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Original research

Is hip muscle strength normalised in patients with femoroacetabular impingement syndrome one year after surgery? Results from the HAFAI cohort

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ABSTRACT

Objectives: Little is known about hip function after hip arthroscopic surgery in patients with femoroacetabular impingement syndrome. Hence, the aim of the study was (1) to investigate changes in hip muscle strength from before to one year after hip arthroscopic surgery, (2) to compare patients with a reference group.
Design: Cohort study with a cross-sectional comparison.
Methods: Before and after hip arthroscopic surgery, patients underwent hip muscle strength testing of their hip flexors and extensors during concentric, isometric and eccentric contraction in an isokinetic dynamometer. Reference persons with no hip problems underwent tests at a single time point. Participants completed completed the Copenhagen Hip and Groin Outcome Score (HAGOS) questionnaire and physical capacity (stair climbing loaded and unloaded, stepping loaded and unloaded and jumping) tests.
Results: After surgery, hip flexion strength improved during all tests (6–13%, $p < 0.01$) and concentric hip extension strength improved (4%, $p = 0.002$). Hip flexion and extension strength was lower for patients than for reference persons (9–13%, $p < 0.05$) one year after surgery. Higher hip extension strength after surgery was associated with better patient reported outcomes. Patients, who were unable to complete at minimum one test of physical capacity, demonstrated significantly weaker hip muscle strength. Compared with their healthy counterparts, female patients were more impaired than male patients.
Conclusions: One year after surgery, patients improved their maximal hip muscle strength. When compared to reference persons, maximal hip muscle strength was still impaired.

1. Introduction

Femoroacetabular impingement syndrome (FAIS) is a motion-related, clinical disorder with bony abnormalities of the hip joint and a triad of symptoms, clinical signs and imaging findings.[1,2] Patients experience motion-related or position related pain in the hip or groin.[1] Through hip surgery, bony abnormalities are corrected and labral tears are repaired.[2] Patients with FAIS undergoing hip preservation surgery experience increased physical function, decreased pain[3] and subsequently, many are able to return to sport at some level.[4] However, at no time point after surgery do the average patient reported outcomes (PROs) correspond to persons without hip problems,[3] and functional problems are still evident.[5]

Patients with FAIS undergoing surgery are mainly young and middle-aged[6] and the majority of patients wish to engage in physical activities.[7] In the literature, studies report on return to sport after hip arthroscopic surgery[4] and on patients' physical function and biomechanical pattern before and after surgery.[8,9] Similarly, hip muscle function in patients with FAIS has been investigated before surgery.[10,11] However, only few studies have investigated hip muscle function both before and after surgery.[11,12]

Casartelli et al.[12] reported that patients experienced full recovery of their hip muscle strength 2.5 years after surgery, except for hip flexor muscles. Nonetheless, no well-powered study could be identified that has examined hip muscle strength in patients with FAIS before and after surgery and compared the hip strength level to matched controls. Of further interest, patient reported out-

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comes on pain, physical function and quality of life change to a level that exceeds the minimal important change one year after surgery.[3] Hence, it is of interest to investigate if hip muscle strength is also increased at this time point and if relevant associations can be found.

The primary aims of the study were (1) to investigate changes in maximal hip muscle strength from before to one year after hip arthroscopic surgery and (2) to compare patients with a matched reference group. Secondary purposes included (3) to investigate associations between hip muscle strength and PROs (4) to compare hip muscle strength in patients who were unable to complete tests of physical capacity to those who were able to complete these tests and (5) to compare gender specific deficits in hip muscle strength. We hypothesized that patients' hip muscle strength would increase one year after surgery, but would remain impaired when compared to matched reference persons without hip problems.

2. Material and methods

The present study is a one-year prospective cohort study with a matched reference group. The study was approved by the Central Denmark Region Committee on Biomedical Research Ethics (1-10-72-239-14) and the Danish Data Protection Agency (1-16-02-499-14) and was registered at www.clinicaltrials.org (ID: NCT02306525). Before inclusion, all participants gave their written, informed consent in accordance with the Declaration of Helsinki II. Patients and reference persons were included and tested from December 2014 to February 2017.

Patients were eligible for inclusion if they were scheduled for primary hip arthroscopic surgery for FAIS.[1,13] Inclusion criteria were: a diagnosis of cam and/or pincer impingement; for patients with cam, an α angle ≥55° on an anteroposterior (AP) standing radiograph or axial view, for patients with pincer, a lateral center edge angle >25° on an AP radiograph and osteoarthritis grade 0–1 according to Tönnis'[14] classification joint space width of >3 mm. All measurements were conducted by the referring surgeon (BL) before inclusion in the project. Furthermore, patient age had to be between 18 and 50 years. Exclusion criteria: previous corrective hip surgery of the included hip, FAIS secondary to other hip conditions, alloplastic surgery at the hip, knee or ankle region (both legs), cancer, neurological diseases and inability to speak Danish.

Age and gender matched reference persons were eligible if they had no self-reported hip problems (further details see[13,15]).

Before and one year after (±0.1 years) surgery, patients underwent isometric (at 45° of hip flexion) and isokinetic (at ±60°/s, range 10–80° of hip flexion) strength testing of their hip flexors and extensors in an isokinetic dynamometer (Humac Norm, CSMi, Stoughton, Massachusetts, USA). The test position was supine with the backrest inclined 15°. The contralateral leg was flexed and the foot placed beside the knee of the leg being tested. Reference persons underwent the same strength test protocol at a single time point. All tests were conducted by the same investigator (SK). Further details on the strength testing have been described elsewhere.[15,16]

All participants completed the Copenhagen Hip and Groin Outcome Score (HAGOS) questionnaire[17] and multiple other questions as described in the study protocol.[13] Furthermore, patients completed physical capacity tests involving; (1) a stair climbing test, where patients were asked to walk up and down a three-cased stair-case three times with and without dumbbells equivalent to approximately 20% of their bodyweight, (2) stepping up and down a 40 cm box three times with each leg with and without dumbbells, and (3) jumping off the 40 cm box three times. A physical capacity test was considered "completed" if the patient was able to complete three trials according to the instructions. A test was considered "uncompleted", if a patient was unable to perform three repetitions, used hand support or was unable to carry a weight corresponding to 20% of their bodyweight. The physical capacity tests were selected based on our clinical experience of specific functions, that patients with FAIS in the clinic had reported to cause problems and inspired by functional problems reported by others.[9]

Patients completed the Flexion, ABduction and External Rotation test (FABER)[18] and anterior impingement tests at 90 and 120° of hip flexion.[18]

Finally, to measure relevant acetabular angles, patients underwent low radiation dose Computed Tomography (CT) scans of the hip joints. The CT scans were acquired on a Philips Brilliance 64 (Philips Medical Systems, Best, The Netherlands) scanner. The patients were scanned in supine position with parallel legs in slight internal rotation.

All sixty patients with FAIS underwent hip arthroscopic surgery performed by the same, experienced surgeon (BL, 15 years of experience, more than 2000 hip arthroscopic procedures performed) at Horsens Hospital, Denmark. Patients were operated in supine position through standard antero-lateral and mid-anterior portals. After a small interportal capsulotomy was created, a diagnostic round was accomplished from both portals and the relevant pathology was addressed. Labral tears were refixated with suture anchors. The number of anchors used for the repair depended on the quality of the labrum, and the size of the tear. In patients with a grade 4 acetabular chondral defect,[19] microfracture was performed unless the area was larger than 2–3 cm^2, then debridement was performed. Bony deformities were addressed by osteoplasty using a motorised burr.[20]

The standard rehabilitation protocol after surgery included full weight bearing as tolerated and the use of crutches for two to six weeks. The patients followed a home-based rehabilitation program inspired by Wahoff and Ryan.[21] The patients were contacted by telephone two to five days after surgery and invited to the Department of Physiotherapy two weeks, six weeks and three months after surgery where they were instructed in progression of the home-training program by a specialised physiotherapist. The rehabilitation program progressed when tolerated by the patient. At zero to two weeks after surgery, rehabilitation mainly focussed on improving blood circulation using an ergometer bike with no load together with supine laying peristaltic pump exercises. After two weeks, bike load was increased and exercises with focus on improving hip range of motion and hip and truncus strength were performed. At four-six weeks after surgery, patients were allowed to bicycle outdoor and to perform strength training at a gym if tolerated. After the 3 months instruction, patients were no longer followed at the hospital but could be assigned for further rehabilitation in the community.

The primary outcome measure of interest was the highest hip muscle strength measurement of three attempts, expressed as torque (Newton-meters, Nm). Data was then scaled to the body mass of the participant to enable comparison between individuals. The CT scan data were transferred to a Philips Mx view station (Philips Medical Systems, Best, The Netherlands). On the reformatted images the center-edge (CE) angle of Wiberg and the acetabular index (AI) of Tönnis[14] was measured in the coronal slice passing through the centers of the femoral heads. The alpha angle of Nötzli[22] was measured on oblique axial views, as the angle between a line from the center of the femoral head through the middle of the femoral neck and a line through a point where the contour of the femoral head-neck junction exceeds the radius of the femoral head. All measurements were conducted by LR.

The sample size calculation was based on hip flexion strength data reported by Casartelli et al.[12] Applying a level of significance of 0.05 and a power of 90%, the patient group should consist of at least 53 persons. The sample size calculation for the reference group has

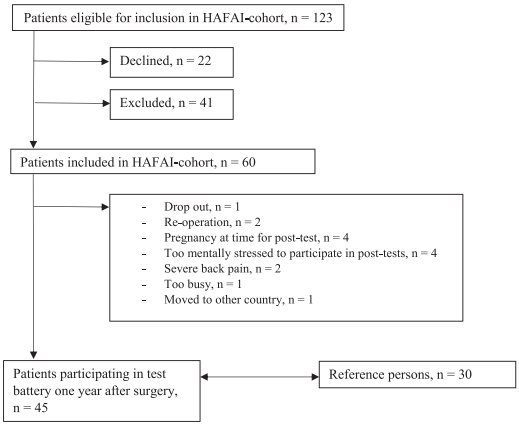

Fig. 1. Flowchart.

been described in the protocol paper.[13] Post-hoc, it was estimated that the sample size did not have as large a power for hip extension strength. Continuous data was checked for normality using histograms and Shapiro–Wilk test. If normally distributed, pre-to post comparisons were made with paired t-tests, while comparisons between patients and reference persons were made with multiple regression analyses adjusted for age and gender. Non-normally distributed data existed in some un-paired analyses (marked with ¤). Here, Wilcoxon rank sum test was applied. Binary data was analysed using Fishers Exact test. All statistical tests were performed in Stata 13® and the significance level was set at $p < 0.05$.

3. Results

Sixty patients and 30 reference persons were included in the study. Of those, 45 patients participated in the one-year follow up test (Flowchart, Fig. 1). After surgery, patients experienced changes that exceeded the minimal important changes[23] for pain, symptoms, activities of daily living (ADL), sport, participation in physical activity and hip related quality of life measured with HAGOS. The number of patients with a positive FABER test decreased from 81% to 48%. For the hip impingement test, more than ¾ of the patients were still positive at both 90 and 120° of flexion. Radiographically, patients' alpha angle measured on CT scans decreased ($p < 0.001$) and their acetabular index increased ($p = 0.008$) after surgery (Table 1 and Supplementary Table 1). No patients underwent psoas release.

Hip flexion strength of the affected hip improved during all contraction types (6–13%, $p < 0.01$) after surgery (Table 2) and hip extension strength improved in the concentric strength test (4%, $p = 0.002$). At follow-up, hip flexion and extension strength was lower for patients than for reference persons (9–13%, $p < 0.05$) (Table 2). For the contralateral leg, only isometric hip flexion strength was significantly improved after surgery.

Higher isometric hip extension strength after surgery was associated with better pain levels, ADL function and quality of life (Supplementary Table 2).

At baseline, 78–97% of patients and 100% of reference persons completed the functional capacity tests. After surgery, this increased to 82–97% (Supplementary Table 1). Both at baseline and after surgery, patients unable to complete at minimum one test demonstrated significantly lower hip muscle strength (Supplementary Table 3). This finding was consistent when clustering patients by age. Furthermore, subgroups of patient completers and non-completers at baseline and after surgery had similar hip muscle strength changes as in the total patient cohort.

Since 16 patients had surgery of their contralateral hip, a subgroup analysis comparing outcomes between bilateral and unilateral patients was made. The proportion of males was larger among bilateral ($p = 0.022$) and bilateral patients had better pain (83 vs 70, ¤ $p = 0.046$), sport (78 vs 52, ¤ $p = 0.043$) and quality of life (70 vs 43, ¤ $p = 0.020$) scores on HAGOS one year after surgery. There were no differences between bilateral and unilateral patients in age, pre or postoperative hip muscle strength levels or ability to complete physical capacity tests.

There was a gender specific impairment in hip muscle strength with females being more impaired compared to their healthy counterparts than males one year after surgery.

A sensitivity analysis was performed investigating if the 15 patients not participating in the one-year follow up test differed from the 45 patients who participated. For baseline characteristics, there were no differences in age, gender, bodyweight, body fat, alcohol consumption, smoking habits, level of education, HAGOS scores, or sick leave before surgery between the groups. At the one-year follow-up, 11 of the 15 patients not participating in the follow-up test completed questionnaires. No significant differences between the groups were seen in any of the HAGOS sub scales after surgery.

4. Discussion

One year after surgery, patients with FAIS experienced improved concentric, isometric and eccentric hip flexion strength and concentric hip extension strength compared to pre surgery levels, but patients were still weaker than reference persons. Better PROs were associated with greater hip extension strength one year after surgery. Both before and after surgery, patients able to complete physical capacity tests were significantly stronger than those unable to. Finally, female patients had larger impairments in hip muscle strength than male patients when compared to their healthy counterparts one year after surgery.

When treating FAIS surgically, the aim is to create impingement-free motion.[1] After surgery, there is a period of intra-articular healing. Hereafter, the patients should – in theory – have an impingement-free hip motion with the possibility of using their hip "normally". Lewis et al.[24] did an experimental study describing how decreased gluteal muscle force during extension and decreased iliopsoas muscle force during flexion might contribute to increased anterior hip contact forces. After surgery, there should be less risk of impingement in the hip due to the surgical removal of hip bony abnormalities. However, if the hip muscles remain weak after surgery, the anterior hip contact forces could still be substantially increased on the newly operated hip joint contributing to possible overload of the structures inside the hip joint.[24] Hence, if patients, as the findings of the current study suggests, have decreased hip flexion and extension strength after surgery, there is still a potential risk of overload of the intraarticular structures in the hip joint, e.g. the hip labrum. To the best of our knowledge, no biomechanical studies have simulated hip contact forces or muscle forces in patients with FAIS. Hence, the hypotheses of Lewis et al.[24] should be tested in studies of patients with FAIS. At the moment, the published studies on hip biomechanics in patients with FAIS have focused on differences among patients and healthy persons in range of motion and hip moments and on post-surgical data.[9] Future studies should also estimate hip contact forces and muscle forces to further describe mechanisms underlying the FAIS.

The finding of consistent impairment of hip muscle strength in the current study is in line with other studies after surgery in patients with FAIS. In a cross sectional study, Kemp et al.[8] reported that 84 patients with chondrolabral pathology had significantly lower hip flexion and extension strength 1–2 years after

Table 1
Participant characteristics and patient reported outcomes.

		n	References (mean ± sd or median [25th, 75th quartile])	n	Patients (baseline) (mean ± sd or median [25th, 75th quartile])	n	Patients (one year) (mean ± sd or median [25th, 75th quartile])	Patients (changes) (mean difference [95% confidence intervals], p-value)
Demographics	Age (years)	30	36 ± 9	60	36 ± 9		–	
	Gender distribution (% females)	30	60	60	63		58	
	Body mass (kg)	30	68 ± 9	60	76 ± 15	45	77 ± 13	
	Height (cm)	30	174 ± 8	60	174 ± 8		–	
	Fat mass (%)	30	23 ± 12	60	27 ± 10	45	27 ± 9	
Affected hip	Symptoms							
	Positive faber (%)			60	81	45	48	
	Positive 90 degree impingement (%)			60	86	45	77	
	Positive 120 degree impingement (%)			60	95	45	84	
	Alpha angle from AP			60	81 ± 10			
	Center edge angle from AP			60	31 ± 6			
	Alpha angle from CT			54	52 ± 10	42	47 ± 8	5 [3;8], p < 0.001
	Center edge angle from CT			54	33 ± 6	42	32 ± 6	1 [−0.1;1.6], p = 0.1
	Acetabular index from CT			54	2 ± 6	42	4 ± 5	1 [0.3;2.0], p = 0.008
	Copenhagen Hip and Groin Outcome Score							
	Pain		100 [100;100]	60	53 [40;65]	56	76 [63;88]	19 [14;23], p < 0.001
	Symptoms		100 [96;100]	60	46 [34;59]	56	64 [50;79]	16 [10;21], p < 0.001
	ADL		100 [100;100]	60	50 [38;70]	56	80 [63;95]	18 [13;24], p < 0.001
	Sport		100 [100;100]	60	31 [20;48]	56	59 [41;78]	22 [16;28], p < 0.001
	PA		100 [100;100]	60	13 [0;31]	56	25 [13;56]	17 [8;25], p < 0.001
	QoL		100 [100;100]	60	30 [23;40]	56	50 [35;70]	19 [14;25], p < 0.001
	Pain level during strength testing (VAS 0-100)							
	Flexion							
	Concentric (mm)			50	25 [5;50]	41	0 [0;0.5]	
	Isometric (mm)			60	22 [7;51]	45	0 [0;1.5]	
	Eccentric (mm)			50	25 [5;50]	41	0 [0;0.5]	
	Extension							
	Concentric (mm)			54	20 [0;44]	42	0 [0;0.5]	
	Isometric (mm)			60	15 [0;43]	45	0 [0;0.5]	
	Eccentric (mm)			54	22 [0;44]	42	0 [0;0.5]	
	Symptoms							
	Bilateral FAI (n)[a]			60	16			
	Alpha angle from CT			54	52 ± 10	42	50 ± 10	
	Lateral center edge angle from CT			54	33 ± 6	42	34 ± 5	
	Acetabular index from CT			54	3 ± 6	42	2 ± 5	
Contralateral hip	Copenhagen Hip and Groin Outcome Score							
	Pain			60	85 [69;100]	56	93 [83;100]	
	Symptoms			50	80 [61;93]	56	89 [79;96]	
	Pain level during strength testing (VAS 0-100)							
	Flexion							
	Concentric (mm)			57	0 [0;16]	42	0 [0;0]	
	Isometric (mm)			60	0 [0;0]	45	0 [0;0]	
	Eccentric (mm)			57	0 [0;8]	42	0 [0;0]	
	Extension							
	Concentric (mm)			58	0 [0;0]	43	0 [0;0]	
	Isometric (mm)			60	0 [0;0]	45	0 [0;0]	
	Eccentric (mm)			58	0 [0;0]	43	0 [0;0]	

Mean ± standard deviation or median [quartiles]. n: number of participants. Faber: flexion, abduction, external rotation test. AP: anterior posterior radiographs or axial view (used for inclusion of patients). CT: scans obtained after inclusion of patients. VAS: visual analogue scale (0 no pain, 100 worst imaginable pain). ADL: activities of daily living. PA: participation in physical activities. QoL: quality of life.

[a] Patients having surgery in contralateral hip before project, under project or listed for surgery.

surgery, when compared to a control group of 60 persons with no hip problems. Partly in line with our findings, Casartelli et al.[12] found improvements in hip flexion and extension strength after surgery in a small sample of eight patients, but they also reported deficits in the hip flexors when compared to reference persons 2.5 years after surgery. Unfortunately, neither of these studies nor the present study have recorded details on the content of the rehabilitation program on the individual level that was performed in

Table 2
Hip muscle strength (Nm/kg).

		References		Patients (baseline)		Patients (one year)		Patients (baseline vs. one year)			Patients (affected vs. contralateral)			Patients one year vs. references		
		n	Right hip	n	Affected	n	Affected	Mean diff	[95% CI]	p-value	% diff	Mean diff	[95% CI]	p-value	% diff	Mean diff	[95% CI]	p-value	% diff
Flexion (Nm/kg)	Concentric	29	1.8 ± 0.4	50	1.4 ± 0.5	41	1.6 ± 0.5	0.2	[0.1; 0.3]	0.0008	13	0.1	[−0.02; 0.17]	0.118	4	0.2	[0.04; 0.37]	0.015	9
	Isometric	30	1.9 ± 0.4	60	1.5 ± 0.7	45	1.7 ± 0.6	0.2	[0.1; 0.2]	0.0002	12	0.1	[0.01; 0.26]	0.032	4	0.2	[0.07; 0.37]	0.006	12
	Eccentric	29	2.5 ± 0.6	50	2.1 ± 0.7	41	2.2 ± 0.7	0.2	[0.03; 0.3]	0.010	6	0.2	[0.01; 0.38]	0.04	5	0.3	[0.07; 0.57]	0.013	11
			Left hip		Contralateral		Contralateral	Mean diff	[95% CI]	p-value						Mean diff	[95% CI]	p-value	% diff
	Concentric	29	1.7 ± 0.4	57	1.5 ± 0.6	42	1.6 ± 0.5	0.04	[−0.06; 0.14]	0.387						0.05	[−0.12; 0.22]	0.559	1
	Isometric	30	1.8 ± 0.4	60	1.6 ± 0.6	45	1.8 ± 0.6	0.1	[0.01; 0.18]	0.0292						0.07	[−0.10; 0.24]	0.42	3
	Eccentric	28	2.4 ± 0.6	57	2.3 ± 0.8	42	2.3 ± 0.8	−0.08	[−0.26; 0.1]	0.390						0.08	[−0.18; 0.33]	0.841	2
		n	Right hip	n	Affected	n	Affected	Mean diff	[95% CI]	p-value	% diff	Mean diff	[95% CI]	p-value	% diff	Mean diff	[95% CI]	p-value	% diff
Extension (Nm/kg)	Concentric	29	2.8 ± 0.7	54	2.1 ± 1.0	42	2.4 ± 0.9	0.3	[0.1; 0.4]	0.002	4	0.1	[−0.03; 0.29]	0.121	4	0.4	[0.03; 0.77]	0.036	13
	Isometric	30	3.0 ± 0.8	60	2.5 ± 1.1	45	2.7 ± 1.0	0.1	[−0.05; 0.2]	0.250	2	0.2	[−0.03; 0.37]	0.097	4	0.4	[0.004; 0.70]	0.048	11
	Eccentric	29	4.4 ± 1.1	54	4 ± 1.2	42	3.9 ± 1.2	−0.04	[−0.3; 0.2]	0.720	−5	0.2	[−0.06; 0.36]	0.151	2	0.5	[0.09; 0.98]	0.02	10
			Left hip		Contralateral		Contralateral	Mean diff	[95% CI]	p-value						Mean diff	[95% CI]	p-value	% diff
	Concentric	28	2.7 ± 0.6	58	2.2 ± 0.9	43	2.5 ± 0.9	0.1	[−0.003; 0.23]	0.056						0.32	[−0.004; 0.65]	0.053	9
	Isometric	30	2.9 ± 0.7	60	2.6 ± 0.9	45	2.8 ± 1.0	0.06	[−0.05; 0.17]	0.270						0.09	[−0.21; 0.38]	0.553	2
	Eccentric	27	4.3 ± 0.8	58	3.9 ± 1.1	43	4 ± 1.1	−0.09	[−0.2; 0.05]	0.220						0.32	[−0.06; 0.70]	0.098	5

Maximal hip muscle strength in Newton Meters per kilogram (mean ± standard deviation), n: number of persons. Mean diff: mean difference. 95% CI: 95% confidence interval. % diff: % difference.

the period after surgery. Some rehabilitation protocols have been proposed,[21,25] but there is lack of evidence to support which rehabilitation approach/protocol is most effective following surgery for FAIS. However, what the studies do show is that the current practice in different countries does not succeed in bringing patients with FAIS back to their expected muscle strength levels. An Australian randomised controlled trial[26] investigated the efficacy of adding further rehabilitation after surgery to their current treatment offer. Their results suggest that it might be beneficial. However, the study was terminated before time and hence, it lacks power to detect how large a benefit the extra rehabilitation sessions provided. Hence, further studies should be conducted on rehabilitation after hip arthroscopic surgery before solid conclusions can be drawn.

Interestingly, both before[15] and one year after surgery female patients had larger impairments compared to their healthy counterparts than male patients did for both hip flexion and extension strength. Despite a trend towards better scores in males, neither baseline PROs nor one year PROs or change in PROs from baseline to one year after surgery differed between genders. However, these subgroup analyses could be affected by lack of power to detect differences, as the study was not specifically powered to capture these. Other studies have demonstrated gender specific affection of function and quality of life in patients with FAIS[27] and in associated disorders,[28] and these support that females have inferior measurements. An association between increased hip extension strength and better PROs was found. Also, patients demonstrating difficulties while performing non-validated functional capacity tests were weaker than patients without difficulties. Hence, further investigation of whether improvement in hip strength will result in better outcomes for females is of great interest.

In the current study, there was an association between PROs and hip extension strength, which was not seen for the hip flexion. However, hip flexion strength increased after surgery and there was less variability in the measurements. When the variability in data is smaller and skewed, there will be a smaller correlation coefficient.[29] Investigating the scatter plot of pain vs. isometric hip flexion strength, there was an increase in the plot up to 1.5 Nm/kg. Hereafter, stronger patients had no further improvement in pain. Hence, muscular impairment might contribute to some of the decreased PROs up to a certain level after surgery, but hereafter a number of other factors seems more important with regard to PROs.

Among the strengths of the current study is the prospective, consecutively included cohort of patients all having surgery performed by a single surgeon and that a single tester performed all assessments. Furthermore, the application of "gold standard" dynamometry also adds credibility to the current study.

The study is limited by the fact that 15 patients did not return for testing after surgery. However, the sensitivity analysis showed that a statistical significant difference could not be found between the two groups. Our sample size calculation required at least 53 persons to show a significant increase in hip flexion strength after surgery. Nevertheless, significant changes in hip flexion strength were found despite a sample size of only 45 persons. Of note, the sample size did not have as large a power for hip extension strength, and since larger standard deviations were seen during this muscle strength test compared to the hip flexion test, a larger sample size might have revealed a significant difference.

A second limitation was the pronounced ceiling effect in our physical capacity tests. Due to the large variation in the patient population with FAIS ranging from sedentary patients to athletes, it was difficult to select proper physical capacity tests. The tests included were conducted exploratively to see if these tests were appropriate for the population, since evidence supporting functional tests was sparse. Almost two-thirds of our patients were able to complete the tests before surgery. How-

ever, the one-third not able to complete the tests demonstrated significant muscle impairments compared to the completers after surgery. Kemp et al.[8] described that single-leg rise, hop and side bridge performance was impaired in patients with chondrolabral pathology after surgery. These tests were designed using a watch or a tape measure to quantify performance. In our tests a dichotomous outcome of "completed vs. not completed" was applied. The idea of measuring performance continuously instead of dichotomous allows a better way of differentiating levels of performance and should be used in future studies of patient function.

Third, no imaging of the reference group hips was performed. Hence, it cannot be excluded that some individuals would show asymptomatic cam or pincer morphology. However, recent research suggests that hip pain and not detected deformities from imaging should be a focus when treating patients.[30] Hence, differentiating patients based upon their pain and symptoms seem to be of highest relevance. Nevertheless, imaging the reference group would have ensured that only persons that were not on the border to develop FAIS were included.

Fourth, compliance with and adherence to the home-based rehabilitation program was not monitored. This should be conducted in future studies.

5. Conclusion

Compared to pre-surgery levels, patients with FAIS showed improved hip flexion strength and hip extension strength, but with muscle strength remaining below the level of reference persons. Patients having higher isometric hip extension strength was associated with better PROs one year after surgery. Patients who were able to complete physical capacity tests were significantly stronger than those unable to. Female patients were more impaired than male patients compared with their healthy counterparts with regard to maximal hip muscle strength. The findings from the present study adds to the growing body of evidence describing decreased function after hip arthroscopic surgery. Future studies should monitor postoperative rehabilitation and investigate how more intensive rehabilitation might improve on patient outcomes.

Practical implications

- Patients with femoroacetabular impingement syndrome (FAIS) improved their hip flexion and extension strength one year after hip arthroscopic surgery, when compared to pre-surgery levels. However, their strength level was still below that of the reference persons.
- Having greater isometric hip extension strength after surgery was associated with better patient reported outcomes.
- Patients with FAIS who were unable to complete physical capacity tests were significantly weaker than patients who were able to complete these, both before and after surgery.
- Female patients were more impaired than their corresponding female references compared to the male patients one year after hip arthroscopic surgery.

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All authors helped design the study. SK collected data and wrote the initial draft for the manuscript, UD helped revise it into a full version. IM, LR, KS and BL gave their input hereafter and all authors approved the final version of the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2018.10.004.

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