Hip Function 6 to 10 Months After Arthroscopic Surgery

A Cross-sectional Comparison of Subjective and Objective Hip Function, Including Performance-Based Measures, in Patients Versus Controls

Tobias Wörner,[*†‡] MSc, Johanna Nilsson,[§] MSc, Kristian Thorborg,[||] PhD, Viktor Granlund,[‡] BSc, Anders Stålman,[‡¶] PhD, and Frida Eek,[†] PhD

Investigation performed at Lund University, Lund, Sweden

Background: Little is known about hip-related function, mobility, and performance in patients after hip arthroscopic surgery (HA) during the time that return to sports can be expected.

Purpose: To evaluate measures of subjective and objective hip function 6 to 10 months after HA in patients compared with healthy controls and to compare objective function in the HA group between the operated and nonoperated hips.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 33 patients who had undergone HA (mean, 8.1 $\pm$ 2.6 months postoperatively) and 33 healthy participants matched on sex, age, and activity level were compared regarding subjective hip function (Copenhagen Hip and Groin Outcome Score [HAGOS]) and objective function including hip range of motion (ROM; flexion, internal rotation, and external rotation), isometric hip muscle strength (adduction, abduction, flexion, internal rotation, and external rotation), and performance-based measures: the Y Balance Test (YBT), medial and lateral triple-hop test, and Illinois agility test. Group differences were analyzed using independent-samples *t* tests. Paired-samples *t* tests were used for a comparison of the operated and nonoperated hips. Standard effect sizes (Cohen *d*) were provided for all outcomes.

Results: The HA group reported worse subjective hip function than the control group (HAGOS subscores: $d = -0.7$ to -2.1; $P \leq .004$). Objective measures of hip ROM ($d = -0.5$ to -1.1; $P \leq .048$), hip flexion strength ($d = -0.5$; $P = .043$), and posteromedial reach of the YBT ($d = -0.5$; $P = .043$) were also reduced in the HA group, although there were no significant differences between groups regarding the remaining objective measures ($d = -0.1$ to -0.4; $P \geq .102$ to $.534$). The only significant difference between the operated and nonoperated hips in the HA group was reduced passive hip flexion ($d = -0.4$; $P = .045$).

Conclusion: Patients who had undergone HA demonstrated reduced subjective hip function compared with controls 6 to 10 months after surgery, when return to sports can be expected. While most objective strength and performance test results were comparable between the HA and control groups at 6 to 10 months after surgery, the HA group presented with impairments related to hip mobility and hip flexion strength. No consistent pattern of impairments was found in operated hips compared with nonoperated hips.

Keywords: femoroacetabular impingement; hip arthroscopic surgery; physical therapy/rehabilitation; athletic performance; muscle strength; range of motion

Femoroacetabular impingement syndrome (FAIS) is a motion-related clinical disorder of the hip affecting physically active patients.[13] Patients with FAIS often undergo hip arthroscopic surgery (HA) with the goal to return to sports.[26] However, despite high rates of return to general sports participation,[33] recent studies have reported that only approximately half of all athletes return to their previous sports and that just 1 in 5 return to previous performance levels.[15,49] Furthermore, patients often present with residual hip pain and reduced self-reported sporting function after HA.[19,40] More knowledge regarding the functional performance of patients who have undergone HA is

The Orthopaedic Journal of Sports Medicine, 7(6), 2325967119844821
DOI: 10.1177/2325967119844821

needed to identify impairments that may be responsible for reduced self-reported sporting function and low rates of return to performance.

Athletes with FAIS who undergo HA often do so with the aim of reducing hip pain and eliminating physical impairments that affect sports performance.[6] Examples of physical impairments that have been observed in patients with FAIS are reduced hip muscle strength[10,11] and reduced dynamic range of motion (ROM) during gait.[10] While strength has been shown to improve after HA and subsequent rehabilitation, results regarding ROM have been conflicting.[10,11] Less than 25% of studies on the surgical treatment of FAIS have reported on postoperative ROM, and only a fraction (2.5%) have reported on hip muscle strength.[32]

In addition to specific impairments such as reduced ROM and muscle strength, performance-based measures (PBMs) such as hop, balance, or change-of-direction tests, which reflect normal athletic requirements, can be conducted in a clinical setting.[22] However, there are currently only a small number of studies reporting on PBMs in patients after FAIS surgery.[7,17,43] More than 2 years after HA, participants in a study by Tijssen et al[43] performed within 90% of the limb symmetry index during tests of single-leg balance, single-leg squat control, and single-leg hop. Two further studies compared patients 1 to 2 years after HA with a control group and reported decreased single-leg squat control as well as reduced hop and single-leg bridge performance.[7,17] A 2015 systematic review on return to sports after HA recommended the implementation of PBMs as a means of monitoring rehabilitation progress and athletic abilities to meet the specific demands required to return to sports.[6]

Patients typically report improvements in hip-related sports function 6 to 12 months after HA[19] but still show marked impairments in perceived sporting ability 12 months after arthroscopic treatment.[40] While the mean time to return to sports for athletes after HA is 7 ± 2.6 months,[33] the extent to which objective hip function such as ROM and strength has recovered at this point in time is currently unknown. Potential impairments in specific hip functions may be responsible for patients' perceived impairments as well as restrictions in sports participation and hence should be recognized. Yet, there is a lack of studies investigating patients' ability to perform hip-challenging tasks with relevance to sports performance, especially during the time when these patients usually return to sports. Thus, there is a need for studies investigating these objective hip functions in patients who have undergone FAIS surgery to identify potential physical impairments, and thereby potential targets for treatment, that will inform future rehabilitation programs.[10]

The purpose of this study was to compare subjective and objective hip-related function, assessed by patient-reported measures as well as objective measures such as ROM, strength, and PBMs, between patients 6 to 10 months after HA and asymptomatic controls. Furthermore, we aimed to compare objective function of the operated hip in relation to the nonoperated hip in the HA patients.

METHODS

Study Design

This cross-sectional study compared patient-reported and objectively measured hip function between patients after HA for FAIS (6-10 months postoperatively) and a control group of asymptomatic participants. The follow-up time was chosen to reflect the time frame in which patients are reported to return to sports after HA. The recruitment of participants and data collection were performed between November 2016 and May 2017. The reporting of results conforms to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[45] This study was approved by Lund University's regional ethics board.

Participants

Patients were recruited from a single surgical center specializing in arthroscopic surgery. Patient selection was based on International Classification of Diseases–10th Revision treatment codes (labrum repair [NFT99], labrum resection [NFH91], rim trimming [NEK19], and cam resection [NFK19]). Patients were included if they (1) had undergone primary HA for FAIS 6 to 10 months before inclusion (February-November 2016; for bilaterally operated patients, the time interval was counted from the most recent surgical procedure), (2) were ≥18 years of age, and (3) lived in the greater Stockholm area. A control group was matched with patients in the HA group according to sex, age, and type of sports/physical activity as well as respective level of participation before hip symptoms according to the Hip Sports Activity Scale (HSAS).[27] Inclusion criteria for control participants were (1) no history of hip surgery, (2) age ≥18 years, and (3) no treatment for back pain and/or injuries in the lower extremities within the past 6 months. Control

*Address correspondence to Tobias Wörner, MSc, Department of Health Sciences, Lund University, Box 157, 221 00 Lund, Sweden (email: tobias.worner@med.lu.se) (Twitter: @wuninho).
†Department of Health Sciences, Lund University, Lund, Sweden.
‡Capio Artro Clinic, Stockholm, Sweden.
§Linnaeus University, Kalmar, Sweden.
||Sports Orthopaedic Research Center–Copenhagen (SORC-C), Department of Orthopaedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Denmark.
¶Department of Molecular Medicine and Surgery, Stockholm Sports Trauma Research Center, Karolinska Institutet, Stockholm, Sweden.
The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Lund University's regional ethics board (No. 2016/472).

participants were recruited consecutively from local sports clubs in an effort to match included patients regarding sex, age, and type of sports as well as level of sports participation.

Assessment Procedure

Before testing, participants provided informed consent as well as demographic information such as profession, hours of exercise per week, leg dominance, and history of lower extremity surgery. Subsequently, patient-reported outcomes, in Swedish or English, were collected through a web survey, and anthropometric measures (body weight, body height, and leg length [distance between the anterior superior iliac spine and medial malleolus in cm]) were obtained. Physical testing was performed in the order described below. To minimize potential learning effects during PBMs, participants were allowed to practice the tests until they felt sufficiently prepared. Furthermore, additional trials for strength measures as well as PBMs were performed in cases where participants improved more than 10% in comparison with the previous trial.

Data Collection

Descriptive Data

Patient charts, surgical reports, and images taken during arthroscopic treatment were retrospectively reviewed to confirm diagnostic codes used as inclusion criteria and to describe arthroscopic treatment procedures as well as cartilage defects at the time of surgery. The alpha angle and center-edge angle were measured on all operated hips to describe cam morphology and confirm the absence of hip dysplasia. In patients who underwent unilateral HA, the alpha angle and center-edge angle were also measured on the nonoperated hip. Participants rated their activity levels (currently and before the onset of hip symptoms) according to the HSAS from 0 to 8, with 8 representing the highest activity level. The HSAS is considered a reliable and valid tool to determine activity levels in patients after HA for FAIS and was used to match activity levels of control participants.[27] The HSAS has not yet been officially translated into Swedish; therefore, a version used in previous research on a Swedish population was used.[34] We also assessed patients' current return-to-sports status on a continuum as recommended in a 2016 consensus statement.[1] Patients were asked to choose 1 of the following statements: (1) I don't participate in sporting activities ("no sport"), (2) I participate in sports/exercise but not in my previous sporting activity ("different sport"), (3) I participate in my previous sporting activity but not at the same performance level ("same sport, lower performance"), or (4) I participate in my previous sporting activity at the same or higher performance level ("same sport, same performance").

Subjective Hip Function

We used the Copenhagen Hip and Groin Outcome Score (HAGOS),[38,39] which is recommended for the evaluation of patients after HA for FAIS,[42] to assess current self-reported hip function. The HAGOS consists of 6 subscales, evaluating symptoms, pain, function during activities of daily living, function during sports and recreation, participation in physical activities, and hip-related quality of life, and it has been shown to be a valid and reliable tool in the active young to middle-aged.[39] Each HAGOS subscale score was computed and converted into a percentage of the total score, with 0% representing extreme amounts of hip and groin problems and 100% representing no hip and groin problems.

Objective Hip Function

ROM and Hip Muscle Strength. A single examiner (T.W.) assessed ROM and muscle strength of both hips according to routine clinical preoperative and follow-up protocols. The reliability of these test protocols was previously assessed on 19 patients with FAIS scheduled for HA (mean age, 33.6 ± 7.7 years; 16% [n = 3] female). Intraclass correlation coefficients (2-way random models [2.1]) for intratester reliability ranged from 0.72 to 0.90 (ROM) and 0.89 to 0.95 (strength). ROM measures were performed in the same order for all participants, while hip muscle strength measures were randomized (www.randomizer.org) according to starting leg, starting position (supine/prone), and starting direction (supine: flexion/abduction/adduction; prone: extension/internal rotation/external rotation) to avoid systematic effects of fatigue or potential pain provocation on individual measurements.

All ROM measures were performed in the supine position. For active hip flexion, participants were asked to maximally flex their hip with a flexed knee while keeping the nontested limb on the treatment table. For passive hip flexion, participants were asked to maximally pull their knee toward their head with both hands while keeping the nontested limb on the treatment table. No abduction or external rotation was permitted. Flexion measures were performed using a goniometer centered on the greater trochanter, distally aligned toward the lateral femoral condyle, and kept parallel to the treatment table. Passive internal and external rotation were measured in the supine position with the hip joint flexed to 90° in neutral by using a bubble inclinometer. The inclinometer was attached to the tibial tuberosity and the knee flexed to 90°. The examiner subsequently performed internal and external rotation until movement of the pelvis was observed.

For hip muscle function, isometric abduction, adduction, flexion, extension, internal rotation, and external rotation strength were measured with a handheld dynamometer (microFET2; Hogan Scientific) by the same examiner. A modified version of an established test protocol that was found to be valid and reliable was used.[41] The most prominent part of the malleolus was used as a reference point for the dynamometer attachment (5 cm proximal). Furthermore, the measurement sequence was modified to increase time efficiency. As opposed to performing 4 consecutive trials in the same direction, tested legs and directions were alternated for a total of 3 trials in each direction. The maximum generated force across trials (in N·m/kg) served as the test outcome.

Performance-Based Measures. The Y Balance Test (YBT), triple-hop test (THT), and Illinois agility test (IAT) were used to measure performance. The YBT is a modification of the Star Excursion Balance Test and is aimed to assess a combination of ROM, flexibility, balance, and strength.[12] In healthy participants, the YBT demonstrates good to excellent intrarater reliability[30] and is closely related to hip abduction strength[48] as well as hip ROM.[22] Information regarding its reliability and validity in populations with hip abnormalities is currently lacking. The participants' starting leg was randomized before testing. The YBT was performed barefoot and according to a previously described protocol.[30] The maximum reach distance of 3 trials, performed on each leg in the anterior, posteromedial, and posterolateral directions, was calculated relative to leg length (in percentages) and served as the test outcome.

Hop performance was measured by the medial and lateral THT, a reliable tool in patients with hip abnormalities that has been demonstrated to be able to distinguish between those with and without hip complaints.[21] The participants' starting leg was randomized before testing, and the length of the maximum triple jump (in cm) served as the test outcome.

The IAT combines maximal acceleration, deceleration, sudden change of direction, and nonlinear running. It was performed according to a previously described protocol, which has demonstrated good test-retest reliability and validity for general athletic ability to effectively change directions.[35] Patients in the HA group started the test on the same side they were operated on (for bilateral HA, the most recent surgical procedure) to force them to turn on the operated hip. The starting side for the first control participant was randomized (www.randomizer.org). Subsequently, every other control participant started the test on either the left or the right leg. All participants ran the course at a self-determined pace as a warm-up and to familiarize themselves with the requirements. Participants then performed 3 trials at maximum pace with 3 minutes' rest between trials, and the fastest time to complete the course (in seconds) served as the outcome.

Statistical Analysis

Data analysis was performed using SPSS (version 24; IBM). Group differences were analyzed using independent-samples *t* tests. Operated hips were compared with the dominant hips of control participants (the most recently treated hip was considered the tested leg for patients who had undergone bilateral HA). In the HA group, objective hip function was compared between the operated and nonoperated sides and analyzed through paired-samples *t* tests. Bilaterally treated patients were excluded from within-participant analysis. Standardized effect sizes (Cohen *d*, with accompanying 95% CIs) were computed. Effect sizes of 0.2 were considered small, 0.5 medium, and 0.8 large.[9]

The sample size was determined with the goal of being able to identify minimal detectable differences of 10% between groups for PBMs (YBT, medial THT, lateral THT, and IAT), corresponding to standardized effect sizes (Cohen *d*) between 0.7 and 0.9. With a significance level of .05 and 80% power, a sample of 20 to 34 participants per group was required. With 33 participants included in each group, the study had 80% power to detect an effect size of $d = 0.7$.

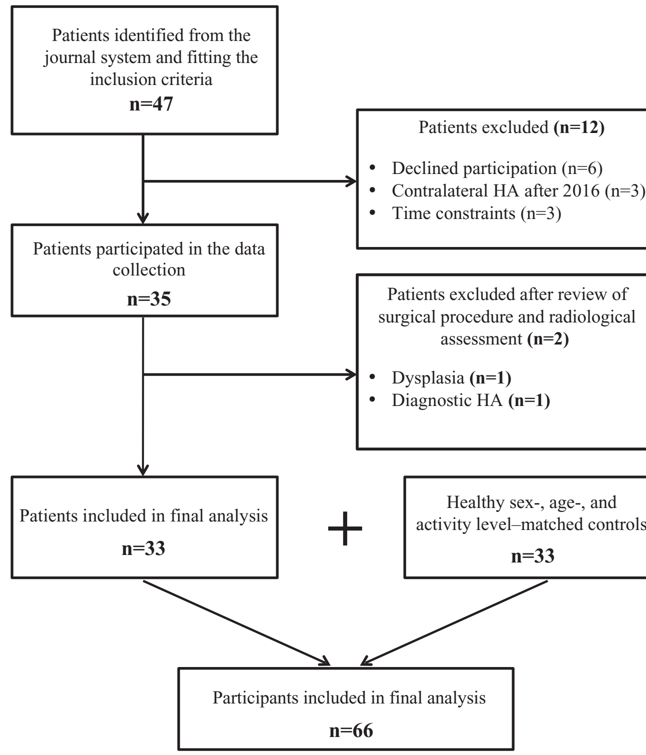

Figure 1. Participant flow into the study.

RESULTS

In total, 66 participants (33 in the HA group and 33 in the control group) were included in the study. The flow of participants into the study is summarized in Figure 1. Patient demographics, arthroscopic procedures, perioperative findings, and activity levels are presented in Table 1. More than one-third of all patients in the HA group (n = 12) were engaged in team sports (ice hockey [n = 7], basketball [n = 3], football [n = 1], bandy [n = 1]); the remaining patients engaged in individual sports (strength sports [n = 9], martial arts [n = 3]), endurance sports (running [n = 4], ice skating [n = 1]), and aesthetic sports (dance and gymnastics [n = 4]). Among the HA group, 70% (n = 23) had undergone unilateral HA (right hip: 64% [n = 21]; left hip: 36% [n = 12]), while 30% (n = 10) underwent subsequent bilateral HA. All patients had an alpha angle of >55°. Among patients who had undergone unilateral HA, 57% (n = 13) also had an alpha angle of >55° on the nonoperated side. None of the patients had dysplasia or radiological osteoarthritis (OA).

The HA group reported worse subjective hip function than the control group, with large and statistically significant effect sizes (Table 2 and Figure 2). We observed small effect sizes for the majority of objective outcomes, indicating generally reduced objective function in the HA group

TABLE 1
Participant Characteristics[a]

	HA (n = 33)	Control (n = 33)
Demographics		
Age, y	32.3 ± 9.4	31.1 ± 10.6
Weight, kg	79.8 ± 9.0	79.0 ± 12.6
Height, cm	179.3 ± 7.1	179.5 ± 7.5
Sex, n (%)		
Female	4 (12.1)	4 (12.1)
Male	29 (87.9)	29 (87.9)
Right leg dominance, n (%)	30 (90.9)	29 (87.9)
Time since surgery, mo	8.1 ± 2.6	—
Arthroscopic procedures, n (%)		
Cam resection	33 (100.0)	—
Combined cam and pincer	6 (18.2)	—
Labral trimming	31 (93.9)	—
Labral repair	1 (3.0)	—
Cartilage defects observed during surgery, n (%)		
Femoral cartilage defects	—	—
Acetabular cartilage defects	27 (81.8)	—
Outerbridge classification (acetabulum)[b]		
1	8 (24.2)	—
2	3 (9.1)	—
3	8 (24.2)	—
4	8 (24.2)	—
Activity level/sports participation		
Training hours per week	6.9 ± 4.0	7.1 ± 4.5
HSAS score, median (IQR)		
Before symptoms	6.5 (3.5-7.0)	—
Currently	4.5 (3.0-5.8)	5.0 (3.0-7.0)
Return-to-sports status, n (%)		
No sport	1 (3.0)	—
Different sport	11 (33.3)	—
Same sport, lower performance	15 (45.5)	—
Same sport, same performance	6 (18.2)	—
Satisfied with current activity level, n (%)	12 (36.4)	21 (63.6)[c]

[a]Data are reported as mean ± SD unless otherwise indicated. HA, hip arthroscopic surgery; HSAS, Hip Sports Activity Scale; IQR, interquartile range.

[b]Outerbridge grade: 1 = rough surface, chondral softening; 2 = irregular surface defects, $<50\%$ cartilage thickness; 3 = loss of $>50\%$ cartilage thickness; and 4 = cartilage loss, exposed bone.

[c]Thirty-two of 33 participants in the control group responded.

compared with the control group. The largest, and the only statistically significant, effect sizes were found for reduced hip ROM, hip flexion strength, and posteromedial reach of the YBT (Table 3 and Figure 3). Within the HA group, no consistent pattern of the observed small effect sizes favoring the function of one hip over the other emerged. Only for hip flexion ROM was there a moderate, statistically significant effect size indicating reduced mobility of the operated hip found (Table 4 and Figure 4).

DISCUSSION

This cross-sectional study compared patients 6 to 10 months after FAIS surgery with a healthy control group regarding subjective and objective hip function in addition to comparing the objective function of operated hips with nonoperated hips. In comparison with the control group, the HA group reported clinically relevant impairments in subjective hip function but generally presented with only minor impairments in objective function. The only marked impairments in objective function were found for measures of hip mobility as well as mobility-related performance measures. A side-to-side comparison in the HA group showed no clear pattern of differences between operated and nonoperated hips.

Patients in our study reported large and clinically relevant reductions in hip function across all HAGOS subscales,[39] with the largest impairments observed for hip-related sporting activity, physical activity, and quality of life. These results are in accordance with recent evidence documenting that patients who have undergone HA continue to have marked impairments in self-reported function, following the same domain-specific pattern of impairments as observed in our sample.[40] These marked reductions in self-reported function relating to the ability to function in sports, combined with the low rates of return to sporting performance seen in the current study and previous research,[15,49] suggest the presence of physical impairments that ought to be objectively measurable.

While a general pattern of reduced objective function for the HA group in comparison with the control group was observed in our sample, standardized effect sizes were small and statistically nonsignificant for the majority of outcomes, and their clinical relevance may therefore be debatable. Only differences in hip mobility, or more precisely, active and passive flexion as well as internal rotation, showed moderate to large effect sizes, indicating worse function in the HA group. FAIS is a motion-related clinical disorder associated with limited hip flexion and rotation ROM,[13] and FAIS surgery involves the correction of hip morphology and is therefore thought to remove anatomic constraints of joint kinematics and hence improve ROM.[14] Nevertheless, patients in this study had less hip mobility 6 to 10 months after HA compared with controls. Even though our data do not include a preintervention and postintervention comparison, our results indicate that patients with FAIS still had impaired hip ROM 6 to 10 months after arthroscopic treatment. In line with this finding, a 2016 systematic review suggested that hip ROM may in fact not improve after arthroscopic surgery.[11]

It is possible that these ROM impairments may also have affected patients' performance during other ROM-dependent measures of objective hip function. We found moderate effect sizes for reduced posteromedial reach of the YBT as well as for hip flexion strength, 2 tests requiring patients to perform tasks in joint ranges and motions known to be provocative in FAIS. During the YBT, the hip is forced into excessive flexion, internal rotation, and adduction, a combination of hip motions frequently used in the diagnostic process.[31] We measured hip flexion strength in the supine position, with the hip in 90° of flexion, consequently asking patients to produce flexion torque close to their end ROM.[8] Thus, impairments in ROM may

TABLE 2
Self-Reported Hip Function on the HAGOS[a]

HAGOS Subscale	HA (n = 33)	Control (n = 33)	Mean Difference (95% CI)	*P* Value[b]	Cohen *d* (95% CI)
Pain	86.1 ± 10.1	96.9 ± 6.3	–10.8 (–14.9 to –6.6)	<.001	–1.3 (–0.7 to –1.8)
Symptoms	74.9 ± 15.5	91.5 ± 10.1	–16.6 (–23.0 to –10.1)	<.001	–1.3 (–0.7 to –1.8)
Activities of daily living	91.4 ± 11.3	98.0 ± 6.0	–6.7 (–11.1 to –2.2)	.004	–0.7 (–0.2 to –1.2)
Sports and recreation	75.7 ± 17.7	95.3 ± 10.4	–19.6 (–26.8 to –12.4)	<.001	–1.4 (–0.8 to –1.9)
Physical activities	58.3 ± 33.5	95.8 ± 10.7	–37.5 (–49.9 to –25.1)	<.001	–1.5 (–1.0 to –2.1)
Quality of life	61.1 ± 22.0	96.2 ± 10.5	–35.2 (–43.7 to –26.6)	<.001	–2.1 (–1.4 to –2.6)

[a]Data are reported as mean ± SD unless otherwise indicated. There was a statistically significant between-group difference in all HAGOS subscores ($P < .05$ for all). HA, hip arthroscopic surgery; HAGOS, Copenhagen Hip and Groin Outcome Score.
[b]Independent-samples *t* test.

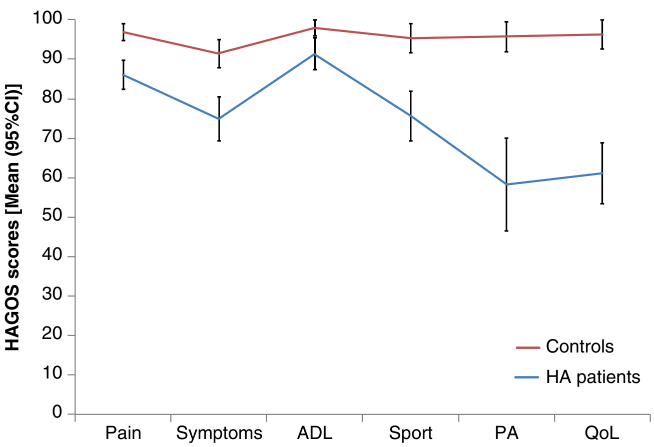

Figure 2. Between-group comparison of self-reported hip function. ADL, activities of daily living; HA, hip arthroscopic surgery; HAGOS, Copenhagen Hip and Groin Outcome Score; PA, physical activities; QoL, quality of life.

be associated with patients' functional performance 6 to 10 months after FAIS surgery.

It is possible that the impairments that we found are caused by residual surgical trauma. However, from a clinical perspective, this reduction in hip mobility is reminiscent of what is typically seen in patients with early manifestations of hip OA.[2-4] As reported in a 2018 meta-analysis, patients with FAIS present with biomechanical alterations in hip biomechanics such as reduced hip extension, and there is insufficient evidence for a change in these alterations after arthroscopic treatment.[20] Reduced hip extension during walking is also commonly seen in patients with early hip OA[46] and is thought to be a compensation strategy to unload the anterior hip joint,[24] the common location of chondrolabral abnormalities associated with FAIS.[36] It is important to note that HA for FAIS changes hip morphology, but much of the intra-articular abnormality remains. More than 80% of all patients in this study had acetabular cartilage defects during the time of arthroscopic surgery, which is a common finding in comparable cohorts.[5,8,25,36] These cartilage defects may represent early structural changes, present before the development of clinical OA.[37] According to current evidence, the presence and size of cam morphology are associated with an increased risk of developing OA in patients older than 45 years, but there are no available data to draw similar conclusions for patients of a younger age, such as those in our study.[44] Nevertheless, the high prevalence of chondropathy in our study and other studies on young to middle-aged adults with cam morphology undergoing HA,[5,8] as well as the observed pattern of physical impairments, suggests that patients with FAIS are clinically not clearly distinguishable from patients with early signs of hip OA. Therefore, it can also be argued that the objective impairments of the small effect sizes that we observed in patients could potentially be caused by their chondropathy, which are large enough to cause patients to perceive impairments in hip function but not yet linked to clinically measurable signs and symptoms.

When comparing the objective function of the operated hip to the nonoperated hip, we generally found only small and nonsignificant effect sizes, with no pattern favoring one hip over the other. The only measure showing a significant reduction of a medium effect size was passive hip flexion of the operated hip. In alignment with these results, Tijssen et al[43] found a limb symmetry index of >90% for PBMs, hip strength measures, and ROM measures except for internal rotation in their cohort of patients who underwent HA. It should be acknowledged that such intraindividual comparisons should be interpreted with caution and not taken as evidence for restored function, as the contralateral limb may have deconditioned after surgery. In patients after anterior cruciate ligament reconstruction, it has been shown that a side-to-side comparison of knee function 6 months after surgery overestimates knee function of the involved side.[47] Furthermore, patients with FAIS often present with bilateral morphological findings,[23] which potentially could affect performance in both hips. In our study, 57% of patients who had undergone unilateral HA had a contralateral alpha angle of >55°, highlighting the fact that the presence of cam morphology does not equal the presence of FAIS[13] and suggesting that other factors such as hip chondropathy may be responsible for the patients' complaints. This may explain why patients continued having impairments after the arthroscopic treatment of FAIS. A 2018 randomized controlled trial comparing the arthroscopic treatment of FAIS with supervised rehabilitation found clinically relevant improvements in both groups, with superior results for the

TABLE 3
Between-Group Comparison of Objective Outcomes[a]

	HA (n = 33)	Control (n = 33)	Mean Difference (95% CI)	*P* Value[b]
Range of motion, deg				
Active flexion	115.2 ± 7.3	120.5 ± 8.0	–5.3 (–9.1 to –1.5)	**.007**
Passive flexion	129.4 ± 8.2	138.3 ± 7.6	–8.9 (–12.8 to –5.1)	**<.001**
Passive internal rotation	27.6 ± 6.4	33.5 ± 9.1	–5.9 (–9.8 to –2.1)	**.003**
Passive external rotation	42.1 ± 8.6	46.1 ± 7.3	–3.9 (–7.8 to –0.1)	**.048**
Strength,[c] N·m/kg				
Abduction	2.26 ± 0.44	2.31 ± 0.25	–0.06 (–0.23 to 0.12)	.534
Adduction	2.28 ± 0.54	2.39 ± 0.40	–0.12 (–0.34 to 0.13)	.392
Flexion	1.49 ± 0.39	1.66 ± 0.27	–0.17 (–0.33 to –0.01)	**.043**
Extension	3.32 ± 0.66	3.45 ± 0.62	–0.14 (–0.45 to 0.18)	.396
External rotation	0.94 ± 0.23	0.99 ± 0.17	–0.05 (–0.15 to 0.05)	.317
Internal rotation	0.81 ± 0.21	0.89 ± 0.14	–0.07 (–0.16 to 0.02)	.102
Performance-based measures				
Medial THT,[d] cm	330.1 ± 120.3	354.1 ± 90.9	–23.9 (–77.6 to 28.8)	.35
Lateral THT,[d] cm	294.9 ± 101.3	329.3 ± 71.1	–34.4 (–77.6 to 8.9)	.117
YBT, % leg length				
Anterior	64.4 ± 6.8	66.2 ± 7.5	–1.8 (–5.4 to 1.7)	.303
Posteromedial	110.0 ± 11.6	115.7 ± 10.7	–5.7 (–11.2 to –0.2)	**.043**
Posterolateral	104.8 ± 14.3	109.7 ± 11.7	–4.9 (–11.3 to 1.5)	.132
IAT,[e] s	18.7 ± 2.7	18.1 ± 1.6	0.6 (–0.5 to 1.7)	.311

[a]Data are reported as mean ± SD unless otherwise indicated. Bolded *P* values indicate statistically significant between-group differences ($P < .05$). HA, hip arthroscopic surgery; IAT, Illinois agility test; THT, triple-hop test; YBT, Y Balance Test.

[b]Independent-samples *t* test.

[c]Lever arms for flexion and rotation measures were calculated according to Pietak et al.[29]

[d]One patient missing because of a sprained ankle during warm-up.

[e]Three patients in the HA group and 1 in the control group missing: ankle sprain during medial THT (n = 1) and declined participation for undisclosed reason (n = 3).

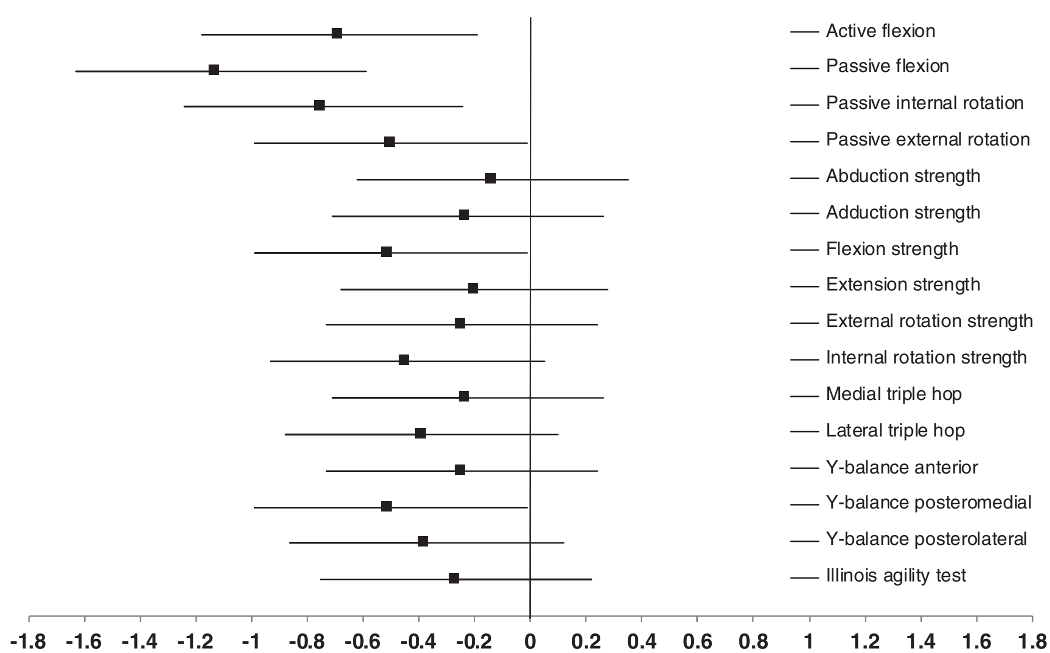

Figure 3. Standardized effect sizes (Cohen *d*) of group differences between patients in the hip arthroscopic surgery group and participants in the control group regarding objective outcomes. Negative effect sizes indicate inferior results in the hip arthroscopic surgery group.

TABLE 4
Within-Patient Comparison of Objective Outcomes in Unilaterally Operated Patients (n = 23)[a]

	Operated Hip	Nonoperated Hip	Mean Difference (95% CI)	*P* Value[b]
Range of motion, deg				
Active flexion	115.0 ± 7.4	115.0 ± 6.2	–0.0 (–1.8 to 1.8)	>.999
Passive flexion	128.9 ± 8.3	132.0 ± 6.9	–3.0 (–6.0 to –0.1)	**.045**
Passive internal rotation	27.6 ± 6.0	29.6 ± 7.1	–2.0 (–4.2 to 0.3)	.083
Passive external rotation	42.8 ± 8.1	40.0 ± 9.4	2.8 (–1.2 to 6.8)	.158
Strength,[c] N·m/kg				
Abduction	2.20 ± 0.46	2.20 ± 0.46	–0.01 (–0.11 to 0.10)	.904
Adduction	2.24 ± 0.59	2.18 ± 0.49	0.06 (–0.08 to 0.20)	.356
Flexion	1.45 ± 0.42	1.48 ± 0.39	–0.03 (–0.10 to 0.04)	.337
Extension	3.23 ± 0.69	3.17 ± 0.64	0.05 (–0.06 to 0.16)	.345
External rotation	0.92 ± 0.23	0.92 ± 0.22	0.01 (–0.03 to 0.04)	.719
Internal rotation	0.79 ± 0.21	0.81 ± 0.18	–0.01 (–0.06 to 0.03)	.464
Performance-based measures				
Medial THT,[d] cm	317.7 ± 127.0	313.3 ± 118.4	4.4 (–9.6 to 18.3)	.523
Lateral THT,[d] cm	285.0 ± 110.5	293.8 ± 108.5	–8.4 (–23.4 to 6.7)	.262
YBT, % leg length				
Anterior	63.3 ± 7.3	63.3 ± 7.2	–0.9 (–2.1 to 1.9)	.924
Posteromedial	108.7 ± 11.3	109.4 ± 12.9	–0.7 (–2.9 to 1.6)	.554
Posterolateral	102.7 ± 14.4	104.5 ± 14.5	–1.8 (–4.4 to 0.8)	.165

[a]Data are reported as mean ± SD unless otherwise indicated. Bolded *P* value indicates a statistically significant difference between the operated and nonoperated hips ($P < .05$). THT, triple-hop test; YBT, Y Balance Test.
[b]Paired-samples *t* test.
[c]Lever arms for flexion and rotation measures were calculated according to Pietak et al.[29]
[d]One patient missing because of a sprained ankle during warm-up.

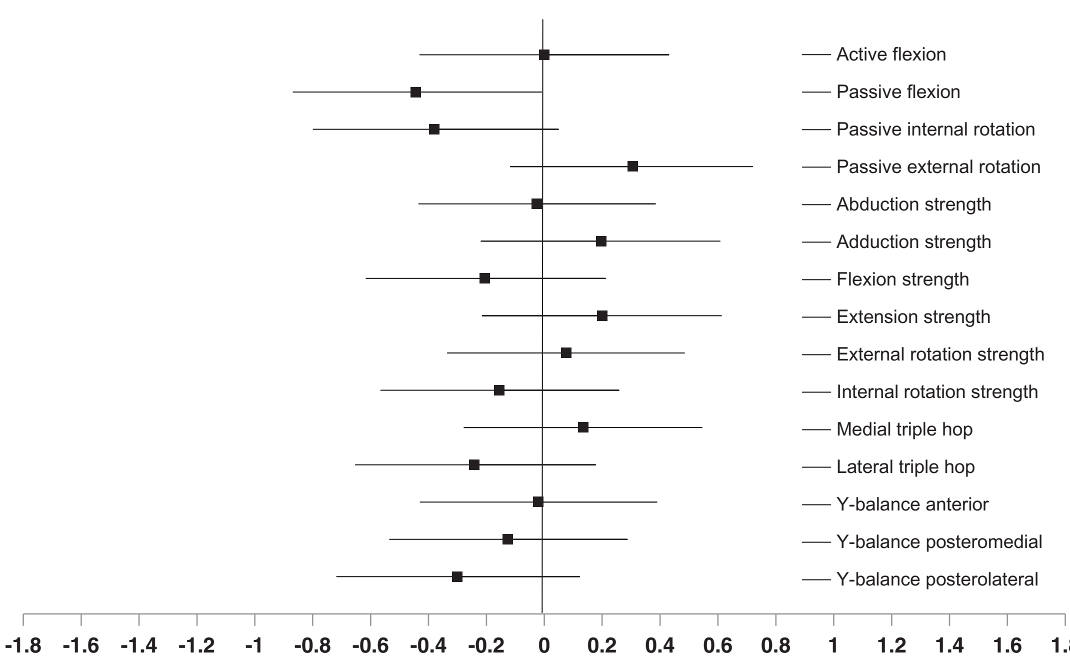

Figure 4. Standardized effect sizes (Cohen *d*) of differences between the operated and nonoperated hips of patients in the hip arthroscopic surgery group. Negative effect sizes indicate inferior results in the operated hip.

surgical treatment.[14] However, patients in that study also continued to have marked impairments in hip-related quality of life 1 year after the initiation of both treatments,[14] just as the patients in our study. As clinicians, we have to acknowledge that patients with FAIS are not likely to be free of intra-articular abnormalities after arthroscopic treatment, and their expectations may therefore need to be managed accordingly.

Although the results of our study demonstrated hip mobility impairments of approximately the same effect sizes as in previous research with a similar methodology,[18] other studies have found larger impairments in hip strength and performance measures.[7,17,18] A potential explanation for this is the choice of specific performance measures; however, the different results are rather likely attributable to differences in study samples. The previous studies[7,17,18] were based on patients who underwent HA for hip pain and a wide range of intra-articular abnormalities (~50% treated for FAIS),[16] while our sample underwent HA specifically for the treatment of FAIS (100% cam resections). Furthermore, the patients included in our study had preoperative activity levels corresponding to pivoting sports such as ice hockey and soccer (HSAS score: median, 6.5 [interquartile range, 3.5-7.0]) compared with the previous studies including patients who reported walking (corresponding to HSAS level 1) to be their primary physical activity.[7] Moreover, we chose to assess patients at 6 to 10 months after HA, when patients are usually discharged and may return to sports,[28,33,49] as opposed to 12 to 24 months after surgery as in previous studies.[7,17,18] Hence, it can be argued that our study is the first to compare objective physical function between a homogeneous group of athletic patients after FAIS surgery and a healthy control group.

There are some methodological considerations to be aware of when interpreting the results of this study. We aimed to match control participants to patients' presymptomatic HSAS levels as reported in data from preoperative visits. At the time of the measurements, participants in both groups reported their current activity levels. However, the patients' presymptomatic HSAS level differed by 1.5 points from the current HSAS level of control participants. This difference could likely be explained by potential discrepancies between our evaluations of control participants' HSAS level and participants' own self-evaluation during data collection. Hence, the lower HSAS level among control participants may have underestimated patients' impairments, as they were compared with a group not completely corresponding to their own preoperative level of activity.

The study sample consisted of a homogeneous group of physically active patients who underwent HA for the treatment of FAIS, and 74% of all potentially eligible patients participated. The results of this study should therefore be generalizable to the typical patient population with FAIS undergoing HA. As a cross-sectional study, our study describes patients' hip function during a specific period of 6 to 10 months after FAIS surgery. This provides a picture of subjective and objective hip function at this time but may not represent the end stage of recovery after HA, which may potentially be a much longer process.[19] It should be acknowledged that the follow-up time point in this study may thus not represent the end stage of recovery. Furthermore, it is unknown to what extent hip chondropathic changes may or may not deteriorate over time and which patients eventually will develop clinical OA. Future research should investigate the development of objective hip function, preferably using prospective study designs with repeated measurements.

CONCLUSION

Subjective hip function was substantially impaired in patients 6 to 10 months after HA for the treatment of FAIS in comparison with healthy controls. The HA group presented with comparable objective hip function for the majority of outcomes, with the exception of hip ROM and functional measures dependent on ROM. No consistent pattern of impairments was found in operated hips compared with nonoperated hips.

REFERENCES

1. Ardern CL, Glasgow P, Schneiders A, et al. 2016 consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *Br J Sports Med*. 2016;50(14):853-864.
2. Arokoski MH, Arokoski JP, Haara M, et al. Hip muscle strength and muscle cross sectional area in men with and without hip osteoarthritis. *J Rheumatol*. 2002;29(10):2185-2195.
3. Arokoski MH, Haara M, Helminen HJ, Arokoski JP. Physical function in men with and without hip osteoarthritis. *Arch Phys Med Rehabil*. 2004;85(4):574-581.
4. Bastick AN, Damen J, Agricola R, Brouwer RW, Bindels PJ, Bierma-Zeinstra SM. Characteristics associated with joint replacement in early symptomatic knee or hip osteoarthritis: 6-year results from a nationwide prospective cohort study (CHECK). *Br J Gen Pract*. 2017;67(663):e724-e731.
5. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br*. 2005;87(7):1012-1018.
6. Casartelli NC, Leunig M, Maffiuletti NA, Bizzini M. Return to sport after hip surgery for femoroacetabular impingement: a systematic review. *Br J Sports Med*. 2015;49(12):819-824.
7. Charlton PC, Bryant AL, Kemp JL, Clark RA, Crossley KM, Collins NJ. Single-leg squat performance is impaired 1 to 2 years after hip arthroscopy. *PM R*. 2016;8(4):321-330.
8. Clohisy JC, Knaus ER, Hunt DM, Lesher JM, Harris-Hayes M, Prather H. Clinical presentation of patients with symptomatic anterior hip impingement. *Clin Orthop Relat Res*. 2009;467(3):638-644.
9. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, New Jersey: Lawrence Erlbaum Associates; 1988.
10. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. *Br J Sports Med*. 2015;49(4):230-242.
11. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med*. 2016;50(19):1180.
12. Fullam K, Caulfield B, Coughlan GF, Delahunt E. Kinematic analysis of selected reach directions of the Star Excursion Balance Test compared with the Y-Balance Test. *J Sport Rehabil*. 2014;23(1):27-35.
13. 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(19):1169-1176.
14. Griffin DR, Dickenson EJ, Wall PDH, et al. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomised controlled trial. *Lancet*. 2018;391(10136):2225-2235.
15. Ishoi L, Thorborg K, Kraemer O, Holmich P. Return to sport and performance after hip arthroscopy for femoroacetabular impingement in 18- to 30-year-old athletes: a cross-sectional cohort study of 189 athletes. *Am J Sports Med*. 2018;46(11):2578-2587.
16. Kemp JL, Makdissi M, Schache AG, Pritchard MG, Pollard TC, Crossley KM. Hip chondropathy at arthroscopy: prevalence and

relationship to labral pathology, femoroacetabular impingement and patient-reported outcomes. *Br J Sports Med*. 2014;48(14):1102-1107.
17. Kemp JL, Risberg MA, Schache AG, Makdissi M, Pritchard MG, Crossley KM. Patients with chondrolabral pathology have bilateral functional impairments 12 to 24 months after unilateral hip arthroscopy: a cross-sectional study. *J Orthop Sports Phys Ther*. 2016; 46(11):947-956.
18. Kemp JL, Schache AG, Makdissia M, Pritchard MG, Sims K, Crossley KM. Is hip range of motion and strength impaired in people with hip chondrolabral pathology? *J Musculoskelet Neuronal Interact*. 2014; 14(3):334-342.
19. Kierkegaard S, Langeskov-Christensen M, Lund B, et al. Pain, activities of daily living and sport function at different time points after hip arthroscopy in patients with femoroacetabular impingement: a systematic review with meta-analysis. *Br J Sports Med*. 2017;51(7): 572-579.
20. King MG, Lawrenson PR, Semciw AI, Middleton KJ, Crossley KM. Lower limb biomechanics in femoroacetabular impingement syndrome: a systematic review and meta-analysis. *Br J Sports Med*. 2018;52(9):566-580.
21. Kivlan BR, Carcia CR, Clemente FR, Phelps AL, Martin RL. Reliability and validity of functional performance tests in dancers with hip dysfunction. *Int J Sports Phys Ther*. 2013;8(4):360-369.
22. Kivlan BR, Martin RL. Functional performance testing of the hip in athletes: a systematic review for reliability and validity. *Int J Sports Phys Ther*. 2012;7(4):402-412.
23. Larson CM, Safran MR, Brcka DA, Vaughn ZD, Giveans MR, Stone RM. Predictors of clinically suspected intra-articular hip symptoms and prevalence of hip pathomorphologies presenting to sports medicine and hip preservation orthopaedic surgeons. *Arthroscopy*. 2018; 34(3):825-831.
24. Lewis CL, Sahrmann SA, Moran DW. Effect of hip angle on anterior hip joint force during gait. *Gait Posture*. 2010;32(4):603-607.
25. Lund B, Nielsen TG, Lind M. Cartilage status in FAI patients: results from the Danish Hip Arthroscopy Registry (DHAR). *SICOT J*. 2017;3:44.
26. Mannion AF, Impellizzeri FM, Naal FD, Leunig M. Fulfilment of patient-rated expectations predicts the outcome of surgery for femoroacetabular impingement. *Osteoarthritis Cartilage*. 2013;21(1):44-50.
27. Naal FD, Miozzari HH, Kelly BT, Magennis EM, Leunig M, Noetzli HP. The Hip Sports Activity Scale (HSAS) for patients with femoroacetabular impingement. *Hip Int*. 2013;23(2):204-211.
28. O'Connor M, Minkara AA, Westermann RW, Rosneck J, Lynch TS. Return to play after hip arthroscopy: a systematic review and meta-analysis. *Am J Sports Med*. 2018;46(11):2780-2788.
29. Pietak A, Ma S, Beck CW, Stringer MD. Fundamental ratios and logarithmic periodicity in human limb bones. *J Anat*. 2013;222(5):526-537.
30. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the Star Excursion Balance Test. *N Am J Sports Phys Ther*. 2009;4(2): 92-99.
31. Reiman MP, Goode AP, Cook CE, Holmich P, Thorborg K. Diagnostic accuracy of clinical tests for the diagnosis of hip femoroacetabular impingement/labral tear: a systematic review with meta-analysis. *Br J Sports Med*. 2015;49(12):811.
32. Reiman MP, Peters S, Sylvain J, Hagymasi S, Ayeni OR. Prevalence and consistency in surgical outcome reporting for femoroacetabular impingement syndrome: a scoping review. *Arthroscopy*. 2018;34(4): 1319-1328.
33. Reiman MP, Peters S, Sylvain J, Hagymasi S, Mather RC, Goode AP. Femoroacetabular impingement surgery allows 74% of athletes to return to the same competitive level of sports participation but their level of performance remains unreported: a systematic review with meta-analysis. *Br J Sports Med*. 2018;52(15):972-981.
34. Sansone M, Ahlden M, Jonasson P, et al. Good results after hip arthroscopy for femoroacetabular impingement in top-level athletes. *Orthop J Sports Med*. 2015;3(2):2325967115569691.
35. Stewart PF, Turner AN, Miller SC. Reliability, factorial validity, and interrelationships of five commonly used change of direction speed tests. *Scand J Med Sci Sports*. 2014;24(3):500-506.
36. Suarez-Ahedo C, Gui C, Rabe SM, Chandrasekaran S, Lodhia P, Domb BG. Acetabular chondral lesions in hip arthroscopy: relationships between grade, topography, and demographics. *Am J Sports Med*. 2017;45(11):2501-2506.
37. Teichtahl AJ, Wang Y, Smith S, et al. Structural changes of hip osteoarthritis using magnetic resonance imaging. *Arthritis Res Ther*. 2014; 16(5):466.
38. Thomee R, Jonasson P, Thorborg K, et al. Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(4):835-842.
39. Thorborg K, Holmich P, Christensen R, Petersen J, Roos EM. The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med*. 2011;45(6):478-491.
40. Thorborg K, Kraemer O, Madsen AD, Holmich P. Patient-reported outcomes within the first year after hip arthroscopy and rehabilitation for femoroacetabular impingement and/or labral injury: the difference between getting better and getting back to normal. *Am J Sports Med*. 2018;46(11):2607-2614.
41. Thorborg K, Petersen J, Magnusson SP, Holmich P. Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports*. 2010;20(3):493-501.
42. Thorborg K, Tijssen M, Habets B, et al. Patient-reported outcome (PRO) questionnaires for young to middle-aged adults with hip and groin disability: a systematic review of the clinimetric evidence. *Br J Sports Med*. 2015;49(12):812.
43. Tijssen M, van Cingel R, de Visser E, Nijhuis-van der Sanden M. A clinical observational study on patient-reported outcomes, hip functional performance and return to sports activities in hip arthroscopy patients. *Phys Ther Sport*. 2016;20:45-55.
44. van Klij P, Heerey J, Waarsing JH, Agricola R. The prevalence of cam and pincer morphology and its association with development of hip osteoarthritis. *J Orthop Sports Phys Ther*. 2018;48(4):230-238.
45. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *PLoS Med*. 2007;4(10): e296.
46. Watelain E, Dujardin F, Babier F, Dubois D, Allard P. Pelvic and lower limb compensatory actions of subjects in an early stage of hip osteoarthritis. *Arch Phys Med Rehabil*. 2001;82(12):1705-1711.
47. Wellsandt E, Failla MJ, Snyder-Mackler L. Limb symmetry indexes can overestimate knee function after anterior cruciate ligament injury. *J Orthop Sports Phys Ther*. 2017;47(5):334-338.
48. Wilson BR, Robertson KE, Burnham JM, Yonz MC, Ireland ML, Noehren B. The relationship between hip strength and the Y-Balance Test. *J Sport Rehabil*. 2018;27(5):445-450.
49. Wörner T, Thorborg K, Stalman A, Webster KE, Momatz Olsson H, Eek F. High or low return to sport rates following hip arthroscopy is a matter of definition? *Br J Sports Med*. 2018;52(22):1475-1476.