

# Arthroscopic Correction of Sports-Related Femoroacetabular Impingement in Competitive Athletes

## 2-Year Clinical Outcome and Predictors for Achieving Minimal Clinically Important Difference

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**Background:** A growing body of literature supports surgical intervention for femoroacetabular impingement (FAI) in young, active athletes. However, factors likely to influence results in this cohort are less clearly defined.

**Purpose:** To quantify changes in validated patient-reported outcome measures (PROMs) and determine whether differences in baseline athlete demographic characteristics, intraoperative findings, and surgical techniques are associated with achieving improved outcomes and minimal clinically important difference (MCID) after arthroscopic management of sports-related FAI.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** Data were prospectively collected from competitive athletes who underwent hip arthroscopy between January 2009 and February 2017. Athletes who underwent primary arthroscopic correction of sports-related FAI with labral repair were included providing they had a Tönnis grade  $\leq 1$  and a lateral center-edge angle  $\geq 20^\circ$ , excluding significant articular cartilage injury and lateral rim dysplasia. The modified Harris Hip Score, Western Ontario and McMaster Universities Osteoarthritis Index, University of California Los Angeles activity scale, and 36-Item Short Form Health Survey were used to measure outcomes at the 2-year follow-up. MCID was measured using 3 methods: a mean change method, a distribution-based method, and the percentage of possible improvement (POPI) method. Multivariate regression models were used to assess a number of diagnostic and surgical variables associated with good outcome and achieving MCID at follow-up.

**Results:** At 2-year follow-up, statistically significant improvements were observed for all PROMs ( $P < .001$  for all), and 84% of athletes continued to play sport. Higher preoperative PROM scores reduced the likelihood of achieving MCID; however, returning to play was the strongest predictor of reaching MCID in this athletic cohort. Using absolute score change (mean change or distribution method) to calculate MCID was less accurate owing to ceiling effects and dependence on preoperative PROM scores.

**Conclusion:** Athletes undergoing arthroscopy for sports-related FAI can expect a successful outcome and continued sports participation at 2 years postoperatively. The majority of athletes will achieve MCID. The POPI method of MCID calculation was more applicable to higher functioning athletic cohorts. Reduced preoperative PROM scores and the ability to return to sport increased the likelihood of achieving MCID in this population.

**Keywords:** femoroacetabular impingement; arthroscopy; athletes; outcomes; MCID

In all field sports, athletes are required to change direction, accelerate, and decelerate at speed,<sup>12,52,54</sup> which can predispose players to injury. One such injury common in multidirectional sports is femoroacetabular impingement (FAI). FAI occurs from abnormal contact between the

acetabular rim and the femoral head-neck junction as a result of progressive bony deformity of the hip joint. Two distinct patterns of hip deformity are recognized: A cam deformity is characterized by excessive bone growth on the femoral head-neck junction, and a pincer deformity is associated with abnormal bony prominence of the acetabular rim. Repetitive contact during hip motion gradually damages both the acetabular labrum and the articular cartilage, increasing the risk of osteoarthritis of the hip joint

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over time. Symptoms in the young athlete include progressive hip pain and stiffness (often insidious in nature), which are exacerbated by physical activity, and reduced range of motion (ROM).<sup>8</sup> Reduced playing time and decreased athletic ability<sup>35</sup> are often associated with prolonged hip pain and discomfort.

FAI can be treated using nonoperative measures or surgical intervention. Although some short-term benefits of nonoperative management for FAI have been reported, longitudinal outcomes for athletic patients are lacking.<sup>31,33</sup> The literature surrounding surgical treatment for FAI is more extensive, and favorable results with few complications are reported in both general<sup>42</sup> and athletic populations.<sup>25,26,34</sup> Some predictors of outcomes have been reported previously among general populations. Nho et al<sup>37</sup> and Sogbein et al<sup>48</sup> highlighted baseline pain levels, symptom duration, levels of intra-articular damage, and decreased physical activity as predictors of surgical outcomes. Predictors such as these are lacking in athletic cohorts, whose functional demands may be greater than those of the general population. Barastegui et al<sup>1</sup> examined the long-term playing ability of 21 professional soccer players and reported that older patients were less likely to continue with sport than were those with a labral excision. No regression analysis was conducted, and the small sample size did not allow for an in-depth analysis.<sup>1</sup>

The current study quantified changes in patient-reported outcome measures (PROMs) at 2-year follow-up in a large cohort of field-sport athletes after arthroscopic management of sports-related FAI (SRFAI). Our aim was to assess whether patient presentation at diagnosis, intraoperative findings, and surgical techniques influence these outcomes and the ability to achieve a minimal clinically important difference (MCID) at follow-up.

## METHODS

### Patients

Institutional approval was provided for the analysis of prospectively collected data as part of a hip registry, and written consent was obtained from the participating athletes. The study cohort consisted of 1171 competitive field-sport athletes who underwent hip arthroscopy by a single experienced hip surgeon (P.C.) at our institution between January 2009 and February 2017. Data were collected both preoperatively and at a minimum of 2 years after surgery. Athletes were diagnosed using a combination of detailed clinical examinations and specialized hip imaging.

A detailed history of symptoms in keeping with SRFAI (eg, groin or hip pain/stiffness during or after physical activity) was recorded. Exclusion criteria for the study included athletes diagnosed with osteoarthritic changes (Tönnis grade >1; n = 78) and evidence of lateral rim dysplasia (lateral center-edge angle [LCEA] <20°; n = 17). Athletes undergoing a revision procedure were excluded (n = 49) as were those who had a labral excision procedure (n = 53) or no viable labral tissue (n = 10). In total, 964 hip surgeries in 760 patients met the inclusion criteria (204 bilateral patients; 26.8%).

### Assessments

Clinical examination entailed hip provocation tests including flexion, adduction, and internal rotation (FADIR) and flexion, abduction, and external rotation (FABER) tests, whereby pain upon examination was considered a positive test. The examination also included hip ROM assessments; hip ROM was assessed at both time points by 2 experienced assessors using a handheld goniometer. The athlete was placed in the supine position for the flexion and abduction measures, with the hip and knee flexed at 90° for the adduction, internal rotation, and external rotation measures. Standardized plain radiographs (which included anteroposterior [AP] pelvis, false-profile, and 90° Dunn views) were used to observe the presence of an anterolateral rim deformity and to measure LCEA and alpha angle both for diagnostic purposes and to quantify extent of surgical resection. The presence of additional characteristics indicative of pincer deformity (crossover, ischial spine, posterior wall signs) was recorded.

Validated measures of joint-specific function and general health were used and included the modified Harris Hip Score (mHHS),<sup>5,29,44</sup> the University of California Los Angeles (UCLA) activity scale,<sup>50,55</sup> the 36-Item Short Form Health Survey (SF-36),<sup>22,30</sup> and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).<sup>32</sup> For all PROMs except the WOMAC, a higher score indicates a better outcome. The PROMs were administered preoperatively and at follow-up. Athletes who were unable to attend the 2-year follow-up appointment received a hard copy of the PROM questionnaires by post and again by email if necessary. Also, at the 2-year follow-up, participants completed an institutionally based survey to assess patient satisfaction (also used for anchor MCID question) and for sports participation to determine whether they were (1) continuing with full participation and (2) continuing to play at their preinjury level of performance. In cases where performance did not match preinjury levels, the reason for this was provided.

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Ethical approval for this study was obtained from UPMC Whitfield Hospital.

## Surgical Intervention and Rehabilitation

The surgical technique has been described previously in detail.<sup>6</sup> Each patient was anesthetized and placed on a distraction table in the supine position. An anterolateral portal and modified midanterior portal were established, and an interportal capsulotomy was performed. In cases where a pincer deformity was identified, a labral “reflection” technique was used for “takedown,” preserving the chondrolabral junction where possible. A 4-mm mechanical bur was used to resect pathological acetabular bone to a preplanned depth with the aim to establish a postoperative LCEA of 30°. A suspension-type, labral cuff repair was used where possible for reattachment to acetabular rim; in some cases where chondrolabral disruption was evident intraoperatively, a looped repair was used. The labrum was then probed to assess stability of the fixation. Distraction was released and the peripheral compartment examined. Femoro-osteoplasty was subsequently undertaken to remove excessive bone on the femoral head-neck junction in cases where a cam deformity was also present. The hip joint was dynamically and radiologically assessed to ensure appropriate impingement-free movement. With the evolution of surgical techniques, routine capsular repair was introduced for all patients in 2013. This was midway through the study period and, as such, approximately half the sample had capsular repair. The interportal capsulotomy was repaired using 2 or 3 nonabsorbable sutures. Bilateral operations were conducted within 6 weeks, with a mean of 17 ± 9 days between procedures.

Postoperatively, a stationary bicycle was used on day 1 to encourage mobilization of the joint. Crutches were used for 5 days after the treatment, with hydrotherapy initiated as soon as the incisions had healed, usually around 10 days after surgery. A 12-week standardized rehabilitation program was provided by the resident physical therapist immediately after surgery, and postoperative reviews were carried out at 6 and 12 weeks. The rehabilitation protocol consisted of 4 phases, which included exercises to increase mobility in the early stages and gradual progression to more functional tasks, with resumption of running from 6 to 8 weeks, sprinting at 10 weeks, and a return to full training at 12 weeks after the operation.

## Statistical Analysis

Statistical analysis was carried out using SPSS 25 software. The number of patients who progressed to total hip replacement or required reoperation were reported but not included in the statistical analysis. For context, 3-month follow-up compared with baseline is provided. Data were first assessed for normality using a Shapiro-Wilk test. Changes in patient-reported outcomes from preoperative to follow-up assessments for the entire group were assessed using a paired-samples *t* test (parametric) or Wilcoxon signed-rank test (nonparametric). Effect sizes (ES) were calculated using the Cohen  $d^{10}$  or  $r = \frac{z}{\sqrt{N}}$  for nonparametric data.<sup>46</sup> A 1-way analysis of variance was used to examine differences in outcomes between subcategories within the entire group based on age (<25, 25-34, ≥35

years), symptom duration (<6 months, 6-12 months, 1-2 years, 2-5 years, >5 years), training frequency before intervention (<3, 3-5, or >5 days/week), radiological findings (LCEA classifications [borderline dysplasia, normal, overcoverage] or alpha angle) and surgical technique (labral repair type, capsular repair vs no repair). Correlations between radiological parameters and hip ROM, radiological parameters and PROM scoring, and hip ROM and PROM scoring pre- and postoperatively were assessed using the Pearson correlation (ES: *r*). Finally, return-to-play rates between subcategories were assessed using chi-square analysis (ES: *phi*).

The MCID is a common metric used in clinical research. Traditional methods used to calculate MCID (eg, distribution based or mean change in PROMs) are flawed owing to their association with baseline scores and because of ceiling effects that occur in higher functioning patients (with higher baseline scores). To counteract this, we additionally used the potential of possible improvement (POPI) method to derive MCID thresholds for each PROM.<sup>7</sup> This was achieved by calculating the mean change as a percentage of the maximum possible change relative to the patient's own baseline score, for each patient:

$$\frac{\text{Change score}}{\text{Maximum possible change}} \times 100$$

To begin, an anchor question was used. Athletes were asked, “How well did the surgery on your joint meet your expectations?” There were 5 possible responses: *excellent*, *very good*, *good*, *fair*, and *poor*. We considered a rating of “fair” to equate an MCID. Athletes who reported a “fair” satisfaction rate were assessed independently. The MCID value for each PROM for this group was quantified using the POPI technique, and the percentage of athletes from the total group meeting or exceeding this figure was determined. For comparison, a mean change method and distribution-based approach was also used. The same athletes who reported “fair” satisfaction were assessed, and the mean change as well as 0.5 SD of the measured change for this group was calculated to determine MCID thresholds.<sup>38</sup> Only athletes who could potentially meet these thresholds (a limitation of the standard MCID metric) were included in the subsequent analysis, which determined the percentage of athletes meeting or exceeding these thresholds.

Bivariate logistic regression analyses were carried out to screen for potential factors associated with achieving MCID for each PROM. Independent variables included were age, symptom duration, Tönnis grade (0 vs 1), the total number of sports in which the participant engaged, frequency of training, preoperative radiographic findings (LCEA and alpha angle), presence of a rim fracture, preoperative ROM, intraoperative variables including labral repair method (looped vs suspension), capsular repair versus noncapsular repair, and rates of continued sports participation. All variables that were found to be significant during these analyses were included in a multivariate forward stepwise regression analysis to determine which variables were associated with achieving MCID.

TABLE 1  
Participant Demographic Characteristics<sup>a</sup>

Variable	Mean $\pm$ SD or %
Age, years	26.3 $\pm$ 6.3 (range, 14.6-49.6)
Sex	
Male	94.8
Female	5.2
Field sport	
Gaelic football	39.4
Hurling	44.2
Soccer	11
Rugby	5.4
Training frequency	
<3 times/week	16.1
3-5 times/week	70.7
>5 times/week	13.2
Symptom duration	
<6 months	22.7
6-12 months	25.8
1-2 years	24.7
2-5 years	18.8
>5 years	8
Tönnis grade	
0	81
1	19
Radiological parameters, deg	
LCEA	33.92 $\pm$ 6.3
Alpha angle (AP)	66.75 $\pm$ 17.7
Alpha angle (Dunn)	59.60 $\pm$ 13.1
Surgical approach to capsule	
Capsular repair	52.1
No repair	47.9
Type of repair	
Cuff repair	70
Loop repair	30

<sup>a</sup>AP, anteroposterior; LCEA, lateral center-edge angle.

## RESULTS

### Athletes and Follow-up

Table 1 shows the demographic characteristics for the 760 patients (964 hips) included in the study. In each case, non-operative management had failed to relieve symptoms; on average, the patients had seen  $2.8 \pm 1.9$  health care professionals before referral to the clinic, and 77% of patients had symptoms for >6 months. Preoperatively, 66.7% and 39.8% of athletes had positive FADIR and FABER tests, respectively.

At the 2-year follow-up (mean  $27.1 \pm 5$  months; range, 18-60 months), 80% of hips were assessed. In total, 6 patients (0.6%) declined to be followed up, whereas the remaining 19.4% were lost to follow-up. Table 2 compares baseline differences between athletes who completed follow-up assessments and those who did not. Of the follow-up cases, 8 hips (1%) were converted to total hip replacement within this time frame, whereas 54 cases (7%) underwent reoperation between the initial surgery and the 2-year follow-up. Table 3 compares characteristics between those who

required a reoperation and those who did not; the primary reasons for reoperation were adhesions in 67.9% of cases and instability requiring capsular plication in 13.2%.

All PROMs showed statistically significant improvements in scores at 2 years, with improvements in hip ROM and radiological features also (Table 4). In total, 84% of cases were continuing with sport at the 2-year review period, with 80% of those competing at their preinjury level (30% were competing at 3 months, with 25% of those playing at preinjury level). Of the 16% that did not continue with sport, the reasons included the same symptoms as before surgery (75%) and other symptoms relating to the hip (25%). The percentage of athletes meeting the MCID for each PROM are documented in Table 5. Inability to meet MCID was due to ceiling effects (ie, a higher preoperative baseline score). For example, with a cutoff value of 8 for mHHS, an athlete presenting with a baseline score of 96 could not reach MCID. Athletes with a maximal preoperative score could not be included in the POPI MCID calculation.

No differences between bilateral and unilateral MCID achievement were recorded.

### Radiological Parameters

Higher baseline alpha angles were associated with lower postoperative mHHS for both the AP view ( $P = .019$ ;  $r = -.090$ ) and the Dunn view ( $P = .001$ ;  $r = -.141$ ).

### Range of Motion

Athletes presenting with a better overall range of hip movement preoperatively had improved WOMAC scores after surgery ( $P = .003$ ;  $r = -.0131$ ), but no other associations between preoperative ROM and outcomes were recorded.

Higher overall postoperative hip ROM was observed in athletes who underwent a labral cuff repair compared with a looped repair ( $272^\circ \pm 23$  vs  $245^\circ \pm 31$ , respectively;  $P < .001$ ; ES, 0.989, large) and in those who did not have their capsule repaired compared with those who did ( $268^\circ \pm 26$  vs  $253^\circ \pm 30$ , respectively;  $P < .001$ ; ES, 0.534, medium). Higher overall postoperative hip ROM was also associated with better outcome scores on the mHHS ( $P < .001$ ;  $r = 0.193$ ), SF-36 ( $P < .001$ ;  $r = 0.175$ ), and WOMAC ( $P < .001$ ;  $r = -.0201$ ).

Athletes with Tönnis grade 1 had significantly lower overall postoperative ROM compared with athletes who had Tönnis grade 0 ( $246^\circ \pm 30$  vs  $265^\circ \pm 27$  respectively;  $P < .001$ ; ES, 0.666, medium).

The association between radiological parameters and individual ROM measures both pre- and postoperatively are presented in Table 6. All significant, negative correlations indicate that higher preoperative radiological angles were associated with lower preoperative ROM. Conversely, lower postoperative radiological angles were associated with higher postoperative ROM.

### Surgical Approaches

Athletes who underwent capsular repair, when compared with athletes who did not undergo capsular repair, had a

TABLE 2  
Baseline Characteristics of Responders and Nonresponders<sup>a</sup>

Variable	Responded to Follow-up (n = 767)	Did Not Respond to Follow-up (n = 197)	P Value (ES)
Sex			.150
Male	95.8	93.4	
Female	4.2	6.6	
Age, years	26.2 ± 6.4	26.5 ± 5.9	.505
Alpha angle (AP), deg	67.0 ± 17.9	65.9 ± 17.3	.442
Alpha angle (Dunn), deg	59.30 ± 13.1	60.55 ± 13.4	.422
LCEA, deg	33.64 ± 6.1	34.98 ± 6.7	.011 (0.209; small)
Preoperative total ROM, deg	244 ± 32	245 ± 30	.735
Preoperative mHHS	81 (72-93)	80 (71-93)	.257
Preoperative UCLA	7 (5-10)	6 (5-9)	.031 (0.163; small)
Preoperative SF-36	74 (61-86)	75 (63-84)	.946
Preoperative WOMAC	15 (7-28)	14 (6-29)	.840
Tönnis grade			.678
0	81.3	79.9	
1	18.7	20.1	
Surgical approach to capsule			<.001 (0.143; small)
No repair	45.9	28.4	
Repair	54.1	71.6	
Type of repair			.957
Loop repair	30.1	29.8	
Cuff repair	69.9	70.2	

<sup>a</sup>Data are presented as mean ± SD, %, or median (interquartile range). The ES is reported for significant between-group differences ( $P < .05$ ). AP, anteroposterior; ES, effect size; LCEA, lateral center-edge angle; mHHS, modified Harris Hip Score; ROM, range of motion; SF-36, 36-Item Short Form Health Survey; UCLA, University of California Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

statistically significantly lower postoperative score on the SF-36 ( $85.23 \pm 13.4$  vs  $87.61 \pm 13$ , respectively;  $P = .039$ ; ES, 0.180, small), but this did not apply to any other postoperative outcome measure ( $P > .05$  for all).

Athletes whose labrum was repaired using a cuff repair, versus those who underwent loop repair, had significantly higher values on the mHHS ( $95.3 \pm 7.3$  vs  $93.6 \pm 8.2$ , respectively;  $P = .017$ ; ES, 0.219, small) and UCLA score ( $9.2 \pm 1.5$  vs  $8.8 \pm 1.6$ , respectively;  $P = .006$ ; ES, 0.258, small). No difference between the groups was recorded for SF-36 or WOMAC ( $P > .05$ ).

### Demographic Subcategories

No differences between male and female patients with respect to outcomes were recorded. Bilateral cases had significantly higher postoperative UCLA scores when compared with unilateral cases ( $9.3 \pm 1.4$  vs  $8.6 \pm 1.9$ , respectively;  $P < .001$ ; ES, 0.153, small) with no differences between unilateral and bilateral patients for any other measure noted. Athletes with a Tönnis grade of 1, compared with those who had a Tönnis grade of 0, had significantly lower postoperative mHHS ( $93.15 \pm 9.2$  vs  $95.48 \pm 7.1$ , respectively;  $P = .006$ ; ES, 0.114, small) and UCLA scores ( $8.7 \pm 1.8$  vs  $9.0 \pm 1.7$ , respectively;  $P = .005$ ; ES, 0.116, small) but no differences in other PROMs. The <25-year age category scored higher on the postoperative UCLA ( $9.2 \pm 1.7$ ) compared with both the 25- to 34-year category ( $8.8 \pm 1.8$ ;  $P = .009$ ; ES, 0.228, small) and the  $\geq 35$ -year

category ( $8.4 \pm 1.9$ ;  $P = .002$ ; ES, 0.555, medium). No other statistical difference between age groups was observed for the other PROMs ( $P > .05$  for all). Those with a symptom duration of <6 months had significantly lower postoperative WOMAC scores compared with patients who had symptom duration >6 months ( $3.6 \pm 6.3$  vs  $8.3 \pm 12$ , respectively;  $P = .028$ ; ES, 0.490, small), but no significant differences in scores were noted between symptom duration categories and any other measure. Similarly, no differences were noted between baseline training frequencies or LCEA classifications and any measure ( $P > .05$  for all).

### Comparisons Between Demographic, Radiological, and Surgical Subcategories and Continued Sports Participation

Female athletes, athletes with longer symptom durations and those with lower preoperative training frequencies were less likely to continue with sport ( $P < .05$  for all). No other differences were recorded between subcategories and continued sports participation rates. Percentages of those returning and not returning to play within each category are presented in Table 7.

### Regression Analysis

Regression analysis was carried out to determine whether certain patient demographic characteristics and/or surgical techniques as well as continued sports engagement were

TABLE 3  
Characteristics of Patients Who Did and Did Not Require Reoperation<sup>a</sup>

Variable	Reoperation (n = 54)	No Reoperation (n = 705)	P Value (ES)
Sex			<.001 (0.157; small)
Male	83.6	96.3	
Female	16.4	3.7	
Age, years	24.63 ± 6.2	26.21 ± 6.3	.076
Preoperative alpha angle (AP), deg	63.4 ± 18.6	67.1 ± 17.7	.104
Preoperative alpha angle (Dunn), deg	59.0 ± 13.1	59.3 ± 13.2	.999
Preoperative LCEA, deg	34.5 ± 6.4	33.6 ± 6.1	.475
Postoperative alpha angle (AP), deg	59.8 ± 16.7	59.5 ± 14.7	.666
Postoperative alpha angle (Dunn), deg	51.2 ± 10.9	49.9 ± 9.1	.695
Postoperative LCEA, deg	30.8 ± 5.8	30.4 ± 5.8	.723
Preoperative total ROM, deg	250 ± 29	244 ± 31	.236
Preoperative mHHS	76 (70-86)	81 (72-93)	.062
Preoperative UCLA	6 (4-10)	8 (5-10)	.154
Preoperative SF-36	71 (62-80)	75 (61-86)	.220
Preoperative WOMAC	23 (9-34)	15 (6-27)	.050
Tönnis grade			.175
0	89.6	80.9	
1	10.4	19.1	
Surgical approach to capsule			.482
No repair	40.7	45.9	
Repair	59.3	54.1	
Type of repair			.432
Loop repair	34.9	29.1	
Cuff repair	65.1	70.9	

<sup>a</sup>Data are presented as mean ± SD, %, or median (interquartile range). Total hip replacement cases were not included in the analysis. The ES is reported for significant between-group differences ( $P < .05$ ). AP, anteroposterior; ES, effect size; LCEA, lateral center-edge angle; mHHS, modified Harris Hip Score; ROM, range of motion; SF-36, 36-Item Short Form Health Survey; UCLA, University of California Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 4  
Changes in Patient-Reported Outcomes, Hip ROM, and Radiological Parameters<sup>a</sup>

	Preoperative	3 Months Postoperative	P Value Preoperative vs 3 Months (ES)	2 Years Postoperative	P Value Preoperative vs 2 Years (ES)
PROMs					
mHHS	82 (72-93)	96 (93-100)	<.001 (0.654; large)	96 (96-100)	<.001 (0.730; large)
UCLA	8 (5-10)	7 (7-9)	<.001 (0.170; small)	10 (9-10)	<.001 (0.501; medium)
SF-36	75 (61-86)	87 (73-93)	<.001 (0.531; large)	91 (83-95)	<.001 (0.597; large)
WOMAC	15 (6-28)	4 (1-10)	<.001 (0.659; large)	2 (0-7)	<.001 (0.701; large)
Hip ROM, deg					
Flexion	114 ± 11	118 ± 7	<.001 (0.471; medium)	117 ± 9	<.001 (0.450; medium)
Adduction	22 ± 7	25 ± 7	<.001 (0.396; medium)	26 ± 8	<.001 (0.470; medium)
Abduction	46 ± 10	49 ± 9	<.001 (0.318; medium)	49 ± 9	<.001 (0.388; medium)
Internal rotation	25 ± 11	31 ± 8	<.001 (0.481; medium)	31 ± 9	<.001 (0.493; medium)
External rotation	38 ± 8	40 ± 8	<.001 (0.228; small)	40 ± 7	<.001 (0.291; small)
Total ROM	244 ± 31	263 ± 26	<.001 (0.531; large)	262 ± 28	<.001 (0.582; large)
Radiological parameters, deg					
LCEA	33.59 ± 6.2	—	—	30.43 ± 5.8	<.001 (0.754; large)
Alpha angle (AP)	67.06 ± 17.7	—	—	59.52 ± 14.7	<.001 (0.455; medium)
Alpha angle (Dunn)	59.25 ± 13.2	—	—	49.92 ± 9.0	<.001 (0.790; large)

<sup>a</sup>Data are presented as mean ± SD or as median (interquartile range). Dashes indicate areas not applicable. AP, anteroposterior; ES, effect size; LCEA, lateral center-edge angle; mHHS, modified Harris Hip Score; PROM, patient-reported outcome measure; ROM, range of motion; SF-36, 36-Item Short Form Health Survey; UCLA, University of California Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

associated with the likelihood of achieving or not achieving MCID based on the POPI method of MCID calculation. Continuing to play sports was associated with a higher chance of achieving MCID for all PROMs. A better preoperative PROM score was associated with a lower chance of achieving MCID for each PROM. Owing to the direction of WOMAC scoring compared with the other PROMs, a higher

value (poorer function) increased the odds of MCID. The results of the regression analysis are presented in Table 8.

## DISCUSSION

This study quantified improvements in PROMs for a cohort of competitive field-sport athletes after surgical intervention for SRFAI.<sup>8</sup> It also determined which demographic, radiographic, and surgical predictors are associated with achieving MCID in these athletes. The main findings of the research are that PROMs significantly improved in this population after surgical intervention, supporting previous literature involving both general and athletic populations.<sup>23,34,53</sup> The percentage of those continuing to play was also high (84%). This is comparable with other multidirectional sports such as soccer, basketball, and baseball,<sup>24,26,43</sup> although female patients, those with longer symptom durations, and those with lower training volumes before surgery were less likely to continue with field sports. The greatest predictor of achieving MCID was whether the athlete continued with sporting engagement. Higher preoperative scoring reduced the odds of achieving MCID.

The observation that a higher baseline PROM score reduces the chance of achieving MCID is supportive of previous studies.<sup>41,49</sup> In contrast to previous research, however, we used a novel method to determine MCID: the POPI. Using the *absolute score change* as a measure of MCID has been shown to be dependent on baseline scores and is limited by ceiling effects, especially in higher functioning patients such as athletes. Both in this analysis and in previous research,<sup>7</sup> exclusion of a sizable proportion of the athletes in the MCID calculations was evident when the *mean change* and *distribution* methods were used, leading to inaccurate MCID calculations in higher functioning athletic cohorts. The use of the POPI technique negates ceiling effects and is independent of baseline score and, as such,

TABLE 5  
Percentage of Athletes Reaching MCID  
at 2-Year Follow-up<sup>a</sup>

	Percentage of Athletes Unable to Meet MCID	MCID Cutoff Value	Percentage of Eligible Athletes Who Met MCID
mHHS			
Mean change method	28	8	86
Distribution method	24	7	86
POPI method	6	58%	72
UCLA			
Mean change method	30	0.5	76
Distribution method	47	1.4	79
POPI method	30	50%	70
SF-36			
Mean change method	42	21	55
Distribution method	14	9	67
POPI method	0.3	58%	50
WOMAC			
Mean change method	26	7	81
Distribution method	30	8	75
POPI method	4	60%	67

<sup>a</sup>MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; POPI, percentage of possible improvement; SF-36, 36-Item Short Form Health Survey; UCLA, University of California Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 6  
Association Between Radiological Parameters and Individual ROM Preoperatively and 2 Years Postoperatively<sup>a</sup>

Radiological Parameter	Range of Motion				
	Flexion	Abduction	Adduction	IR	ER
Preoperative					
Alpha angle (AP)	$P = .002$ $r = -0.121$	$P < .001$ $r = -0.280$	$P < .001$ $r = -0.155$	$P < .001$ $r = -0.233$	$P = .004$ $r = -0.111$
Alpha angle (Dunn)	NS	$P = .002$ $r = -0.126$	$P = .001$ $r = -0.138$	$P < .001$ $r = -0.322$	$P = .026$ $r = -0.092$
LCEA	$P < .001$ $r = -0.152$	$P = .018$ $r = -0.092$	NS	$P < .001$ $r = -0.170$	$P = .044$ $r = -0.078$
Postoperative					
Alpha angle (AP)	NS	$P < .001$ $r = -0.209$	NS	$P = .001$ $r = -0.180$	NS
Alpha angle (Dunn)	NS	NS	NS	$P < .001$ $r = -0.233$	NS
LCEA	NS	$P = .005$ $r = -0.147$	NS	NS	NS

<sup>a</sup>Pearson correlation ( $r$ ):  $-0.0$  to  $-0.3$  = small association;  $-0.3$  to  $-0.5$  = medium association;  $-0.5$  to  $1$  = large association. AP, anteroposterior; ER, external rotation; IR, internal rotation; LCEA, lateral center-edge angle; NS, nonsignificant.

TABLE 7  
Proportion of Athletes Continuing to Play, by Category<sup>a</sup>

	Continuing to Play, %		P Value (ES)
	Yes	No	
Sex			.008 (0.125; small)
Male	85.2	14.8	
Female	60	40	
Age			.167
<25 years	74.1	25.9	
25-34 years	82.0	18.0	
>35 years	80.6	19.4	
Tönnis grade			.051
0	86.2	13.8	
1	76.8	23.2	
Symptom duration			.001 (0.234; small)
<6 months	90.8	9.2	
6-12 months	90.1	9.9	
1-2 years	81.2	18.8	
2-5 years	83.9	16.1	
>5 years	56.5	43.5	
Training frequency before surgery			.019 (0.134; small)
<3 days/week	75.3	24.7	
3-5 days/week	87.5	12.5	
>5 days/week	79.3	20.7	
LCEA classification			.615
Overcoverage (LCEA >30°)	78.8	21.2	
Normal (LCEA 25°-30°)	86.0	14.0	
Borderline dysplasia (LCEA 20°-25°)	84.5	15.5	
Surgical approach to capsule			.078
Capsular repair	87.1	12.9	
No capsular repair	81.1	18.9	
Type of repair			.141
Loop repair	79.7	20.3	
Cuff repair	86.3	13.7	
Type of injury			.103
Unilateral	82.2	17.8	
Bilateral	87	13.0	

<sup>a</sup>ES, effect size; LCEA, lateral center-edge angle.

may be a more accurate method of MCID determination, allowing inclusion of the entire cohort in analysis. Therefore, we propose the use of the POPI method in MCID calculation when athletic cohorts are considered. Despite differences in calculation methods, the vast majority of athletes achieved MCID after intervention, which supports previous findings among adolescent<sup>11,40</sup> and adult patients.<sup>17,39</sup>

A number of different PROMs have been used in the hip arthroscopy literature to date,<sup>45</sup> and developing a new method for athletes specifically may not alleviate ceiling effects entirely. Rather, adopting a holistic approach to post-treatment assessment may be more appropriate. Specifically, the addition of quantitative methods of assessment, including ROM, in routine practice and further qualitative measures of patient satisfaction in conjunction with the already established and validated PROMs could

TABLE 8  
Factors Associated With MCID  
for Each Patient-Reported Outcome<sup>a</sup>

Outcome Measure	Odds Ratio	95% CI	P Value
mHHS			
Higher preoperative mHHS	0.958	0.939-0.978	<.001
Continuing to play	5.920	3.327-10.553	<.001
UCLA			
Higher preoperative UCLA	0.794	0.702-0.900	<.001
Continuing to play	9.418	5.000-17.738	<.001
SF-36			
Higher preoperative SF-36	0.947	0.933-0.961	<.001
Continuing to play	6.375	3.365-12.076	<.001
WOMAC			
Higher preoperative WOMAC	1.026	1.010-1.042	.001
Continuing to play	3.697	2.098-6.516	<.001

<sup>a</sup>An odds ratio >1 indicates a positive relationship with achieving MCID, whereas a value <1 indicates a negative relationship with achieving MCID. MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; SF-36, 36-Item Short Form Health Survey; UCLA, University of California Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

serve to better inform clinicians as to treatment effectiveness.

Postoperative improvements were noted across all PROM outcomes. The differences in PROM scores reported in unilateral athletes, older athletes, those with higher Tönnis grades, and athletes with longer symptom durations compared with other subcategories within the cohort were statistically significant yet small in magnitude. This indicates that similar benefits can be expected after intervention despite slight differences in athlete presentation.

In the clinical presentation of SRFAI, a reduced hip ROM was observed particularly in hip flexion, adduction, and internal rotation<sup>8</sup>; similar reductions in preoperative hip ROM have been reported with progressive FAI.<sup>19-21</sup> The current study demonstrated improvements in postoperative ROM that are not only statistically significant but also likely to be clinically relevant and supportive of the limited previous reports.<sup>2,9</sup> Athletes with a higher ROM both preoperatively and postoperatively reported better outcomes. Removing obstructing bone and repairing the underlying tissue to facilitate fluid, impingement-free movement of the femoral head within the acetabulum are the fundamental concepts of surgical intervention for SRFAI and may allow for greater pain-free movement required for sporting involvement. This is further supported by the association between more pronounced radiological morphologic findings and poorer outcomes both before and after arthroscopy.<sup>51</sup> ROM was also affected by the extent of bony resection; higher preoperative alpha angle and increased LCEA were associated with limited preoperative ROM scores, which improved after removal of the bony morphology. Our results are contrary to those of Briggs et al,<sup>4</sup> who found no association between postoperative alpha angle



and 5-year outcomes. Briggs and colleagues used cross-table lateral views to measure the alpha angle, whereas we provided both AP and Dunn views, which may account for this difference. The Dunn view is considered a better diagnostic tool for cam deformities, as it provides a better view of the superior-anterior section where most pronounced deformities are found.<sup>13</sup>

Routine capsular repair was introduced into our clinical practice from 2013 onward to optimize postoperative hip stability, potentially improving outcomes.<sup>36</sup> Lower postoperative SF-36 scores were observed in athletes who underwent capsular repair (mean score, 85) compared with those with an unrepaired capsule (mean score, 88;  $P = .039$ ). Although statistically significant, this small difference may not be clinically relevant. No differences in other PROMs were found between patients with repaired versus unrepaired capsule. Lower postoperative ROM, however, was observed in the capsular repair group; the repair possibly created a more constrained joint than was present with the unrepaired capsule. Ambiguity exists as to the effectiveness of the capsular repair on PROM scoring. Frank et al<sup>18</sup> reported that complete repair of the capsule yielded better outcomes than partial repair. Domb et al<sup>15</sup> did not report superior outcomes at 2 years after surgery when using a capsular repair technique. However, significant limitations were highlighted within that study, including the heterogeneous nature of the study cohorts, which included patients in the nonrepair group who actually had partial repair (<50% repair) and a wide variety of additional supplementary surgical techniques in each group.<sup>15</sup> The follow-up analysis to that report, which found lower mHHS<sup>14</sup> in the nonrepair group at 5 years, should also therefore be interpreted with caution.

In a more standardized approach, Bolia et al<sup>3</sup> found superior midterm results after capsular repair. However, in a large comparative cohort study, Filan and Carton<sup>16</sup> demonstrated no overall superior clinical benefit of routine capsular repair in the short term (2 years after surgery) compared with patients without repair. The results of the current study are also short term, and so it is not yet determined whether longer term benefits of the technique will become evident.

The current study found some improved outcomes in athletes who underwent a suspension-type, labral cuff repair compared with those undergoing a looped labral repair, including increased hip ROM. An intact chondrolabral junction with a stable, mobile labrum acts as a sealant, restricting the movement of fluid out of the joint while also providing stability.<sup>28</sup> A loop repair bunches, elevates, and stiffens the labrum, inhibiting its ability to act as an optimum seal. In contrast, a cuff repair aims to restore normal chondrolabral status, promoting stabilization and optimizing joint lubrication. In this study, a cuff repair was associated with improved range of overall hip ROM and superior outcomes in mHHS and UCLA activity level, although no differences in return-to-play rates were noted. Previous research has not found superior clinical outcomes between repair techniques<sup>27,47</sup>; however, the results of the current study highlight the importance of preserving the

chondrolabral junction in order to optimize outcomes in young athletic patients.

## Strengths and Limitations

The large cohort of competitive field-sport athletes in this study allowed for a more robust investigation of predictors of surgical outcomes and the true improvements in athletic cohorts. Although the majority of athletes included were Gaelic games athletes, all were field-sport athletes with similar game demands, reducing the risk of bias and allowing comparisons with field sports across other countries. All athletes underwent surgery by a single high-volume surgeon, adding considerable consistency to the surgical approach. Standardized ROM assessment is rarely reported in the FAI literature, owing to limitations in both intra- and interoperator reliability in clinical settings, but is essential in determining true differences after surgery. In this study, 2 trained operators (one examining and the other measuring) were employed throughout to minimize the error in repeated examination technique and present a thorough investigation of ROM. The POPI method for MCID threshold calculation is a clinically relevant metric for high-functioning athletic cohorts who would otherwise be unable to achieve MCID if using raw scores.

More recent disease-specific outcome measures (eg, International Hip Outcome Tool, The Copenhagen Hip and Groin Outcome Score) were not used in this research because they had not been established at the onset of the data collection. All PROMs used in this study, however, are well established, validated measures of hip-specific function, activity level, and general health, with high sensitivity and specificity. The mHHS is the most expansively used outcome measure in FAI research, whereas the UCLA activity scale quantifies sporting engagement. The WOMAC has also formed the basis of more recent FAI specific outcome measures. Finally, the SF-36 incorporates the emotional state of the athlete; combining these tools gives a comprehensive evaluation of patient status with high reliability over time.

## CONCLUSION

Athletes undergoing arthroscopy for SRFAI can expect to achieve a successful outcome at 2 years after surgery with continued competitive engagement. Higher preoperative alpha angle led to reduced hip ROM and poorer postoperative outcome; improved bony deformity correction led to increased postoperative hip ROM and better outcome. Preservation of the chondrolabral junction with labral cuff repair demonstrated improved outcome when compared with looped labral repair. Capsular repair did not lead to significant improvement in outcomes compared with the unrepaired capsule.

The majority of athletes will achieve MCID. The POPI method of MCID calculation is more applicable to higher functioning athletic cohorts, as it eliminates both the ceiling effects and the dependence on preoperative outcome scores associated with absolute score methods. Lower

preoperative PROM scores and the ability for the athlete to continue to play will increase the likelihood of achieving MCID in this population. Further follow-up studies are needed to determine the longer term outcome of arthroscopic management of SRFAI in this competitive athletic cohort.

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