Journal of Hip Preservation Surgery Vol. 6, No. 2, pp. 124–133
doi: 10.1093/jhps/hnz017
Advance Access Publication 5 June 2019
Research article

The association between specific sports activities and sport performance following hip arthroscopy for femoroacetabular impingement syndrome: A secondary analysis of a cross-sectional cohort study including 184 athletes

Lasse Ishøi[1], Kristian Thorborg[1,2], Otto Kraemer[1] and Per Hölmich[1]*

[1]Sports Orthopaedic Research Center—Copenhagen (SORC-C), Department of Orthopaedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Kettegård Allé 30, 2650 Hvidovre, Denmark and
[2]Physical Medicine & Rehabilitation Research—Copenhagen (PMR-C), Department of Orthopaedic Surgery and Physical Therapy, Copenhagen University Hospital, Amager-Hvidovre, Kettegård Allé 30, 2650 Hvidovre, Denmark.
*Correspondence to: P. Hölmich. Email: per.hoelmich@regionh.dk
Submitted 1 November 2018; Revised 15 February 2019; revised version accepted 5 May 2019

ABSTRACT

The main purpose of this secondary analysis was to compare the proportion of athletes with moderate-to-extreme difficulties in eight specific sport activities in athletes with optimal versus impaired sport performance after a hip arthroscopy for femoroacetabular impingement syndrome. Subjects were identified in a nationwide registry and invited to answer a return to sport and performance questionnaire, and the Copenhagen Hip and Groin Outcome Score Sport subscale investigating difficulties in eight specific sports activities (HAGOS sport items) as; none, mild, moderate, severe or extreme. Subjects were divided into two groups based on sport performance (optimal or impaired). The proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in the eight specific sport activities was compared between groups. The association between difficulties in sport activities and sport performance were investigated using logistic regression analysis. One hundred and eighty-four athletes (31 athletes with optimal and 153 athletes with impaired sport performance) were included at a mean follow-up of 33.1 ± 16.3 months. Up to six athletes (<20%) with optimal sport performance had moderate-to-extreme difficulties in sport activities. Contrary, 43–108 athletes (28.1–70.6%) with impaired performance had moderate-to-extreme difficulties in sport activities. Furthermore, moderate-to-extreme difficulties in HAGOS sport items: 'running as fast as you can' and 'kicking, skating etc.' increased the odds (14.7 and 6.1 times, respectively) of having impaired sport performance. Many athletes with impaired sport performance reported moderate-to-extreme difficulties in sport activities, specifically moderate-to-extreme difficulties in 'running as fast as you can' and 'kicking, skating etc.' were associated with patients having impaired sport performance.

INTRODUCTION

During the last decade, hip arthroscopy has been widely adopted as a treatment for femoroacetabular impingement syndrome (FAIS) [1, 2] with several studies yielding beneficial improvements from pre-to-post surgery in hip function and pain [3, 4]. However, despite such improvements, only a small proportion may regain normal self-reported sport and physical function when compared with healthy individuals [5]. Although, most athletes seem to return to sport [6], impairments in self-reported sport function may affect the ability to return to optimal sport performance following hip arthroscopy for FAIS [7, 8]. Recent studies from Scandinavia using detailed information on return to sport and performance status, which has not previously

been reported [9], have independently shown that ~20% return to optimal sport performance following hip arthroscopy for FAIS [7, 8]. In a study evaluating 189 athletes between 18 and 30 years old, only 16.9% were engaged in their preinjury sport at preinjury level with optimal performance at a mean follow-up of 33.1 months post-hip arthroscopy for FAIS [8], Furthermore, the ability to return to optimal sport performance seemed to be driven by better post-operative hip and groin function assessed with the 'Function in Sport and Recreation' subscale of the Copenhagen Hip and Groin Outcome Score (HAGOS Sport subscale) [8]. However, the score of the HAGOS Sport subscale is calculated based on eight items, each representing a specific sport activity and corresponding answer scored on a 5-point Likert scale (none, mild, moderate, severe or extreme) to assess difficulty in the specific sport activity [10]. Thus, it is still unknown whether difficulties in specific sports activities from the HAGOS Sport subscale are associated with actual sport performance following a hip arthroscopy for FAIS. Thus, this secondary analysis aimed to compare the proportion of athletes with moderate-to-extreme difficulties in eight specific sport activities (HAGOS sport items) in athletes with optimal versus impaired sport performance after a hip arthroscopy for FAIS.

MATERIALS AND METHODS

Study design

This cross-sectional explorative study investigated difficulties in eight specific sport activities, measured using the HAGOS Sport subscale (Table I) [10], between athletes with optimal and impaired sport performance assessed 6 months to 6 years following hip arthroscopy for FAIS. It includes data from a previously published cohort study [8]. Participants were retrospectively recruited between 6 September 2017 and 5 October 2017. The reporting adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [11]. Approval was obtained from the Danish Ethics Committee of the Capital Region (ID: H-17016762) and the Data Agency of the Capital Region (ID: AHH-2016-053).

Participants

Three hundred and fifty eligible participants were identified in the Danish Hip Arthroscopy Registry [12] based on the following inclusion and exclusion criteria. Inclusion criteria were: age of 18–30 years at the time of surgery and ≤35 years at the time of follow-up; pre-surgery cam morphology on plain radiograph (Alpha Angle ≥55°) [13]; surgical procedure consisting of at least cam resection and acetabular labral surgery performed during the preceding 6 months to 6 years as these are the two most common FAIS procedures performed in Denmark [14]. Exclusion criteria were: pre-surgery joint space width <3 mm [15]; grade 4 on Becks and/or ICRS cartilage classification identified during surgery [16]; any of the following surgical procedures at any time: extra articular surgery of the hip joint (except capsular closure), microfracture in the hip joint, periacetabular osteotomy and surgery to the ligamentum teres; previous hip arthroscopy in the same hip joint; previous hip pathology such as Perthes' disease, slipped capital femoral epiphysis, hip dysplasia (lateral center edge angle (Wiberg) <25°) and/or avascular necrosis of the femoral head; any rheumatoid disease in the hip joint such as synovial chondromatosis. Eligible participants were invited to answer a web-based survey delivered using the Research Electronic Data Capture (REDCap) tool (v. 7.1.1, Vanderbilt University) hosted at the Capital Region of Denmark [17]. The survey consisted of (i) a return to sport questionnaire collecting information on preinjury and present sport participation, including type of sport and self-reported performance [8] and (ii) assessment of self-reported hip and groin function using the HAGOS [10, 18]. Subjects were included if they reported participation in sport prior to onset of initial hip and groin pain, an intention to return to preinjury sport at preinjury level following hip arthroscopy, and completed the HAGOS Sport subscale (Table I). Informed consent was provided by the participants by responding to the survey.

Outcome measures

The outcome measures were: (i) the between-group difference in the proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in eight specific sport activities (HAGOS Sport subscale items; Table I) based on sport performance (optimal versus impaired); (ii) the association between difficulties (none-to-mild versus moderate-to-extreme) in HAGOS Sport subscale items and sport performance (optimal versus impaired); (iii) the between-group difference in the proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in HAGOS Sport subscale items based on type of sport (contact, pivoting versus non-contact, pivoting versus non-contact, non-pivoting) and acetabular cartilage status identified during surgery (Beck grade 0–1 versus Beck grade 2 versus Beck grade 3).

Data collection

Difficulties in specific sport activities were assessed using the eight individual items, defined as a question and corresponding answer, from the HAGOS Sport subscale (Table I). From here referred to as: SP1 ('squatting'); SP2 ('running'); SP3 ('twisting/pivoting'); SP4 ('walking on an uneven surface'); SP5 ('running as fast as you can'), SP6

Table I. Copenhagen Hip and Groin Outcome Score (HAGOS), function, sports and recreational subscale [10]

Instruction: The following questions concern your physical function when participating in higher-level activities. Answer every question by ticking the appropriate box. If a question does not pertain to you or you have not experienced it in the past week please make your 'best guess' as to which response would be the most accurate. The questions should be answered considering what degree of difficulty you have experienced during the following activities in the past week due to problems with your hip and/or groin.

SP1 Squatting				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP2 Running				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP3 Twisting/pivoting on a weight bearing leg				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP4 Walking on an uneven surface				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP5 Running as fast as you can				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP6 Bringing the leg forcefully forward and/or out to the side, such as in kicking, skating etc.				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP7 Sudden explosive movements that involve quick footwork, such as accelerations, decelerations, change of directions etc.				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
SP8 Situations where the leg is stretched into an outer position (such as when the leg is placed as far away from the body as possible)				
None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

('kicking, skating etc.'); SP7 ('explosive movements'); SP8 ('stretched into an outer hip position') (Table I) [10]. Each question, representing a specific sport activity, is scored on a 5-point Likert scale ranging from no to extreme hip and groin difficulties (none; mild; moderate; severe; extreme). Difficulties in the specific sport activities were divided into 'none-to-mild' or 'moderate-to-extreme' based on normative responses from athletes with no hip and pain [19].

The type of sport and self-reported sport performance were collected using a self-report return to sport questionnaire described in detail in Ishoi *et al.* [8]. In brief, athletes

were instructed to indicate if they were engaged in their preinjury sport at preinjury level at the time of follow-up. Athletes who were engaged in their preinjury sport at preinjury level were asked to state their current sport performance and participation as: (i) optimal sports performance including full sports participation, (ii) impaired sports performance but full sports participation and (iii) impaired sports performance including restricted sports participation [20]. Athletes who reported optimal sport performance including full participation were defined as athletes with 'optimal sport performance', whereas athletes with impaired performance, restricted participation or athletes not engaged in their preinjury sport at preinjury level were defined as athletes with 'impaired sport performance'.

Acetabular cartilage status identified during surgery was extracted from the Danish Hip Arthroscopy Registry [12].

Statistical methods

The proportion of athletes with none-to-mild and moderate-to-extreme difficulties in each of the eight specific sport activities (HAGOS Sport subscale items, Table I) were calculated by use of percentages with corresponding 95% confidence interval (95% CI). A chi-square test of homogeneity was used to assess the following outcome measures: (i) differences in the proportion of none-to-mild versus moderate-to-extreme difficulties in each HAGOS Sport subscale item (dependent variable) based on the independent variables of either sport performance (optimal versus impaired), type of sport (contact, pivoting versus non-contact, pivoting versus non-contact, non-pivoting) and acetabular cartilage status (Beck grade 0–1 versus Beck grade 2 versus Beck grade 3). The association between sport performance (optimal versus impaired) and difficulties (none-to-mild versus moderate-to-extreme) in HAGOS Sport subscale items was assessed using a logistic regression with backward selection of variables with sport performance as the dependent variable and difficulties in HAGOS Sport subscale items as independent variables. All statistical analyses were performed in SPSS (v. 23, IBM Corporation, New York, USA) with significance set at $P < 0.05$.

RESULTS

Participants

A total of 184 athletes were included (age at follow-up: 26.8 ± 3.4 years; male: 50%) at a mean follow-up of 33.1 ± 16.3 months (range: 6.3–67.8 months) (Fig. 1). Thirty-one athletes [16.8%; 95% CI (11.8; 22.3)] were classified with optimal sport performance, whereas 153 athletes [83.2%; CI 95% (77.1; 88.1)] were classified with impaired sport performance. A detailed overview of demographic, radiographic and operative findings is provided in Table II. An overview of sports participation is provided in Table III.

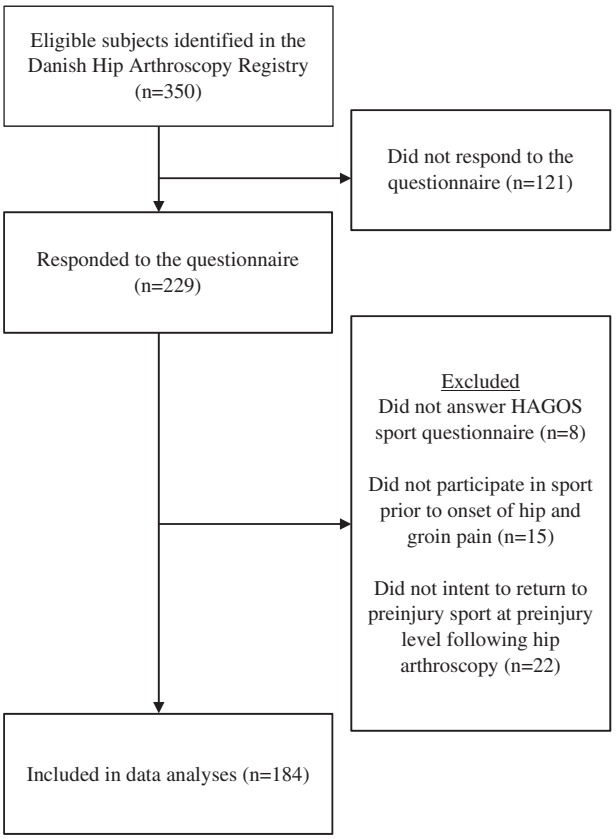

Fig. 1. Flow of participants.

Athletes with optimal sport performance versus impaired sport performance

The proportion of athletes reporting moderate-to-extreme difficulties in specific sport activities (HAGOS Sport subscale items) was significantly higher in athletes with impaired sport performance compared with athletes with optimal sport performance (28.1–70.6% versus 0–19.4%, $P \leq 0.001$) (Table IV). For athletes with impaired sport performance, moderate-to-extreme difficulties in sport activities were most pronounced in the following HAGOS Sport subscale items; SP8 ('stretched into an outer hip position') [70.6%; 95% CI (62.9; 77.2)], SP5 ('running as fast as you can') [64.1%; 95% CI (56.2; 71.2)], SP7 ('explosive movements') [61.1%; 95% CI (52.2; 67.6)], and SP6 ('kicking, skating etc.') and SP2 ('running') [58.8%; 95% CI (50.6; 66.6)]. An overview of HAGOS scores are provided in Supplementary Table 1.

The association between sport performance and difficulties in HAGOS Sport subscale items were found to be significant ($P < 0.001$) with adequate goodness of fit

Table II. Demographic, radiographic and operative data of included athletes

	Included athletes (n = 184)
Demographic data	
Follow-up, months (SD), range	33.1 (16.3), 6.3–67.8
Gender, no. males (%)	92 (50.0)
Level of sport	
Elite/professional, no. (%)	32 (17.4)
Competitive, no. (%)	75 (40.8)
Recreational, no. (%)	77 (41.8)
Mean age at surgery, years (SD)	23.5 (3.3)
Mean age at follow-up, years (SD)	26.8 (3.4)
Radiographic data	
Alpha Angle, ° (SD)	72.8 (10.9)
Lateral center edge angle, ° (SD)	32.2 (4.9)
Joint space width, no. >4.0 mm (%)	154 (83.7)
Operative data	
Bilateral operation, no. (%)	23 (12.5)
Becks classification	
Normal cartilage, no. (%)	3 (1.6)
Fibrillation, no. (%)	45 (24.5)
Wave sign, no. (%)	78 (42.4)
Cleavage tear between labrum and articular cartilage, no (%)	58 (31.5)
ICRS classification	
Normal cartilage, no. (%)	138 (75.0)

(Hosmer and Lemeshow test, χ^2 (2) = 0.503, $P = 0.0.778$). Moderate-to-extreme difficulties in SP5 ('running as fast as you can fast') and SP6 ('kicking, skating etc.') were significantly associated with impaired sport performance, corresponding to an odds ratio (OR) of 14.7 [95% CI (3.3; 66.3)] and 6.1 [95% CI (1.7; 22.3)], respectively (Supplementary Table 2A–C).

Type of sport

No between-group differences were observed in the proportion of athletes with moderate-to-extreme difficulties in specific sport activities (HAGOS Sport subscale items) ($P \geq 0.148$) (Table V). An overview of HAGOS scores are provided in Supplementary Table 3.

Acetabular cartilage status

No between-group differences were observed the proportion of athletes with moderate-to-extreme difficulties in specific sport activities (HAGOS Sport subscale items) ($P \geq 0.069$) (Table VI). An overview of HAGOS scores are provided in Supplementary Table 4.

DISCUSSION

Optimal sport performance versus impaired sport performance

The main finding of this explorative analysis was that a large proportion of athletes with impaired sports performance had moderate-to-extreme difficulties in the following HAGOS Sport subscale items; SP8 ('stretched into an outer range hip position'), SP5 ('running as fast as you can'), SP7 ('explosive movements'), SP6 ('kicking, skating etc.'), and SP2 ('running'), all being high joint load activities. In contrast, difficulties in SP1 ('squatting'), SP3 ('twisting/pivoting') and SP4 ('walking on an uneven surface') were reported by a minority of athletes, indicating that these activities may only provide little stress to the joint hip following hip arthroscopy for FAIS, and thus are not important for optimal sport performance. In line with this, Domb *et al.* [21] observed that athletes who returned to sport were better able to perform high-load sport activities. Furthermore, Naal *et al.* [22] noted a shift from high-impact sports (soccer, jogging, indoor sports) to lower impact activities (cycling, Nordic walking, fitness/weight training) following open surgery for FAIS, indicating that the hip joint was less able to tolerate high loads.

Moderate-to-extreme difficulties with SP8 ('stretched into an outer hip position') were reported by 70.6% of athletes with impaired sport performance. Interestingly, a systematic review reported no differences in isolated passive hip range of motion between patients with FAIS and healthy controls [23], indicating that other factors are responsible for difficulties in SP8 ('stretched into an outer hip position'). As outer range hip positions are associated with large lever arms, such activities likely result in considerable hip joint moments (force acting across the hip joint) and contact forces in the hip joint [24]. Additionally, a systematic review observed a lower peak hip extension angle during walking in patients with FAIS compared with healthy controls, which may reduce anterior hip joint forces [25]. Collectively, these observations suggest that difficulties in SP8 ('stretched into an outer hip position')

Table III. Number of athletes participating in different sports

Type of sport	*n (%)*
Non-contact, pivoting ($n = 37$)	
Dancing	12 (32.4)
Gymnastic	11 (29.7)
Badminton	5 (13.5)
Tennis	3 (8.1)
Golf	2 (5.4)
Volleyball	2 (5.4)
Cross-fit	1 (2.7)
Skateboarding	1 (2.7)
Non-contact, non-pivoting ($n = 65$)	
Running	27 (41.5)
Horse riding	12 (18.5)
Fitness/strength training	11 (16.9)
Cycling	5 (7.7)
Athletics	3 (4.6)
Swimming	3 (4.6)
Triathlon	3 (4.6)
Motocross	1 (1.5)
Contact, pivoting ($n = 82$)	
Football (soccer)	48 (58.5)
Handball (team)	19 (23.2)
Basketball	6 (7.3)
Martial art	6 (7.3)
Ice hockey	2 (2.4)
Boxing	1 (1.2)

may be due to inability to tolerate load rather than reduced isolated hip range of motion *per se* [23, 25, 26].

Moderate-to-extreme difficulties in the high-load HAGOS Sport subscale items; SP2 ('running'), SP5 ('running as fast as you can'), SP6 ('kicking, skating etc.') and SP7 ('explosive movements') were reported by most athletes with impaired sport performance (≥58.8%). These findings are not surprising since large forces are distributed across the hip joint during these activities [24, 27–29]. During running, vertical ground reaction forces easily exceed three times body weight [30] whereas the peak magnitude of the resultant hip joint contact forces (forces measured in the hip joint) can reach 11 times body weight for a running pace of 3.47 m s^{-1} [24]. As the hip joint contact forces are primarily influenced by the activity of the hip muscles [24], even higher hip joint contact forces are likely to occur during high-speed running due to large increases in hip muscle peak forces with increasing speed [24, 27]. Additionally, explosive activities such as running acceleration are associated with significant increased hip joint work compared with steady state running [28], whereas single-leg landing, an activity often present in various sports, is associated with vertical ground reaction forces up to 5.30 times body weight [29]. The ability of the hip joint to tolerate and attenuate ground reaction forces during high load sport activities are not yet clear in athletes who have had a hip arthroscopy for FAIS [25]. However, 1–2 years following hip arthroscopy for intra-articular hip pathology subjects demonstrate increased hip adduction and knee valgus angle during single-leg squatting [31]. Interestingly, such movement pattern is associated with less hip joint loading [32], indicating a compensatory movement pattern. Supporting this, patients with FAIS show reduced hip joint contact forces during walking indicative of a protective mechanism [26].

Reduced force absorption capacity may be due to degradation of the hip cartilage properties [33]. Thus, FAIS patients with cam morphology undergoing surgery have markedly reduced proteoglycan content in the acetabular cartilage including a 70% reduced compressive stiffness of the cartilage [33]. Such degeneration is likely to shift the load imposed on the hip joint during sport activities to the acetabular subchondral bone, leading to increased bone plate stiffness and further increases in cartilage tensile stresses over time [33, 34]. Impaired hip and lower limb muscle function, often observed in FAIS patients [23], may also contribute to reduced force absorption capacity [35] and low self-reported hip function [36, 37]. However, as muscle force production is a major contributor to hip joint contact forces [24], the ability to produce high muscles forces could mimic an increased ability to tolerate load across the hip joint rather than an effect of muscle strength *per se*.

Type of sport

The proportion of athletes with moderate-to-extreme difficulties in HAGOS Sport subscale items were not different based on type of sport. In line with this, several reports suggest that athletes in different sports can expect to obtain a similar sporting ability post-hip arthroscopy [38, 39],

Table IV. Proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in specific sport activities (HAGOS sport items) based on sport performance

Sport activities	*Optimal sport performance (n = 31[a])*		*Impaired sport performance (n = 153)*		*Chi-square test of homogeneity*
	Difficulties, no. (%)		*Difficulties, no. (%)*		
	Yes	*No*	*Yes*	*No*	
SP1 ('squatting')	3 (9.7)	28 (90.3)	64 (41.8)	89 (58.2)	$P = 0.001$
SP2 ('running')	2 (6.5)	29 (93.5)	90 (58.8)	63 (41.2)	$P < 0.001$
SP 3 ('twisting/pivoting')	1 (3.3)	29 (96.7)	61 (39.9)	92 (60.1)	$P < 0.001$
SP4 ('walking on an uneven surface')	0 (0)	31 (100)	43 (28.1)	110 (71.9)	$P = 0.001$
SP5 ('running as fast as you can')	2 (6.5)	29 (93.5)	98 (64.1)	55 (35.9)	$P < 0.001$
SP6 ('kicking, skating etc.')	3 (9.7)	28 (90.3)	90 (58.8)	63 (41.2)	$P < 0.001$
SP7 ('explosive movements')	4 (12.9)	27 (87.1)	92 (60.1)	61 (39.9)	$P < 0.001$
SP8 ('stretched in an outer hip position')	6 (19.4)	25 (80.6)	108 (70.6)	45 (29.4)	$P < 0.001$

[a]Thirty athletes in twisting/pivoting. Difficulties are based on the HAGOS Sport/recreational subscale and dichotomized as 'Yes' (moderate-to-extreme) and 'No' (none-to-mild).

Table V. Proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in specific sport activities (HAGOS sport items) based on type of sport

Sport activities	*Non-contact, pivoting sport (n = 37[a])*		*Non-contact, non-pivoting sport (n = 65)*		*Contact, pivoting sport (n = 82)*		*Chi-square test of homogeneity*
	Difficulties, no. (%)		*Difficulties, no. (%)*		*Difficulties, no. (%)*		
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	
SP1 ('squatting')	12 (32.4)	25 (67.6)	23 (35.4)	42 (64.6)	32 (39.0)	50 (61.0)	$P = 0.769$
SP2 ('running')	20 (54.1)	17 (45.9)	35 (53.8)	30 (46.2)	37 (45.1)	45 (54.9)	$P = 0.495$
SP 3 ('twisting/pivoting')	11 (30.6)	25 (69.4)	22 (33.8)	43 (66.2)	29 (35.4)	53 (64.6)	$P = 0.879$
SP4 ('walking on an uneven surface')	13 (35.1)	24 (64.9)	12 (18.5)	53 (81.5)	18 (22.0)	64 (78.0)	$P = 0.148$
SP5 ('running as fast as you can')	22 (59.5)	15 (40.5)	36 (55.4)	29 (44.6)	42 (51.2)	40 (48.8)	$P = 0.690$
SP6 ('kicking, skating etc.')	18 (48.6)	19 (51.4)	30 (46.2)	35 (53.8)	45 (54.9)	37 (45.1)	$P = 0.557$
SP7 ('explosive movements')	19 (51.4)	18 (48.6)	31 (47.7)	34 (52.3)	46 (56.1)	36 (43.9)	$P = 0.595$
SP8 ('stretched in an outer hip position')	25 (67.6)	12 (32.4)	37 (56.9)	28 (43.1)	52 (63.4)	30 (36.6)	$P = 0.531$

[a]Thirty-six athletes in twisting/pivoting. Difficulties are based on the HAGOS Sport/recreational subscale and dichotomized as 'Yes' (moderate-to-extreme) and 'No' (none-to-mild).

Table VI. Proportion of athletes with none-to-mild versus moderate-to-extreme difficulties in specific sport activities (HAGOS sport items) based on acetabular cartilage status

Athletic movement	*Beck grade 0–1 (n = 48)*[b]		*Beck grade 2 (n = 78)*		*Beck grade 3 (n = 58*[a]*)*		*Chi-square test of homogeneity*
	Difficulties, no. (%)		*Difficulties, no. (%)*		*Difficulties, no. (%)*		
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	
SP1 ('squatting')	19 (39.6)	29 (60.4)	32 (41.0)	46 (59.0)	16 (27.6)	42 (72.4)	$P = 0.237$
SP2 ('running')	23 (47.9)	25 (52.1)	45 (57.7)	33 (42.3)	24 (41.4)	34 (58.6)	$P = 0.161$
SP 3 ('twisting/pivoting')	22 (45.8)	26 (54.2)	25 (32.1)	53 (67.9)	15 (26.3)	42 (73.7)	$P = 0.099$
SP4 ('walking on an uneven surface')	11 (22.9)	37 (77.1)	24 (30.8)	54 (69.2)	8 (13.8)	50 (86.2)	$P = 0.069$
SP5 ('running as fast as you can')	24 (50.0)	24 (50.0)	48 (61.5)	30 (38.5)	28 (48.3)	30 (51.7)	$P = 0.240$
SP6 ('kicking, skating etc.')	26 (54.2)	22 (45.8)	38 (48.7)	40 (51.3)	29 (50.0)	29 (50.0)	$P = 0.834$
SP7 ('explosive movements')	26 (54.2)	22 (45.8)	42 (53.8)	36 (46.2)	28 (48.3)	30 (51.7)	$P = 0.772$
SP8 ('stretched in an outer hip position')	29 (60.4)	19 (39.6)	50 (64.1)	28 (35.9)	35 (60.3)	23 (39.7)	$P = 0.876$

[a]Fifty-seven athletes in twisting/pivoting. Difficulties are based on the HAGOS Sport/recreational subscale and dichotomized as 'Yes' (moderate-to-extreme) and 'No' (none-to-mild).
[b]Three athletes had Beck grade 0.

although positional differences have been observed [40]. In relation to this, Menge *et al.* [40] noted a lower return to sport rate in offensive linemen compared with other positions in a cohort of elite American Football players. Offensive linemen were characterized by the largest body mass index and all had cartilage injuries; furthermore, they push off forcefully from the line with the hip in flexion, and thus create a large hip extension moment which may cause difficulties/pain in the anterior superior aspect of the acetabulum [40].

Acetabular cartilage status

The proportion of athletes with moderate-to-extreme difficulties in HAGOS Sport subscale items was not different based on acetabular cartilage status. This is surprising since damaged cartilage may reduce the force absorption capacity of the hip joint [41] leading to increased impact forces acting on the subchondral bone [42]. However, 98.4% of athletes had an acetabular cartilage lesion (≥Becks grade 1), and it could be speculated whether having a cartilage lesion or not is more important for post-surgery sport performance rather than the severity. Furthermore, resection of a cam deformity may alleviate excessive stress on the acetabular cartilage potentially lowering hip pain during specific sport activities for some athletes [43–45].

Clinical relevance

Current rehabilitation strategies following hip arthroscopy for FAIS are based on expert opinions [46, 47] and physical impairments such as information on hip muscle strength and range of motion [48, 49] including biomechanical analyses of low-load activities such as walking [25]. However, information on which factors contribute to optimal sport performance in athletes is uncertain but could further guide rehabilitation and return to sport strategies of athletes with an intention to return to optimal sport performance. The present findings suggest the ability to perform sport activities such as SP5 ('running as fast as you can') and SP6 ('kicking, skating etc.') without difficulties are important for obtaining optimal sport performance following hip arthroscopy for FAIS. Since these activities are associated with considerable load distributed across the hip joint, focusing on improving intra-articular load bearing capacity as an adjunct to hip muscle strengthening may be an important component in rehabilitation after hip arthroscopy for FAIS.

Methodological considerations and limitations

The present study is not without limitation. A cross-sectional design was used; thus, it remains to be investigated if rehabilitation targeting the specific sport activities with moderate-to-extreme difficulties will result in a higher

return to optimal sport performance rate following hip arthroscopy for FAIS. Furthermore, as subjects were identified retrospectively 6.3–67.8 months following hip arthroscopy for FAIS it is possible that some athletes may not have been fully rehabilitated at the time of inclusion. However, the decision to include athletes from 6 months was based on recommendations from high-volume hip arthroscopy centers [46]. Finally, although the HAGOS is recommended as a reliable and valid patient-reported outcome in patients with FAIS [18], the reliability of the specific items is unknown.

CONCLUSION

Following hip arthroscopy for FAIS most athletes with impaired performance have moderate-to-extreme difficulties in HAGOS Sport subscale items such as SP8 ('stretched into an outer hip position'), SP5 ('running as fast as you can'), SP7 ('explosive movements') SP2 ('running') and SP6 ('kicking, skating etc.'). Furthermore, moderate-to-extreme difficulties in 'running as fast as you can' and 'kicking, skating etc.' were associated with increased odds of reporting impaired sport performance.

SUPPLEMENTARY DATA

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

ACKNOWLEDGEMENTS

The authors would like to thank all patients at our facility involved in pilot testing of the return to sport questionnaire, the Steering committee at the Danish Hip Arthroscopy Registry for providing the patient records and all the subjects who responded to the questionnaire.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. de Sa D, Holmich P, Phillips M. Athletic groin pain: a systematic review of surgical diagnoses, investigations and treatment. *Br J Sports Med* 2016; **50**: 1181–6.
2. Reiman MP, Thorborg K, Holmich P. Femoroacetabular impingement surgery is on the rise-but what is the next Step? *J Orthop Sports Phys Ther* 2016; **46**: 406–8.
3. 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**: 572–9.
4. 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**: 2225–35.
5. Thorborg K, Kraemer O, Madsen AD *et al.* 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**: 2607–14.
6. Reiman MP, Peters S, Sylvain J *et al.* 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**: 972–81.
7. Worner T, Thorborg K, Stalman A *et al.* High or low return to sport rates following hip arthroscopy is a matter of definition? *Br J Sports Med* 2018; **52**: 1475–76.
8. Ishoi L, Thorborg K, Kraemer O *et al.* 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**: 2578–87.
9. Reiman MP, Peters S, Sylvain J *et al.* 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**: 972–81.
10. Thorborg K, Holmich P, Christensen R *et al.* The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med* 2011; **45**: 478–91.
11. Vandenbroucke JP, von Elm E, Altman DG *et al.* Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. *Epidemiology* 2007; **18**: 805–35.
12. Mygind-Klavsen B, Gronbech Nielsen T, Maagaard N *et al.* Danish Hip Arthroscopy Registry: an epidemiologic and perioperative description of the first 2000 procedures. *J Hip Preserv Surg* 2016; **3**: 138–45.
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**: 1169–76.
14. Lund B, Mygind-Klavsen B, Nielsen TG *et al.* Danish Hip Arthroscopy Registry (DHAR): the outcome of patients with femoroacetabular impingement (FAI). *J Hip Preserv Surg* 2017; **4**: 170–7.
15. Philippon MJ, Briggs KK, Yen YM *et al.* Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg Br* 2009; **91**: 16–23.
16. Lund B, Nielsen TG, Lind M. Cartilage status in FAI patients—results from the Danish Hip Arthroscopy Registry (DHAR). *SICOT J* 2017; **3**: 44.
17. Harris PA, Taylor R, Thielke R *et al.* Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009; **42**: 377–81.

18. 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**: 812.
19. Thorborg K, Branci S, Stensbirk F *et al*. Copenhagen Hip and Groin Outcome Score (HAGOS) in male soccer: reference values for hip and groin injury-free players. *Br J Sports Med* 2014; **48**: 557–9.
20. 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**: 853–64.
21. Domb BG, Dunne KF, Martin TJ *et al*. Patient reported outcomes for patients who returned to sport compared with those who did not after hip arthroscopy: minimum 2-year follow-up. *J Hip Preserv Surg* 2016; **3**: 124–31.
22. Naal FD, Schär M, Miozzari HH *et al*. Sports and activity levels after open surgical treatment of femoroacetabular impingement. *Am J Sports Med* 2014; **42**: 1690–5.
23. Freke MD, Kemp J, Svege I *et al*. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med* 2016; **50**: 1180.
24. Schache AG, Lin YC, Crossley KM *et al*. Is running better than walking for reducing hip joint loads? *Med Sci Sports Exerc* 2018; **50**: 2301–10.
25. King MG, Lawrenson PR, Semciw AI *et al*. Lower limb biomechanics in femoroacetabular impingement syndrome: a systematic review and meta-analysis. *Br J Sports Med* 2018; **52**: 566–80.
26. Ng KCG, Mantovani G, Modenese L *et al*. Altered walking and muscle patterns reduce hip contact forces in individuals with symptomatic cam femoroacetabular impingement. *Am J Sports Med* 2018; **46**: 2615–23.
27. Dorn TW, Schache AG, Pandy MG. Muscular strategy shift in human running: dependence of running speed on hip and ankle muscle performance. *J Exp Biol* 2012; **215**: 1944–56.
28. Williams DS 3rd, Cole JH, Powell DW. Lower extremity joint work during acceleration, deceleration, and steady state running. *J Appl Biomech* 2017; **33**: 56–63.
29. Wang LI, Peng HT. Biomechanical comparisons of single- and double-legged drop jumps with changes in drop height. *Int J Sports Med* 2014; **35**: 522–7.
30. Nilsson J, Thorstensson A. Ground reaction forces at different speeds of human walking and running. *Acta Physiol Scand* 1989; **136**: 217–27.
31. Charlton PC, Bryant AL, Kemp JL *et al*. Single-leg squat performance is impaired 1 to 2 years after hip arthroscopy. *PM R* 2016; **8**: 321–30.
32. Tamura A, Akasaka K, Otsudo T *et al*. Dynamic knee valgus alignment influences impact attenuation in the lower extremity during the deceleration phase of a single-leg landing. *PloS One* 2017; **12**: e0179810.
33. Speirs AD, Beaule PE, Huang A *et al*. Properties of the cartilage layer from the cam-type hip impingement deformity. *J Biomech* 2017; **55**: 78–84.
34. Speirs AD, Beaule PE, Rakhra KS *et al*. Increased acetabular subchondral bone density is associated with cam-type femoroacetabular impingement. *Osteoarthritis Cartilage* 2013; **21**: 551–8.
35. Zhang SN, Bates BT, Dufek JS. Contributions of lower extremity joints to energy dissipation during landings. *Med Sci Sports Exerc* 2000; **32**: 812–9.
36. Kemp JL, Makdissi M, Schache AG *et al*. Is quality of life following hip arthroscopy in patients with chondrolabral pathology associated with impairments in hip strength or range of motion? *Knee Surg Sports Traumatol Arthrosc* 2016; **24**: 3955–61.
37. Davis CC, Ellis TJ, Amesur AK *et al*. Improvements in knee extension strength are associated with improvements in self-reported hip function following arthroscopy for femoroacetabular impingement syndrome. *Int J Sports Phys Ther* 2016; **11**: 1065–75.
38. Schallmo MS, Fitzpatrick TH, Yancey HB *et al*. Return-to-play and performance outcomes of professional athletes in North America after hip arthroscopy from 1999 to 2016. *Am J Sports Med* 2018; **46**: 1959–69.
39. Weber AE, Kuhns BD, Cvetanovich GL *et al*. Amateur and recreational athletes return to sport at a high rate following hip arthroscopy for femoroacetabular impingement. *Arthroscopy* 2017; **33**: 748–55.
40. Menge TJ, Bhatia S, McNamara SC *et al*. Femoroacetabular impingement in professional football players: return to play and predictors of career length after hip arthroscopy. *Am J Sports Med* 2017; **45**: 1740–4.
41. Kumar D, Dillon A, Nardo L *et al*. Differences in the association of hip cartilage lesions and cam-type femoroacetabular impingement with movement patterns: a preliminary study. *PM R* 2014; **6**: 681–9.
42. Carballo CB, Nakagawa Y, Sekiya I *et al*. Basic science of articular cartilage. *Clin Sports Med* 2017; **36**: 413–25.
43. Beaule PE, Speirs AD, Anwander H. Surgical correction of cam deformity in association with femoroacetabular impingement and its impact on the degenerative process within the hip joint. *J Bone Joint Surg Am* 2017; **99**: 1373–81.
44. Ganz R, Leunig M, Leunig-Ganz K *et al*. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res* 2008; **466**: 264–72.
45. Liu Q, Wang W, Thoreson AR *et al*. Finite element prediction of contact pressures in cam-type femoroacetabular impingement with varied alpha angles. *Comput Methods Biomech Biomed Engin* 2017; **20**: 294–301.
46. Domb BG, Stake CE, Finch NA *et al*. Return to sport after hip arthroscopy: aggregate recommendations from high-volume hip arthroscopy centers. *Orthopedics* 2014; **37**: e902–5.
47. Cheatham SW, Enseki KR, Kolber MJ. Postoperative rehabilitation after hip arthroscopy: a search for the evidence. *J Sport Rehabil* 2015; **24**: 413–8.
48. Heerey J, Risberg MA, Magnus J *et al*. Impairment-based rehabilitation following hip arthroscopy: postoperative protocol for the HIP ARThroscopy International Randomized Controlled Trial. *J Orthop Sports Phys Ther* 2018; **48**: 336–42.
49. Bennell KL, Spiers L, Takla A *et al*. Efficacy of adding a physiotherapy rehabilitation programme to arthroscopic management of femoroacetabular impingement syndrome: a randomised controlled trial (FAIR). *BMJ Open* 2017; **7**: e014658.