Journal of Hip Preservation Surgery, 2025, **12**, 46–53
DOI: https://doi.org/10.1093/jhps/hnae042
Advance access publication date: 19 December 2024
Research Article

OXFORD

Six-month rehabilitation following surgical hip dislocation for femoroacetabular impingement restores the preoperative strength of most hip muscles, except for external rotators

Guillaume Servant[1‡], Hugo Bothorel[2‡], Anthony Pernoud[2*], Susan Mayes[3,4], François Fourchet[1,5‡], Panayiotis Christofilopoulos[6‡]

[1]Physiotherapy Department and Motion Analysis Lab, Swiss Olympic Medical Center, La Tour Hospital, Av. J.-D.-Maillard 3, Meyrin 1217, Switzerland, [2]Research department, La Tour Hospital, Av. J.-D.-Maillard 3, Meyrin 1217, Switzerland, [3]The Australian Ballet, Level 6, 2 Kavanagh Street, Southbank, Victoria 3006, Australia, [4]La Trobe Sports and Exercise Medicine Research Centre, La Trobe University, Plenty Road, Bundoora, Victoria 3086, Australia, [5]French Society of Sports Physical Therapist (SFMKS Lab), 32 rue Charles Perrin, Pierrefitte-sur-Seine, 93380 France and [6]Orthopedic Department, La Tour Hospital, Av. J.-D.-Maillard 3, Meyrin 1217, Switzerland

‡The first two authors and last two authors contributed equally to this work
*Corresponding author. Research department, La Tour Hospital, Avenue Jacob-Daniel Maillard 3, Meyrin, Geneva 1217, Suisse. E-mail: Anthony.pernoud@latour.ch

ABSTRACT

The aim of this study was to evaluate the bilateral changes in hip muscle strength after a 6-month rehabilitation period for patients undergoing surgical hip dislocation (SHD) to treat femoroacetabular impingement syndrome (FAIS). We conducted a retrospective analysis on a cohort of 22 patients (mean ± SD age: 26 ± 7, 68% male) who underwent SHD for FAIS between March 2020 and January 2023 at La Tour Hospital. Bilateral isometric strength of eight hip muscle groups (abductors, adductors, hamstrings, quadriceps, extensors, flexors, internal, and external rotators) was assessed using a handheld dynamometer before surgery, and at 3 and 6 months postoperatively. After 6 months of rehabilitation, only the external rotators were weaker compared to preoperative levels (−13% ± 23%, $P = .021$). Strength levels were similar to preoperative levelsfor adductors (−2% ± 21%, $P = .309$), internal rotators (0% ± 25%, $P = .444$), quadriceps (0%± 23%, $P = .501$), hamstrings (7%± 20%, $P = .232$), extensors (7%± 19%, $P = .336$), flexors (8%± 34%, $P = .781$), and abductors (8% ± 25%, $P = .266$). At 6 months, 59% (abductors) to 82% (adductors) of patients did not achieve a clinically relevant strength improvement (>15%) compared to their preoperative status for aforementioned muscles. Additionally, 50% of the cohort experienced a clinically relevant loss of strength in the external rotators at 6 months post-surgery. To conclude, after SHD, most FAIS patients regained their preoperative strength for all muscle groups except the external rotators with a 6-month rehabilitation program. However, the effectiveness of the rehabilitation protocol varies on an individual level.

INTRODUCTION

Femoroacetabular impingement syndrome (FAIS) is a motion-related disorder of the hip joint in which abnormal contact between the acetabulum and the proximal femur can lead to hip pain and is associated with clinical and radiologic signs [1]. The prevalence of FAIS is as high as one fifth of the general population and tends to affect young and active individuals, potentially contributing to cartilage degeneration and early osteoarthritis of the hip joint [2, 3]. In cases where nonsurgical management of FAIS fails, surgical intervention may be indicated to treat the abnormal bone morphology, either by arthroscopy or surgical hip dislocation (SHD), both of which have shown satisfactory short- and long-term outcomes [4–7].

To date, arthroscopy is increasingly performed due to its presumed less invasive nature and shorter rehabilitation period [8–11]. However, SHD offers several advantages, such as greater joint access and dynamic joint assessment, facilitating the treatment of abnormal bone morphology and concomitant hip pathologies. This makes SHD particularly appropriate for patients with more severe or complex pathology [12–14]. A negative consequence of SHD, as it involves a trochanteric osteotomy, is a longer rehabilitation due to a potentially more aggressive attitude toward extensive tissue damage and impairment of the supporting hip muscles [15]. Consequently, post-operative rehabilitation programs are crucial for addressing patients' functional impairmentsand should be guided by objec-

Received 2 May 2024; revised version accepted 5 November 2024

tive measures such as range of motion, specific functional tests (e.g. neuromuscular control assessment), and bilateral strength evaluation [13, 16].

Assessing hip muscle strength in FAIS patients has been a topic of interest over the past decade, enhancing our understanding of the condition's impact [17–19] and of muscle strength impairments following surgery [20, 21]. However, there are currently no published data on hip muscle strength once patients have completed their entire rehabilitation program after SHD. Therefore, the purpose of the present study was to compare the bilateral changes in hip muscle strength following SHD and a 6-month rehabilitation program for the treatment of FAIS. We hypothesized that patients would lose hip muscle strength within 3 months post-surgery, but would at least recover their preoperative level of hip muscle strength after completing the 6-month rehabilitation program.

MATERIAL AND METHODS

Patients

This retrospective cohort study was conducted on a consecutive series of patients who underwent SHD for FAIS at La Tour Hospital (Meyrin, Switzerland). All surgeries were performed by the same senior surgeon (PC) using a consistent surgical technique between March 2020 and January 2023, followed by a standardized 6-month rehabilitation program. Only patients residing in the Geneva area who completed their entire rehabilitation program at La Tour Hospital and without torsional malalignments requiring a correction by derotational osteotomy were included in the study. All patients were diagnosed with cam, pincer, or subspine impingement morphology (or a combination of these) with or without labral lesions. The diagnostic workup consisted of plain X-rays, magnetic resonance (MR)-arthrograms and complete computed tomography (CT) coxometry [22]. The decision to treat them with SHD rather than arthroscopy was taken based on the location of the bony abnormality and the concomitant anatomical variations detected during the preoperative workup. Exclusion criteria were contralateral hip surgery, dysplasia, previous lower extremity surgeries, arthritis, or any type of neurological disease that could lower limb musculature. Postoperative X-rays at 1 and 3 months were performed to evaluate trochanteric osteotomy healing as well as signs of necrosis and pseudarthrosis. Since this study was exploratory and based on routinely collected clinical data, an a priori approval from our ethical committee was not required. However, all the patients included in this study gave their written informed consent for the use of their data in research projects.

Preoperative and postoperative hip muscles strength assessment

Isometric muscle strength of both hips (maximal voluntary contraction, MVC) was evaluated prior to surgery and at 3 and 6 months postoperatively, using a handheld dynamometer (Hoggan MicroFET2, Scientific L.L.C., Salt Lake City, USA) with a sampling frequency of 100 Hz [23]. The measures included eight hip-related muscle groups: (1) abductors, (2) adductors, (3) flexors, (4) extensors, (5) external rotators, (6) internal rotators, (7) quadriceps, and (8) hamstrings. All evaluations were performed according to a strict methodology by a senior physiotherapist (GS). Following a 6-min warm up on a stationary bike, patients were evaluated in different testing positions, as described by Thorborg *et al.* in 2013 and Servant *et al.* [19, 21]. According to Thorborg *et al.*'s recommendations, the subjects stabilized themselves by holding the examination table while a fixation-belt was used in order to obtain better test–retest reliability [19]. After explaining the procedures, three isometric MVCs of 6 s, separated by 30 s of rest, were performed on each muscle group with verbal encouragement. The highest value of the three repetitions was recorded. If the last measurement was the highest, another measurement was conducted until no further force increase was measured. Peak forces were measured in Newtons and then normalized to arm-lever length (meters (m)) and body weight (kilograms (kg)), in order to calculate Nm/kg.

Surgical technique—surgical hip dislocation

Patients were placed under general anesthesia and positioned in lateral decubitus. Antibiotic prophylaxis was administered, followed by disinfection and draping of the entire operated lower limb. A Gautier approach [24] was used with a Z-shaped trochanteric osteotomy [25], followed by detachment of the gluteus minimus muscle from the joint capsule and using a Z-shaped capsulotomy. The hip was dislocated in flexion–external rotation, and an inspection of the central compartment was performed to look for possible labral or articular cartilage lesions. The status of the acetabular and cephalic cartilage was also assessed. An acetabuloplasty was then performed, if needed, and the labrum was reinserted using a variable number of JuggerKnot® anchors (Zimmer Biomet, Warsaw, IN, USA). A plasty of the anterior inferior iliac spine was performed if it was protruding and impinging on the femoral neck while limiting internal rotation. The proximal femur was then examined for signs of FAIS, such as bulging on the head–neck junction and filling of the anterior and antero-lateral parts of the cervicocephalic junction. The round ligament was excised and then an osteochondroplasty of the head–neck junction was performed while respecting the retinacular vessels. The hip was thereafter reduced and its stability as well as correct mobility were verified (approximately 30° of internal rotation in flexion). An abundant lavage was performed, followed by closure of the joint capsule and an osteosynthesis of the greater trochanter with two 4.5 mm screws. Radiological monitoring was performed intraoperatively to confirm good reduction of the acetabular coverage and adequate osteosynthesis of the greater trochanter. Finally, an abundant lavage was repeated before closing the incision with sutures.

Postoperative patient rehabilitation

In absence of recent published guidelines on SHD rehabilitation, this study followed the recommendations from the 2019 International Society for Hip Arthroscopy consensus [26].

First stage—immediate postoperative

During hospitalization, patients walked using crutches with 15 kg partial weight bearing on the operated limb. Three or four days after surgery, the patients went home and were asked to keep using a continuous motion device.

Second stage—early impairment

The second stage began 10 days post-surgery, once the surgical scar had healed sufficiently to allow patients to enter the water. Nine hydrotherapy groupsessions were then performed in a pool to mobilize the tissues and facilitate the kinematics of the hip while paying attention to the patients' constraints and mobilization limitations. A land-based physiotherapy session was added between the fourthand fifth hydrotherapy sessions to teach the

Table 1. Preoperative and postoperative hip muscles strength (Nm/kg) of the operated side

	Operated hips ($n = 22$)			
	Mean ±SD	**Median**	**(IQR range)**	***P*-value**
Quadriceps				
Preoperative	3.23 ± 0.97	2.96	(2.66 –3.75)	
3 months	2.68 ± 0.95	2.75	(1.74 –3.25)	***.002***
Change (%)	*−16% ± 20%*	*−11%*	*(−30% –1%)*	
6 months	3.11 ± 0.78	3.09	(2.55 –3.61)	*.501*
Change (%)	*0% ± 23%*	*−2%*	*(−11% –17%)*	
Hamstrings				
Preoperative	1.62 ± 0.33	1.61	(1.35 –1.87)	
3 months	1.52 ± 0.38	1.53	(1.21 –1.83)	*.153*
Change (%)	*−5% ± 20%*	*−8%*	*(−15% –5%)*	
6 months	1.71 ± 0.37	1.77	(1.38 –1.98)	*.232*
Change (%)	*7% ± 20%*	*3%*	*(−6% –22%)*	
Extensors				
Preoperative	2.47 ± 0.85	2.53	(1.89 –3.04)	
3 months	2.23 ± 0.75	2.36	(1.54 –2.80)	***.013***
Change (%)	*−8% ± 16%*	*−6%*	*(−15% –1%)*	
6 months	2.56 ± 0.76	2.55	(2.05 –3.10)	*.336*
Change (%)	*7% ± 19%*	*7%*	*(−7% –18%)*	
Flexors				
Preoperative	2.41 ± 0.79	2.44	(1.58 –3.02)	
3 months	2.14 ± 1.05	2.20	(1.39 –2.55)	***.036***
Change (%)	*−11% ± 31%*	*−16%*	*(−24% –5%)*	
6 months	2.53 ± 0.92	2.43	(1.81 –2.93)	*.781*
Change (%)	*8% ± 34%*	*2%*	*(−12% –20%)*	
Abductors				
Preoperative	1.97 ± 0.53	1.95	(1.59 –2.27)	
3 months	1.81 ± 0.46	1.79	(1.46 –2.23)	*.076*
Change (%)	*−7% ± 20%*	*−13%*	*(−21% –4%)*	
6 months	2.09 ± 0.59	1.91	(1.71 –2.40)	*.266*
Change (%)	*8% ± 25%*	*11%*	*(−16% –25%)*	
Adductors				
Preoperative	2.34 ± 0.76	2.34	(1.70 –2.94)	
3 months	2.17 ± 0.75	2.22	(1.64 –2.75)	***.036***
Change (%)	*−7% ± 16%*	*−7%*	*(−17% –6%)*	
6 months	2.22 ± 0.69	2.30	(1.68 –2.80)	*.309*
Change (%)	*−2% ± 21%*	*−1%*	*(−11% –4%)*	
Internal rotators				
Preoperative	1.40 ± 0.40	1.35	(1.12 –1.68)	
3 months	1.13 ± 0.42	1.12	(0.76 –1.34)	***<.001***
Change (%)	*−20% ± 16%*	*−21%*	*(−30% –5%)*	
6 months	1.35 ± 0.35	1.33	(1.06 –1.52)	*.444*
Change (%)	*0% ± 25%*	*−4%*	*(−18% –11%)*	
External rotators				
Preoperative	1.17 ± 0.36	1.10	(0.85 –1.45)	
3 months	0.98 ± 0.32	1.02	(0.74 –1.20)	***.008***
Change (%)	*−15% ± 21%*	*−11%*	*(−29% –5%)*	
6 months	1.00 ± 0.34	0.93	(0.77 –1.27)	***.021***
Change (%)	*−13% ± 23%*	*−15%*	*(−27% –0%)*	

Nm, Newton per meter; IQR, interquartile range; SD, Standard deviation.
P-values in bold indicate significant differences (in reference to the preoperative status).

exercises to be performed independently at home. A booklet was then distributed at the end of the session to help the patients reproduce these exercises correctly .

Third stage—late impairment

Full weight-bearing was then progressively allowed in a third stage but adapted to the patients' symptoms that were monitored closely during bi-weekly individual sessions of 30 min with the physiotherapist until the first functional test at 3 postoperative months.

Fourth stage—functional restoration

A progressive loading program was then applied during the fourth and last stage to increase hip muscle strength, endurance, function, dynamic balance, and gait pattern. Progressive and adapted physical activities were recommended and manual therapy techniques were used to improve hip range of motion and reduce pain [26–29]. Rehabilitation was finally completed with a phase of heavy-load-based muscle strengthening exercises and a return to full function of the hip. An additional stage of return to sports activity until return to presymptomatic performance if necessary was also carried out, which generally lasted for 1 to 3 months according to patient functional needs (see Supplementary material 1).

Sample size calculation and statistical analyses

Residual abductor weakness has been reported as a potential complication of surgical hip dislocation [30, 31]. Casartelli *et al.* [17] reported an abductor strength of 1.81 $\pm$ 0.43 Nm/kg in nonoperated FAIS patients, with a 15% difference in muscle strength of 15% considered clinically relevant [32]. Based on these findings, 20 FAIS patients would be required to significantly detect a 15% difference in abductor strength (MVC) on operated hips with a statistical power of 0.80 and a significant alpha level of 0.05.

Descriptive statistics were used to summarize the data. Continuous variables were presented as mean $\pm$ standard deviation, median and interquartile range. For categorical variables, the number of cases and proportions were reported. Normality of the data distribution of continuous variables was assessed using the Shapiro–Wilk test. Wilcoxon signed-rank tests or paired Student's t-tests were used to compare the muscle strength between the different stages of rehabilitation, and between operated and nonoperated hips. Strength changes between time points were interpreted using a threshold of 15% [32]. Casartelli *et al.* [17] reported differences in muscle strength between healthy (non-FAIS patients) and nonoperated hips (FAIS patients) for extensors (1%), abductors (11%), internal rotators (14%), external rotators (18%), flexors (26%), and adductors (28%). Variations in strength at 6 months postoperatively were then interpreted according to these thresholds to determine if the patients reached a healthy state. Analyses were performed using R (version 4.1.3, R Foundation for Statistical Computing, Vienna, Austria) and P-values <.05 were considered significant.

RESULTS

Fifty-eight cases were operated on during the period of interest, and 23 were included in the study. One patient (4%) was

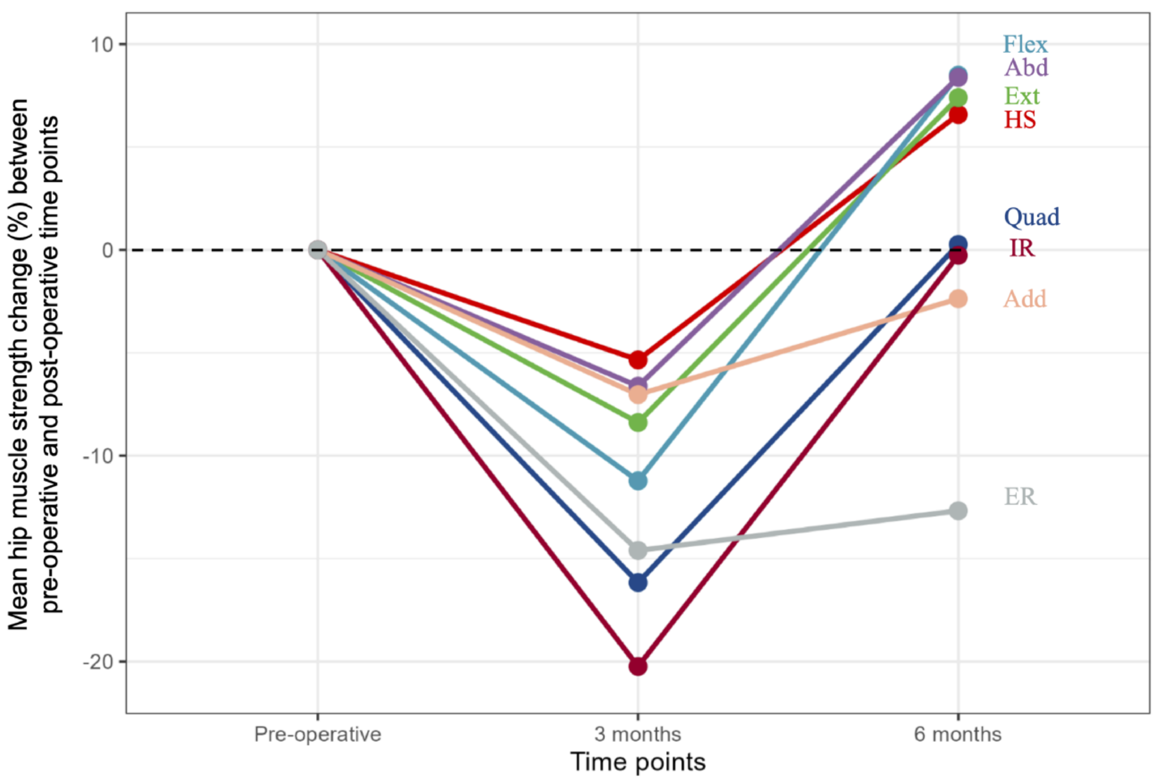

Figure 1. Line plot illustrating the muscles strength changes (%) from preoperative to postoperative time points.

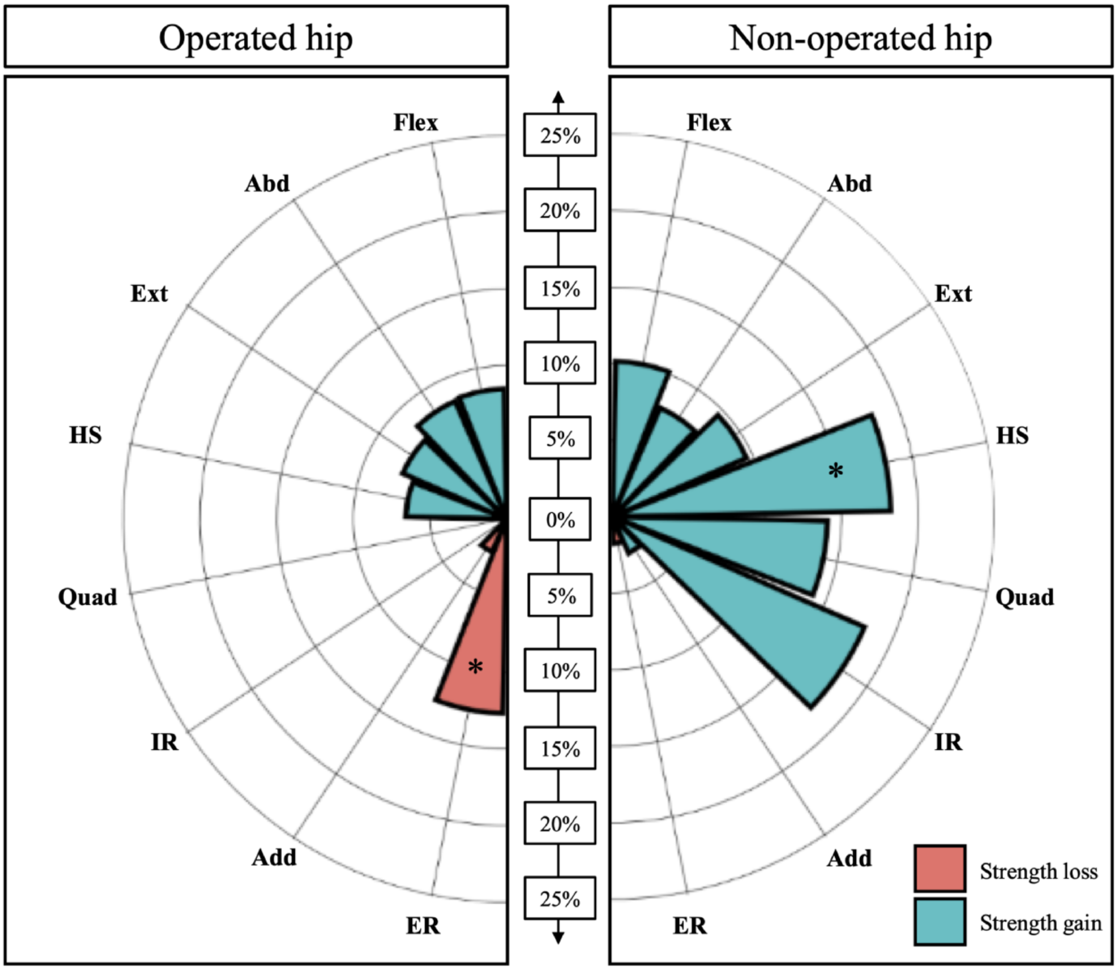

Figure 2. Preoperative to postoperative changes (at 6 months) in muscle strength (%) on the operated and nonoperated hips. *Indicates a statistically significant variation. Internal Rotators (IR), External Rotators (ER), Quadriceps (Quad), Abductors (Abd), Extensor (Ext), Hamstrings (HS), Flexors (Fl), and Adductors (Add).

excluded due to a previous operation on the opposite hip, leaving a cohort of 22 patients (68% male) aged 27 ± 7 years at the time of surgery for further analysis.

No intraoperative or postoperative complications occurred among the included patients. At 3 postoperative months, all patients had radiographic evidence of trochanteric osteotomy healing without any sign of necrosis or pseudarthrosis. On the operative side, all muscle groups, except the hamstrings and abductors, were statistically weaker at 3 postoperative months (Table 1, Fig. 1).

At 6 postoperative months, patients exhibited strength levels that did not statistically differ from preoperative measurements for most of the operated hip muscles: adductors (−2% ± 21%, $P = .309$), internal rotators (0% ± 25%, $P = .444$), quadriceps (0% ± 23%, $P = .501$), hamstrings (7% ± 20%, $P = .232$), extensors (7% ± 19%, $P = .336$), flexors (8% ± 34%, $P = .781$), abductors (8% ± 25%, $P = .266$). Only the external rotators of the operated hips remained significantly weakened at 6 months (−13% ± 23%, $P = .021$) (Table 1, Fig. 2).

Depending on the muscle group, 59% (abductors) to 91% (external rotators) of patients did not achieve a clinically relevant strength improvement (>15%) compared with their preoperative status at 6 months. The proportion of patients who experienced a clinically relevant decrease in hip muscle strength ranged from 9% (extensors) to 50% (external rotators) (Fig. 3).

At 6 months postoperatively, 36% of the patients did not achieve a healthy strength level for the extensors, 50% for the abductors, 77% for the internal rotators, 82% for the flexors, and 91% for the adductors and external rotators (Fig. 4).

On the nonoperated side, only the hamstrings showed a statistically significant improvement at 6 months compared to the preoperative status (18% ± 48%, $P = .030$). All other muscle groups showed no statistically significant change ($P > .05$, see Supplementary material 2).

DISCUSSION

This study revealed that FAIS patients who underwent SHD and a progressive loading rehabilitation regained at least their preoperative strength (not necessarily healthy) for most hip muscle groups in both operated and nonoperated hips. External rotator muscles, however, remained significantly weaker at 6 postoperative months.

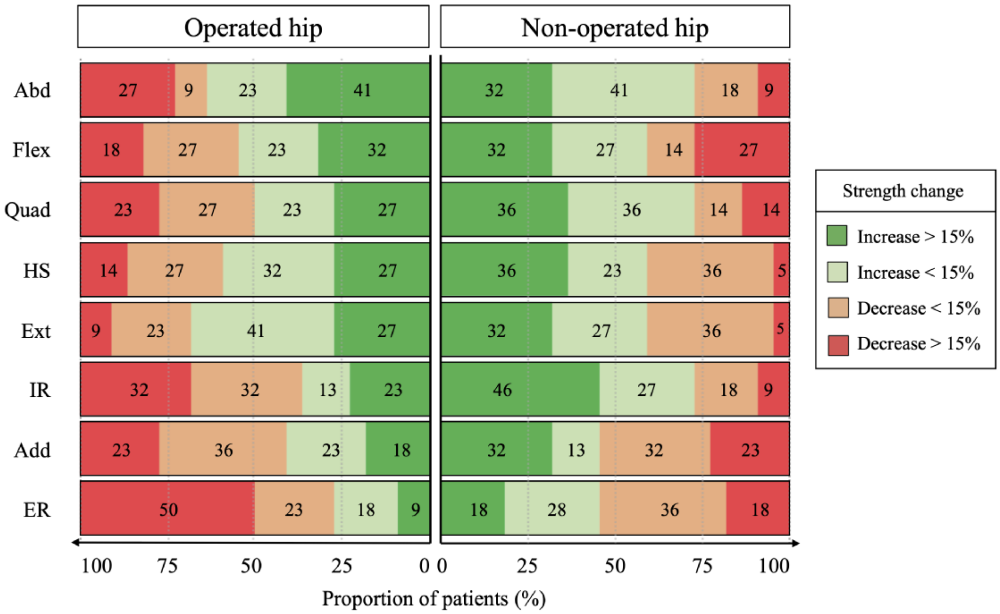

Figure 3. Patients distribution according to the relevance of their muscle strength change at 6 months following SHD on the operated and nonoperated hip. Dark green and red indicate clinically relevant variations. Internal Rotators (IR), External Rotators (ER), Quadriceps (Quad), Abductors (Abd), Extensor (Ext), Hamstrings (HS), Flexors (Fl), and Adductors (Add).

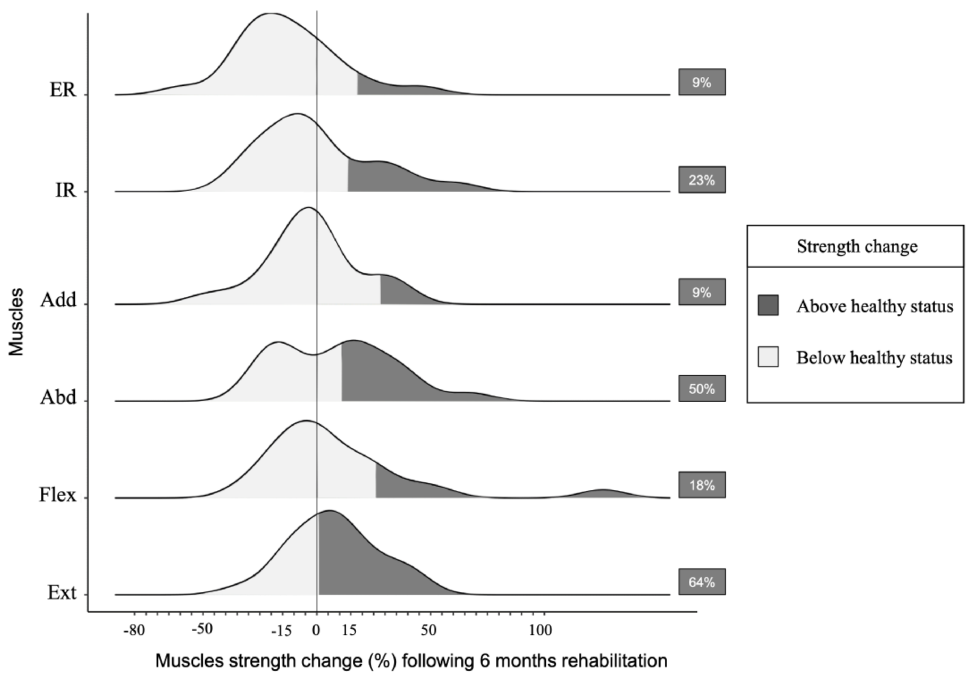

Figure 4. Ridge line plot illustrating patients' distribution and muscles strength changes according to healthy levels. Internal Rotators (IR), External Rotators (ER), Quadriceps (Quad), Abductors (Abd), Extensor (Ext), Hamstrings (HS), Flexors (Fl), and Adductors (Add).

At 3 postoperative months, patients exhibited a decrease in hip muscle strength ranging from 5% to 20%. After 6 months of progressive loading rehabilitation, the average strength of flexors, abductors, extensors, hamstrings, quadriceps, internal rotators, and adductors returned to preoperative levels (or higher). The rehabilitation program appeared to be effective in mitigating the negative consequences of SHD on most hip muscles. However, when examining individual changes and considering clinically relevant change (≥15%), only 18% (adductors) to 41% (abductors) of patients showed a strength improvement of their operated hip muscles compared to preoperative levels. Furthermore, regaining preoperative hip muscle strength may not be a sufficient rehabilitation target. Casartelli *et al.* [17] noted that hip strength levels in FAIS patients measured preoperatively are already lowered by the effects of the syndrome, suggesting that rehabilitation goals should be higher than preoperative strength for most hip muscles. For the aforementioned muscle groups, a limited proportion of patients improved their strength levels to healthy levels for extensors (64%), abductors (50%), internal rotators (23%), flexors (18%), and adductors (9%). These results suggest that a 6-month rehabilitation period may still be insufficient to restore healthy muscle strength levels after SHD.

A significant finding of this study was the lack of recovery observed in the operated hip external rotators at 6 months (−13%± 23%) compared to the preoperative status, with half of the patients experiencing a clinically relevant decrease. According to Casartelli *et al.* findings on healthy strength levels [17], approximately 90% of the operated patients exhibited external rotator strength below a healthy level. A possible explanation, which the authors will further investigate, is the possible irritation of the gluteus maximus by the screw heads on the lateral aspect of the greater trochanter. In addition, the external rotators exhibited the lowest strength improvement on the contralateral side despite bilateral strengthening exercises. The rehabilitation program appears to be ineffective in increasing external rotator strength. These findings illustrate the need for targeted strengthening exercises for this specific muscle group or further investigation into more effective exercises to regain external rotator muscle strength. For instance, in our postoperative rehabilitation protocol, we favored isometric strengthening exercises to improve hip muscle strength. However, hip external rotator muscles may benefit from other modes of strengthening such as dynamic or endurance exercises.

Limitations

This study has several limitations. First, our sample size might not be sufficient to statistically detect subtle muscle strength changes and it did not include a healthy control group. Moreover, even though it would have been unethical to do so, this study did not include a control group that did not receive the intervention of a progressive rehabilitation and therefore we cannot be sure that strength gains were due to the exercise program. Also, the strength assessments were not randomized. However, the assessment protocol followed the same order at each time point, and adequate resting periods were included to minimize the impact of fatigue. This study was only focused on objective strength assessments and did not comprise radiological measurements or patient-reported outcome measures. Although the senior physiotherapist ensured that pain did not limit MVC, collecting data on pain status could have helped to definitively rule out this potential bias. Future research could evaluate patients in the long-term to determine if gains in muscle strength correlate with improved symptoms and clinical signs. This study's cohort might not be comparable to FAIS patients followed in other institutions, and therefore, our results might not be generalizable. Last, the authors did not use Bonferroni correction in the analyses since this study was exploratory and aimed to reveal potentially interesting trends [33, 34]. Despite these limitations, this exploratory study adds relevant results to the existing scientific literature on the functional evolution of FAIS patients following SHD and complete rehabilitation.

CONCLUSION

A 6-month rehabilitation program following SHD restored strength to preoperative levels for most hip muscle groups in FAIS patients. However, the external rotators remained considerably weakened for half of the patients compared to preoperative levels. Given that hip muscles can be weaker than healthy levels preoperatively due to pain associated with pathology, further improvements in our rehabilitation program are needed to reach higher/healthy strength levels of all hip muscles.

AUTHORS' ROLE (CREDIT TAXONOMY)

GS: Conceptualization; Data curation; Investigation; Writing—original draft; Writing—review & editing; HB: Conceptualization; Methodology; Validation; Writing—original draft; Writing—review & editing; AP: Formal analysis; Methodology; Visualization; Validation; Writing—original draft; Writing—review & editing; SM: Writing—review & editing; Supervision; FF: Conceptualization; Writing—review & editing; Supervision PC: Conceptualization; Writing—review & editing; Supervision.

SUPPLEMENTARY DATA

Supplementary data is available at *Journal of Hip Preservation Surgery* online.

CONFLICT OF INTEREST

None declared.

FUNDING

This research received no specific grants from any funding agency in the public, commercial or not-for-profit sectors.

The authors received no financial or material support for the research, authorship, and/or publication of this article.

DATA AVAILABILITY

The data underlying this article will be shared upon reasonable request to the corresponding author.

REFERENCES

1. Griffin DR, Dickenson EJ, O'Donnell J *et al.* The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med* 2016;**50**:1169–76.
2. Frank JM, Harris JD, Erickson BJ *et al.* Prevalence of femoroacetabular impingement imaging findings in asymptomatic volunteers: a systematic review. *Arthroscopy* 2015;**31**:1199–204.
3. Harris-Hayes M, Royer NK. Relationship of acetabular dysplasia and femoroacetabular impingement to hip osteoarthritis: a focused review. *PM R* 2011;**3**:1055–67e1.
4. Grammatopoulos G, Laboudie P, Fischman D *et al.* Ten-year outcome following surgical treatment of femoroacetabular impingement: does the evolution of surgical technique influence outcome? *Bone Jt Open* 2022;**3**:804–14.
5. Schwabe MT, Clohisy JC, Cheng AL *et al.* Short-term clinical outcomes of hip arthroscopy versus physical therapy in patients with femoroacetabular impingement: a systematic review and meta-analysis of randomized controlled trials. *Orthop J Sports Med* 2020;**8**:2325967120968490.
6. Mahmoud SSS, Takla A, Meyer D *et al.* Arthroscopic hip surgery offers better early patient-reported outcome measures than targeted physiotherapy programs for the treatment of femoroacetabular

impingement syndrome: a systematic review and meta-analysis of randomized controlled trials. *J Hip Preserv Surg* 2022;**9**: 107–18.

7. Lund B, Mygind-Klavsen B, Gronbech Nielsen T *et al*. Danish Hip Arthroscopy Registry (DHAR): the outcome of patients with femoroacetabular impingement (FAI). *J Hip Preserv Surg* 2017;**4**:170–77.
8. Colvin AC, Harrast J, Harner C. Trends in hip arthroscopy. *J Bone Joint Surg Am* 2012;**94**:e23.
9. Gatz M, Driessen A, Eschweiler J *et al*.. Arthroscopic surgery versus physiotherapy for femoroacetabular impingement: a meta-analysis study. *Eur J Orthop Surg Traumatol* 2020;**30**: 1151–62.
10. Palmer AJR, Ayyar Gupta V, Fernquest S *et al*. Arthroscopic hip surgery compared with physiotherapy and activity modification for the treatment of symptomatic femoroacetabular impingement: multicentre randomised controlled trial. *BMJ* 2019;**364**: l185.
11. Tibor LM, Leunig M. The pathoanatomy and arthroscopic management of femoroacetabular impingement. *Bone Joint Res* 2012;**1**:245–57.
12. Ahmad SS, Heilgemeir M, Anwander H *et al*.. Surgical hip dislocation is more powerful than arthroscopy for achieving high degrees of acetabular correction in pincer type impingement. *Orthop Traumatol Surg Res* 2019;**105**:1339–44.
13. Domb BG, Stake CE, Botser IB *et al*.. Surgical dislocation of the hip versus arthroscopic treatment of femoroacetabular impingement: a prospective matched-pair study with average 2-year follow-up. *Arthroscopy* 2013;**29**:1506–13.
14. Hassan MM, Farooqi AS, Feroe AG *et al*. Open and arthroscopic management of femoroacetabular impingement: a review of current concepts. *J Hip Preserv Surg* 2022;**9**:265–75.
15. van der Grinten M, Reijman M, van Biezen FC *et al*. Trochanteric osteotomy versus posterolateral approach: function the first year post surgery. A pilot study. *BMC Musculoskelet Disord* 2011; **12**:138.
16. Wilson AS, Cui Q. Current concepts in management of femoroacetabular impingement. *World J Orthop* 2012;**3**:204–11.
17. Casartelli NC, Maffiuletti NA, Item-Glatthorn JF *et al*. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. *Osteoarthritis Cartilage* 2011;**19**:816–21.
18. Mayne E, Memarzadeh A, Raut P *et al*.. Measuring hip muscle strength in patients with femoroacetabular impingement and other hip pathologies: a systematic review. *Bone Joint Res* 2017;**6**:66–72.
19. Thorborg K, Bandholm T, Holmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surg Sports Traumatol Arthrosc* 2013;**21**:550–55.
20. Servant G, Bothorel H, Pernoud A *et al*. Hip arthroscopy followed by 6-month rehabilitation leads to improved periarticular muscle strength, except for abductors and external rotators. *Arthrosc Sports Med Rehabil* 2024;**6**:100900.
21. Servant G, Fourchet F, Pernoud A *et al*. Evolution of hip muscles strength in femoroacetabular impingement patients treated by arthroscopy or surgical hip dislocation: a retrospective exploratory study. *Biology* 2022;**11**:1765.
22. Dolan MM, Heyworth BE, Bedi A *et al*. CT reveals a high incidence of osseous abnormalities in hips with labral tears. *Clin Orthop Relat Res* 2011;**469**:831–38.
23. Mentiplay BF, Perraton LG, Bower KJ *et al*. Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: a reliability and validity study. *PLoS One* 2015;**10**:e0140822.
24. Ganz R, Gill TJ, Gautier E *et al*. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br* 2001;**83**:1119–24.
25. Bastian JD, Wolf AT, Wyss TF *et al*. Stepped osteotomy of the trochanter for stable, anatomic refixation. *Clin Orthop Relat Res* 2009;**467**:732–38.
26. Takla A, O'Donnell J, Voight M *et al*. The 2019 International Society of Hip Preservation (ISHA) physiotherapy agreement on assessment and treatment of femoroacetabular impingement syndrome (FAIS): an international consensus statement. *J Hip Preserv Surg* 2020;**7**:631–42.
27. Kemp JL, Johnston RTR, Coburn SL *et al*. Physiotherapist-led treatment for femoroacetabular impingement syndrome (the PhysioFIRST study): a protocol for a participant and assessor-blinded randomised controlled trial. *BMJ Open* 2021;**11**:e041742.
28. Kemp JL, Risberg MA, Mosler A *et al*. Physiotherapist-led treatment for young to middle-aged active adults with hip-related pain: consensus recommendations from the International Hip-related Pain Research Network, Zurich 2018. *Br J Sports Med* 2020;**54**:504–11.
29. Wahoff M, Dischiavi S, Hodge J *et al*. Rehabilitation after labral repair and femoroacetabular decompression: criteria-based progression through the return to sport phase. *Int J Sports Phys Ther* 2014;**9**:813–26.
30. Sierra RJ, Trousdale RT, Ganz R *et al*. Hip disease in the young, active patient: evaluation and nonarthroplasty surgical options. *J Am Acad Orthop Surg* 2008;**16**:689–703.
31. Tibor LM, Sink EL. Pros and cons of surgical hip dislocation for the treatment of femoroacetabular impingement. *J Pediatr Orthop* 2013;**33**:S131–6.
32. Hallberg S, Sansone M, Augustsson J. Full recovery of hip muscle strength is not achieved at return to sports in patients with femoroacetabular impingement surgery. *Knee Surg Sports Traumatol Arthrosc* 2020;**28**:1276–82.
33. Bender R, Lange S. Multiple test procedures other than Bonferroni's deserve wider use. *BMJ* 1999;**318**:600–01.
34. Perneger TV. What's wrong with Bonferroni adjustments. *BMJ* 1998;**316**:1236–38.