**Purpose:** To investigate the impact of arthroscopic correction of symptomatic femoroacetabular impingement on postoperative hip range of motion (ROM), as an objectively measured postoperative clinically reported outcome. **Methods:** A systematic review of the current literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, OVID/MEDLINE, EMBASE, and Cochrane databases were queried in November 2020. Studies not reporting pre- to postoperative ROM measurements were excluded. Methodologic quality was assessed using the MINORS assessment, and certainty of evidence was assessed using the GRADE approach. Effect size using standardized mean differences assessed magnitude of change between pre- and postoperative ROM. **Results:** In total, 23 studies were included evaluating 2,332 patients. Mean age ranged from 18 to 44.2 years. Flexion, internal rotation (IR), and external rotation (ER) were the predominantly measured ROMs reported in 91%, 100%, and 65% of studies, respectively. Observed change following hip arthroscopy was considered significant in 57.1% (flexion), 74% (IR), and 20% (ER). Effect size of change in significantly improved ROMs were weak (16.7% flexion, 33.3% ER), moderate (58.3% flexion, 29.4% IR), and large (25% flexion, 64.7% IR, 66.7% ER). For goniometric assessment mean observed changes ranged as follows: flexion: 0.1° to 12.2°; IR: 3.6° to 21.9°; ER: −2.6° to 12.8°. For computed tomography—simulated assessment, the mean observed change ranged as follows: flexion: 3.0° to 8.0°; IR 9.3° to 14.0°. **Conclusions:** Outcome studies demonstrate overall increased range of flexion and IR post-hip arthroscopy, with a moderate and large effect respectively. Change in ER is less impacted following hip arthroscopy. Certainty of evidence to support this observation is low. Current research evaluating changes in this functional ability is limited by a lack of prospective studies and non-standardized measurement evaluation techniques. **Level of Evidence:** Level IV, systematic review of Level II-IV studies.

Femoroacetabular impingement (FAI) is primarily considered a mechanical, motion-related hip disorder, exacerbated by abnormal bony morphology of the acetabulum (overcoverage, pincer deformity), femur (asphericity, cam deformity) or both (mixed impingement).

Progressive in their development, these bony prominences in an otherwise-healthy hip can be considered analogous to mechanical blocks to end range of motion (ROM). Clinical examination typically reproduces pain upon specific patterns of hip movement: flexion, adduction and internal rotation (FADIR, impingement test), and/or flexion, abduction, and external rotation (FABER test). Additional diagnostic workup includes a loss or marked reduction in hip ROM between the affected and unaffected contralateral joint, or in the case in which symptoms are experienced bilaterally, significant restriction in the available ROM from the acceptable normative ranges. Owing to the typical location of these deformities, movements such as flexion, adduction, and internal rotation often are reduced with abduction and external rotation being spared. While some previous studies have indicated reduced ROM in the presence of FAI-related morphology compared with controls without such deformities, the available evidence is conflicting.

Hip arthroscopy (HA) is an effective and increasingly performed surgical intervention established in...
alleviating associated pain and functional disabilities for patients with symptomatic FAI. As part of this surgical correction, a primary focus is the removal of contributory abnormal bone, to reshape and restore the hip’s normal anatomy and movement pattern, free from impingement. However, the literature describing the mechanical impact of this surgery on ROM is a less frequently reported clinical outcome overall, despite this being a consideration in resolving the pathology. Consequently, evidence-based normative values and scope for improvement in ROM following HA for FAI is under-reported and in stark contrast to the abundance of patient-reported outcome (PRO) studies available.18,19

The purpose of this systematic review was to investigate the impact of arthroscopic correction of symptomatic FAI on postoperative hip ROM, as an objectively measured postoperative clinically reported outcome. We hypothesize that measurable ROM would be significantly improved following HA for FAI.

**Methods**

**Search Strategy**

This systematic review was performed in accordance with 2020 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.20 Our research question was established a priori as “What are the quantifiable changes to hip range of motion following the arthroscopic correction of femoroacetabular impingement?”

In accordance with PICO framework, our population of interest included human cases diagnosed with FAI, the intervention was hip arthroscopy, there was no comparison control group (i.e., exclusively assessing for those with diagnosed FAI undergoing arthroscopic treatment), and the outcome of interest was hip joint ROM. Electronic searches for all eligible studies was performed within each of the following databases: PubMed, OVID/MEDLINE, EMBASE, and the Cochrane database (Appendix Table 1, available at www.arthroscopyjournal.org). The search query was performed November 2020 independently by 2 reviewers (D.F. and K.M.).

**Eligibility Criteria**

Inclusion criteria consisted of original studies involving patients >16 years of age, no upper age limit, undergoing arthroscopic FAI-corrective surgery, reporting a change in ROM as a clinical outcome and published in English. Exclusion criteria were (1) review articles/systematic reviews/meta-analyses/basic science/surgical techniques/letter to editor/narrative review/animal studies/cadaveric studies/conference abstracts/case reports; (2) surgical procedures other than HA; (3) hip pathology other than true FAI (e.g., patients with hip dysplasia, slipped capital femoral epiphysis, Legg–Calve–Perthes disease, avascular necrosis, osteoarthritis; (4) studies only reporting preoperative ROM; and (5) studies involving revision cases or where a concomitant pathology also was addressed.

**Study Selection**

Two reviewers independently screened articles identified following database query using the inclusion and exclusion criteria mentioned. Studies that did not adequately report relevant information in the title or abstract were selected for full text review. Following full-text review, studies that met the eligibility criteria were included for systematic review. Any discrepancy between reviewers during the search process was discussed in a consensus meeting with the assistance of a third reviewer (P.C.).

**Quality Assessment**

Two experienced clinical researchers (D.F., K.M.) independently assessed the methodologic quality of included studies. The validated MINORS (methodologic items for nonrandomized studies) criteria was used for quality assessment,21 which assess 8 critical aspects of study design for noncomparative clinical studies and an additional 4 aspects of study design for comparative clinical studies. Each item is given a score of 0 if information is not reported, 1 if information is reported but inadequate, and 2 if information is reported and adequate. The maximum possible score is 16 for noncomparative studies and 24 for comparative studies. For noncomparative studies, quality is assessed as follows: 0-4 very low quality; 5-8 low quality; 9-12 fair quality; and 13-16 high quality. For comparative studies quality is assessed as follows: 0-6 very low quality; 7-12 low quality; 13-18 fair quality; and 19-24 high quality.22 Any disagreements in overall rating were resolved by a third reviewer (P.C.). A kappa statistic was used to evaluate the level of interrater agreement with agreement classified a priori as: <0.2 poor; 0.21-0.4 fair; 0.41-0.60 moderate; 0.61-0.80 good; and 0.81-1.00 very good. Certainty of evidence was assessed using the Grades of Recommendation, Assessment, Development and Evaluation (GRADépro GDT, McMaster University, 2020).

**Data Extraction**

Study identifiers (title, year, author, journal), study design, patient demographics (number of included hips, sex, age), follow-up duration, pre- and postoperative ROM details, technique used to evaluate ROM, pre- and postoperative radiographic measurements
were extracted from the included studies by one reviewer (D.F.).

The primary outcome measure of interest for this review was a ROM in any plane. To illustrate the change from preoperative to postoperative ROM scores, while accommodating variability within studies, a standardized mean difference (SMD) was calculated to estimate effect size using Cochrane Review Manager (RevMan v.5.4). If no standard deviation (SD) or standard error (SE) was reported by the authors, and a range of scores was given, the SD was estimated by dividing the range of scores by 6.23 and the SMD was then calculated. If no range, SD or SE was given, the SMD was estimated using the sample size and t-value of the t-test used in the study. We calculated 95% confidence intervals (CIs) assuming normal distribution using the formula SMD ± 1.96 × SE of the SMD.24 Cohen criteria were used to interpret individual study SMD where a large effect size was interpreted as SMD ≥0.8, a moderate effect size >0.5 and <0.8, and a weak effect size ≤0.5 and ≤0.2. Forest plots using generic inverse variance data type were produced in RevMan to facilitate the interpretation of mean differences and 95% CIs wherein the same system of units and measurement technique was used.

Results

Study Characteristics/Demographics

Twenty-three articles (Fig 1), evaluating 2,332 patients having undergone HA for FAI were included. The number of patients per study ranged from 10 to 688 with 11 studies evaluating unilaterally operated patients, 10 studies including at least one bilaterally operated patient in the cohort, and the remaining 2 studies not distinguishing between hips/patients. The mean age at time of surgery ranged from 18.0 to 44.2 years. One study did not report age. The proportion of female patients ranged from 0% to 100%, with 11 studies having a predominantly female cohort, 9 predominantly male cohort, 1 had equal male-to-female cohort, and 2 did not distinguish. Follow-up time for the purpose of each study’s primary outcome ranged from the day of surgery (ROM assessed intraoperatively) to a mean of 31.3 months (range 23.1-67.3 months).

Methodologic Quality

There were 3 Level II studies, 9 Level III studies, and 11 Level IV studies included.25

MINORS assessment rated the quality of the included studies as fair in 17/23, high in 3/23, low in 9% (2/23), and very low in 4% (1/23) (Table 1). The
| Author, year          | Level of Evidence | Journal       | Population             | Study Size (Patients) | Study Size (Hips) | Sex (F/M) | Mean Age, y | Follow-up * | MINORS Quality Rating | Study Purpose                                                                                                                                                                                                 |
|----------------------|-------------------|---------------|------------------------|-----------------------|-------------------|-----------|-------------|-------------|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Keating et al., 2020 | IV                | JHPS          | FAIS patients          | 22                    | 22                | 22/0      | 38.1 ± 10.8 | Minimum 24 mo   | Fair (10/16)          | (i) Evaluate patients' ability to, and rate of, return to Pilates after hip arthroscopy for FAIS and (ii) assess postoperative performance and weekly involvement compared with preinjury participation. |
| Ragab et al., 2018   | IV                | Alexandria Journal of Medicine | FAI patients | 40                    | 40                | 20/20     | 38.6 ± 11.1 | 12.5 ± 4.7 mo  | Very low (4/16)       | To assess the results of arthroscopic treatment of FAI.                                                                                                                                                    |
| Waterman et al., 2018| IV                | Arthroscopy   | Golfers with FAIS      | 29                    | 31                | 6/23      | 36.0 ± 11.9 | Minimum 2 y    | Fair (10/16)          | (i) Investigate whether patients who reported playing golf before arthroscopic hip surgery for FAIS were able to return to playing golf postoperatively. (ii) To determine whether hip range of motion was associated with improvement in PROs and golf-specific metrics. |
| Flores et al., 2018  | II                | OJSM          | FAI patients           | 58                    | 60                | Early: 15/15 Late: 13/17 | Early: 37.2 ± 11.5 Late: 35.3 ± 10.8 | Early: 15.5 ± 4.7 mo Late: 13.1 ± 2.7 | High (13/16)          | To evaluate the relationship between surgeon experience and patient outcomes for the arthroscopic treatment of FAI. Primary outcome measures were PRO scores, secondary outcomes included operation times and complication rates. |
| Carton and Filan, 2020| III               | OJSM          | Athletes with FAI      | 429                   | 576               | 23/553 (hips) 21/408 (patients) | 25.9 ± 9.7 | 2.4 ± 0.7 y (range 2.0-2.5) | Fair (10/16)          | (i) Define the MCID at 2 years postoperatively in competitive athletes undergoing hip arthroscopy for symptomatic sports-related FAI using existing anchor- and distribution-based methods; (ii) derive a measure of the MCID using the percentage of possible improvement method and compare against existing techniques. |

(continued)
| Author, year       | Level of Evidence | Journal          | Population                  | Study Size (Patients) | Study Size (Hips) | Sex (F/M) | Mean Age, y | Follow-up | MINORS Quality Rating | Study Purpose                                                                 |
|-------------------|-------------------|-------------------|-----------------------------|-----------------------|-------------------|-----------|-------------|-----------|----------------------|--------------------------------------------------------------------------------|
| Stone et al., 2019 | III               | JHPS              | FAIS patients (with and without GJL) | 125 (NGJL=100 GJL=25) | 125 (100/25)      | NGJL:ancements (NGJL=100 GJL=25) | NGJL: 22.7 ± 8.7 GJL: 18 ± 6.3 | 29.3 ± 8.0 mo | Fair (17/24) | To evaluate the postoperative clinical and functional outcomes in patients with and without generalized joint laxity following hip arthroscopy for FAIS and capsular plication |
| Ross et al., 2018  | II                | HSS Journal       | American football linesmen  | 13                    | 17                | 0/13       | 24.7±4.0    | n/a       | Fair (11/16) | (i) to characterize the radiographic deformity and dynamic impingement observed in a consecutive series of American football linesmen with symptomatic, mechanical hip pain who underwent surgical treatment for FAI; (ii) to use software analysis to identify the location of impingement and terminal range of motion and the effects of simulated correction |
| Polecello et al., 2009 | IV              | Revista Brasileira de Orthopédia | FAI patients | 28 | 9/19 | 34 | 27 mo (range 12-60) | Low (7/16) | To assess the short-term results of the arthroscopic treatment of FAI |
| Mullins et al., 2020 | II              | KSSTA             | Athletes with FAI vs control | 47 (32 controls) | 70 hips | 0/47 | 24.6 ± 4.8 | 1 year | High (19/24) | To measure the changes in athletic performance in athletes treated arthroscopically for FAI and compare results to a matched controlled athletic cohort, over a 1-year period |
| Stone et al., 2019 | III              | AJSM              | FAIS patients                | 688 Nonpersistent, 514; persistent 174 | 688 Nonpersistent, 514; persistent 174 | Nonpersistent 334/180 Persistent 115/59 | Nonpersistent 32.4 ± 12.6 Persistent group 35.9 ± 12.2 | Min 2 years | Fair (17/24) | To identify patient characteristics that predict persistent postoperative pain and function among people undergoing hip arthroscopy for FAIS |
| Frank et al., 2018  | IV               | Sports & Health   | FAIS patients participating in yoga | 42 | 45 | 38/4 | 35 ± 9 | 30.5 ± 12.0 mo (range 12-44 mo) | Fair (12/16) | To evaluate patients' ability to return to yoga after hip arthroscopy for FAIS |
| Frank et al., 2018  | IV               | Sports & Health   | FAIS patients participating in cycling | 58 patients | 60 hips | 36/22 | 30.0 ± 7.1 | 31.1 ± 0.7 mo | Fair (11/16) | To evaluate patients' ability to return to cycling after hip arthroscopy for FAIS |

(continued)
| Author, year | Level of Evidence | Journal | Population | Study Size (Patients) | Study Size (Hips) | Sex (F/M) | Mean Age, y | Follow-up | MINORS Quality Rating | Study Purpose |
|--------------|-------------------|---------|------------|----------------------|------------------|-----------|-------------|-----------|------------------------|---------------|
| Levy et al., 2017 | III | AJSM | FAI patients | Atypical: 28 | Atypical: 18/10 | Typical: 56 | Typical: 36/20 | All: 35.4 ± 9.8 | 2.6 ± 0.6 y | Fair (17/24) | To compare outcomes of hip arthroscopy for FAI in patients who experience atypical posterior pain versus a matched control group who report the typical anterior groin pain presentation |
| Nawabi et al., 2016 | III | AJSM | FAI patients (BD versus no dysplasia) | BD Group: 46 Control: 131 | BD Group: 22/24 Control: 73/58 | BD Group: 55 Control: 152 | BD Group: 29.8 ± 9.4 Control: 29.6 ± 10.3 | 31.3 ± 7.6 months (range 23.1-67.3) | Fair (17/24) | To compare outcomes after hip arthroscopy for FAI in patients with BD compared with a control group of patients without BD. Focus on PROMs and reoperation rates |
| Fabricant et al., 2015 | III | JBJS (Am) | FAI patients | All: 243 Decreased: 37 Normal: 149 Increased: 57 | Total: 123/120 Decreased: 41%/59% Normal: 50%/50% Increased: 58%/42% | All: 29.2 y Decreased: 28 ± 9 Normal: 30 ± 11 Increased: 29 ± 10 | 21 mo (range 12-42) | Fair (12/16) | To (i) investigate the association between proximal femoral version and disease-specific, patient-reported clinical outcomes following arthroscopic decompression of FAI; (ii) to investigate associations of combined femoral and acetabular version (the McKibbin index) with patient-reported outcomes. |
| Ross et al., 2015 | III | CORR | FAI patients | Revision group: 47 Successful group: 65 | Revision group: 27/23 Successful group: 37/28 | Revision group: 50 Successful group: 65 | Revision group: 29 ± 9 Successful group: 25 ± 9 | n/a | Fair (12/16) | To (i) define the 3D morphology of hips with residual pain and/or restricted ROM after corrective arthroscopic FAI surgery before revision surgery; (ii) determine the residual limitation in ROM in these patients using dynamic, computer-assisted, 3D analysis; (iii) compare the 3D morphology of hips undergoing revision FAI surgery with post-operative 3D morphology of hips that underwent successful primary surgical treatment. |
| Author, year          | Level of Evidence | Journal                     | Population                                      | Study Size (Patients) | Study Size (Hips) | Sex (F/M) | Mean Age, y | Follow-up | MINORS Quality Rating | Study Purpose                                                                                                                                                                                                 |
|----------------------|-------------------|-----------------------------|-------------------------------------------------|-----------------------|-------------------|------------|-------------|-----------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stähelin et al., 2008 | IV                | Arthroscopy                 | FAI patients (specifically cam impingement)     | 14                    | 14                | 6 / 8      | 41.8 ± 13.8 | 6 mo      | Fair (10/16)        | To determine the accuracy of arthroscopic restoration of femoral offset as well as the early clinical outcomes of arthroscopic debridement and femoral offset restoration and whether there is a correlation between accuracy and outcome. |
| Riff et al., 2018    | IV                | AJSM                        | HIIT athletes                                    | 32                    | 37                | 19/13      | 34.7 ± 6.9  | 27.2 ± 6.0 mo (range 12-44 mo) | High (13/16)                                                                | To evaluate patients' ability to return to HIIT after hip arthroscopic surgery for FAI. |
| Matsuda et al., 2014  | IV                | Arthroscopy                 | FAI patients                                     | 30                    | 30                | 16/14      | 37.8        | Intraoperative | Fair (10/16)        | To evaluate the concept of cam FAI occurring medial to the classic AL quadrant. Hypothesis was that the addition of anteromedial femoroplasty would improve hip internal rotation beyond that achieved with classical anterolateral femoroplasty. |
| Choi et al., 2018     | IV                | Journal of the American Academy of Orthopaedic Surgeons | FAI patients (Asian population) | 109                  | 109               | 39/70      | 44.2        | 27 mo (range 24-54) | Fair (10/16)        | To evaluate an Asian cohort for changes in ROM and clinical function scales after they underwent arthroscopic femoroplasty of the hip. |
| Kelly et al., 2012    | III               | AJSM                        | FAI patients (specifically cam presence)        | 55                    | 56                | 11/44      | 24.7 ± 6.3  | After decompression (day of surgery in operating room) and again 3 mo postoperative | Fair (10/16)        | To determine the alteration in rotation of the hip after arthroscopic cam decompression, as assessed by correction of the alpha angle. To describe the role of femoral neck version in determining hip rotation in the setting of FAI and arthroscopic cam decompression and to determine whether improvement in internal rotation can be achieved independent of the underlying femoral version. |

(continued)
methodologic quality scores ranged from 4 to 13 of 16 for noncomparative studies and from 17 to 19 points of 24 for comparative studies (Appendix Table 2, available at www.arthroscopyjournal.org). The Kappa inter-rater agreement value was 0.822 (95% CI 0.587-1.057), indicating excellent agreement between the 2 reviewers (D.F. and K.M.).

Technique of ROM Evaluation

In total, 52% of the included studies did not describe the technique with which any of the ROMs were assessed. Eight of 23 (35%) of the included studies described the use of a goniometer as the primary ROM measurement technique, with 5 of these studies specifying the use of a manual/handheld goniometer. Of those that used goniometric evaluation, 2 studies reported dual-operator evaluation, 1 study evaluated with a single operator, and the remaining did not distinguish. In 1 additional study, although not the primary purpose of the study, the authors did also report single-operator goniometric evaluation of ROM at 3-month clinical follow-up. Certainty of evidence for studies that used goniometric assessment of hip ROM was very low (Appendix Table 3, available at www.arthroscopyjournal.org).

In total, 3 of 23 (13%) of the included studies assessed ROM via computed tomography (CT) simulation using a 3-dimensional-generated model. During simulated ROM maneuvers, the pelvis was fixed in space while the femur was free to move in a specified motion of interest. The resultant point of osseous collision between the proximal femur and acetabulum represented the range of motion in degrees. Certainty of evidence for studies using CT-simulated assessment of hip ROM was low (Appendix Table 4, available at www.arthroscopyjournal.org).

Hip ROM

ROM measures reported most frequently were flexion (21/23), internal rotation (IR) (23/23), and external rotation (ER) (17/23). Less frequently reported was abduction (4/23), adduction (3/23), total ROM (1/23), and extension (1/23).

The combination of flexion, IR, and ER was exclusively reported in 10 studies and in conjunction with additional measurements in 5 further studies. Five studies reported flexion and IR only, with 1 further study assessing these measurements in addition to IR at 90° hip flexion with 15° adduction [FADIR]. The remaining 2 studies reported IR only. The measured pre- and postoperative ROMs and corresponding estimates of effect size (SMD) are presented in Table 2. Heterogeneity of the measurement techniques used, patient demographics, follow-up duration, methodologic quality, and low certainty of
| Author (year) | Study Size | ROM Assessed | Preoperative | Postoperative | $P$ Value* | SMD (95% CI) [Size] | Technique Used to Measure ROM |
|--------------|------------|--------------|--------------|--------------|-----------|-------------------|-----------------------------|
| Keating et al., 2020* | 22 patients | Flexion | 114.4 ± 8.4 | 120.5 ± 8.9 | $< .004$ | 0.78 (0.16-1.39) [moderate] | Not described |
|              |            | External rotation | 39.6 ± 7.9 | 40.6 ± 4.6 |           | 0.15 (−0.44 to 0.74) | (P = .50, NS) |
|              |            | Internal rotation | 18.0 ± 6.8 | 24.6 ± 6.8 |           | 0.95 (0.33-1.58) [large] | Internal rotation at 90° flexion, but measurement instrument/technique not described |
| Ragab et al., 2018** | 40 patients | Flexion | 92.88 ± 4.79 | 105.63 ± 8.26 | $< .001$ | 1.86 (1.33-2.38) [large] | Not described |
|              |            | Internal rotation | 8.25 ± 7.30 | 14.74 ± 6.40 |           | 0.92 (0.46-1.39) [large] | |
| Waterman et al., 2018*** | 29 patients | Flexion | 110.3 ± 11.4 | 117.1 ± 8.4 | $< .01$ | 0.67 (0.14-1.20) [moderate] | Not described |
|              |            | External rotation | 39.2 ± 8.5 | 40.5 ± 11.1 |           | 0.13 (−0.37 to 0.63) | (P = .608, NS) |
|              |            | Internal rotation | 12.6 ± 9.9 | 21.0 ± 9.6 |           | 0.85 (0.31-1.39) [large] | |
| Flores et al., 2018**** | 58 patients | Early group: Flexion | 115.9 ± 6.3 | 118.4 ± 4.8 |           | 0.44 (−0.07 to 0.95) | Not described |
|              |            | Early group: Extension | 8.4 ± 3.6 | 9.3 ± 2.6 |           | 0.28 (−0.23 to 0.79) | (P = .786, NS) |
|              |            | Early group: Internal rotation | 15.2 ± 8.2 | 27.1 ± 5.4 |           | 1.69 (1.10-2.29) [large] | Internal rotation at 90° flexion, but measurement instrument/technique not described |
|              |            | Early group: External rotation | 49.8 ± 7.1 | 46.6 ± 6.0 |           | −0.48 (−0.99 to 0.03) | (P = .646, NS) |
| Carton and Filan, 2020***** | 576 hips (n = 410 with ROM follow-up) | Early group: Flexion | 113.4 ± 11.2 | 118.0 ± 4.8 |           | 0.53 (0.01-1.04) | Not described |
|              |            | Early group: Extension | 9.6 ± 3.3 | 9.8 ± 0.9 |           | 0.08 (−0.42 to 0.59) | (P = .786, NS) |
|              |            | Early group: Internal rotation | 19.5 ± 5.8 | 28.0 ± 3.7 |           | 1.72 (1.13, 2.32) [large] | Internal rotation at 90° flexion, but measurement instrument/technique not described |
|              |            | Late group: External rotation | 45.0 ± 6.7 | 46.1 ± 2.5 |           | 0.21 (−0.29 to 0.72) | (P = .431, NS) |
| Stone et al., 2019****** | 125 patients (25 GJL and 100 no GJL) | Total ROM | 237.2 ± 31.7 | 262.1 ± 27.8 |           | 0.74 (0.60-0.88) [moderate] | Dual operator, hand-held goniometer |
|              |            | GJL group: Flexion | 118 ± 10.7 | 124 ± 8.93 |           | 0.45 (0.31-0.59) [weak] | (P = .025); |
|              |            | GJL group: External rotation | 50.0 ± 11.1 | 48.1 ± 13.3 |           | 0.57 (0.43-0.71) [moderate] | |
|              |            | GJL group: Internal rotation | 17.9 ± 9.8 | 25.5 ± 5.17 |           | 0.34 (0.20-0.48) [weak] | (P = .001) |
|              |            | No-GJL group: Flexion | 113 ± 13.6 | 120 ± 6.6 |           | 0.60 (0.03-1.17) [moderate] | Single senior author, goniometer, external rotation and internal rotation with hip flexed to 90° |
|              |            | No-GJL group: External rotation | 44.6 ± 10.5 | 45.2 ± 11.9 |           | 0.65 (0.37-0.94) [moderate] | (P = .003); |
|              |            | No-GJL group: Internal rotation | 17.3 ± 11.0 | 23.0 ± 6.1 |           | 0.64 (0.35-0.92) [moderate] | (P < .001)|

(continued)
| Author (year) | Study Size | ROM Assessed | Preoperative | Postoperative | P Value* | SMD (95% CI) [Size] | Technique Used to Measure ROM |
|--------------|------------|--------------|--------------|--------------|----------|-------------------|-------------------------------|
| Ross et al., 2018<sup>13</sup> | 13 patients (17 hips) | Flexion | 108.2 ± 17.3 (range 73-127) | 114.8 ± 12.1 (range 94-135) | **P < .001** | 0.47 (0.22, 1.15) [weak] | CT-simulated ROM using 3D-generated model (pelvis fixed in space, femur rotated until contact between the femur and the acetabulum occurred, causing a femoral head translation). Specifically, measured direct hip flexion; internal rotation in 90° flexion; internal rotation in 90° hip flexion with 15° adduction. |
| Internal rotation | 20.5 ± 17.4 (range 0-52) | 31.8 ± 16.4 (range 7-58) | **P < .001** | 0.65 (0.04, 1.34) [moderate] |
| IR + adduction | 12.3 ± 13.3 (range 0-39) | 22.9 ± 16.2 (range 0-47) | **P < .001** | 0.70 (0.00-1.39) [moderate] |
| Polesello et al., 2009<sup>39</sup> | 28 patients | Internal rotation | 17 ± 16.9 (range −15 to 45) | 36 ± 11.6 (range 0-50) | Δ Internal rotation = 19 (range 0-40) | Internal rotation **P < .001** | 1.29 (0.71-1.87) [large] | Supine position with 90° flexion and maximum internal rotation |
| Mullins et al., 2020<sup>39</sup> | 47 patients (70 hips) - 36 athletes returned for 1-year | Flexion | 116.7 ± 8.7 | 117.2 ± 6.9 | flexion (NS) | 0.06 (−0.40 to 0.53) Dual-operator, hand-held goniometer |
| Abduction | 50.9 ± 9.8 | 52.2 ± 6.4 | Abduction (NS) | 0.16 (−0.31 to 0.62) |
| Adduction | 24.6 ± 6.1 | 27.8 ± 2.8 | Adduction | 0.67 (0.19-1.14) [moderate] |
| External rotation | 38.7 ± 7.6 | 44.5 ± 5.3 | **P < .012** | 0.88 (0.39-1.36) [large] |
| Stone et al., 2019<sup>32</sup> | 688 patients | Internal rotation | 23.8 ± 8.5 | 27.4 ± 3.9 | Internal rotation **P < .003** | 0.54 (0.07-1.01) [moderate] | Not reported. Statistical significance between typical and atypical groups only reported, not the change from baseline |
| Mullins et al., 2020<sup>39</sup> | 58 patients | Flexion | 110.3 ± 11.4 | 118.1 ± 8.44 | Not reported (preoperative to postoperative not reported, only the significance of difference between groups at postoperative time point) | Flexion **P < .0025** | 0.77 (0.34-1.19) [moderate] | Not described |
| Internal rotation | 12.58 ± 9.91 | 20.97 ± 9.62 | External rotation | 0.13 (−0.28 to 0.54) |
| Frank et al., 2018<sup>18</sup> (yoga) | 42 patients | Flexion | 111.81 ± 10.83 | 119.23 ± 8.15 | Flexion **P < .001** | 0.77 (0.34-1.19) [moderate] | Not described |
| Internal rotation | 19.17 ± 7.32 | 23.46 ± 5.64 | Internal rotation **P < .001** | 0.66 (0.23-1.08) [moderate] |
| External rotation | 39.2 ± 8.5 | 40.5 ± 11.1 | External rotation | 0.13 (−0.28 to 0.54) |
| Frank et al., 2018<sup>18</sup> (cyclists) | 58 patients | Flexion | 110.3 ± 11.4 | 118.1 ± 8.44 | Flexion **P < .01** | 0.77 (0.40-1.15) [moderate] | Not described |
| Internal rotation | 12.58 ± 9.91 | 20.97 ± 9.62 | Internal rotation **P < .001** | 0.86 (0.48-1.23) [large] |
| Levy et al., 2017<sup>18</sup> | 84 patients (28 atypical; 56 typical) | Flexion | Atypical group: | Atypical group: | Not reported. Statistical significance between typical and atypical groups only reported, not the change from baseline | 0.86 (0.31-1.41) | Not described |
| External rotation | 44.1 ± 12.1 | 47.1 ± 6.6 | 0.30 (−0.22 to 0.83) |
| Internal rotation | 16.6 ± 11.9 | 21.1 ± 8.9 | 0.42 (−0.11 to 0.95) |
| Typical group: | Flexion | 114 ± 13.2 | 118 ± 14.9 | 0.28 (−0.09 to 0.65) |
| External rotation | 43.0 ± 9.2 | 43.1 ± 10.4 | 0.01 (−0.36 to 0.38) |
| Internal rotation | 14.6 ± 11.9 | 22.0 ± 5.5 | 0.79 (0.41-1.18) | (continued) |
| Author (year) | Study Size | ROM Assessed | Preoperative | Postoperative | P Value* | SMD (95% CI) [Size] | Technique Used to Measure ROM |
|--------------|------------|--------------|--------------|--------------|----------|---------------------|-------------------------------|
| Nawabi et al., 2016 | BD group: 46 cases, Control: 131 cases | Flexion | BD group: 108.1 ± 7.3 | BD group: 105.9 ± 5.3 | Not reported. Statistical significance between BD group and control group only | −0.34 (−0.75 to 0.07) | Not described |
| | | External rotation | 41.9 ± 5.8 | 42.2 ± 3.6 | | | |
| | | Internal rotation | 14 ± 11.6 | 25.4 ± 4.9 | | | |
| | | Control group: | | | | | |
| | | Flexion | 107 ± 9.9 | 104.5 ± 5.7 | | −0.31 (−0.55 to −0.06) | |
| | | External rotation | 43 ± 10.2 | 44.2 ± 6.9 | | 0.14 (−0.11 to 0.38) | |
| | | Internal rotation | 13.5 ± 11.9 | 27.5 ± 4.6 | | 1.55 (1.27-1.82) | |
| Fabricant et al., 2015 | 243 cases (243 ROM available for 227 cases) | Decreased version: Internal rotation | 6 ± 6 | No postoperative values reported, only mean change from baseline | Not reported as a statistically significant change from preoperative to postoperative scores within the different groups. Only reports significance between the 3 groups at either of the time points. | 3.33 (2.26-4.41) | Flexion, internal, and external rotation at 90° of flexion were measured using a goniometer |
| | | Decreased version: Flexion | 104 ± 7 | | | 1.0 (0.0-0.0) | |
| | | Decreased version: External rotation | 44 ± 10 | | | −0.20 (−0.14 to 0.26) | |
| | | Normal version: Internal rotation | 12 ± 8 | Δ internal rotation: 20 ± 7 | | 1.88 (1.57-2.18) | |
| | | Normal version: Flexion | 105 ± 8 | Δ flexion: 0 ± 8 | | −0.13 (−0.1 to 0.15) | |
| | | Normal version: External rotation | 42 ± 9 | Δ external rotation: −2 ± 12 | | 0.22 (0.19-0.26) | |
| | | Increased version: Internal rotation | 22 ± 15 | Δ internal rotation: 15 ± 8 | | 0.67 (0.49-0.84) | |
| | | Increased version: Flexion | 109 ± 8 | Δ flexion: −1 ± 8 | | −0.63 (−0.46 to 0.79) | |
| | | Increased version: External rotation | 42 ± 10 | Δ external rotation: 2 ± 9 | | 0.30 (0.22-0.38) | |
| Ross et al., 2015 | Revision group: 47 patients (50 hips), Nonrevision group: 65 patients (65 hips) | Revision group (prior to revision): Flexion | 114 ± 14 (range 78-145) | 121 ± 11 (range 97-145) | Revision group (P < .001) Flexion (P < .001) | 0.55 (0.15-0.95) [moderate] | CT-simulated ROM using a 3D-generated model |
| | | Revision group (after virtual revision Sx): Flexion | 121 ± 11 (range 97-145) | 121 ± 11 (range 97-145) | Internal rotation (P < .001) | 0.42 (0.03-0.82) [weak] | |
| | | Revision group (after virtual revision Sx): Internal rotation | 34 ± 13 (range 8-60) | 34 ± 13 (range 8-60) | | | |
| | | Nonrevision group: Flexion | 121±11 | 129 ± 10 (range 105-155) | Revision (P < .001) Internal rotation (P < .001) | 0.76 (0.40-1.11) [moderate] | During the simulated ROM maneuvers, the femur was moved in a specific motion until contact between the femur and acetabulum occurred (detected by the resultant translation of the femoral head). The point of osseous collision was defined as the occurrence of mechanical impingement, which was recorded in degrees of motion. Supine position |
| | | Nonrevision group: Internal rotation | 35±13 | 49 ± 11 (range 25-90) | | 1.16 (0.78-1.53) [large] | |
| Stähelin et al., 2008 | 14 patients | Flexion | 112 ± 14.1 | 132 ± 8.0 | Not reported | 1.69 (0.81-2.58) [large] | 90° of hip flexion with a handheld goniometer |
| | | Internal rotation | 8 ± 8.0 | 19 ± 11.0 | | 1.11 (0.31-1.91) [large] | |
| Riff et al., 2018 | 32 patients | Flexion | 111.4 ± 10.0 | 120.8 ± 5.6 | Flexion (P < .001) | 1.15 (0.65-1.64) [large] | |
| | | External rotation | 39.7 ± 11.5 | 41.4 ± 8.4 | External rotation (P = .50, NS) | 0.17 (−0.29 to 0.62) | |
| | | Internal rotation | 11.1 ± 8.8 | 21.7 ± 7.5 | Internal rotation (P < .001) | 1.28 (0.78-1.79) [large] | | (continued) |
| Author (year) | Study Size | ROM Assessed | Preoperative | Postoperative | P Value* | SMD (95% CI) | Technique Used to Measure ROM |
|--------------|------------|--------------|--------------|---------------|----------|-------------|-------------------------------|
| Matsuda et al., 2014 | 30 patients | Internal rotation | 20.8 (10-29) | After AL femoroplasty 29.5 (18-39) [Δ8.7] After AM femoroplasty: 42.7 (32-61) [Δ13.2] | | 2.56 (1.87-3.25) large | Intraoperative dynamic testing with hip at 90° flexion and 0° adduction using large metal goniometer placed in the center of the patella with one arm on the pretibial crest and the other aligned with the longitudinal axis of the patient. A surgical assistant performed internal rotation |
| Choi et al., 2018 | 109 patients | Flexion | 106.3 ± 9.3 | | Flexion: 106.6 ± 9.4 | Between preoperative and 2 y: 0.01 (−0.25, 0.28) | Internal rotation and external rotation measured at 90° hip flexion, using a manual goniometer |
| Kelly et al., 2012 | 55 patients | Internal rotation (all): 9.9 ± 6.6 Internal rotation (increased FV): 15.7 ± 5.4, (normal FV): 10.6 ± 5.4 Internal rotation (decreased FV): 7.1 ± 8.3 Internal rotation (all, postoperative) | 45.9 ± 10.2 | After decompression (day of Sx) Internal rotation (all) (P < .001) Internal rotation (increased FV) (P < .001) Internal rotation (normal FV) (P < .001) | | 2.70 (2.19-3.22) large | Manual goniometer, supine. Internal rotation and external rotation measured at 90° hip flexion. Internal rotation was measured by rotating the hip until just before elevation of the pelvis. External rotation was determined as the degree of rotation with leg weight or gravity only. |
| | | | | | | | |

(continued)
# Table 2. Continued

| Author (year) | Study Size | ROM Assessed | Preoperative | Postoperative | P Value* | SMD (95% CI) [Size] | Technique Used to Measure ROM |
|---------------|------------|--------------|--------------|---------------|----------|---------------------|--------------------------------|
| Bedi et al., 2011 | 10 patients | Internal rotation | Simulated ROM: 19.1 ± 13.0 (−1.9 to 32.0) 107.4 ± 11.6 (87.5-127.3) Clinically assessed ROM: 17.5 ± 11.37 | Simulated ROM: 28.4 ± 12.9 (Δ9.3) 110.4 ± 10.0 (Δ3.8) Clinically assessed ROM: 31.0 ± 8.43 | 0.09 (−0.22 to 1.60) | moderate 0.27 (−0.62 to 1.15) weak 1.29 (0.31-2.28) | Simulated ROM — CT images were used to generate patient-specific 3D models of the hip joint. In the simulation the proximal femur and the acetabulum were set to collide. The pelvis was fixed in space and the femur was free to translate in all directions but constrained to rotate about the proscribed rotation axis (simulation previously validated by Tannast et al. and Kubiak-Langer et al.) Also clinically assessed by the senior author. The pelvis was stabilized to record measurements using a goniometer (measured in 5° intervals). Internal rotation was assessed at 90° of hip flexion. |
| Di Benedetto et al., 2016 | (65 patients) 37 in group A 28 in group B | No preoperative values reported | Postoperative values not reported, only the change over time | Not reported | Group A: Group A (12 mo) Flexion Δ 10 Group B: Group B (6 mo) Flexion Δ 12 Abduction Δ 5 Adduction Δ 2 External rotation Δ 3 Internal rotation Δ 4 | |

**NOTE.** Δ indicates the change in ROM from baseline to postoperative assessment. Significant changes from preoperative to postoperative are displayed in bold. AL, anterolateral; AM, anteromedial; FV, femoral anteversion; ROM, range of motion; SMD, standardized mean difference.

*P value as reported in original study.

1Size of SMD effect (weak, 0.2-0.49; moderate, 0.5-0.79; large, >0.8) is reported for those with statistically significant improvements preoperative to postoperative only.

2Stähelin et al. 2008 — this paper does contain Tönnis 2+ but also reports specifically for those Tönnis <2, thus why it was included in this review. The n = 14 sample size reflects only those Tönnis 0, where subanalysis of the entire cohort has been reported.
evidence precluded meta-analysis to be undertaken in this review.

**Flexion**

Flexion was reported as an outcome measure in 91% (n = 21) of the included studies. Postoperative changes in flexion from each study’s baseline were reported as statistically significant in 57.1% (12/21), not statistically significant in 14.3% (3/21), and statistical significance was not reported in 28.6% (6/21). For those studies reporting statistically significant change in flexion, effect size was weak in 16.7% (2/12), moderate in 58.3% (7/12), and large in 25% (3/12) of studies. Pre- to postoperative measured changes in flexion for studies evaluating unilaterally operated patients are presented in Figure 3A, whereas those studies evaluating a mix of unilateral and bilateral patients are presented in Figure 3A. Where simulated CT assessment was used, the postoperative measured change from baseline ranged from 3.0° to 8.0° for unilateral studies and 6.6° in the study including bilateral patients. Where goniometric assessment was used, the postoperative measured change from baseline ranged from 0.1° to 7.0° (unilateral) and 5.0° to 12.2° (mixed). Where details of measurement technique were not provided, the postoperative measured change from baseline ranged from 6.1° to 20.0° (unilateral) and −2.5° to 7.8° (mixed). Overall, for the majority, flexion trended to be higher postoperatively. In one study, the authors assessed ROM in 2 groups (borderline dysplasia vs no borderline dysplasia). For both these groups flexion was reduced postoperatively. Of note, while this study also had the longest period between comparative assessments (mean 31.3 months), it is unclear whether ROM clinical assessment was also undertaken at this time point or whether this postoperative period reflects the time point of PRO score, the major focus evaluation modality within this paper.

**Internal Rotation**

IR was reported as an outcome measure in 100% (23/23) of studies. Postoperative changes in IR from each study’s baseline were statistically significant in 74% (17/23), whereas statistical significance was not reported in 26% (6/23). For those studies reporting statistically significant improvements in IR, effect size was moderate in 29.4% (5/17) of studies, and large in 64.7% (11/17) of studies. One further study (1/17) evaluating 2 groups of patients, reported a moderate effect size in patients without generalized joint laxity and a large effect size in those with generalized joint laxity. Pre- to postoperative measured changes in IR are presented in Figure 2B, whereas those studies evaluating a mix of unilateral and bilateral patients are presented in Figure 3B. Where simulated CT assessment was used, the postoperative measured change from baseline ranged from 9.3° to 14.0° (unilateral) and 11.3° (mixed). Where goniometric assessment was used, the postoperative measured change from baseline ranged from 5.7° to 21.9° (unilateral) and 3.6° to 18.6° (mixed). Where details of measurement technique were not provided, the postoperative measured change from baseline ranged from 6.5° to 19.0° (unilateral) and 4.3° to 14.0° (mixed). Across all studies, IR measured greater postoperatively. The study reporting the largest effect size assessed IR intraoperatively.

**External Rotation**

ER was reported in 65% (n = 15) of the included studies. Postoperative changes in ER from each study’s baseline were statistically significant in 20% (3/15), not statistically significant in 46.7% (7/15), and statistical significance was not reported in 33.3% (5/15). For those studies reporting statistically significant improvements in ER, effect size was weak in 33.3% (1/3) of studies and large in 66.7% (2/3) of studies. Pre- to postoperative measured changes in external rotation were presented in Figure 2C, whereas those studies evaluating a mix of unilateral and bilateral patients are presented in Figure 3C. ER was not assessed in any of the CT simulation studies included. Where goniometric assessment was used, the postoperative measured change from baseline ranged from 0.6° to 12.8° (unilateral) and −2.6° to 5.8° (mixed). In the study by Stone et al., ROM was reported for 2 groups (generalized joint laxity [GJL] vs no GJL). Although those without GJL had a mean increase on 0.6° following surgery, those with GJL reported a reduced range for ER postoperatively (−1.9°). The largest gained increase in ER was reported by Choi et al. Of note, this study also reported the lowest pre- and postoperative mean value for this movement (22.6° and 35.4°, respectively). Where details of measurement technique were not provided, the postoperative measured change from baseline was 1.0° (unilateral) and ranged from −3.2° to 1.3° (mixed). All but one of these studies reported increased measurements postoperatively, albeit to weak effect sizes. One study reported ROM for 2 groups (early vs later in surgeon’s career). In this study ER was reduced (−3.2°) postoperatively in the early group, whereas there was a slight increase (1.1°) in the later operated group. While this measured change difference between groups was statistically significant, the change in ER from baseline to postoperative was not significantly different for either group.

**Quantification of Bony Deformity Correction**

In total, 13 (57%) of the included studies reported pre- and postoperative alpha angle measurements,
quantifying the degree of femoroplasty relative to cam deformity correction (Table 3). Across the studies included, the mean extent of alpha angle correction (on any view) ranged from 1.7° to 28.2°. Only 2 studies included in this review evaluated the impact of bony resection on ROM: Kelly et al. reported a change in alpha angle correlated with the magnitude of increase in IR (r = 0.35) whereas Stähelin et al. reported that neither postoperative alpha value or difference in alpha value achieved by correction correlated with any of the ascertained clinical parameters. Eight (32%) of the included studies reported pre and postoperative LCEA measurements, quantifying the degree of acetabuloplasty (Table 3). The mean extent of LCEA correction ranged from 1.2° to 6.8°.

**Discussion**

All studies included in this review reported favorable ROM scores, with significant improvements from baseline postoperatively in at least one movement. Flexion, IR, and ER were the 3 most frequently reported measurements reported in 91%, 100%, and 65% of studies, respectively. Where the change in measurable ROM following hip arthroscopy was evaluated, the observed change was reported to be statistically significant in 57.1% (flexion), 74% (IR), and 20% (ER). In total, 52% of the included studies did not describe the technique with which ROM was evaluated. Where goniometric assessment was used, the mean change in predominant ROMs ranged as follows: flexion: 0.1° to 12.2°; IR: 3.6° to 21.9°; external rotation —2.6° to 12.8°. Where CT-simulated assessment was used, the mean change was as follows: flexion: 3.0° to 8.0°; internal rotation: 9.3° to 14.0°.

It is generally accepted that decreased motion in patients with symptomatic FAI occurs primarily because of a mechanical block to movement from abnormal bony morphology of the proximal femur and/or acetabulum. The extent of bony morphology can be quantified through radiographic analysis, measuring alpha angle and LCEA. Comparative and investigative studies for the majority have been focused on the cam morphology influencing ROM with studies demonstrating negative correlations between internal rotation and alpha angle.
of this bony deformity may also impact certain movements over others. A superiorly placed cam deformity has been shown to correlate with reduced ER, whereas a more anteriorly placed cam deformity correlates with a reduced IR.3 A superolateral cam lesion may impinge more in flexion and abduction.32 The size or presence of this bony deformity alone, however, may not be solely associated with an observed decrease in ROM14,17,50 and therefore overall structural anatomy should be considered. While morphology with respect to the acetabular side(pincer) is less well investigated for its influence on ROM, an association with lower abduction12 has been reported. In the case of rim fractures, which are indicative of a more chronic and severe type of pincer impingement, adduction and IR have been shown to be significantly reduced.51

Surgical removal of the abnormal bone, verified and quantified by the change in the osseous angular measurements, should therefore result in a greater range of unobstructed hip movement, particularly hip flexion and IR. Although only a proportion of all studies included in this systematic review quantified the change in the osseous angular measurements from pre- to postoperative (13 reporting alpha angle changes; 8 reporting LCEA changes), in all of these studies there was significant improvements in these measurements following arthroscopic surgery. Similarly, among these studies, there was significant improvements in
measured ROMs from baseline to postoperative (100% of the studies evaluating IR; 76.9% of the studies evaluating flexion; 23% of the studies evaluating ER). Despite this, the association between the extent of resection with any changes in ROM was not wholly explored. For the majority, changes in ROM from baseline were largely reported as an incidental and accompanying outcome, and not the major focus of

| Study | Preoperative | Postoperative | Mean Change |
|-------|--------------|---------------|-------------|
| Keating et al., 2020 | AA (Dunn) 57.9 ± 7.3 | 36.1 ± 4.1 | 21.8 |
| | LCEA 32.1 ± 4.6 | 30.9 ± 5.2 | 1.2 |
| Flores et al., 2018 | Early group AA (Dunn) 61.6 ± 7.0 | 46.6 ± 2.4 | 15.0 |
| | LCEA 36.7 ± 6.4 | 30.3 ± 3.9 | 6.4 |
| | Late group AA (Dunn) 59.8 ± 3.8 | 46.5 ± 3.4 | 13.3 |
| | LCEA 34.1 ± 7.2 | 28.2 ± 3.4 | 5.9 |
| Carton and Filan, 2020 | AA (Dunn) 59.8 ± 12.9 | 50.9 ± 10.0 | 8.9 |
| | AA (AP) 68.4 ± 17.5 | 61.4 ± 15.1 | 7.0 |
| | LCEA 34.0 ± 6.1 | 30.4 ± 5.7 | 3.6 |
| Stone et al., 2019 | GJL group AA (Dunn) 60.6 ± 8.19 | 41.1 ± 5.03 | 19.5 |
| | LCEA 30.6 ± 6.17 | 27.4 ± 5.31 | 3.2 |
| | acea 31.2 ± 7.22 | 29.7 ± 5.14 | 1.5 |
| | Non-GJL group AA (Dunn) 59.3 ± 8.48 | 42.7 ± 4.58 | 16.6 |
| | LCEA 31.2 ± 4.77 | 27.3 ± 5.08 | 3.9 |
| | acea 32.3 ± 5.51 | 30.3 ± 5.13 | 2.0 |
| Ross et al., 2018 | AA 69.2 ± 12.9 | 41.0 ± 3.4 | 28.2 |
| | LCEA 31.7 ± 5.6 | Not reported | − |
| Mullins et al., 2020 | AA 65.0 ± 18.0 | 56.0 ± 14.1 | 9.0 |
| | AA (dunn) 58.9 ± 11.8 | 49.8 ± 10.1 | 9.1 |
| | LCEA 35.7 ± 6.5 | 28.9 ± 5.8 | 6.8 |
| Frank et al., 2018 (yoga) | AA (Dunn) 59.2 ± 15.26 | 38.79 ± 9.9 | 20.4 |
| | LCEA 32.87 ± 9.17 | 27.74 ± 7.9 | 5.1 |
| Frank et al., 2018 (cyclists) | AA (Dunn) 61.7 ± 10.3 | 39.05 ± 4.31 | 22.6 |
| | LCEA 31.39 ± 5.6 | 26.89 ± 4.32 | 4.5 |
| Ross et al., 2015 | Revision group AA 68 ± 16 | Not reported | − |
| | LCEA 35 ± 7 | Not reported | − |
| Nonrevision group | AA 62 ± 12 | 39 ± 4 | 23.0 |
| Rill et al., 2018 | AA (Dunn) 63.6 ± 6.7 | 37.8 ± 3.0 | 25.8 |
| | LCEA 32.8 ± 5.7 | 31.2 ± 4.9 | 1.6 |
| Choi et al., 2018 | AA (AP) 60.7 | 59.0 | 1.7 |
| | AA (Dunn) 64.5 | 50.0 | 14.5 |
| | AA (cross table lateral) 59.4 | 49.2 | 10.2 |
| Kelly et al., 2012 | AA (modified lateral) 68.0 ± 10.0 | 43.4 ± 4.0 | 24.6 |
| | AA (AP) 73.8 ± 7.5 | 51.9 ± 10.3 | 21.9 |
| Bedi et al., 2011 | AA (CT) 59.8 (36-76) | 36.4 (22-46) | 23.4 |

AA, alpha angle; ACEA, anterior center-edge angle; AP, anteroposterior view radiograph; CT, computed tomography; GJL, generalized joint laxity; LCEA, lateral center-edge angle.
each included study. Without the authors assessing for a relationship between these 2 variables (ROM and bony resection) it cannot be concluded that resection alone impacted the change in ROM, however it is reasonable to assume a connection. For example, Kelly et al.32 did investigate this and reported that a change in alpha angle correlated with magnitude of increase in IR measured immediately after cam decompression \((r = 0.35)\) supporting a link between these 2 variables. In this same study, however, flexion was reported to be not significantly improved immediately following cam decompression; however, there was a significant improvement in flexion when this measurement was repeated at 3-months postoperatively. On the one hand, this may hint at factors beyond bony correction influencing this particular ROM; however, it also may suggest inconsistencies in measurement technique between the 2 time points. The time point at which ROM is assessed postoperatively may also influence the acquired measurable change in ROM. For example, Choi et al.30 longitudinally assessed flexion, IR and ER at 3 months, 6 months, 1 year, and 2 years’ postoperatively and compared time-related measured values with baseline scores. While the association of bony resection with any changes to ROM was not evaluated, the time point at which significant improvement in ROM was achieved varied: IR by 3 months and ER by 6 months, whereas flexion did not significantly increase at any stage postoperatively.

Stähelin et al.47 reported that neither postoperative alpha value nor difference in alpha value achieved by correction (average 21.3°) correlated with any clinical parameters, despite significant increases postoperatively for IR and flexion reported. In this early study as part of the surgical technique the authors described a “large opening of the capsule,” which was not reported to have been repaired. In this instance, therefore, the unrepaired capsulotomy may have, in part, contributed to the observed increase in IR and flexion. Subsequent research has since demonstrated an associated lack of restraint with an unrepaired capsule and therefore increased ROM following capsulotomy.52-54 In predisposed stiff hips, a capsulotomy may be therapeutic.55 Conversely, an overzealous capsular plication may constrain hip motion but may be potentially warranted in certain demographic instances. In the included study by Frank et al.,38 assessing patients involved in yoga, an activity where patients typically exceed the physiologic joint tolerance, the authors state capsular plication may be critical to enhance joint kinematics while maintaining stability. As such, while the fundamentals of arthroscopic correction of cam and pincer deformities aim to restore joint mechanics to a more optimal physiologic state by increasing the available ROM in the typical FAI candidate, subsequent management of the capsule may also dictate the extent of available ROM postoperatively.

Overall bony anatomy beyond isolated cam and/or pincer deformities should be considered for their influence on restricted ROM. Two studies in this systematic review31,32 evaluated the impact of femoral version on hip ROM using goniometric measurements. Fabricant et al.31 reported a greater postoperative change in IR in a decreased version group; however, this difference was determined to be largely owing to the significantly lower measured preoperative IR compared with normal and increased version groups. No differences in postoperative improvements in flexion or ER between version groups were observed. Similarly, Kelly et al.32 reported improved IR in all version groups following arthroscopic cam decompression, with a change in alpha angle correlating with magnitude of increase in IR. Another study51 compared the arthroscopic treatment of FAI among patients with borderline dysplasia versus nondysplasia and found there to be no significant differences in flexion, IR, or ER between groups at any time point. The significance of the change from preoperative to postoperative was not reported; however, both groups similarly trended with an increase in the measured mean IR and ER and a decrease in the measured flexion from baseline to postoperative. Natural structural differences (including decreased femoral anteversion,56 increased acetabular retroversion,14 anterior pelvic tilt, coxa vara/valga, or prominence of the anterior inferior iliac spine resulting from traction hypertrophy during adolescent development,57 etc.) may restrict hip rotation through various planes and result in variations of baseline measurements between patients, an important consideration when making cross-comparisons between studies. However, these natural structural variations are not addressed with typical FAI-corrective arthroscopic surgery and therefore their presence is independent of any acquired ROM change postarthroscopy.

Additional structural components, considered barriers to movement, may influence the measurement to end-range, such as surrounding periarticular soft tissues, capsule, cartilage, labrum, and muscles and based on the particular technique with which ROM is assessed, these structures may lead to either an under- or over-estimation of functional range. Historically, the modality through which hip joint ROM has to be measured is variable, including use of goniometer, inclinometer, photometer, radiographs, and video tracking.58,59 Within this systematic review the predominantly reported ROM measurement techniques were goniometer and CT simulation. Where CT-simulation studies provide an understanding of the ROM in terms of bone-to-bone available range, such studies ignore the aforementioned secondary stabilizing structures and may
overestimate the functional benefits gained from arthroscopic correction for the patient. Goniometric evaluation is more appropriate in a clinical setting. The goniometer has demonstrated excellent intra-rater reliability even in the unskilled examiner (intraclass correlation coefficient 0.906, P < .05) and good-to-excellent intra-rater, test–retest reliability for measuring hip flexion ROM. Of note, Nussbaum et al. has shown some overestimation of hip ROM with the use of goniometer versus an electromagnetic tracking system.

Within interventional outcome studies, a number of PROs have been developed and validated to capture and quantify perceived change following arthroscopic correction of FAI and a description of these are generally required to be defined within a study’s methodology. Similarly, when reporting the outcomes of surgical intervention of any type, a prerequisite is a comprehensive description of the surgical intervention technique with which the results have been conceived. Upon reviewing the literature retrieved during the search process, it is apparent that surgical outcome studies were overall lacking in their reporting of ROM changes following surgical correction of FAI. In particular, the sustainability of any acquired change over time in the form of longer-term outcome research is in stark contrast to the vast body of research evaluating outcomes from the perspective of PROs. An observation within this systematic review is the lack of any standardized or even descriptive “per-study” measurement protocol for clinically assessing ROM. Only 48% of the included studies reported the instrument with which ROM was measured, and even fewer detailing the technique. As such, guidance for repeatability of reported results in a clinical setting is inconsistent and poorly defined within the clinical outcome studies, which impacts the generalizability and direct comparability between cohorts.

The factors that have led to an under-reporting of ROM change over time is unclear. Considering these data can only be accurately captured via a third-party assessor (not the patient themselves), it can be assumed that logistics and practicality for a patient to return to a clinical setting for full assessment may be a significant hurdle. Large hip registries, which are the source of data retrieval for the majority of HA outcome studies, may be particularly affected by this. Sansone et al. have previously commented on the revision of a Swedish hip arthroscopy registry to exclude ROM owing to the fact they found this to be unreliable. Further, as there is no standardized technique with which all clinicians measure ROM (1 vs 2 operators, patient positioning (supine, seated, prone), same assessor(s) at different time points, manual/electronic goniometer, standardized technique/protocol to control for anatomic or environmental variations which may contribute to inaccuracies in true end range measurement, etc.), comparisons across studies are therefore less reliable and valid. From a clinical perspective, any change in measurable compound movements may lead to a more subjective feeling of improvement for the patient and should be considered for future studies assessing clinical outcome of HA in these cohorts.

**Limitations**

Retrospective design of the included studies may introduce selection bias. The predominance of studies of lower level of evidence, underlying fair methodologic design and unavailability of randomized controlled trials assessing the influence of arthroscopic treatment on ROM may introduce further bias. Although the search was carried out in a systematic way, it is possible that studies which do report comparative ROM values were missed. English-only language search is also a limitation. In addition, only 52% of the papers provided enough detailed information with respect to the technique used to measure ROM, which may have introduced heterogeneity in the study methods and subsequent outcomes. The inclusion of bilateral patients when assessing ROM may result in reported CIs to be artificially narrow owing to correlation between 2 hip measurements from the same patient. The follow-up duration and sample sizes between studies included were variable. Finally, given the available evidence, the current study only assessed the influence of HA on the three more commonly assessed ROMs in isolation.

**Conclusions**

Outcome studies demonstrate overall increased range of flexion and IR post-HA, with a moderate and large effect respectively. Change in ER is less impacted following HA. Certainty of evidence to support this observation is low. Current research evaluating change in this functional ability is limited by a lack of prospective studies and nonstandardized measurement evaluation techniques.

**References**

1. Byrd JWT. Evaluation of the hip: History and physical examination. *N Am J Sports Phys Ther* 2007;2:231–240.
2. Frangiamore S, Mannava S, Geeslin AG, Chahla J, Cinque ME, Philippon MJ. Comprehensive clinical evaluation of femoroacetabular impingement: Part 1, Physical examination. *Arthrosc Tech* 2017;6:e1993–e2001. doi:10.1016/j.eats.2017.03.027.
3. Jönasson P, Thoresen O, Sansone M, et al. The morphologic characteristics and range of motion in the hips of athletes and non-athletes. *J Hip Preserv Surg* 2016;3: hnw023. doi:10.1093/jhps/hnw023.
4. Nieszporska O, Truszczynska-Baszak A. Functional condition of patients after unilateral hip arthroscopy in the process of FAI—femoroacetabular impingement: A
case–control study and preliminary report. J Clin Med 2021;10:1023. doi:10.3390/jcm10051023.
5. Philipp MJ, Briggs KK, Yen YM, Kuppersmith DA. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondralobal dysfunction: Minimum two-year follow-up. J Bone Joint Surg Br 2009;91:16-23. doi:10.1302/0301-620X.91B1.21329.
6. Philipp MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. Knee Surg Sports Traumatol Arthrosc 2007;15:1041-1047. doi:10.1007/s00167-007-0348-2.
7. Roach KE, Miles TP. Normal hip and knee active range of motion: The relationship to age. Phys Ther 1991;71:656-665. doi:10.1093/ptj/71.9.656.
8. Agricola R, Heijboer MP, Ginai AZ, et al. A cam deformity is gradually acquired during skeletal maturation in adolescent and young male soccer players: A prospective study with minimum 2-year follow-up. Am J Sports Med 2014;42:798-806.
9. Anwander H, Beck M, Büchler L. Influence of evolution on cam deformity and its impact on biomechanics of the human hip joint. J Orthop Res 2018;36:2071-2075. doi:10.1002/jor.23863.
10. Kapron AL, Anderson AE, Peters CL, et al. Hip internal rotation is correlated to radiographic findings of cam femoroacetabular impingement in collegiate football players. Arthroscopy 2012;28:1661-1670. doi:10.1016/j.arthro.2012.04.153.
11. van Klij P, Ginai AZ, Heijboer MP, Verhaar JAN, Waarsing JH, Agricola R. The relationship between cam morphology and hip and groin symptoms and signs in young male football players. Scand J Med Sci Sports 2020;30:1221-1231. doi:10.1111/smss.13660.
12. Mosler AB, Agricola R, Thorborg K, et al. Is bony hip morphology associated with range of motion and strength in asymptomatic male soccer players? J Orthop Sports Phys Ther 2018;48:250-259. doi:10.2519/jospt.2018.7848.
13. Wyss TF, Clark JM, Weishaupt D, Nötzli HP. Correlation between internal rotation and bony anatomy in the hip. Clin Orthop Rel Res 2007;460:152-158. doi:10.1097/BLO.0b013e3180399430.
14. Audenaert EA, Peeters I, Vigneron L, Baelde N, Pattyn C. Hip morphological characteristics and range of internal rotation in femoroacetabular impingement. Am J Sports Med 2012;40:1329-1336. doi:10.1177/0363546512441328.
15. Frasson VB, Vaz MA, Morales AB, et al. Hip muscle weakness and reduced joint range of motion in patients with femoroacetabular impingement syndrome: A case-control study. Braz J Phys Ther 2020;24:39-45. doi:10.1016/j.bjpt.2018.11.010.
16. Wörner T, Nilsson J, Thorborg K, Granlund V, Stålmán A, Eek F. 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. Orthop J Sports Med 2019;7:1-10. doi:10.1017/5325967119844821.
17. 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;50:1180. doi:10.1136/bjsports-2016-096152.
impingement surgery. J Bone Joint Surg Am 2015;97:537-543. doi:10.2106/JBJS.N.00266.

32. Kelly BT, Bedi A, Robertson CM, Dela Torre K, Giveans MR, Larson CM. Alterations in internal rotation and alpha angles are associated with arthroscopic cam decompression in the hip. Am J Sports Med 2012;40:1107-1112. doi:10.1177/0363546512437731.

33. Matsuda DK, Schnieder CP, Sehgal B. The critical corner of cam femoroacetabular impingement: Clinical support of an emerging concept. Arthroscopy 2014;30:575-580. doi:10.1016/j.arthro.2014.01.009.

34. Riff AJ, Ukwuani G, Clapp I, Movassaghi K, Kelly DM, Nho SJ. High rate of return to high-intensity interval training after arthroscopic management of femoroacetabular impingement syndrome. Am J Sports Med 2018;46:2594-2600. doi:10.1177/0363546518776638.

35. Bedi A, Dolan M, Hetrsconi I, et al. Surgical treatment of femoroacetabular impingement improves hip kinematics: A computer-assisted model. Am J Sports Med 2011;39(1_suppl):43S-49S. doi:10.1177/0363546511414635.

36. Ross JR, Khan M, Noonan BC, Larson CM, Kelly BT, Bedi A. Characterization and correction of symptomatic hip impingement in American football linemen. HSS J 2018;14:128-133. doi:10.1007/s11420-018-9605-9.

37. Ross JR, Larson CM, Adeyo O, Kelly BT, Bedi A. Residual deformity is the most common reason for revision hip arthroscopy: A three-dimensional CT study. Clin Orthop Rel Res 2015;473:1388-1395. doi:10.11999/014-04069-9.

38. Frank RM, Ukwuani G, Allison B, Clapp I, Nho SJ. High rate of return to yoga for athletes after hip arthroscopy for femoroacetabular impingement syndrome. Sports Health 2018;10:1511-1517. doi:10.1177/1941738116635209.

39. Keating TC, Chahla J, Beck EC, et al. Return to Pilates following hip arthroscopy for treatment of femoroacetabular impingement syndrome. J Hip Preserv Surg 2019;6:339-345. doi:10.1093/jhps/hnz053.

40. Levy DM, Cvetanovich GL, Kuhn BD, Greenberg MJ, Alter JM, Nho SJ. Hip arthroscopy for atypical posterior hip pain: A comparative matched-pair analysis. Am J Sports Med 2017;45:1627-1632. doi:10.1177/0363546516692983.

41. Kawabi DH, Degen RM, Fields KG, et al. Outcomes after arthroscopic treatment of femoroacetabular impingement for patients with borderline hip dysplasia. Am J Sports Med 2016;44:1017-1023. doi:10.1177/0363546515624682.

42. Stone AV, Malloy P, Beck EC, et al. Predictors of persistent postoperative pain at minimum 2 years after arthroscopic treatment of femoroacetabular impingement. J Hip Preserv Surg 2019;4:75-81. doi:10.1093/jhps/hnz053.

43. Waterman BR, Ukwuani G, Clapp I, Malloy P, Neal WH, Nho SJ. Return to golf after arthroscopic management of femoroacetabular impingement syndrome. Arthroscopy 2018;34:3187-3193.e1. doi:10.1016/j.arthro.2018.06.042.

44. Flores SE, Borak KR, Zhang AL. Hip arthroscopic surgery for femoroacetabular impingement: A prospective analysis of the relationship between surgeon experience and patient outcomes. Orthop J Sports Med 2018;6:1-8. doi:10.1177/232596718755048.

45. Frank RM, Ukwuani G, Clapp I, Chahla J, Nho SJ. High rate of return to cycling after hip arthroscopy for femoroacetabular impingement syndrome. Sports Health 2018;10:259-265. doi:10.1177/1941738117747851.

46. Ragab R, Elkhadrwe R, Housden P, Abotaleb A. Results of arthroscopic treatment of femoroacetabular impingement (FAI). Alexandria J Med 2018;54:361-363. doi:10.1016/j.ajme.2018.04.002.

47. Stähelin L, Stähelin T, Jolles BM, Herzog RF. Arthroscopic offset restoration in femoroacetabular cam impingement: Accuracy and early clinical outcome. Arthroscopy 2008;24:51-57.e1. doi:10.1016/j.arthro.2007.08.010.

48. Guler O, Isyar M, Karataş D, Ormeci T, Cerci H, Mahirougullar M. A retrospective analysis on the correlation between hip pain, physical examination findings, and alpha angle on MR images. J Orthop Surg Res 2016;11:1-5. doi:10.1186/s13018-016-0476-9.

49. Tak I, Glasgow P, Langhout R, Weir A, Kerkhoffs G, Agricola R. Hip range of motion is lower in professional soccer players with hip and groin symptoms or previous injuries, independent of cam deformities. Am J Sports Med 2016;44:682-688. doi:10.1177/0363546515617747.

50. Carton PF, Filan DJ. The clinical presentation, diagnosis and pathogenesis of symptomatic sports-related femoroacetabular impingement (SRFAI) in a consecutive series of 1021 athletic hips. Hip Int 2019;29:665-673. doi:10.1177/112070018825430.

51. Abrams GD, Hart MA, Takami K, et al. Biomechanical evaluation of capsulotomy, capsulectomy, and capsular repair on hip rotation. Arthroscopy 2015;31:1511-1517. doi:10.1016/j.arthro.2015.02.031.

52. Bayne CO, Stanley R, Simon P, et al. Effect of capsulotomy on hip stability—a consideration during hip arthroscopy. Am J Orthop (Belle Mead NJ) 2014;43:160-165.

53. Filan D, Carton P. Routine interportal capsular repair does not lead to superior clinical outcome following arthroscopic femoroacetabular impingement correction with labral repair. Arthroscopy 2020;36:1323-1334. doi:10.1016/j.arthro.2019.12.002.

54. Harris JD, Slikker W, Gupta AK, McCormick FM, Nho SJ. Routine complete capsular closure during hip arthroscopy. Arthrosc Tech 2013;2:e89-e94. doi:10.1016/j.eats.2012.11.007.

55. Ejnisman L, Philippin MJ, Lertwanich P, et al. Relationship between femoral anteversion and findings in hips with femoroacetabular impingement. Orthopedics 2013;36:293-300. doi:10.3928/01477447-20130222-17.

56. Carton P, Filan D. Anterior inferior iliac spine (AIIS) and subspine hip impingement. Muscles Ligaments Tendons J 2016;6:324-336. doi:10.11138/mltj/2016.6.3.24.

57. Kouyoumdjian P, Coulomb R, Sanchez T, Asencio G. Clinical evaluation of hip joint rotation range of motion in adults. Orthop Traumatol Surg Res 2012;98:17-23. doi:10.1016/j.otsr.2011.08.015.

58. Yazdifar M, Yazdifar MR, Mahmud J, Esat I, Chizari M. Evaluating the hip range of motion using the goniometer and video tracking methods. Proced Eng 2013;68:77-82. doi:10.1016/j.proeng.2013.12.150.
60. Prather H, Harris-Hayes M, Hunt D, Steger-May K, Mathew V, Clohisy JC. Reliability and agreement of hip range of motion and provocative physical examination tests in asymptomatic volunteers. *PM R* 2010;2:888-895. doi:10.1016/j.pmrj.2010.05.005.

61. Kim SG, Kim EK. Test-retest reliability of an active range of motion test for the shoulder and hip joints by unskilled examiners using a manual goniometer. *J Phys Ther Sci* 2016;28:722-724. doi:10.1589/jpts.28.722.

62. Pua YH, Wrigley TW, Cowan SM, Bennell KL. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. *Arch Phys Med Rehab* 2008;89:1146-1154. doi:10.1016/j.apmr.2007.10.028.

63. Nussbaumer S, Leunig M, Glatthorn JF, Stauffacher S, Gerber H, Maffiuletti NA. Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskelet Disord* 2010;11:194. doi:10.1186/1471-2474-11-194.

64. Sansone M, Ahldén M, Jonasson P, et al. A Swedish hip arthroscopy registry: Demographics and development. *Knee Surg Sports Traumatol Arthrosc* 2014;22:774-780. doi:10.1007/s00167-014-2840-9.
Appendix Table 1. Search Terms Used

((((("femoroacetabular") OR (‘femoro acetabular’) OR (‘femoro-acetabular’)) AND (‘impingement’ OR (‘impingement syndrome’))) AND (‘hip arthroscopy’ OR (‘arthroscopic correction’))) AND (‘hip range of motion’ OR (range of motion) OR (range of motion, articular) OR (‘range of motion’) OR (‘range of movement’) OR (ROM) OR (‘flexion’) OR (‘abduction’) OR (‘adduction’)) OR (‘external rotation’) OR (‘internal rotation’) OR (‘squat’) OR (‘depth’) OR (‘rotation’)))
### Appendix Table 2. MINORS Quality Assessment

| Study                | Non-Comparative (/16) | Comparative (/24) | MINORS Score | Study Quality |
|---------------------|-----------------------|-------------------|--------------|---------------|
| Keating et al.      | 2 2 1 2 0 2 1 0       |                   | 10           | Fair          |
| Ragab et al.        | 1 0 0 2 0 1 0 0       |                   | 4            | Very low      |
| Waterman et al.     | 2 2 1 2 0 2 1 0       |                   | 10           | Fair          |
| Flores et al.       | 2 2 2 2 0 1 2 2      |                   | 13           | High          |
| Carton and Filan    | 2 1 2 2 0 2 1 0       |                   | 10           | Fair          |
| Stone et al.        | 2 0 2 2 0 2 0 2       |                   | 17           | Fair          |
| Ross et al.         | 2 2 1 2 0 2 2 0       |                   | 11           | Fair          |
| Polesello et al.    | 2 0 0 1 0 2 2 0       |                   | 7            | Low           |
| Mullins et al.      | 2 0 2 2 0 2 1 2       |                   | 19           | High          |
| Stone et al.        | 2 2 2 2 0 2 1 0       |                   | 17           | Fair          |
| Frank et al.        | 2 2 2 2 0 2 2 0       |                   | 12           | Fair          |
| Frank et al.        | 2 2 2 2 0 2 1 0       |                   | 11           | Fair          |
| Levy et al.         | 2 2 0 2 0 2 1 0       |                   | 17           | Fair          |
| Nawabi et al.       | 2 2 2 2 0 2 0 2       |                   | 17           | Fair          |
| Fabricant et al.    | 2 2 2 2 0 2 2 0       |                   | 12           | Fair          |
| Ross et al.         | 2 2 0 2 0 2 2 0       |                   | 10           | Fair          |
| Stühelin et al.     | 2 2 2 2 0 1 2 2      |                   | 10           | Fair          |
| Riff et al.         | 2 2 2 2 0 2 2 1       |                   | 13           | High          |
| Matsuda et al.      | 2 2 0 2 0 2 2 0       |                   | 10           | Fair          |
| Choi et al.         | 2 2 0 2 0 2 2 0       |                   | 10           | Fair          |
| Kelly et al.        | 2 2 0 2 0 2 2 0       |                   | 10           | Fair          |
| Bedi et al.         | 2 0 0 2 0 2 2 0       |                   | 8            | Fair          |
| Di Benedetto et al. | 1 2 0 2 0 1 0 0       |                   | 6            | Low           |
### Appendix Table 3. Question: Postoperative Goniometer Measurement Compared With Preoperative Goniometer Measurements for Assessing Hip ROM Following Hip Arthroscopy for FAI

|                | Certainty Assessment | No. of Patients | Effect                           | CI, confidence interval; FAI, femoroacetabular impingement; MD, mean difference; ROM, range of motion. |
|----------------|----------------------|-----------------|----------------------------------|--------------------------------------------------------------------------------------------------|
|                | Study Design         | Risk of Bias    | Inconsistency | Indirectness | Imprecision | Other Considerations | Postoperative Goniometer Measurement | Preoperative Goniometer Measurements | Relative (95% CI) | Absolute (95% CI) | Certainty | Importance |
| Flexion_Goniometer | 6 Observational studies | Serious* Serious* | Not serious | Not serious | Publication bias strongly suspected* | 748 | 748 | – | MD 5.98 higher (2.99 higher to 8.98 higher) | ⬤ ⬤ ⬤ IMPORTANT | VERY LOW |
| Internal Rotation_Goniometer | 8 observational studies | Serious* Serious* | Not serious | Not serious | Publication bias strongly suspected* | 787 | 787 | – | MD 11.68 higher (8.13 higher to 15.23 higher) | ⬤ ⬤ ⬤ IMPORTANT | VERY LOW |
| External Rotation_Goniometer | 6 Observational studies | Serious* Serious* | Not serious | Not serious | Publication bias strongly suspected* | 748 | 748 | – | MD 2.68 higher (1.21 lower to 6.56 higher) | ⬤ ⬤ ⬤ IMPORTANT | VERY LOW |

*Retrospective study designs, measurement techniques not fully described and variation across studies, examiner not blinded.
| Study Design | Risk of Bias | Inconsistency | Indirectness | Imprecision | Other Considerations | No. of Studies | Flexion All Studies - Simulated | No. of Patients | Effect | Certainty | Importance |
|--------------|--------------|---------------|---------------|-------------|----------------------|----------------|---------------------------------|----------------|--------|-----------|------------|
| Observational studies | Not serious | Not serious | Not serious | Not serious | None | 3 | Postoperative CT Simulation | 92 | Preoperative CT Simulation | 92 | MD 7.28 higher (4.1 higher to 10.45 higher) | @ @ O O IMPORTANT | LOW |
| Internal Rotation All Studies - Simulated | Observational studies | Not serious | Not serious | Not serious | None | 3 | Postoperative CT Simulation | 92 | Preoperative CT Simulation | 92 | MD 13.22 higher (9.54 higher to 16.9 higher) | @ @ O O IMPORTANT | LOW |

CI, confidence interval; FAI, femoroacetabular impingement; MD, mean difference; ROM, range of motion.