and reduce pain within the symptomatic hip joint in FAIS patients, the evidence of the effects of hip arthroscopy on lower extremity joint mechanics are contradictory [5,7-9,19]. Previous work has demonstrated that at one year after hip arthroscopy, hip joint sagittal and transverse plane RoM increased within FAIS patients and was restored to similar levels as healthy controls, primarily due to an increase in peak hip flexion and internal rotation [8,9]. Another study demonstrated that at approximately 21 months after hip arthroscopy, FAIS patients walked with lower hip joint sagittal and frontal plane RoM compared to healthy controls [7] and did not display any significant changes in hip joint mechanics within the affected limb after surgery [7]. Although these longitudinal (> 1 year) studies provide vital information on post-operative gait mechanics in FAIS patients, it is important to understand the short-term (i.e. < 1 year) effects of hip arthroscopy on gait mechanics as a majority of FAIS patients are allowed to return to pre-surgical activity levels at approximately six-months post-surgery. Identification of altered gait patterns at an early time point after hip arthroscopy may help clinicians to develop better post-surgical rehabilitation protocols for FAIS patients with the intention of improving hip joint function.

Numerous studies have utilized T1ρ and T2 mapping via magnetic resonance imaging (MRI) to provide indirect measures of proteoglycan content and collagen structure, respectively, and have demonstrated worse hip joint cartilage health in the pre-surgical FAIS population compared to healthy controls [20-23]. Assessment of hip joint cartilage health after hip arthroscopy in the FAIS population is limited [5] and requires further investigation. A previous study demonstrated that at two years post hiparthroscopy FAIS patients exhibit a reduction in T1ρ relaxation times (improved proteoglycan content) within the anterosuperior hip joint cartilage [5], indicating an improvement in cartilage health after hip arthroscopy. Although beneficial, the results of the Beaule *et al* (2017) study does not allow for an understanding of the short-term outcomes (< 1 year) of hip arthroscopy on hip joint cartilage health, which may be important in developing post-surgical rehabilitation protocols aimed at preventing the onset of hip joint degeneration.

These aforementioned biomechanics- and imaging-based studies that assess the effects of hip arthroscopy on hip joint mechanics and cartilage health provide vital information to the orthopaedics-based community yet the direct relationship between hip joint loading and corresponding cartilage health after hip arthroscopy requires investigation. Therefore, the purposes of this study were to: 1) compare hip joint kinematics and kinetics prior to and seven months after hip arthroscopy within FAIS patients; 2) compared pre- and post-operative hip joint kinematics and kinetics in FAIS patients to an asymptomatic control group; and 3) evaluate the relationship between hip joint kinetics and cartilage health in the FAIS patients. It was hypothesized that after hip arthroscopy, FAIS patients would demonstrate altered hip joint mechanics compared to healthy controls and that hip joint mechanics within the surgical limb, which would be associated with hip joint cartilage health within the FAIS patients.

2. Methods

2.1. Study Participants

The affected hip joint of 10 FAIS patients (4 cam-type, 6 cam+pincer-type) were tested both before and after unilateral hip arthroscopy (Table 1). All FAIS patients were referred to the current study from the Hip Arthroscopy Clinic at our institution. All FAIS patients were tested approximately 1 month prior to and at 7.5±1.3 months after hip arthroscopy. Each FAIS patient possessed both clinical symptoms (symptom provocation with flexion adduction internal rotation [FADIR] test [24]) and abnormal hip joint morphology. A fellowship-trained orthopaedic surgeon evaluated each FAIS patient as exhibiting cam-type (alpha angle > 55° [25]) or mixed-type impingement (alpha angle > 55° and lateral center edge angle > 35°) [25,26]. Axial magnetic resonance images and anterior-posterior (AP) pelvic radiographs were used to measure alpha and lateral center edge (LCE) angles, respectively. This same orthopaedic surgeon (A.L.Z.) performed hip arthroscopic femoroplasty and labral repair in each FAIS patient, as well as acetabuloplasty in mixed-type impingement patients, utilizing a single surgical technique. It should also be noted that none of the FAIS patients in the current study received microfracture nor underwent revision hip arthroscopy.

All FAIS patients underwent the same post-surgical rehabilitation protocol. Post-operative protocol for all patients included use of crutches with foot-flat touchdown weight-bearing for two weeks without brace immobilization. Physical therapy was initiated one week after surgery with a strengthening program added at six weeks after surgery. Progression to running begins at three months, and return to sport at five to six months following surgery.

In addition, 10 age-, sex- and body mass index (BMI)-matched healthy controls with no clinical signs of impingement (negative FADIR test) were used in this study and were obtained from prior longitudinal studies of hip OA[14,27]. All controls underwent MR-imaging and AP pelvic radiographs to assess alpha and LCE angles as describe above.

Presence of radiographic hip joint OA was assessed using the Kellgren-Lawrence (KL) grading system [28] based on AP pelvic radiographs. Participants were excluded from this study if they possessed: 1) BMI > $35 kg \cdot m^{-2}$, 2) radiographic hip joint OA (KL grade >1), 3) previous hip surgery on the test limb, 4) total replacement of any lower extremity joint, 5) no pain in any lower extremity joint for the control group and no pain at any lower extremity joint other than the study hip for the FAIS group, 6) neurological, spine or lower extremity conditions that may affect gait mechanics or 7) contraindications to MRI (i.e. pregnancy, pacemaker, etc.). This study was approved by the University's Institutional Review Board and all participants provided written informed consent prior to any testing.

2.2. Gait Analysis

A 10-camera motion capture system (Vicon, Oxford, UK) and two in-ground force plates (AMTI, Watertown, MA, USA) were used to simultaneously obtain three-dimensional marker position and ground reaction force (GRF) data at 250Hz and 1000Hz, respectively. A marker set consisting of 41 retroreflective markers were used to track three-dimensional position data [13,14]. Calibration markers were placed bilaterally at the greater trochanters, medial and lateral femoral epicondyles, medial and lateral malleoli and first metatarsal head. Pelvic segment tracking was performed using retroreflective markers placed at the anterior superior iliac spines, iliac crests and the L5/S1 joint. Rigid clusters consisting of 4 markers each were placed on the lateral thighs and shanks and used for femur and tibia tracking. In addition, rigid clusters of 3 markers each were placed on the heel shoe counters and along with a retroreflective marker placed at the fifth metatarsal head were used for tracking of the foot. A one-second static calibration trial was obtained and then all calibration markers were removed.

Utilizing similar methodologies as our previous work [14], all participants were asked to perform five successful walking trials at a self-selected speed. A walking trial was considered successful if the participant maintained their speed within ±5% of their first successful trial and the entire foot of the test limb made a clean strike on one of the two force plates. All raw marker position and GRF data were filtered using a 4^{th} order, zero-lag, low-pass Butterworth filter at cut-off frequencies of 6Hz and 50Hz, respectively. The standing calibration trial was used to create a seven-segment kinematic model consisting of the pelvis, bilateral thighs, shanks and feet in Visual3D (C-Motion, Germantown, MD, USA). Local joint coordinate systems were created and an unweighted least squares method was used to describe segment position and orientation [29]. Joint coordinates were resolved using a Cardan sequence of X-Y'-Z'', representing the medial-lateral, anterior-posterior and superior-inferior directions, respectively [30]. Joint angles were normalized to the standing calibration trial. External joint moments were calculated using a standard inverse dynamics approach and were expressed in the same coordinate system as the joint angles[31]. Three-dimensional hip joint kinematics and moments were analyzed during the stance phase of the gait trial. The stance phase was defined as initial contact (vertical GRF > 20N) to toe-off.

The kinematic variables of interest for this study were peak hip flexion, extension, adduction, internal rotation as well as sagittal, frontal and transverse plane hip joint RoM. External 3D hip joint moments were computed and normalized by body mass ($Nm \cdot kg^{-1}$). For both joint kinematics and moments, a positive value indicates hip flexion, adduction and internal rotation. Hip flexion, extension, adduction, internal and external rotation joint moment impulses ($Nm \cdot ms \cdot kg^{-1}$) were calculated as the integral of the particular joint moment with respect to time (ms). In addition, the duration of each of the particular joint moments were also computed. The dependent variables were computed for each individual trial and the average of each dependent variable across all five trials was used for statistical analyses. All biomechanical data reduction and analyses were performed using custom written MATLAB programs (The MathWorks, Natick, MA, USA).

2.3. Magnetic Resonance Imaging

Each FAIS patient underwent a 3-Tesla MR exam (MR750, GE Healthcare, Waukesha, WI, USA) of the surgical hip joint using an 8-channel cardiac coil (GE Healthcare, Waukesha, WI, USA) at both the pre- and post-surgical time points. FAIS patients were positioned supine and were secured with straps on the MR-scanner. In addition, the feet of the FAIS patients were secured to prevent excessive hip rotation during the MR-exam. A combined $T1\rho$/T2 mapping sequence [32,33] was utilized to assess hip joint cartilage composition. An atlas-based method was used to perform fully automatic-segmentation of the acetabular and femoral cartilage layers [34]. $T1\rho$ and T2 values estimated using this fully automatic-segmentation method for both the acetabular and femoral cartilage were highly correlated (R=0.79 – 0.90) and were similar (coefficient of variation < 3%) to $T1\rho$ and T2 values computed using manual-based segmentation by an expert user.[35] The acetabular and femoral cartilage were subdivided into 8 sub-regions [34,36] with $T1\rho$ and T2 values quantified in each of these regions. Region 1 corresponds to the posterior hip joint while Region 8 corresponds to the anterior hip joint.[34,37] Small regions consisting of less than 50 voxels over all segmented slices were excluded from the analysis. $T1\rho$ and T2 mapping provides an indirect measure of the cartilage proteoglycan content[38,39] and collagen structure[40], respectively, whereby a larger $T1\rho$ or T2 value indicates worse proteoglycan content or collagen structure.

2.4. Patient Reported Outcomes (PRO)

All participants were asked to fill out the Hip disability and Osteoarthritis Outcome Score (HOOS) [41], in order to obtain self-reported measures of hip joint pain, function and quality of life (QOL). The HOOS sub-scores are based on a 0 to 100-point scale, where 0 represents severe pain, disability and poor QOL and 100 represents no pain, disability and excellent QOL. Femoroacetabular impingement syndrome patients completed the HOOS at both the pre- and post-surgical time points.

2.5. Statistical Analyses

Between-group differences in PRO, walking speeds, alpha and lateral center edge angles were assessed using independent t-tests ($p<0.05$). Group differences in hip joint kinematics and kinetics between controls and FAIS (pre- and post-surgical) patients were assessed using separate analyses of variance (ANOVAs), with a Bonferroni correction to adjust for multiple comparisons ($p<0.05$). Distributions of the dependent variables were tested using Levene's Test of Equality. Dependent variables that exhibited non-uniform distributions were assessed using Mann-Whitney U-Tests. Within group differences in PRO, walking speeds and gait mechanics for the FAIS patients were assessed using paired t-tests ($p<0.05$). Also, associations between the changes in the statistically significant hip joint mechanics with the changes in the T1ρ and T2 relaxation times within the FAIS group, whereby changes were defined as post-operative values minus pre-operative values, were assessed using Pearson's correlation coefficients (r). All statistical analyses were performed using SPSS (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Demographics and PRO

Age, BMI, sex, alpha and LCE angles of the FAIS and control groups were similar ($p>0.05$). Prior to surgery, the FAIS patients exhibited significantly worse hip joint pain ($p<0.01$), function ($p<0.01$) and QOL ($p<0.01$) compared to controls. After surgery, FAIS patients demonstrated a significant improvement in self-reported hip joint pain ($p<0.01$), function ($p<0.01$) and QOL ($p<0.01$) yet these improved PRO did not return to a similar level ($p<0.05$) as the controls (Table 1).

3.2. Biomechanics and Magnetic Resonance Imaging

Prior to hip arthroscopy, FAIS patients exhibited similar walking speeds ($p=0.31$), and hip joint sagittal, frontal and transverse plane joint kinematics and all joint moment-related parameters (Table 2). After hip arthroscopy, FAIS patients ambulated with a higher peak hip internal rotation (HIR) moment ($p=0.02$), HFMI ($p<0.01$), HIR moment impulse ($p=0.03$) and a lower duration of the hip extension moment ($p=0.03$) compared to the controls.

For the within-group comparison of gait mechanics before and after hip arthroscopy, FAIS patients ambulated with an increased hip flexion moment impulse (HFMI; $p<0.01$) and a corresponding decrease in the hip extension moment impulse (HEMI; $p<0.01$). The duration of the hip flexion moment increased ($p=0.01$) while the duration of the hip extension moment decreased ($p=0.01$) within the surgical limb. It should be noted that no significant differences were observed in sagittal plane hip joint kinematics or peak moments within the surgical limb after hip arthroscopy. Also, no significant changes in hip frontal or transverse plane joint kinematics or moment-related parameters were observed within the surgical limb of the FAIS patients after hip arthroscopy (Fig. 1).

Within the FAIS patients, an increased HFMI was associated with reduced T1ρ within the anterior femur (region 7; r = −0.69, p=0.04) within the surgical limb after surgery (Fig. 2). No significant relationships (p>0.05) were observed between changes in the HFMI and changes in the acetabular cartilage T1ρ or T2 relaxation times. It should be noted that post-arthroscopy T1ρ/T2 images were not useable for one of the FAIS patients due to poor image quality. Therefore, only nine complete pre- and post-surgical FAIS-related imaging data sets were used for the imaging-based analyses in our study.

4. Discussion

In this exploratory study, PRO and hip joint mechanics were examined in 10 FAIS patients before and seven months after hip arthroscopy. Hip joint mechanics did not differ between the FAIS patients and healthy controls prior to hip arthroscopy. FAIS patients reported a significant improvement in self-reported hip joint pain, function and QOL after hip arthroscopy yet ambulated with increased hip joint sagittal plane loading within the surgical limb after hip arthroscopy. More specifically, the FAIS patients ambulated with increased HFMI and reduced HEMI within the surgical limb suggesting altered sagittal plane hip joint kinetics despite the lack of kinematic differences following arthroscopy. Also, increased HFMI within the surgical limb of the FAIS patients was associated with improved femoral cartilage composition after hip arthroscopy, indicating increased sagittal plane hip joint loading after hip arthroscopy is associated with improved femoral cartilage health.

Similar to previous work [7,10], the FAIS patients in our study self-reported worse hip joint pain, function and QOL and ambulated with similar self-selected walking speeds at the pre-surgical time point compared to asymptomatic controls. Although previous studies demonstrated differences in hip joint mechanics during walking in FAIS patients compared to asymptomatic controls[10,12,42,43], our results are similar to previous work that did not observe any differences in hip joint kinematics or moments between FAIS patients and asymptomatic controls during walking [11,13,44]. It should be noted that two previously published studies[8,44] did not assess for FAI-based morphology in their healthy control group and similar to our study, may have included asymptomatic healthy controls with FAI-morphology into their study cohorts. Furthermore, previous work showed that participants with FAI-morphology demonstrated lower hip joint RoM compared to those participants without FAI-morphology [45], indicating additional factors such as assessment of the femoral neck-shaft angle and pelvic incidence [46,47], hip joint muscle force production [15,37] and strength [44,48-50] may be associated with the presence of altered hip joint mechanics in those with FAI-morphology regardless of hip joint symptoms.

The FAIS patients in our study exhibited significant improvements in self-reported hip joint pain, function and QOL after hip arthroscopy yet despite these improvements, self-reported hip joint symptoms in the FAIS patients did not normalize to similar levels as the controls.

Compared to the controls, the FAIS patients in our study did not demonstrate any alterations in hip joint kinematics at seven months after hip arthroscopy. Our results are in contrast to previous studies which demonstrated increased hip sagittal and transverse plane RoM at one-year post hip arthroscopy [8,9] yet reduced hip sagittal and frontal plane RoM at two-years post hip arthroscopy [7] in FAIS patients when compared to controls. A potential explanation for these differences in results between our study and those of Rylander *et al* (2011; 2013) and Brisson *et al* (2013), is the difference in the time of assessment after hip arthroscopy (7 months vs. 1 – 2 years).

The FAIS patients ambulated with a significantly higher HFMI compared to the control group after hip arthroscopy. The FAIS patients in our study, similar to a previous study [7], did not demonstrate any differences in hip joint kinematics, frontal or transverse plane hip joint moments within the surgical limb after hip arthroscopy. Despite a lack of change in hip joint kinematics, the FAIS patients exhibited an increased HFMI (average increase after surgery of 37.4 $Nm \cdot ms \cdot kg^{-1}$) within the surgical hip joint after hip arthroscopy. It should be noted that as there were no significant between-group differences in the peak hip flexion moment, the trend towards a longer duration of the hip flexion moment with a corresponding significant decrease in the duration of hip extension moment are the primary contributors to the higher HFMI observed in the post-surgical FAIS group. The increased HFMI indicates an alteration in the sagittal plane hip joint loading within the surgical limb of the FAIS patients after hip arthroscopy. These results help to further support that the moment impulse (discrete measure with a temporal component) may be a more sensitive parameter in detecting abnormalities in joint loading compared to peak joint moment when taken as a discrete measure. The long-term consequences of the temporal shift within the sagittal plane hip joint moment which leads to higher HFMI and lower HEMI and its relationship with long term (> 7 months) hip joint health remains unknown. Furthermore, this study only evaluated FAIS patients at an average of seven months post-surgery thereby requiring longer follow-up in order to determine the long-term habitual alterations in joint kinetics in patients post hip arthroscopy.

In addition, similar to previous work [7], the FAIS patients exhibited a significantly higher peak hip internal rotation moment as well as a significantly higher hip internal rotation moment impulse compared to the control group after hip arthroscopy. It should be noted that the average increase in the hip internal rotation moment and moment impulse after hip arthroscopy within the surgical limb of the FAIS patients is minimal (Table 2) and may not be clinically meaningful despite a statistically significant between-group difference.

Previous work has demonstrated an improvement in anterior superior (combined acetabular and femoral cartilage region of interest) hip joint cartilage health at two-years after hip arthroscopy and it was suggested that post-surgical normalization of hip joint mechanics was associated with improved cartilage health [5]. The increased HFMI within the surgical hip joint after hip arthroscopy, may suggest that the FAIS patients adopt modified gait patterns that may be associated with hip joint cartilage health. More specifically, after hip arthroscopy, the FAIS patients that ambulated with higher HFMI within the surgical hip joint exhibited improved anterior femoral cartilage health (reduced $T1\rho$ and T2 values; Figure 2) within the surgical hip joint. Our previous work in the pre-surgical FAIS population, demonstrated that better hip joint symptoms was associated with better anterior-superior femoral cartilage composition with no corresponding association observed between hip joint symptoms and acetabular composition.[51] A similar trend may exist post-operatively, as demonstrated in our current study, whereby FAIS patients that experience a larger improvement in hip joint symptoms are able to ambulate with an increased HFMI, which may provide an adequate amount of loading to the anterior femoral cartilage and lead to improvements in cartilage composition. Despite the ability to make definitive conclusions, the relationship between the HFMI and hip joint cartilage health reported in our study suggests that the HFMI is an important biomechanical parameter in the post-surgical FAIS population. Longitudinal studies with additional follow-up times are needed in order to understand the potential long-term effects of the HFMI on both acetabular and femoral cartilage health in the post-surgical FAIS population.

FAIS patients exhibit lower anterior and superior hip joint contact forces during walking both prior to and at two years post hip arthroscopy[19] compared to healthy controls. Compared to healthy controls, FAIS patients continue to exhibit weaker hip musculature despite an overall improvement in hip muscle strength at one-year post hip arthroscopy [52]. Weaker musculature present in the post-operative FAIS population may lead to the abnormal contact forces observed in the FAIS population after hip arthroscopy and may result in altered hip joint cartilage loading patterns. Although not evaluated in our study, the FAIS patients in our study that exhibit higher HFMI and corresponding improvements in hip joint cartilage health may possess higher hip joint muscle strength than those that exhibit lower HFMI and worse cartilage health. These results suggest that at this early time point after hip arthroscopy, mechanical- and physiological-based factors should be taken into consideration during post-operative rehabilitation.

Some of the limitations of this study include the small sample size of FAIS patients, short term follow-up as well as the lack of hip joint muscle strength and electromyography assessments. Hip muscle strength and electromyography data should be included in future work as hip muscle strength and muscle activity may be affected by surgical intervention and in turn affect post-surgical gait mechanics in the FAIS population. Also, it is unknown what effects the post-surgical rehabilitation protocol may have on the FAIS patients' gait mechanics observed in this study. It should be noted that despite the short-term follow-up in the current study, our group utilized one surgeon, a single surgical approach and did not include FAIS patients that underwent cartilage micro-fracture which eliminates the potential effects of surgical technique and pre-existing cartilage damage on the results of the study.

5. Conclusion

Hip joint kinematics during gait are unchanged at seven months after hip arthroscopy within FAIS patients and are similar to asymptomatic controls. However, the hip joint sagittal plane moment shows a temporal shift leading to increased hip flexion and decreased hip extension moment impulses within the surgical limb of FAIS patients after hip arthroscopy. FAIS patients that ambulated with an increased hip flexion moment impulse at seven months after hip arthroscopy demonstrated a corresponding improvement in femoral cartilage health, indicating a relationship between hip joint loading and cartilage health after hip arthroscopy.

These results suggest that the hip flexion moment impulse is an important biomechanical parameter to consider in the FAIS population. Also, short-term follow-up (i.e. 7 months) after hip arthroscopy may be an important time point to consider in the overall rehabilitation phase of FAIS patients that undergo hip arthroscopy, as it may provide insight into gait patterns that are associated with longitudinal hip joint cartilage health.

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Highlights

- Pre- & post-surgical hip joint kinematics are similar between controls & patients
- Hip flexion moment impulse increased in the patients' surgical limb after surgery
- Increased hip joint loading (post-surgery) was related to improved cartilage health

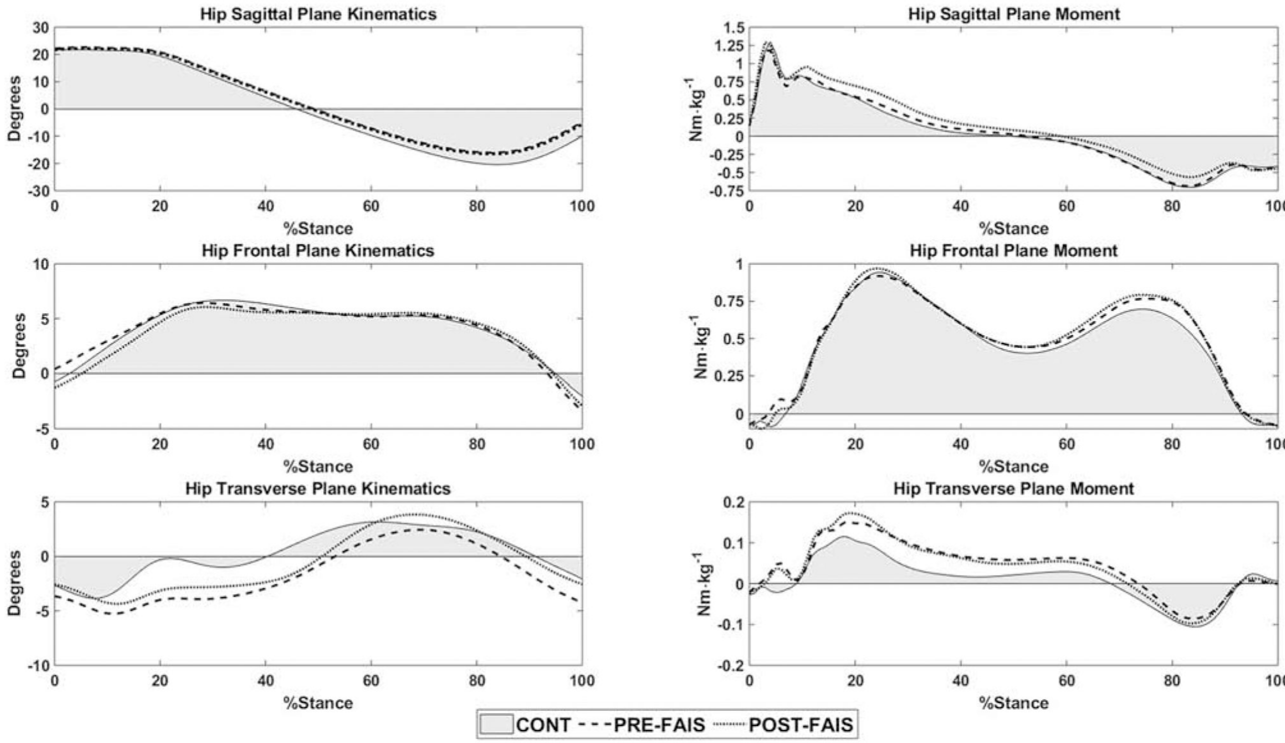

Fig. 1:

Hip joint kinematics and external joint moments for the pre-arthroscopy femoroacetabular impingement (PRE-FAIS), post-arthroscopy FAIS (POST-FAIS) and healthy control (CONT) groups are displayed. Positive values indicate hip flexion, adduction and internal rotation joint angles and moments.

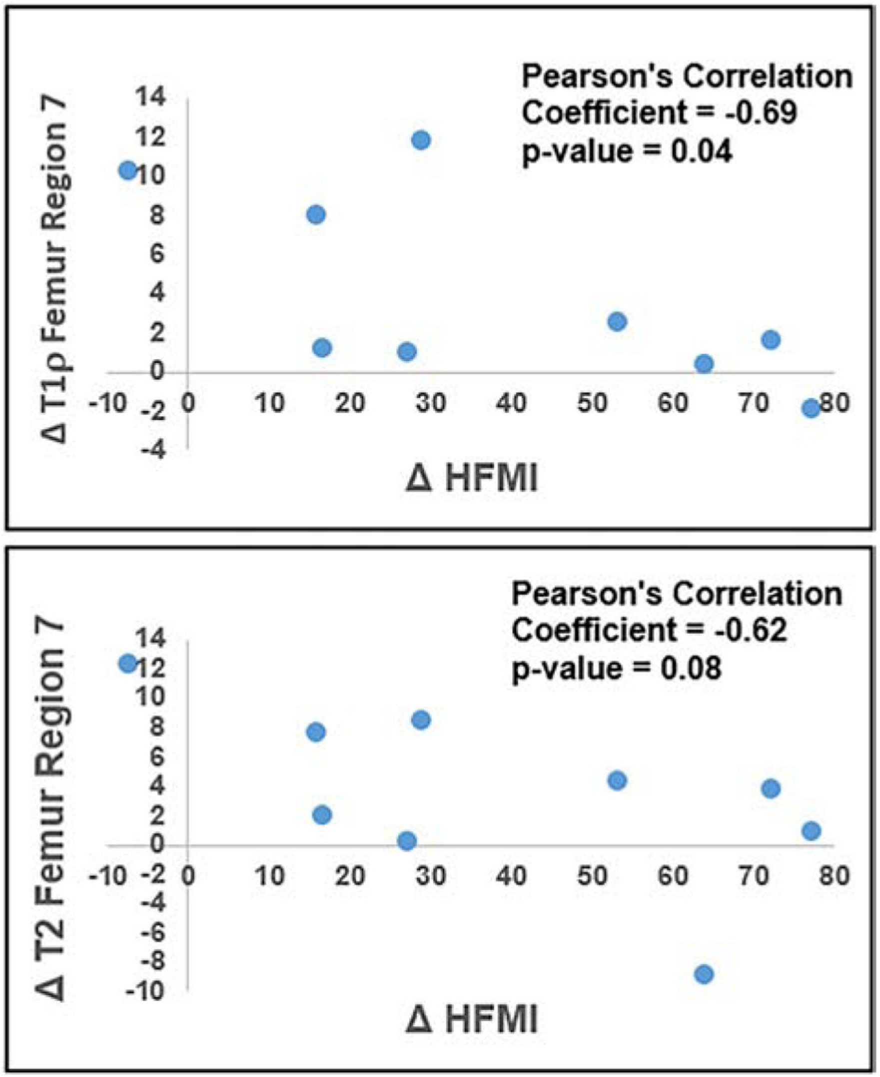

Fig 2:

An increase in the hip flexor moment impulse (HFMI) was associated with reduced T1ρ (top) and reduced T2 (bottom) cartilage relaxation times within the anterior femur of the FAIS patients after hip arthroscopy.

TABLE 1.

Demographics, Hip disability and Osteoarthritis Outcome scores (HOOS) and walking speeds presented as the Mean(Standard Deviation) for the pre- (PRE) and post-arthroscopy (POST) femoroacetabular impingement (FAIS) and healthy control (CONT) groups.

	PRE-FAIS (N=10 hips)	POST- FAIS (N=10 hips)	CONT (N=10 hips)
Age (years)	40.3(8.7)	X	35.7(4.5)
Sex (Males:Females)	8:2	X	8:2
Body Mass Index ($kg \cdot m^{-2}$)	24.8(4.4)	24.6(4.3)	24.0(3.7)
Alpha Angle (°)	62.0(2.4)	X	58.2(9.9)
Lateral Center Edge Angle (°)	34.1(7.4)	X	33.0(4.1)
Cam Type: Mixed Type	4:6	X	X
HOOS Pain *,†,‡	66.0(20.1)	90.3(7.0)	99.3(1.7)
HOOS Function *,†,‡	68.9(22.9)	95.4(6.5)	99.3(2.3)
HOOS Quality of Life *,†,‡	30.6(18.9)	71.3(16.2)	97.5(7.9)
Walking Speed ($m \cdot s^{-1}$)	1.55(0.20)	1.63(0.20)	1.65(0.26)

* Significant difference between PRE-FAIS and CONT ($p < 0.05$)

† Significant difference between POST-FAIS and CONT ($p < 0.05$)

‡ Significant difference between PRE- and POST-FAIS ($p < 0.05$)

Table 2.

Hip joint kinematics and kinetics, reported as the Mean(Standard Deviation), for the pre- (PRE) and post-arthroscopy (POST) femoroacetabular impingement (FAIS) and healthy control (CONT) groups.

	Group Data			p-values		
	PRE-FAIS	POST-FAIS	CONT	PRE-CONT	POST-CONT	PRE-POST
Kinematics (°)						
Peak Hip Flexion	24.2(8.4)	24.9(5.3)	22.3(6.9)	0.57	0.35	0.82
Peak Hip Extension	15.9(9.8)	14.4(8.6)	20.5(5.9)	0.23	0.08	0.53
Peak Hip Adduction	6.78(2.4)	6.28(2.7)	7.78(2.1)	0.34	0.18	0.44
Peak Hip Internal Rotation	2.01(10.8)	3.57(3.2)	5.69(5.3)	0.35	0.29	0.61
Hip Sagittal RoM	40.5(4.6)	39.3(5.8)	42.7(5.9)	0.35	0.20	0.43
Hip Frontal RoM	9.3(14)	9.9(2.1)	11.0(3.3)	0.14	0.37	0.26
Hip Transverse RoM	12.2(3.3)	10.7(3.8)	12.2(3.3)	0.97	0.34	0.12
Moments ($Nm \cdot kg^{-1}$)						
Peak Hip Flexion	1.35(0.30)	1.55(0.33)	1.39(0.40)	0.82	0.37	0.05
Peak Hip Extension	0.75(0.20)	0.65(0.14)	0.73(0.30)	0.86	0.43	0.14
Peak Hip Adduction	0.95(0.15)	0.97(0.13)	0.98(0.12)	0.69	0.86	0.81
Peak Hip Internal Rotation †	0.21(0.10)	0.22(0.08)	0.13(0.07)	0.07	0.02	0.80
Peak Hip External Rotation	0.12(0.06)	0.11(0.06)	0.14(0.08)	0.58	0.36	0.54
Moment Impulses ($Nm \cdot ms \cdot kg^{-1}$)						
Hip Flexion †,‡	139.2(49.5)	176.6(46.6)	125.9(24.2)	0.68	<0.01	<0.01
Hip Extension ‡	116.2(49.3)	85.8(38.1)	110.79(44.5)	0.80	0.19	<0.01
Hip Adduction	313.3(73.5)	310.7(63.6)	304.9(83.8)	0.82	0.86	0.92
Hip Internal Rotation †	40.9(10.8)	42.8(21.5)	21.5(19.6)	0.15	0.03	0.85
Hip External Rotation	10.2(9.3)	8.7(7.9)	10.2(9.3)	0.31	0.05	0.64
Moment Durations (ms)						
Hip Flexion ‡	322.8(105.7)	376.2(76.6)	305.7(83.2)	0.69	0.06	0.01
Hip Extension †,‡	302.8(91.9)	241.2(58.9)	312.2(74.8)	0.80	0.03	0.01
Hip Adduction	560.3(73.6)	539.4(58.4)	543.0(85.6)	0.63	0.91	0.24

	Group Data			p-values		
	PRE-FAIS	POST-FAIS	CONT	PRE-CONT	POST-CONT	PRE-POST
Hip Internal Rotation	438.6(117.2)	450.6(124.3)	342.1(169.3)	0.16	0.12	0.73
Hip External Rotation	187.0(95.3)	166.9(110.5)	275.8(218.3)	0.68	0.17	0.60

RoM: Range of Motion

† Significant difference between POST-FAIS and CONT ($p < 0.05$)

‡ Significant difference between PRE- and POST-FAIS ($p < 0.05$)