Preoperative Hip Extension Strength Is an Independent Predictor of Achieving Clinically Significant Outcomes After Hip Arthroscopy for Femoroacetabular Impingement Syndrome

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Background: The effect of preoperative hip strength on outcomes after hip arthroscopy for femoroacetabular impingement syndrome (FAIS) is unclear. The purpose of this study was to determine whether preoperative isometric hip strength is associated with outcome scores at 6 months as well as achieving the minimal clinically important difference (MCID) and patient acceptable symptomatic state (PASS) in patients undergoing hip arthroscopy for FAIS.

Hypothesis: Increased preoperative isometric strength will be correlated with short-term postoperative outcomes and will be predictive of achieving higher functional status.

Study Design: Case series.

Level of Evidence: Level 4.

Methods: Data from 92 consecutive patients undergoing primary hip arthroscopy for treatment of FAIS from March through August 2018 were analyzed. All patients included in the analysis had preoperative measures of isometric hip strength on both affected and unaffected limbs, as well as preoperative and 6-month patient-reported outcome (PRO) scores. Analysis was performed to determine correlations between normalized isometric hip strength measurements and PROs and whether strength measurements were predictive of achieving MCID or PASS.

Results: A total of 74 (80.4%) patients had 6-month PROs and were included in the final analysis. Hip extension strength on both sides was correlated with all postoperative PROs (all $P > 0.05$). Abduction strength on both sides was correlated with postoperative Hip Outcome Score–Activities of Daily Living subscale score, achieving MCID on at least 1 score threshold, and reaching the international Hip Outcome Tool-12 threshold score for achieving PASS (all $P < 0.05$). Regression analysis showed that extension strength on the affected side was the only strength measurement predictor of achieving PASS (1.043; $P = 0.049$).

Conclusion: Preoperative isometric hip extension and abduction strength are correlated with 6-month postoperative PRO scores. Furthermore, hip extension strength is a predictor of achieving clinically meaningful outcomes.

Clinical Relevance: This study highlights the possible importance of preoperative optimization of hip function to maximize outcomes in patients undergoing hip arthroscopy for FAIS.

Keywords: preoperative hip strength; MCID; PASS; FAIS

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Hip arthroscopy for the treatment of femoroacetabular impingement syndrome (FAIS) continues to rapidly evolve due to advanced instrumentation and surgical technique. More recently, advances in labral repair and capsular management have led to increased functional outcomes, decreased pain, and higher satisfaction.[4,18] In addition, structured physical therapy programs starting from postoperative day 1 have been established for hip arthroscopy patients treated for FAIS, limiting the time spent being immobile and incorporating hip strength training early after surgery.[16]

Previous investigations have studied hip strength in patients undergoing hip arthroscopy treatment for FAIS. Kierkegaard et al[13] investigated changes in muscle function in FAIS patients 1 year after surgical intervention, comparing their reported outcomes and postoperative hip strength with healthy controls. Despite this postsurgical increase in strength, these patients still had overall weaker hip strength compared with healthy controls receiving no intervention. However, this study did not examine the relationship between preoperative hip strength and patient-reported outcomes (PROs). Other studies have examined the association between preoperative strength and outcomes in patients undergoing total knee arthroplasty. Skoffer et al[23] determined that there was no difference in outcomes between patients who underwent preoperative training and those who did not. To our knowledge, there have not been any similar studies performed previously in the FAIS patient population.

Overall there is a paucity of evidence on the relationship of preoperative isometric hip strength, short-term PROs, and likelihood for achieving meaningful clinical outcomes in patients undergoing arthroscopic treatment for FAIS. As such, the purposes of this study were to (1) identify whether a correlation exists between preoperative isometric hip strength and PROs and (2) determine whether isometric hip strength is predictive of achieving the minimal clinically important difference (MCID) and patient acceptable symptomatic state (PASS). We hypothesized that patients with increased preoperative isometric strength will be correlated with short-term postoperative functional outcomes and will be predictive of achieving higher functional status.

METHODS

Patient Selection

This study was approved by the institutional review board of the senior author's institution. Prospective data on all patients undergoing hip arthroscopy for the treatment of FAIS were collected and analyzed in a clinical repository. All patients undergoing primary hip arthroscopy for the treatment of FAIS between March 1, 2018, and August 31, 2018, and who had hip strength testing performed preoperatively were included in this study. Inclusion criteria consisted of clinical and radiographic diagnosis of symptomatic FAIS,[6] failure of conservative management (physical therapy, activity modification, oral anti-inflammatories, and for some patients, a fluoroscopically guided intra-articular cortisone injection), and hip arthroscopy to address the FAIS with a minimum of 6-month follow-up. Exclusion criteria consisted of patients undergoing hip arthroscopy for an indication other than FAIS or prior history of surgery on the operative or nonoperative hip. In addition, general exclusion criteria for undergoing surgery by the senior author include signs of osteoarthritis (Tönnis grade >1), hip dysplasia (lateral center-edge angle <20°), or a history of congenital hip disorders (slipped capital femoral epiphysis, developmental hip dysplasia, etc).

Hip Strength Testing

Surgical candidates scheduled for hip arthroscopy underwent isometric hip strength testing prior to surgery. All testing was performed by the same 2 trained investigators using a handheld dynamometer (Lafayette Manual Muscle Testing System, Model-12-0380; Lafayette Instrument Co). For each of the hip strength measurements, the patient was instructed to press into the dynamometer by slowly building to maximal effort over a 5-second period and to avoid rapid or jerky movements. Each patient underwent hip strength testing on both the unaffected and affected hip.

Isometric hip flexion strength was measured by having the patient sit at the end of the bed, with both hips and knees flexed at 90°, and without the feet contacting the floor. The dynamometer was placed on the anterior aspect of the thigh, approximately 2 inches proximal to the superior patellar pole. The patient was instructed to "push as hard as possible" into the dynamometer (Figure 1). Isometric hip external rotation and internal rotation strength were measured with the patient in the seated position with the hip in 90° of flexion and neutral frontal and transverse plane rotation. The patients crossed their arms across their legs and placed the hand on the opposite anterior thigh to prevent hip flexion. For isometric external rotation strength testing, the dynamometer was placed 1 inch proximal to the medial malleolus of the ankle and the patient was instructed to "push the leg inward into the pad" (Figure 2). For internal rotation, the dynamometer was placed 1 inch proximal to the lateral malleolus of the ankle and the patient was instructed to "push the leg outward into the pad" (Figure 3). Isometric hip extension strength was measured with the patient in the standing position with an assistive pole to help with balance. The hip was held in neutral position in both the frontal and transverse planes and the knee was bent at 90°. The dynamometer was placed on the plantar surface of the heel of the test limb, and the patient was instructed to "push the leg backward, pressing the heel into the pad without bending or straightening the knee" (Figure 4). Isometric hip abduction strength was measured with the patient in the standing position and the hip in neutral position with the thigh positioned approximately 6 inches from a wall (Figure 5). The dynamometer was placed 1 inch proximal to the lateral condyle of the femur and the patient was instructed to apply force to the dynamometer against the wall. All isometric force measured with the handheld dynamometer was recorded and was subsequently normalized to individual body weight in kilograms

Figure 1. Measurement of isometric hip flexion strength. The patient was asked to sit at the end of the bed, with both hips and knees flexed at 90°. The dynamometer was placed on the anterior aspect of the thigh, and the patient was instructed to apply maximum force into the dynamometer for 5 seconds.

(N/kg). Isometric force was measured twice for each position and limb, and both measurements were averaged.

Surgical Technique

All hip arthroscopies were performed at a high-volume academic hospital using a technique that has been well-described in the literature.[4,7] Depending on intra-articular findings, central compartment procedures included acetabuloplasty, labral repair, or labral debridement. Cam morphology was meticulously resected until an adequate femoral head-neck offset was achieved. On completion, a dynamic examination of the operative leg was performed to confirm an appropriate resolution of impingement. The capsule was then repaired using a suture shuttling system, and plication was performed depending on degree of capsular laxity.

Postoperative Rehabilitation

Rehabilitation started on postoperative day 1 for all patients as previously described.[14,16] Patients went through a 4-phase rehabilitation protocol that lasted on average 16 to 18 weeks

Figure 2. Measurement of isometric hip external rotation strength. In the seated position with the hip in 90° of flexion and neutral frontal and transverse plane rotation, the patient was instructed to apply maximum force into the dynamometer for 5 seconds. The dynamometer was placed just proximal to the medial malleolus of the ankle. Additionally, the patient was instructed to apply pressure to the inner thigh with the opposite hand to prevent hip adduction.

(Table 1). Rehabilitation phase 1 prioritized joint protection and soft tissue mobilization techniques. The surgical limb was initially restricted to 20-pound flat-foot weightbearing with crutches during this phase. Patients were weaned off crutches if they demonstrated ambulatory capabilities without significant pain or compensatory movements 3 weeks postoperatively. Patients advanced to phase 2 if they demonstrated full weightbearing capabilities. Phase 2 concentrated on normal gait maintenance, full range of motion restoration, improvement of neuromuscular control, and maintenance of pelvic and core stability. Patients progressed to phase 3 if gait was determined to be normal and pain-free with adequate neuromuscular control. Phase 3 included single-leg squats and strengthening, soft tissue and joint mobilization, and cardiovascular fitness. Phase 4 emphasized return to preinjury level of sports participation. If a patient was involved in sports, he or she was cleared to return to sport if able to participate without pain, had full dynamic functional control, and passed all return-to-sport tests.

Functional Outcome Evaluation

Preoperatively, demographic data, including sex, age, operative extremity, body mass index, sports participation, duration of

Figure 3. Measurement of isometric hip internal rotation strength. In the seated position with the hip in 90° of flexion and neutral frontal and transverse plane rotation, the patient was instructed to apply maximum force into the dynamometer for 5 seconds. The dynamometer was placed just proximal to the lateral malleolus of the ankle. Additionally, the patient was instructed to apply pressure to the outer thigh with the opposite hand to prevent hip abduction.

Figure 4. Measurement of isometric hip extension strength. The patient was asked to stand with the hip in neutral position and the knee of the tested limb bent at 90°. The dynamometer was placed on the plantar surface of the limb being tested, and the patient was instructed to apply maximum force to the dynamometer located on the wall behind him or her.

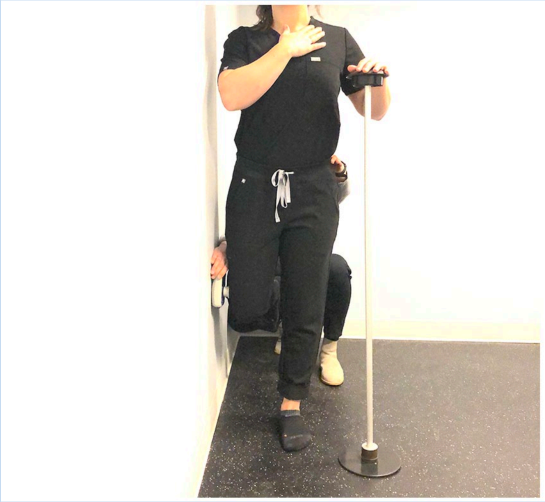

Figure 5. Measurement of isometric hip abduction strength. The patient was asked to stand with the hip of the tested side in neutral position approximately 6 inches from a wall. The dynamometer was placed 1 inch proximal to the lateral condyle of the knee and the patient was instructed to apply force to the dynamometer against the wall.

symptoms, and comorbidities, were collected from all patients. All patients completed preoperative and 6-month postoperative hip-specific PRO instruments, including the Hip Outcome Score–Activities of Daily Living subscale (HOS-ADL),[17] HOS-Sports subscale (HOS-SS), and the international Hip Outcome Tool–12 (iHOT-12).[19]

To quantify the clinical significance of outcome achievement, the principles of MCID and PASS as defined for functional PRO measures were applied. Prior work has proposed that MCID be considered a minimum target and lower bound of outcome improvement, while PASS can be considered to represent a comparatively higher outcome status rooted in the satisfaction domain.[20,21] PASS thus represents that state of health that is acceptable to the patient. MCID can be calculated using anchor-based distribution, each with its own set of limitations. The anchor-based method is limited and not suitable for patients undergoing hip arthroscopy for FAIS, where most patients will

Table 1. Postoperative rehabilitation protocol for patients with femoroacetabular impingement syndrome

Phase	Goal	Restrictions	Techniques
1	Protect the joint	• 20-lb of flat-foot weightbearing at 3 weeks • Limit flexion, abduction, extension at 3 weeks • No active sitting greater than 30 minutes at 3 weeks	• Soft tissue mobilization • Isometrics
2	Noncompensatory gait progression and active range of motion	• Work to avoid compensatory gait	• Joint mobilization • Gait training • Core strengthening/lumbar stabilization • Scar mobilization • Lumbar stabilization • Elliptical at week 6
3	Return to preinjury function	• Avoid agility drills until week 10 • Avoid hip rotational activities until week 10	• Single-leg squat • Soft tissue and joint mobilization • Core strengthening • Joint mobilization • Gait training
4	Return to sport	• Muscle strength and full range of motion goals at week 12	• Soft tissue and joint mobilizations • Cardio, strength exercises • Agility training • Plyometrics • Slow progression to return to presurgery level

report improvement and few will remain unchanged. The anchor-based method is also inherently limited by the number of patients who answer anchor-based questions. For the current study, MCID for 6-month HOS-ADL, HOS-SS, and iHOT-12 scores was determined using the distribution-based method by calculating the 0.5 SD of the change in each outcome score among the study patients, as described in the literature.[12,15,19,22]

PASS for 6-month HOS-ADL, HOS-SS, and iHOT-12 scores was calculated using an anchor-based method with an anchor satisfaction. To identify PRO scores consistent with PASS, patients were asked the following question: "Taking into account all the activities you have during your daily life, your level of pain, and also your functional impairment, do you consider that your current state is satisfactory?" The PASS value was then identified using a receiver operating characteristic curve analysis, as previously done in prior studies (see Appendix 1, available in the online version of this article).[1,2] In addition, the Youden index was used to optimize the sensitivity and specificity for determining PASS on the HOS-ADL score, HOS-SS score, and modified Harris Hip Score.[20] Consistent with prior psychometric studies in the orthopaedic literature, an area under the receiver operating characteristic curve >0.8 was considered acceptably predictive of a score defining patients who do and do not achieve PASS.

Statistical Analysis

All data were screened to determine whether parametric statistical assumptions were met prior to analysis. In cases of parametric analysis violation, nonparametric analog tests were applied. Paired-samples *t* tests were used to compare preoperative and 6-month postoperative PRO scores in FAIS patients and muscle strength between the affected and unaffected limbs. Pearson and Spearman covariate analysis was carried out to identify correlations between preoperative patient variables and 6-month reported outcomes, PASS, and MCID. The strengths of the correlation were defined as follows: excellent, >0.8; very good, 0.71-0.8; good, 0.61-0.7; moderate, 0.41-0.6; and weak, 0.21-0.4. Variables with a statistically significant correlation, including patient demographics, were entered into logistic regression models in a stepwise forward and backward method, with variables ≤0.05 remaining in the models. Two logistic regression models were created—1 for achieving PASS using any threshold and 1 for achieving MCID using any threshold to identify whether any preoperative hip strength measurement is a predictor of achieving each.

Descriptive statistics for all continuous variables are reported as means and standard deviations, and frequency statistics were reported for all noncontinuous variables. Statistical significance

Table 2. Patient Characteristics

Characteristic	Mean ± SD or n (%)
Age, y	31.9 ± 12.4
Sex	
Male	17 (23)
Female	57 (77)
Body mass index, kg/m^2	26.2 ± 5.9
Laterality	
Left	36 (48.6)
Right	38 (51.4)
Procedure performed	
Femoroplasty	74 (100)
Acetabuloplasty	74 (100)
Labral repair	74 (100)
Capsular plication	74 (100)

for all analysis was set at an $\alpha \le 0.05$. All statistical analyses were performed using SPSS (Version 25; IBM Corp).

RESULTS

Of the 92 patients with preoperative hip strength measures, 74 (80.4%) had completed 6-month outcome scores and were included in the final analysis (Table 2). The majority of patients were female (77%), with a mean age of 31.9 ± 12.4 years and a mean body mass index of 26.2 ± 5.9 kg/m^2. Just over half (51.4%) of patients underwent arthroscopy to the right hip, and all (100%) underwent labral repair, femoroplasty, acetabular rim trimming, and capsular plication.

Hip Outcome Scores, MCID, and PASS

Comparison of hip strength averages between the affected and unaffected limb showed statistically significant differences in hip flexion (27.5 vs 31.2 N/kg; $P < 0.001$), hip extension (33.6 vs 37.6 N/kg; $P = 0.008$), hip abduction (23.5 vs 25.2 N/kg; $P = 0.049$), and hip external rotation (12.9 vs 14.5 N/kg; $P = 0.014$) (Table 3). There was no statistical difference in hip internal rotation strength averages between the 2 limbs. Paired-samples *t* test analysis demonstrated a statistically significant difference between pre- and postoperative scores at 6 months for HOS-ADL (63.0 ± 17.0 vs 84.5 ± 15.9; $P < 0.001$), HOS-SS (40.1 ± 21.7 vs 68.5 ± 23.7; $P < 0.001$), and iHOT-12 (56.9 ± 16.6 vs 70.4 ± 21.1; $P < 0.001$) (Table 4).

Six-month MCID values for the HOS-ADL, HOS-SS, and iHOT-12 instruments were 12.2, 15.7, and 13.8, respectively. The HOS-ADL, HOS-SS, and iHOT-12 threshold scores for achieving PASS at 6 months were 88.9, 80.9, and 75.1, respectively (Table 5). A total of 76.8% achieved MCID on at least 1 of the 3 threshold scores, with patients most often achieving the HOS-ADL threshold for MCID. A majority (74.3%) of patients achieved PASS on at least 1 of the 3 threshold scores, with patients most often achieving the iHOT-12 threshold score for PASS.

Coefficient Analysis

The analysis of patient characteristics demonstrated a statistically moderate and significant inverse correlation between the female sex and hip strength in extension ($r = -0.524$; $P < 0.001$), abduction ($r = -0.526$; $P < 0.001$), flexion ($r = -0.354$; $P = 0.001$), external rotation ($r = -0.342$; $P = 0.002$), and internal rotation ($r = -0.451$; $P < 0.001$) on the affected limb. The results of the correlation analysis for the affected limb isometric strength testing and 6-month reported outcomes, MCID, and PASS are detailed in Table 6. Briefly, extension strength of the affected side had a weak-to-moderate statistically significant correlation with all 6-month postoperative reported outcome scores, achieving all MCID score thresholds and achieving PASS for any score (all $P < 0.05$). Abduction strength of the affected side had a weak-to-moderate statistically significant correlation with postoperative HOS-ADL, achieving any MCID threshold and achieving PASS on the iHOT-12 (all $P < 0.05$). Flexion, internal rotation, and external rotation strength of the affected side did not have any statistically significant correlations with any of the reported outcomes, achieving MCID, or achieving

Table 3. Paired *t* test analysis of affected and unaffected hip strength

	Affected	Unaffected	*P*
Flexion, N/kg	27.5 ± 10.5	31.2 ± 10.3	<0.001
Extension, N/kg	33.6 ± 17.7	37.6 ± 20.6	0.008
Abduction, N/kg	23.5 ± 10.2	25.2 ± 8.9	0.049
Internal rotation, N/kg	14.6 ± 5.9	14.7 ± 5.9	0.619
External rotation, N/kg	12.9 ± 4.9	14.5 ± 5.5	0.014

Table 4. Paired *t* test analysis of pre- and postoperative patient-reported outcome score averages

	Preoperative	Postoperative	*P*
HOS-ADL	63.0 ± 17.0	84.5 ± 15.9	<**0.001**
HOS-SS	40.1 ± 21.7	68.5 ± 23.7	<**0.001**
iHOT-12	56.9 ± 16.6	70.4 ± 21.1	<**0.001**

Boldfaced values are statistically significant ($P < 0.05$). HOS-ADL, Hip Outcome Score–Activities of Daily Living subscale; HOS-SS, Hip Outcome Score–Sports subscale; iHOT-12, international Hip Outcome Tool–12.

Table 5. MCID and pass threshold scores

	Threshold Score	Patients Achieving Threshold Scores, %
MCID		
HOS-ADL	12.2	66.2
HOS-SS	15.7	64.9
iHOT-12	13.8	56.3
Any MCID		76.8
PASS		
HOS-ADL	88.9	58.9
HOS-SS	80.9	47.7
iHOT-12	75.1	66.7
Any PASS		74.3

HOS-ADL, Hip Outcome Score–Activities of Daily Living subscale; HOS-SS, Hip Outcome Score–Sports subscale; iHOT-12, international Hip Outcome Tool–12; MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state.

PASS. None of the isometric strength measurements of the affected side were correlated with preoperative functional scores (all $P > 0.05$).

For the unaffected limb, analysis of patient characteristics also demonstrated a moderate and inverse correlation between the female sex and hip strength in extension ($r = -0.454$; $P < 0.001$),

Table 6. Correlation analysis of strength of the affected hip and reported outcomes

	Internal Rotation	External Rotation	Flexion	Abduction	Extension
Sex	**–0.451**	**–0.342**	**–0.354**	**–0.526**	**–0.524**
P	<**0.001**	**0.002**	**0.001**	<**0.001**	<**0.001**
Body mass index	0.161	0.005	–0.043	0.284	0.044
P	0.085	0.483	0.359	0.02	0.374
Age	–0.094	–0.201	–0.19	–0.087	–0.119
P	0.213	0.051	0.052	0.267	0.192
Preoperative					
HOS-ADL	–0.166	–0.033	–0.084	–0.268	–0.169
P	0.081	0.393	0.242	0.056	0.107
HOS-SS	–0.157	–0.025	–0.107	–0.143	–0.019
P	0.094	0.42	0.185	0.155	0.446
iHOT-12	–0.157	–0.025	–0.107	–0.143	–0.019
P	0.094	0.42	0.185	0.155	0.446
Postoperative					
HOS-ADL	0.131	–0.006	0.145	**0.252**	**0.328**
P	0.136	0.479	0.111	**0.035**	**0.007**
HOS-SS	0.023	0.029	0.079	0.178	**0.232**
P	0.428	0.41	0.266	0.108	**0.048**
iHOT-12	0.009	–0.059	0.059	0.196	**0.29**
P	0.472	0.313	0.311	0.082	**0.016**
Achieving MCID					
HOS-ADL	0.075	0.135	0.189	**0.405**	**0.447**
P	0.279	0.147	0.067	**0.002**	**0.001**
HOS-SS	0.051	0.12	0.086	0.231	**0.271**
P	0.338	0.169	0.243	0.055	**0.025**
iHOT-12	0.108	0.245	0.189	0.188	**0.307**
P	0.212	0.052	0.079	0.113	**0.018**
Any MCID	0.124	0.088	0.061	**0.294**	**0.274**
P	0.155	0.24	0.309	**0.02**	**0.024**
Achieving PASS					
HOS-ADL	0.12	–0.018	0.077	0.23	0.206
P	0.157	0.44	0.26	0.05	0.066

(continued)

Table 6. (continued)

	Internal Rotation	External Rotation	Flexion	Abduction	Extension
HOS-SS	–0.003	–0.003	0.03	0.168	0.177
P	0.49	0.492	0.408	0.124	0.104
iHOT-12	0.089	0.024	0.081	**0.281**	**0.314**
P	0.228	0.422	0.25	**0.023**	**0.01**
Any PASS	0.079	–0.016	0.07	0.186	**0.268**
P	0.252	0.447	0.278	0.091	**0.023**

Boldfaced values are statistically significant ($P < 0.05$). HOS-ADL, Hip Outcome Score–Activities of Daily Living subscale; HOS-SS, Hip Outcome Score–Sports subscale; iHOT-12, international Hip Outcome Tool–12; MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state.

abduction ($r = -0.394$; $P = 0.001$), flexion ($r = -0.415$; $P < 0.001$), and internal rotation ($r = -0.373$; $P = 0.001$) strength. The results of the correlation analysis for the unaffected limb and 6-month reported outcomes, MCID, and PASS are detailed in Table 7. Briefly, extension strength of the unaffected side had a weak to moderate statistically significant correlation with all 6-month postoperative reported outcome scores, achieving MCID on the HOS-SS and iHOT-12 and achieving PASS for any score (all $P < 0.05$). Abduction strength of the unaffected side had a weak and statistically significant correlation with postoperative HOS-ADL, achieving any MCID threshold and achieving PASS for any score (all $P > 0.05$). Flexion, internal rotation, and external rotation strength of the unaffected side did not have any statistically significant correlations with any of the reported outcomes, achieving MCID, or achieving PASS.

Regression Analysis

To prevent collinearity of variables, each position and limb were entered into separate regression models. Regression analysis demonstrated that hip extension strength measures of the affected side were the only strength measurement significantly predictive of achieving either MCID or PASS (1.043; $P = 0.049$) once other variables were controlled for (Table 8). Sex was entered into the regression analyses to control for possible confounders, which did not affect the log-linear relationship between extension strength and achieving PASS or MCID.

DISCUSSION

In this study, we sought to investigate the relationship between preoperative isometric hip strength and short-term clinically significant outcome improvement. The primary findings in this study were that isometric hip strength measurements, particularly abduction and extension, are positively correlated with 6-month postoperative hip function scores and likelihood for achieving MCID on at least 1 threshold score. Flexion, internal rotation, and external rotation strength of the affected side did not have any statistically significant correlations with any of the reported outcomes, achieving MCID, or achieving PASS. In regression analysis, ipsilateral hip extension strength was the only independent predictor for the achievement of PASS and MCID on hip-specific PROs. Notably, female sex was inversely correlated with all isometric hip strength measurements, including lower extension, flexion, external and internal rotation, and internal rotation strength. The findings of this study suggest that preoperative hip extension strength is an important predictor of short-term postoperative clinically significant outcomes. We believe that hip extension strength deficits can be used preoperatively to identify patients at risk for worse postoperative outcome. These patients can be appropriately triaged to targeted presurgical rehabilitation.

Prior studies have examined the relationship between sex, hip strength, and lower extremity kinematics. Jacobs et al[10] evaluated sex-based differences in hip abductor function in relation to lower extremity landing kinematics and demonstrated that females have lower hip abductor isometric peak torque and increased knee valgus peak joint displacement when landing from a jump, potentially increasing the risk of acute knee injury.

No prior study has evaluated the association between sex-based strength deficits and outcomes. In the current study, female sex was associated with lower hip-specific strength testing; however, sex was not independently predictive of outcome. Although women were more likely to be weaker in hip extension, it is the weakness in extension and not the female sex that influences the likelihood for achievement of a clinically significant outcome. Previous studies have identified sex-based differences in pre- and postoperative functional scores; however, this may in fact be attributable to kinematic derangements caused by deficits in hip strength.[5,11]

Prior studies have examined the relationship between isometric extensor hip strength and lower extremity kinematics.

Table 7. Correlation analysis of strength of the unaffected hip and reported outcomes

	Internal Rotation	External Rotation	Flexion	Abduction	Extension
Sex	**–0.373**	–0.137	**–0.415**	**–0.394**	**–0.454**
P	**0.001**	0.122	<**0.001**	**0.001**	<**0.001**
Body mass index	0.064	0.163	0.07	0.209	0.043
P	0.293	0.082	0.277	0.051	0.366
Age	–0.047	0.009	–0.144	–0.073	–0.01
P	0.345	0.47	0.111	0.287	0.469
Preoperative					
HOS-ADL	–0.188	–0.157	–0.171	**–0.374**	**–0.242**
P	0.061	0.051	0.08	**0.004**	**0.039**
HOS-SS	–0.088	–0.149	–0.058	**–0.342**	–0.007
P	0.242	0.12	0.321	**0.009**	0.482
iHOT-12	–0.195	–0.187	–0.143	**–0.426**	–0.138
P	0.058	0.069	0.127	**0.001**	0.163
Postoperative					
HOS-ADL	–0.013	–0.064	0.217	**0.3**	**0.435**
P	0.458	0.297	0.052	**0.014**	<0.001
HOS-SS	–0.103	–0.133	0.16	0.233	**0.386**
P	0.207	0.15	0.102	0.052	**0.002**
iHOT-12	–0.084	–0.138	0.171	0.196	**0.418**
P	0.242	0.128	0.076	0.082	**0.001**
Achieving MCID					
HOS-ADL	0.043	0.135	0.139	0.249	0.186
P	0.365	0.135	0.13	0.061	0.078
HOS-SS	0.013	0.004	0.086	0.156	**0.329**
P	0.461	0.487	0.262	0.14	**0.008**
iHOT-12	0.122	0.151	0.175	**0.277**	**0.34**
P	0.169	0.117	0.084	**0.02**	0.005
Any MCID	0.129	0.062	0.128	**0.294**	0.177
P	0.145	0.306	0.146	**0.013**	0.086
Achieving PASS					
HOS-ADL	0.018	–0.028	0.124	0.276	**0.217**
P	0.438	0.406	0.149	0.52	**0.043**

(continued)

Table 7. (continued)

	Internal Rotation	External Rotation	Flexion	Abduction	Extension
HOS-SS	−0.173	−0.154	0.031	0.221	**0.431**
P	0.084	0.111	0.403	0.051	<0.001
iHOT-12	0.062	−0.028	0.142	**0.291**	**0.362**
P	0.303	0.407	0.117	**0.012**	**0.002**
Any PASS	0.031	−0.071	0.102	**0.268**	**0.249**
P	0.396	0.274	0.193	**0.018**	**0.023**

Boldfaced values are statistically significant ($P < 0.05$). HOS-ADL, Hip Outcome Score–Activities of Daily Living subscale; HOS-SS, Hip Outcome Score–Sports subscale; iHOT-12, international Hip Outcome Tool–12; MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state.

Table 8. Logistic regression analysis of achieving MCID/PASS versus hip strength

	Odds Ratio	95% CI	SE	*P*
Achieving MCID				
Extension (affected side)	1.046	(0.997-1.096)	0.024	0.066
Extension (unaffected side)	1.018	(0.983-1.054)	0.018	0.312
Abduction (unaffected side)	1.069	(0.99-1.155)	0.039	0.088
Achieving PASS				
Extension (affected side)	1.043	(1.01-1.089)	0.022	**0.049**
Extension (unaffected side)	1.043	(1.00-1.087)	0.012	0.05
Abduction (unaffected side)	1.066	(0.994-1.144)	0.036	0.073

Boldfaced value is statistically significant ($P < 0.05$). MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state.

Homan et al[8] evaluated the influence of hip strength on gluteal activation and knee valgus motion. While the authors did not specifically focus on hip motion analysis, they concluded that patients with weaker isometric abduction and external rotation compensate for a lack of force production via heightened neural drive in the gluteus medius and maximus. In the present study, we found that affected hip extension strength was consistently correlated with PRO scores and was the only independent predictor of achieving a clinically significant outcome. Interestingly, flexion, internal rotation, and external rotation strength of the affected side did not have any statistically significant correlations with any of the reported outcomes, achieving MCID, or achieving PASS. We believe that hip extension strength is an important proxy for the overall hip neuromuscular envelope. Specifically, we hypothesize that patients demonstrating good hip extensor strength are more likely to achieve a normalized gait at earlier time points in their rehabilitation and thus may have the potential for accelerated improvements in short-term outcome. These findings warrant further study and have important implications for preoperative counseling and perioperative rehabilitation assessment.

Limitations

Most important, the study had very short-term follow-up, meaning these findings can only be considered preliminary. The current study has several more limitations that must be addressed. First, a small number of patients were analyzed that could have led to the study being underpowered. An a priori power analysis was not performed since an effect size was not previously established for a study assessing the association between strength and outcomes. A priori analysis inherently has its limitations, as its estimation is based on assuming that there will be a statistically significant difference between the scores. In this study, it is possible that the score difference among limbs could decrease if the sample size increased, which would further decrease the effect size and consequently increase the minimum sample size. In an ideal world, we would have used the difference in score from another study that identified statistical difference among affected and unaffected limbs, but to our knowledge, there is none. A post hoc test was performed based on the flexion strength of the affected and unaffected limb. The calculated post hoc statistical power was 0.784, which is slightly underpowered. Second, a number of different models were analyzed using the variables in the factor analysis; however, it is possible that confounders and other nonlinear associations exist between the primary outcomes and other variables not tested. Third, hip arthroscopy has a well-documented and steep learning curve[3,9]; thus, the results of the current study should be extrapolated cautiously. Last, external and internal rotation were performed with the researcher holding the dynamometer, which could have led to significant variation in measurements, resulting in the lack of correlation found with PROs.

CONCLUSION

Preoperative isometric hip extension and abduction strength are correlated with 6-month postoperative PRO scores. Furthermore, hip extension strength is a predictor of achieving clinically meaningful outcomes. The current study findings may have implications for maximizing preoperative rehabilitation and hip muscle strengthening as a means to optimize postoperative outcome.

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