Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence

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ABSTRACT

Background Femoroacetabular impingement (FAI) and associated pathologies are associated with pain and reduced quality of life. Physical impairments can be associated with worse symptoms and may be an important target of rehabilitation programmes in this patient group. Knowledge regarding physical impairments in people with symptomatic FAI is limited.

Hypothesis In adults aged 18–50 years with symptomatic FAI: (1) to identify physical impairments in range of motion (ROM), hip muscle function and functional tasks; (2) to compare physical impairments with healthy controls; and (3) to evaluate the effects of interventions targeting physical impairments.

Study design Systematic review.

Methods A systematic review of the literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. The modified Downs and Black checklist was used for quality appraisal. Studies of adults aged 18–50 years with symptomatic FAI that examined ROM, hip muscle function and functional tasks were included. Standardised mean differences were calculated where possible or best evidence synthesis and study conclusions were presented.

Results Twenty-two studies fulfilled all inclusion criteria. Methodological quality was varied. Results for hip joint ROM differences between people with symptomatic FAI compared and control subjects were varied. People with symptomatic FAI demonstrated some deficits in hip muscle strength and reduced balance on one leg when compared with control subjects. For hip joint ROM and hip muscle strength results for within-group differences between preintervention and postintervention time points were limited and inconclusive. No randomised controlled trials evaluated the effect of different types of interventions for symptomatic patients with symptomatic FAI.

Conclusions People with symptomatic FAI demonstrate impairments in some hip muscle strength and single leg balance. This information may assist therapists in providing targeted rehabilitation programmes for people with FAI and associated pathology. Further research is needed to determine whether symptomatic FAI affects other aspects of functional performance; and to evaluate whether targeted interventions are effective in symptomatic FAI.

Clinical relevance This information may assist therapists in providing targeted rehabilitation programmes for people with symptomatic FAI.

What is already known

► Femoroacetabular impingement (FAI) is associated with pain and reduced quality of life. Physical impairments can be associated with worse symptoms and may be an important target of rehabilitation programmes in this patient group. Knowledge regarding physical impairments in people with symptomatic FAI is limited.

What are the new findings

► People with symptomatic FAI demonstrate impairments in some hip muscle strength and single leg balance. This information may assist therapists in providing targeted rehabilitation programmes for people with symptomatic FAI.

INTRODUCTION

Femoroacetabular impingement (FAI) is a recognised cause of hip pain in young and middle-aged adults, and is associated with an increased risk of end-stage radiographic hip osteoarthritis (OA) and total hip arthroplasty.[1] FAI is a clinical condition, where affected patients may present with a morphological variant in hip shape on radiographs, with or without associated labral and/or chondral pathology,[2] resulting in increased hip/groin pain[3] and reduced activity and quality of life.[1 4] FAI and associated pathologies are characterised by abutment of the femoral neck against the acetabular rim. Impingement occurs via the jamming of a non-spherical extension of the femoral head into the acetabular cavity[5] causing damage to the antero-superior acetabular cartilage and potentially leading to OA changes in the hip.[1 6] FAI and associated pathologies may be considered to represent early-stage hip degenerative joint disease in the disease continuum.[4 7] These pathologies will be referred to collectively as 'symptomatic FAI' in this systematic review.

Symptomatic FAI can have a significant impact on pain, function and quality of life outcomes in young and middle-aged people[4 8] that may ultimately reduce their capacity to lead active and productive lives. Identifying potentially modifiable impairments in patients with symptomatic FAI is important. If they can be identified when

hip degenerative disease is in its early stages, it may be possible to design rehabilitation interventions to slow the symptomatic progression of symptomatic FAI. Arthroscopic surgery of the hip to reshape impingement lesions and salvage acetabular labarum and chondral surfaces is the most common treatment at present.[9] Postsurgical rehabilitation programmes have been described in detail.[10 11] High-quality evidence to support the effect of either surgical, non-surgical or postsurgical interventions for patients with symptomatic FAI is currently lacking. At present the impairments and disabilities of patients with symptomatic FAI are poorly understood.[12] A greater understanding may lead to the development of effective interventions (both non-operative and postoperative) that can reduce pain, improve activity and enhance quality of life in affected individuals.

The physical impairments and activity limitations of people with all forms of FAI (cam, pincer and mixed) have been previously systematically reviewed,[12] however that study combined clinical and laboratory-based biomechanical data and did not provide standardised effect size measures to facilitate comparisons between studies. Moreover, a large number of studies have been published since the search date of the previous review (June 2013). The goal of this review was to examine physical impairments that can be measured in the clinical setting and encompass much of the rapidly expanding knowledge and available literature in the area of physical impairments in people with symptomatic FAI.

The aim of this review was to systematically appraise the literature: (1) to identify physical impairments in adults aged 18–50 years with symptomatic FAI; (2) to compare physical impairments in people with symptomatic FAI with healthy controls; and (3) to evaluate the effects of interventions targeting physical impairments in patients with symptomatic FAI.

METHODS

The systematic review protocol was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[13] Literature search criteria and methods were proposed and agreed on by two authors and were established a priori to minimise selection bias.

Search strategy

A comprehensive, reproducible search strategy was performed on the following databases for dates of publication between 1 January 1990 and 22 August 2015: Scopus, Medline, CINAHL, PubMed, Ausport, SportDiscus, PEDro, PsycINFO and Google Scholar. January 1990 was selected as the earliest retrieval record due to the paucity of literature on FAI prior to this date.[9] Reference lists of appropriate studies were manually searched for relevant papers. The search strategy used the PICO format, and included:

P=human adults with symptomatic FAI, diagnosed by MRI or at arthroscopy ('femoracetabular impingement', 'labr*', 'chondr*', 'pathology', 'osteoarthritis', 'arthritis', 'pain', 'hip joint')

I=surgical and non-surgical interventions ('arthroscop*', 'physiotherapy', 'physical therapy', 'exercise', 'therapy')

C=people without FAI, labral or chondral pathology ('control', 'healthy', 'asymptomatic')

O=physical impairments of the hip. This may include hip joint ROM, hip muscle strength, measures of functional performance, EMG, gait analysis ('hip', 'muscle strength', 'range of motion', 'range of movement', 'range', 'movement', 'EMG', 'impairment', 'musculoskeletal', 'proprioception', 'balance', 'motor control', 'gait', 'kinematic'. 'stiffness', 'weakness', 'function*', 'performance').

The strategy was modified for each database. Titles and abstracts were screened for relevant studies by two independent reviewers (JLK, IS). Any disagreements regarding inclusion were resolved by an independent arbitrator (KMC). All potential references were imported into Endnote X6 (Thomson Reuters, Carlsbad, California, USA) and duplicates were removed. Full-text versions of identified papers were then retrieved for final eligibility screening by a single reviewer (JLK).

Eligibility criteria

Studies were eligible for inclusion if they were reported in English; report level IV evidence or above; contained human subjects with symptomatic FAI assessed using preoperative diagnostic imaging techniques or hip arthroscopy; had at least five participants; and examined physical impairments of the hip or functional performance. Symptomatic FAI was defined as the presence of an impingement variant at the head-neck junction, and/or associated impingement-type pathologies (such as chondral or labral pathology). Physical impairments included hip joint range of motion (ROM), hip muscle function (including strength test and measures of muscular activity collected as electromyography (EMG), motor control; balance or proprioception) and functional task performance (including squatting, walking and other activities of daily living). Studies specifically examining kinematics or joint torques were excluded. All quantitative study designs were considered, including randomised controlled trials (RCT), prospective or retrospective approaches.[14] Studies were excluded if they were case series with less than five participants, published abstracts, non-peer reviewed or in a language other than English.

Quality evaluation

The Downs and Black checklist was used to appraise the methodological quality of included studies.[15] This has adequate reliability and validity for assessing non-randomised studies. The original 27 items were modified to 17 items following the exclusion of criteria 4, 13, 14, 15, 17, 19, 22, 23, 24 and 27. There were no RCTs found, therefore only criteria that were applicable for non-randomised studies were evaluated. Included studies were rated by two independent reviewers (IS, MF). A third reviewer audited the ratings of a random selection of included studies (JLK). Any disagreements between reviewers were discussed and consensus determined by an independent arbitrator (JLK). Studies were considered high quality with a score of more than 60% (10 points or more out of 17).[16]

Statistical analyses and data management

All statistical analyses were performed by a single author (JLK) using SPSS V.21.0 software (SPSS). The 'meta' package (version 4.9-5), from the R statistical software package (version 3.5.1) was used to calculate effect sizes (wth 95% CI) and present forest plots (https://www.r-project.org/). Eligible papers were grouped where possible based on (1) type of physical impairment or functional performance task reported; and (2) whether a between-group comparison (symptomatic FAI vs healthy controls) or within-group comparison (preintervention to postintervention) was undertaken. Inter-rater agreement on the included Downs and Black criteria was evaluated using the kappa (κ) statistic, where 0.01–0.20 represents slight agreement; 0.21–0.40 represents fair agreement; 0.41–0.60 represents moderate

agreement; 0.61–0.80 represents substantial agreement; and 0.81–1.0 represents almost perfect agreement.[14 17]

Data from included studies were extracted by two reviewers (JLK, IS). Authors of included studies were contacted for additional data where reported data were inadequate for standardised mean difference (SMD) calculation. Findings were summarised in tables. Population characteristics (age, gender, type and description of hip OA, duration of symptoms), and details of level of evidence, outcome measures, length of follow-up and any intervention undertaken were collated. SMDs were calculated to determine the magnitude of differences in impairments between groups; and was calculated as the mean difference between groups (between-group), divided by the patient group SD. Standardised paired differences (SPD) were calculated to determine the magnitude of the effect between time points in the patient group (within-group); divided by the preintervention SD. SMD or SPD magnitude was interpreted as: ≥0.8 large effect; 0.5–0.79 moderate effect; and 0.2–0.49 weak effect. Where SMDs or SPDs could not be calculated, study conclusions were presented. Meta-analysis was undertaken where study homogeneity and available data allowed. A best-evidence synthesis[18] was conducted where pooling of data was not possible for each of hip joint ROM, hip muscle function and functional task performance. In the best-evidence syntheses, where a study may have examined an impairment in the same patients using two different methods, we only counted that study once, to ensure double counting did not occur. If one study used two different measurement techniques, and the results from the study were conflicting, we removed this study from the best-evidence synthesis. Evidence was categorised as 'strong' if there were multiple high-quality cohort studies; 'moderate' if there was either one high-quality cohort study and more than two high-quality case–control studies, or more than three high-quality case–control studies; 'limited' if there were either one or two case–control studies, or multiple cross-sectional studies; and 'insufficient' if there was not more than one cross-sectional study. Evidence was summarised as 'conflicting' if findings were consistent in <75% of the studies, taking into account the participants, interventions, controls, outcomes and methodological quality of the original studies. These classifications were based on the recommendations of van Tulder *et al*.[18]

RESULTS

Search strategy

Results of the search strategy are contained in figure 1. One hundred and eighteen full texts were screened, however 96 papers did not meet inclusion criteria, leaving 22 papers in the final analyses.

Methodological quality

Initial agreement between the two raters was substantial (κ=0.626). Agreement was reached on 328 items out of 381 items in total (81%) (online supplementary appendix 1). Consensus was obtained on the quality rating for the remaining 77 items. The methodological quality scores ranged from 14 points out of 17 (82%)[19 20] to 8 points out of 17 (47%).[3 21–23] The overall mean (SD) rating was 10.69 (1.89) points out of 17 (63%).

Participants

The 22 included studies contained 819 patients with FAI in total, with sample sizes ranging from 7 [21] to 112 patients.[20] Sixteen studies included age-matched healthy control groups

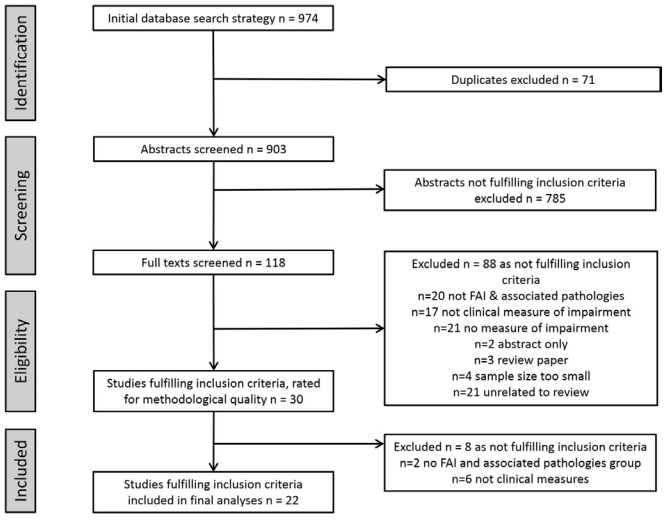

Figure 1 Summary of search strategy results. FAI, femoroacetabular impingement.

(12 non-surgery, 1 presurgery, 3 postsurgery) and five within-group studies investigated the change in outcome before and after intervention. One study contained men only.[21] The remaining 21 studies contained both men and women. The mean (SD) ages for patients in the included studies ranged from 24[5 21] to 37[12 24] years. All studies included participants based on a diagnosis of FAI and associated labral and/or chondral pathology. The method of diagnoses ranged from arthroscopic findings[19 20 24 25] to positive clinical signs on physical examination,[21 23 26–30] to radiographic, CT or MRI diagnosis.[3 21–23 26–29 31–35]

Outcomes measured

Physical impairment outcomes reported included hip joint ROM,[3 19 20 22 24 30 31 33 34 36–39] hip muscle function,[19 23 26–28 30] simulated hip joint ROM using three-dimensional CT or three-dimensional kinematics,[21 25 29 31 35 40] hip muscle volume,[28] hip muscle EMG,[26 27] and functional performance tasks such as single leg balance,[24] squat depth and pelvic ROM,[41] and number of strides per day.[32] The reliability of physical impairment outcomes measured was reported in 7 out of the 23 studies. Reported intracorrelation coefficients ranged from 0.72[24] to 1.0.[28]

Main findings

Due to study heterogeneity, it was not possible to conduct meta-analyses, and therefore a best-evidence synthesis was conducted. The results for hip joint ROM, hip muscle function and functional task performance are outlined below. Data were obtained on request for two papers.[19 38] There were no RCTs or non-randomised trials found examining the effect of different types of interventions for patients with FAI on physical impairments. All papers included were case–control or case series studies only, and SMDs and SPDs have been reported for these studies where able.

Hip joint ROM

Between-group comparison of hip ROM in symptomatic FAI to pain-free controls

Twelve studies examined hip joint ROM in people with FAI using goniometers,[3 19 20 22 24 30 31 33 34 36–38] while simulated hip joint ROM was reported in five studies (table 1).[21 25 29 31 35]

Table 1 Summary of included between-group case–control studies evaluating the effect of FAI and associated pathologies on hip range of movement

	Study characteristics				Sample characteristics			Results			
Paper (total score using modified Downs and Black appraisal)	Inclusion pathology	Outcome measured	Method of measurement	Level of evidence	Sample size	Gender	Age (years)*	Hip group mean (SD)	Control group mean (SD)	Standardised mean difference (SMD) magnitude or standardised paired difference (SPD) (95% CI)	Overall main findings (if unable to calculate SMD)
Audenaert *et al*[21] (8/17)	Male elite sportsman; cam or combined FAI presented with °typical° signs of FAI and confirmed with standard diagnostic imaging (radiographic and arthro-MRI)	% Cam engagement using 3-D bony models generated from MRI (flexion; abduction; IR in 90° flexion; N IR)	3-D bony models	Cross sectional	7 hip groups (13 hips)	7 M/0 W	25 (5)	n/a	n/a	n/a	Number of cases of cam engagement in flexion 54%; abduction 84%; IR in 90° flexion 77%; IR in N 0% ROM flexion 110.2 (7.4); abduction 50.5 (8.8); IR in 90° flexion 18.9 (6.2); IR in N 29.4 (8.7)
Audenaert *et al*[25] (13/17)	Chondropathy at arthroscopy	Simulated 3-D CT modelling of hip ROM (IR) during high flexion and impingement testing (cam patients; asymptomatic and controls)	3-D CT models	Cross sectional	10 hip groups/ 10 controls	10 M/0 W	Range 18–35	Cam: hip IR (high flexion)=12.9° (6.4); hip IR (impingement testing)=12.3° (6.5)	Asymptomatic: hip IR (high flexion)=20.9° (9.1); hip IR (impingement testing)=21.1° (8.8) Controls: hip IR (high flexion)=27.8° (7.6); hip IR ROM (impingement testing)=27.9° (7.4)	**Hip versus asymptomatic ROM** −0.97 (−1.91 to −0.03). **Hip versus control ROM** −2.03 (−3.15 to −0.91)	
Clohisy *et al*[3] (8/17)	One or more of the following: acetabular retroversions: coxa profunda; coxa protrusion; aspherical femoral head; or femoral head-neck offset <9 mm	ROM (Flex, Ext, Abd, Add, IR/ER at N and 90°) Active versus passive not specified	Goniometer	Cross sectional	51 hip groups (52 hips) 51 controls	29 M/22 W	35 (range 15–61)	Symptomatic hip: Flex 97° (9); Ext 4° (6); Abd 38° (11); Add 17° (7); IR N 15° (9); ER N 26 (12); IR@90° 9 (8); ER@90° 28 (15)	Asymptomatic hip: Flex 101° (11); Ext 4° (6); Abd 41° (10); Add 19° (8); IR N 1518° (11); ER N 27 (12); IR@90° 12 (8); ER@90° 30 (16)	**Symptomatic versus asymptomatic hip** Flex −0.40 (−0.79 to 0.00), Ext 0 (−0.39 to 0.39), Abd −0.28 (−0.67 to 0.11), Add −0.26 (−0.65 to 0.12), IR@90 −0.37 (−0.76 to 0.02), ER@90 −0.13 (−0.52 to 0.26)	
Emara *et al*[22] (8/17)	Unilateral FAI (clinical and radiological diagnosis)	ROM (Flex, Ext, Abd, Add, IR/ER at N and 90') Active versus passive not specified	Not specified	Case series (control=opposite leg)	37	37 M/10 W	33 (5)	Symptomatic hip: Flex 95' (0.4); Ext 4' (1.6); Abd 37' (0.4); Add 17' (7); ER in Flex 28.5 (0.5); ER in Ext 25.3 (0.3); IR in Flex 9.4 (0.3); IR in Ext 15.8 (0.4)	Asymptomatic hip: Flex 103' (3); Ext 4' (2); Abd 43' (3); Add 19' (8); ER in Flex 34 (4); ER in Ext 30 (3); IR in Flex 15 (3); IR in Ext 19 (3)	**Symptomatic versus asymptomatic hip** Flex −3.70 (−4.46 to −2.94), Ext 0.0 (−0.46 to 0.46), Abd −2.77 (−3.42 to −2.13), Add −0.26 (−0.72 to 0.20), ER@90 −1.70 (−2.23 to −1.16), IR@90 −2.79 (−3.43 to −2.14), ER@0 −2.32 (−2.92 to −1.73), IR@0 −1.39 (−1.90 to −0.88)	
Harris-Hayes *et al*[30] (10/17)	Chronic hip joint or anterior groin pain >3 months+positive FADIR	ROM	Not stated	Cross sectional	35 hip groups/35 controls	7 M/28 W	37 (12)	ER@90° flexion 40 (10); IR@90° flexion 39 (7); ER in N 42 (8); IR in N 32 (10)	ER@90° flexion 39 (7); IR@90° flexion 39 (6); ER in N 40 (10); IR in N 31 (9)	ER@90 0.12 (−0.35 to 0.58), IR@90 0 (−0.47 to 0.47), ER in N 0.22 (−0.25 to 0.69), IR in N −0.10 (−0.37 to 0.57)	
Kapron *et al*[36] (10/17)	Female athletes	ROM	Goniometer	Cross sectional	63 hip groups	0 M/63 W	19.6 (1.4)	IR@90° flexion 31.2 (10.2); ER@90° flexion 43.8 (10.7)	n/a	n/a	
Kemp *et al*[4] (14/17)	Chondrolabral pathology at arthroscopy	12–24 months after arthroscopy—ROM measured with inclinometer (°)	Inclinometer	Cross sectional	84 hip groups/ 60 controls	42 M/42 W	36 (10)	Flex ROM men 105 (10); women 108 (17); Ext ROM men 23 (10); women 25 (10); ER ROM men 43 (10); women 33 (10); IR ROM men 29 (8); women 31 (12)	Flex ROM men 112 (12), women 116 (9); Ext ROM men 20 (9); 21 (7); ER ROM men 44 (8), women 36 (8); IR ROM men 35 (8), women 36 (7)	**Men versus controls** Flex −0.65 (−1.20 to 0.09), Ext −0.31 (−0.24 to 0.85), ER −0.10 (−0.65 to 0.44), IR −0.74 (−1.30 to −0.18) **Women versus controls** Flex −0.58 (−1.02 to −0.14), Ext −0.46 (0.02 to 0.89), ER −0.33 (−0.76 to 0.11), IR −0.50 (−0.94 to −0.07)	

Continued

Table 1 Continued

Paper (total score using modified Downs and Black appraisal)	Study characteristics: Inclusion pathology	Outcome measured	Method of measurement	Sample characteristics: Level of evidence	Sample size	Gender	Age (years)*	Results: Hip group mean (SD)	Control group mean (SD)	Standardised mean difference (SMD) magnitude or standardised paired difference (SPD) (95% CI)	Overall main findings (if unable to calculate SMD)
Kennedy *et al*[33] (11/17)	Cam FAI: pain on WOMAC; had positive FADIR; alpha angle >50.5 on AP or Dunn, controls—no hip pain and no cam on X-ray	3-D kinematic dynamic ROM measured in standing	Vicon	Cross sectional	17 hip groups/ 14 controls	10 M/7 W	36 (11)	Flex 110 (10); Ext 21 (10); total sagittal 131 (14); Abd 38 (9); Add 23 (8); total frontal 63 (12); IR 8 (3); ER 20 (4); total transverse 28 (7)	Flex 114 (9); Ext 27 (5); total sagittal 141 (9); Abd 48 (6); Add 23 (8); total frontal 63 (12); IR 12 (5); ER 26 (7); total transverse 39 (10)	Flex −0.41 (−1.12 to 0.31), Ext −0.78 (−1.52 to −0.04), Abd −1.25 (−2.03 to −0.47), Add 0.0 (−0.71 to 0.71), ER −1.05 (−1.81 to −0.29), IR −0.97 (−1.72 to −0.22)	
Kubiak-Langer *et al*[29] (11/17)	People awaiting hip scope with pain, positive FADIR and positive radiology. Controls=contralateral leg of people awaiting THA	3-D CT modelling measure of hip ROM simulated pre-op to simulated post-op and to controls	3-D CT models	Case–control	28 hip groups/33 controls	24 M/4 W	35 (10)	Flex 105 (12); Ext 61 (32); Abd 52 (12); Add 35 (12); IR 11 (7); ER 83 (33)	Flex 122 (16); Ext 57 (20); Abd 64 (11); Add 33 (12); IR 35 (7); ER 103 (14)	Flex −1.17 (−1.72 to 0.63), Ext 0.15 (−0.35 to 0.66), Abd −0.95 (−1.48 to −0.41), Add 0.17 (−0.34 to 0.67), IR −3.39 (−4.18 to −2.59), ER −0.78 (−1.31 to −0.26)	
Lahner *et al*[38] (11/17)	Volunteers with no history of hip pathology	Radiograph (alpha angle of Nötzli). Active IR ROM	1. Goniometer 2. Kinect	Cross sectional	24 hip groups	8 M/16 W	46.8 (10.6)	24.2 (8.5)	27.6 (5.1)	0.6 (−3.24 to 4.4)	
Nussbaumer *et al*[34] (10/17)	Unilateral FAI (clinical and radiological Dx)	Passive ROM hip	1. Goniometer 2. Electromagnetic tracking system (ETS)	Cross sectional	15 hip groups/ 15 controls	8 M/7 W	35 (11)	Goniometer: Flex 104 (16); Abd 30 (7); Add 23 (4); IR 26 (11); ER 36 (10) ETS: Flex 85 (15); Abd 29 (7); Add 22 (4); IR 24 (10); ER 30 (8)	Goniometer: Flex 112 (11); Abd 39 (7); Add 27 (6); IR 34 (10); ER 45 (5) ETS: Flex 94 (8); Abd 37 (8); Add 22 (3); IR 29 (9); ER 35 (4)	**Goniometer ROM versus controls** Flex −0.57 (−1.30 to 0.17), Abd −1.25 (−2.04 to −0.46), Add −0.76 (−1.51 to −0.02), ER −1.11 (−1.88 to 0.33), IR −0.74 (−1.48 to 0.00) **ETS ROM versus controls** Flex −0.73 (−1.47 to 0.01), Abd −1.04 (−1.80 to −0.27), Add 0.0 (−0.72 to 0.72), ER −0.77 (−1.52 to −0.02), IR −0.51 (−1.24 to 0.22)	
Philippon *et al*[20] (14/17)	FAI and chondrolabral pathology at arthroscopy	ROM hip (active/passive not specified)	Goniometer	Cross sectional	112 operated hips/112 non-operated hips	50 M/62 W	41	n/a	n/a	n/a	**Pain versus non-pain leg ROM MD (95% CI)** Flex −10 (−13 to −7) p<0.001; IR −5 (−7 to −3) p<0.001; ER −3 (−1 to −3) p=0.001; Add −4 (−7 to −3) p<0.001; Abd −5 (−6 to −3) p<0.001
Ross *et al*[37] (10/17)	Ice hockey players who underwent arthroscopic correction for symptomatic FAI	Simulated 3-D CT hip ROM (Flex; IR@90° flexion)	3-D CT models	Prognostic case series	44 hip groups (68 hips)	Not specified	21.1 (5.7)	n/a	n/a	n/a	**Goalies** Flexion 121.3 (77–149); abduction 69.7 (41–82); IR@90° 26.4 (0–54); FADIR 17.8 (0–45); butterfly 33.5 (2–65) **Positional players** Flexion 115.6 (93–138); abduction 70.8 (58–84); IR 90° 29 (3–51); FADIR 20.1 (0–41); butterfly 40 (15–67)

Continued

Table 1 Continued

Paper (total score using modified Downs and Black appraisal)	Study characteristics: Inclusion pathology	Outcome measured	Method of measurement	Level of evidence	Sample characteristics: Sample size	Gender	Age (years)*	Results: Hip group mean (SD)	Control group mean (SD)	Standardised mean difference (SMD) magnitude or standardised paired difference (SPD) (95% CI)	Overall main findings (if unable to calculate SMD)
Tannast *et al*[25] (11/17)	FAI (cam n=12, pincer n=7, combined n=12) CT diagnosis	3-D CT modelling measure of hip ROM simulated	3-D CT models	Cross sectional	31 hip groups/ 36 controls	27 M/4 W	31 (10)	All hips: Flex 105 (16); Ext 60 (32); Abd 52 (12); Add 34 (13); IR 12 (7); ER 83 (33). Cam—Flex 111 (18); Ext 86 (30); Abd 47 (13); Add 41 (14); IR 10 (6); ER 99 (27)	Flex 121 (12); Ext 58 (20); Abd 63 (11); Add 33 (12); IR 35 (12); ER 101 (15)	**All hips versus controls** Flex −1.13 (−1.65 to 0.61), Ext 0.08 (−0.41 to 0.56), Abd −0.95 (−1.46 to −0.44), Add 0.08 (−0.40 to 0.56), IR −2.27 (−2.89 to −1.65), ER −0.71 (−1.21 to −0.22) **Cam versus controls** Flex −0.72 (−1.39 to −0.05), Ext 1.21 (0.51 to 1.91), Abd −1.37 (−2.08 to −0.65), Add 0.63 (−0.04 to 1.30), IR −2.26 (−3.07 to −1.46), ER −0.11 (−0.76 to 0.55)	

No randomised clinical trials were available to include in this review. Significant positive SMDs indicate greater ROM in the hip group.
*Mean (SD).
3-D, three dimensional; AP, anterior/posterior; Abd, abduction; Add, adduction; ER, external rotation; Ext, extension; FADIR, flex/adduction/internal rotation; FAI, femoral acetabular impingement; Flex, flexion; IR, internal rotation; M, male; MD, mean difference; N, neutral hip position; n/a, not applicable; ROM, range of movement; THA, total hip arthroplasty; W, woman; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

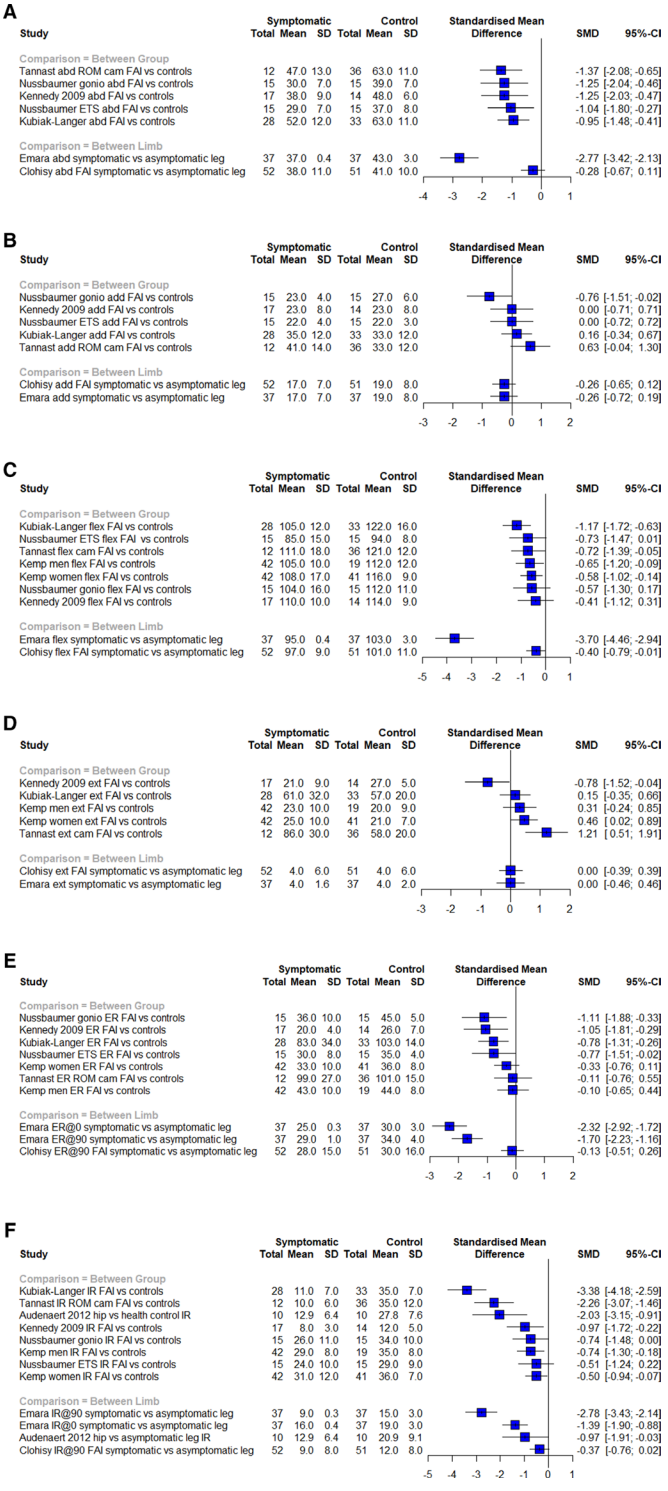

Figure 2 (A–F) Between-group SMDs for hip ROM (based on only case–control studies, no randomised controlled trials (RCT) were found). Significant positive SMDs indicate greater ROM in the hip group. abd, abduction; add, adduction; ER, external rotation; ETS, electromagnetic tracking system; ext, extension; FAI, femoroacetabular impingement; flex, flexion; IR, internal rotation; ROM, range of movement; SMD, standardised mean difference.

Between-group SMD data for case–control studies examining hip muscle ROM are contained in figure 2. SMDs were able to be calculated for eight case–control studies.[3 19 22 25 29–31 33 34] Compared with healthy controls there is limited evidence that

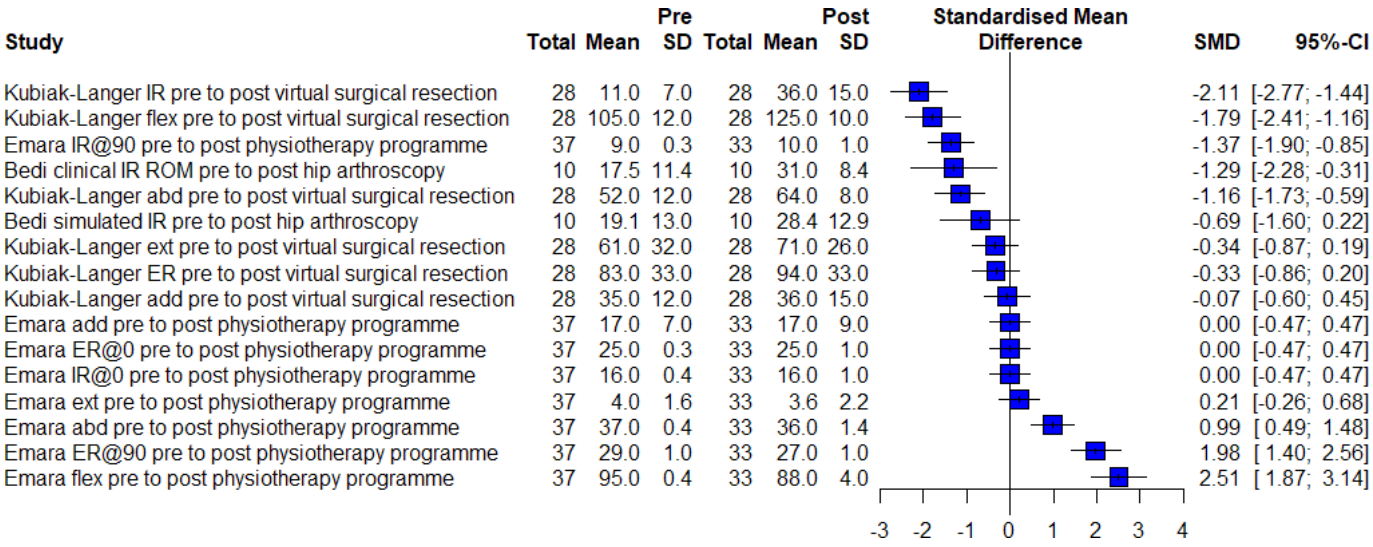

Figure 3 Within-group SMDs for hip ROM. Significant positive SMDs indicate greater ROM at the postintervention time point. abd, abduction; add, adduction; ER, external rotation; ext, extension; flex, flexion; IR, internal rotation; ROM, range of movement; SMD, standardised mean difference.

those with FAI syndrome have reduced hip abduction and flexion ROM, no differences in hip adduction or extension ROM and conflicting results for external rotation (ER) and internal rotation (IR) ROM. In studies where SMDs were not able to be calculated, results were also conflicting. Ross *et al* reported no difference in ROM, except flexion (p=0.03) between hockey goalies with greater alpha angles and femoral retroversion, compared with positional players.[37] In contrast, Philippon *et al* compared the painful with the non-painful leg in people with symptomatic FAI prior to hip arthroscopy, and reported reduced ROM in all planes of movement (p=0.001 to p<0.001).[20]

Within-group comparison of effect of intervention on hip ROM

Within-group SPD data for studies examining hip joint ROM are contained in figure 3 and table 2. Evidence for within-group change from preintervention to post-treatment time points remains limited and inconclusive. Three studies examined within-group change over time, and results were mixed in each, and therefore remain inconclusive. One high-quality case series,[31] one moderate-quality case series[29] and one low-quality case series[22] all demonstrated conflicting SPDs comparing prephysiotherapy to postphysiotherapy treatment for FAI.

Hip muscle function

Hip muscle function (including strength, electrical activity and muscle volume) was examined in six studies.[19 23 26–28 30] Results are contained in tables 2 and 3. Between-group SMD for hip muscle function contained in table 2 and figure 4 and within-group SPDs contained in table 3 and figure 5. Hip muscle strength was measured and reported in all six studies,[19 23 26–28 30] in addition hip muscle cross-sectional area was examined in one study[28] and two studies reported on hip muscle EMG activity.[26 27] SMDs for hip muscle strength were able to be calculated for all six studies.[19 23 26–28 30] Results were mixed, with moderate conflicting evidence for greater strength in hip adduction and ER; limited evidence for greater hip flexion strength; and limited conflicting evidence for greater hip extension and abduction strength favouring controls, compared with FAI syndrome participants (table 3). In addition, strength deficits are apparent in women with FAI in all hip muscle compared controls, whereas deficits in men appear only in flexion and adduction strength. For muscle size, results were mixed, where tensor fascia lata (TFL), sartorius and psoas were significantly smaller in the injured leg of the person with FAI compared with healthy controls.[28] Hip muscle EMG amplitude was reported in two studies, and SMDs were able to be calculated for both studies.[26 27] There were significant between-group effects for rectus femoris and TFL EMG activity when comparing people with FAI to controls during a resisted hip flexion exercise task in standing.[27] For within-group effects, one study compared hip muscle strength before hip arthroscopy with 2.5 years after hip arthroscopy.[23] Calculation of SPDs revealed no significant within-group change from the preoperative to the postoperative time point for hip muscle strength measures except hip IR.

Best-evidence synthesis for hip muscle strength indicated evidence of limited quality, with one high-quality case–control study[19] and no RCTs. The remaining studies were moderate or low in quality.

Functional tasks (squat depth, pelvic ROM, single leg balance, number of strides)

A number of different clinical measures of functional tasks were reported. SMD data for case–control studies examining hip functional tasks are contained in table 3 and figure 6. These included squat depth, pelvic ROM, single leg balance and number of strides.[24 26–28 32 41] There were no significant differences for squat depth[41] pelvic ROM,[41] or total number of daily strides[32] between people with FAI and controls. In addition, when people after hip arthroscopy undertook a dynamic single leg squat task, significant moderate between-group effects were noted compared with controls, where patients with FAI demonstrated increased medial-lateral sway (effect size (ES) −0.57, 95% CI −0.76 to −0.38) and worse anterior-posterior control (−0.45, 95% CI −0.57 to −0.34),[24] both indicators of reduced dynamic balance.[24]

Best-evidence synthesis for functional tasks provided varying evidence depending on the challenges of the activity. One high-quality case–control study[24] reported significant between-group SMDs for a dynamic balance task, while the remaining study

Table 2 Summary of included between-group case–control studies evaluating the effect of FAI and associated pathologies on hip muscle function

Paper (total score using modified Downs and Black appraisal)	Study characteristics			Sample characteristics				Results			
	Inclusion pathology	Outcome measured	Method of measurement	Level of evidence	Sample size	Gender	Age (years) *	(Between-group) Hip group mean (SD)	(Between-group) Control group mean (SD)	Standardised mean difference (SMD) magnitude (95% CI)	Overall main findings
Casartelli *et al*[17] (10/17)	Unilateral FAI (clinical and radiological diagnosis)	Isometric MVC (hip adduction; abduction; IR; ER; Flex; Ext) Hip flexor EMG activity (RF+TFL)	Isokinetic dynamometry EMG	Case–control	Hips 22 Controls 22	8 M/14 W 8 M/14 W	32 (9) 32 (9)	Adduction 1.57 Nm/kg (0.82); abduction 1.81 Nm/kg (0.43); IR 0.47 Nm/kg (0.16); ER 0.46 Nm/kg (0.21); Flex 0.87 Nm/kg (0.46); Ext 1.64 Nm/kg (1.00); RF 186 (131); TFL 401 (251)	Adduction 2.17 Nm/kg (0.49); abduction 2.03 Nm/kg (0.31); IR 0.55 Nm/kg (0.17); ER 0.56 Nm/kg (0.15); Flex 1.17 Nm/kg (0.37); Ext 1.66 Nm/kg (0.86); RF 294 (184); TFL 582 (323)	Add −0.87 (−1.49 to −0.25), Abd −0.58 (−1.18 to 0.03), IR −0.48 (−1.08 to 0.12), ER −0.54 (−1.14 to 0.06), Flex −0.71 (−1.32 to −0.09), Ext −0.02 (−0.61 to 0.57) RF −0.66 (−1.27 to −0.06), TFL −0.62 (−1.22 to −0.01)	
Casartelli *et al*[16] (Experiment 1) (9/17)	Unilateral FAI (clinical and radiological diagnosis)	Hip flexor Isometric MVC torque Hip flexor EMG activity (RF+TFL)	Isokinetic dynamometry EMG	Case–control	Hips 15 Controls 15	6 M/9 W 6 M/9 W	31 (10) 31 (9)	Isometric MVC torque hip flexors 0.96 (0.46) Nm/kg	Isometric MVC torque hip flexors 1.21 (0.38) Nm/kg	−0.58 (−1.31 to 0.16)	Additional findings to between-group mean: EMG—no group effect and interaction were observed for RMS and MDF of both RF and TFL (p>0.05), whereas a significant effect of time was observed for EMG RMS and MDF of both muscles (p<0.001)
Casartelli *et al*[16] (Experiment 2) (8/17)	Unilateral FAI (clinical and radiological diagnosis)	Hip flexor torque decline (maximal dynamic contractions)	Isokinetic dynamometer	Case–control	Hips 15 Controls 15	6 M/9 W 6 M/9 W	32 (10) 33 (10)	Maximal isokinetic torque hip flexors 0.97 (0.38)	Maximal isokinetic torque hip flexors 1.16 (0.36)	−0.50 (−1.23 to 0.23)	
Casartelli *et al*[23] (8/17)	Unilateral FAI (clinical and radiological diagnosis)	Strength: MVC (hip Abd, Add, IR, ER, Flex and Ext muscle groups)	Handheld dynamometer (Abd, Add, IR and ER) Isokinetic dynamometer (Flex and Ext)	Case series	Hips 8 Controls 8	3 M/5 W	29 (10)	Hip Add 1.64 (0.84); hip Abd 1.93 (0.51); hip IR 0.49 (0.18); hip ER 0.51 (23); hip flexors 1.24 (0.41); hip extensors 1.72 (1.18)	Hip Add 2.39 (0.61); hip Abd 2.23 (0.25); hip IR 0.62 (0.13); hip ER 0.62 (0.14); hip Flex 1.86 (0.31); hip extensors 2.20 (1.13)	Add −0.97 (−2.02 to 0.09), Abd −0.71 (−1.73 to 0.31), IR −0.78 (−1.81 to 0.25), ER −0.55 (−1.55 to 0.46), Flex −1.61 (−2.79 to −0.44), Ext −0.39 (−1.39 to 0.60)	
Harris-Hayes *et al*[30] (10/17)	Chronic hip joint or anterior groin pain >3 months+positive FADIR	Normalised peak muscle torque (hip ER and IR at 90' Flex and N; Abd)	Handheld dynamometer	Case–control	Hips 35 Controls 35	7 M/28 W 7 M/28 W	28 (5) 28 (6)	ERs@90' 3.58 (0.80); IRs@90' 3.57 (1.09); ERs@0' 2.84 (0.80); IRs@0' 2.38 (0.71); Abd 6.98 (2.05)	ERs@90' 4.24 (1.06); IRs@90' 4.96 (1.63); ERs@0' 3.65 (0.89); IRs@0' 3.01 (0.81); Abd 8.95 (1.78)	ER@90 −0.70 (−1.18 to −0.21), IR@90 −0.99 (−1.49 to −0.49), ER@0 −0.95 (−1.44 to −0.45), IR@0 −0.82 (−1.31 to −0.33), Abd −1.01 (−1.51 to −0.52)	
Kemp 2014[19] (14/17)	Chondrolabral pathology at arthroscopy	12–24 months after arthroscopy—normalised peak torque measured with HHD (Nm/kg)	Handheld dynamometer	Case–control	Hips 84 Controls 60	42 M/42 W 19 M/41 W	36 (10) 36 (10)	Strength Abd men 1.73 (0.45), women 1.16 (0.43); Add men 1.36 (0.35), women 0.99 (0.36); Ext men 1.36 (0.56), women 0.95 (0.49); Flex men 1.19 (0.37), women 0.99 (0.35); ER men 0.82 (0.29); women 0.56 (0.22); IR men 0.61 (0.22); women 0.43 (0.15)	Strength Abd men 1.85 (0.44), women 1.61 (0.35); Add men 1.68 (0.48), women 1.41 (0.36); Ext men 1.62 (0.46), women 1.43 (0.44); Flex men 1.50 (0.34), women 1.44 (0.35); ER men 0.94 (0.32), women 0.72 (0.20); IR men 0.68 (0.22), women 0.55 (0.15)	**Men strength versus controls** Abd −0.27 (−0.81 to 0.28), Add −0.80 (−1.36 to −0.24), Ext −0.48 (−1.03 to 0.07), Flex −0.85 (−1.41 to −0.28), ER −0.40 (−0.94 to 0.15), IR −0.31 (−0.86 to 0.23) **Women strength versus controls** Abd −1.14 (−1.60 to −0.67), Add −1.16 (−1.62 to −0.69), Ext −1.02 (−1.48 to −0.56), Flex −1.27 (−1.75 to −0.80), ER −0.75 (−1.20 to −0.31), IR −0.79 (−1.24 to −0.35)	Additional findings to between-group difference—interaction effect for abduction strength group × sex (p=0.036)

Continued

Table 2 Continued

Paper (total score using modified Downs and Black appraisal)	Study characteristics			Sample characteristics				Results			
	Inclusion pathology	Outcome measured	Method of measurement	Level of evidence	Sample size	Gender	Age (years) *	(Between-group) Hip group mean (SD)	(Between-group) Control group mean (SD)	Standardised mean difference (SMD) magnitude (95% CI)	Overall main findings
Mendis *et al*[28] (11/17)	Unilateral labral tear awaiting hip arthroscopy (MRI and clinical exam)	1. Hip Flex torque (Nm). 2. Hip flexor CSA (cm^2).	1. Handheld dynamometer. 2. MRI.	Case–control	Hips 12 Controls 12	4 M/8 W 4 M/8 W	35 (13) 35 (12)	Injured side. Flex strength 37(19). CSA iliacus 9.1 (3.8); psoas 11.5 (4.0); iliopsoas 9.6 (2.0); sartorius 3.1 (0.9); RF 7.1 (2.5); TFL 6.2 (2.5)	Non-injured 47(15). CSA iliacus 9.1 (3.8); psoas 12.0 (3.7); iliopsoas 9.6 (1.8); sartorius 3.0 (0.9); RF 7.4 (2.7); TFL 5.9 (2.2) Controls strength Flex 51 (17); CSA iliacus 9.2 (3.3); psoas 10.9 (3.5); iliopsoas 9.7 (1.7); sartorius 3.0 (0.8); RF 7.9 (2.2); TFL 5.8 (2.2)	**Strength versus non-injured** Flex −0.56 (−1.38 to 0.26) **CSA versus non-injured** Iliacus 0.00 (−0.80 to 0.80), psoas −0.13 (−0.93 to 0.68), iliopsoas 0.00 (−0.80 to 0.80), sartorius 0.11 (−0.69 to 0.91), RF −0.11 (−0.91 to 0.69), TFL 0.12 (−0.68 to 0.92) **Strength versus controls** Flex −0.75 (−1.58 to 0.08) **CSA versus controls** Iliacus −0.03 (−0.83 to 0.77), psoas 0.15 (−0.65 to 0.96), iliopsoas −0.05 (−0.85 to 0.75), sartorius 0.11 (0.69 to 0.91), RF −0.31 (−1.12 to 0.49) TFL 0.16 (−0.64 to 0.97) **Strength non- injured versus controls** Flex −0.24 (−1.05 to 0.56) **CSA non- injured versus controls** Iliacus −0.03 (−0.83 to 0.77), psoas 0.30 (−0.51 to 1.10), iliopsoas −0.06 (−0.86 to 0.75), sartorius 0.00 (−0.80 to 0.80), RF −0.20 (−1.00 to 0.61), TFL −1.45 (−2.37 to −0.53).	

No randomised clinical trials were available to include in this review. Significant positive SMDs indicate greater strength in the hip group.
*Mean (SD).
Abd, abduction; Add, adduction; CSA, cross-sectional area; EMG, electromyography; ER, external rotation; Ext, extension; FADIR, flex/adduction/internal rotation; FAI, femoral acetabular impingement; Flex, flexion; HHD, handheld dynamometer; IR, internal rotation; M, male; MDF, median frequency; MVC, maximal voluntary contraction; Nm, Newton metres; RF, rectus femoris; RMS, root mean square; ROM, range of movement; TFL, tensor fascia lata; W, woman.

Table 3 Summary of included studies evaluating the within-group effect of FAI and associated pathologies on hip range of movement, strength and functional performance between preintervention and postintervention time points

	Study characteristics			Sample characteristics				Results			
Paper (total score using modified Downs and Black appraisal)	**Inclusion pathology**	**Outcome measured**	**Method of measurement**	**Level of evidence**	**Sample size**	**Gender**	**Age (years) ***	**(Within-group) Preintervention mean (SD)**	**(Within-group) Postintervention mean (SD)**	**Standardised mean difference (SMD) magnitude or standardised paired difference (SPD)‡ (95% CI)**	**Overall main findings (if unable to calculate SMD)**
Bedi *et al*[31] (13/17)	FAI (focal cam and/or pincer lesions) CT diagnosis before arthroscopic osteoplasty	Simulated 3-D CT hip ROM (Flex; IR 90 flexion) Clinically measured hip ROM (Flex; IR 90 flexion) Active versus passive not specified	3-D CT models Goniometer	Case series	10	Not specified	26 (R19–31)	(**Intervention=arthroscopy**) Hip IR@90'=19.10° (13.03) Hip IR@90'=17.5° (11.37)	Hip IR@90'=28.4° (12.86) Hip IR@90'=31.0° (8.43)	**Simulated IR ROM** −0.69 (−1.60 to 0.22). **Clinical IR ROM** −1.29 (−2.28 to −0.31)	Additional findings to within-group differences: mean hip flexion (simulation) increased by 3.8' (range 0.3–10.8, p=0.002)
Emara *et al*[22] (8/17)	Unilateral FAI (clinical and radiological diagnosis)	ROM (Flex, Ext, Abd, Add, IR/ER at N and 90') Active versus passive not specified	Not specified	Case series	37 (33 at follow-up)	37 M/10 W	33 (5)	(**Intervention=four-stage conservative treatment**) Flex 95' (0.4); Ext 4' (1.6); Abd 37' (0.4); Add 17' (7); ER in Flex 28.5 (0.5); ER in Ext 25.3 (0.3); IR in Flex 9.4 (0.3); IR in Ext 15.8 (0.4)	Flex 88' (3.5); Ext 3.6' (2.2); Abd 36' (1.4); Add 17' (9); ER in Flex 27 (1.1); ER in Ext 24.6 (1.0); IR in Flex 10 (0.6); IR in Ext 15.8 (0.7)	Pre-ROM to post-ROM‡ Flex 2.51 (1.87 to 3.14), Ext 0.21 (−0.26 to 0.68), Abd 0.99 (0.49 to 1.48), Add 0 (−0.47 to 0.47), ER@90 1.98 (1.40 to 2.56), IR@90 −1.37 (−1.90 to −0.85), ER@0 0.0 (−0.47 to 0.47), IR@0 0.0 (−0.47 to 0.47)	
Kubiak-Langer *et al*[29] (11/17)	People awaiting hip scope with pain, positive FADIR and positive radiology. Controls=contralateral leg of people awaiting THA	3-D CT modelling measure of hip ROM simulated pre-op to simulated post-op and to controls	3-D CT models	Case series/case–control	28 (33 controls)	24 M/4 W	35 (10)	(**Intervention=arthroscopy with osteoplasty**) Flex 105 (12); Ext 61 (32); Abd 52 (12); Add 35 (12); IR 11 (7); ER 83 (33)	Flex 125 (10); Ext 71 (26); Abd 64 (8); Add 36 (15); IR 36 (15); ER 94 (33)	Pre-ROM to post-ROM‡ Flex −1.79 (−2.41 to −1.16), Ext −0.34 (−0.87 to 0.19), Abd −1.16 (−1.73 to −0.59), Add −0.07 (−0.60 to 0.45), ER −0.33 (−0.86 to 0.20), IR −2.11 (−2.77 to −1.44)	

Continued

Table 3 Continued

	Study characteristics			Sample characteristics				Results			
Paper (total score using modified Downs and Black appraisal)	**Inclusion pathology**	**Outcome measured**	**Method of measurement**	**Level of evidence**	**Sample size**	**Gender**	**Age (years) ***	**(Within-group) Preintervention mean (SD)**	**(Within-group) Postintervention mean (SD)**	**Standardised mean difference (SMD) magnitude or standardised paired difference (SPD)‡ (95% CI)**	**Overall main findings (if unable to calculate SMD)**
Casartelli *et al*[23] (8/17)	Unilateral FAI (clinical and radiological diagnosis)	Strength—MVC (hip Abd, Add, IR, ER, Flex and Ext muscle groups)	Handheld dynamometer (Abd, Add, IR and ER) Isokinetic dynamometer (Flex and Ext)	Case series	8	3 M/5 W	29 (10)	Hip Add 1.64 (0.84); hip Abd 1.93 (0.51); hip IR 0.49 (0.18); hip ER 0.51 (23); hip flexors 1.24 (0.41); hip extensors 1.72 (1.18)	**Intervention=arthroscopy** Hip Add 2.19 (0.79); hip Abd 2.11 (0.41); hip IR 0.78 (0.15); hip ER 0.70 (0.23); hip Flex 1.52 (0.38); hip Ext 2.46 (0.75)	Pre>post strength‡ Add −0.64 (−1.65 to 0.38), Abd −0.37 (−1.36 to 0.62), IR −1.66 (−2.84 to 0.47), ER −0.78 (−1.81 to 0.25), Flex −0.67 (−1.69 to 0.35), Ext −0.71 (−1.73 to 0.31)	

Significant negative SMDs indicate improvement from the preintervention to postintervention time point.
*Mean (SD).
Abd, abduction; Add, adduction; 3-D, three dimensional; ER, external rotation; Ext, extension; FADIR, flex/adduction/internal rotation; FAI, femoral acetabular impingement; Flex, flexion; IR, internal rotation; M, male; MVC, maximal voluntary contraction; ROM, range of movement; W, Woman.

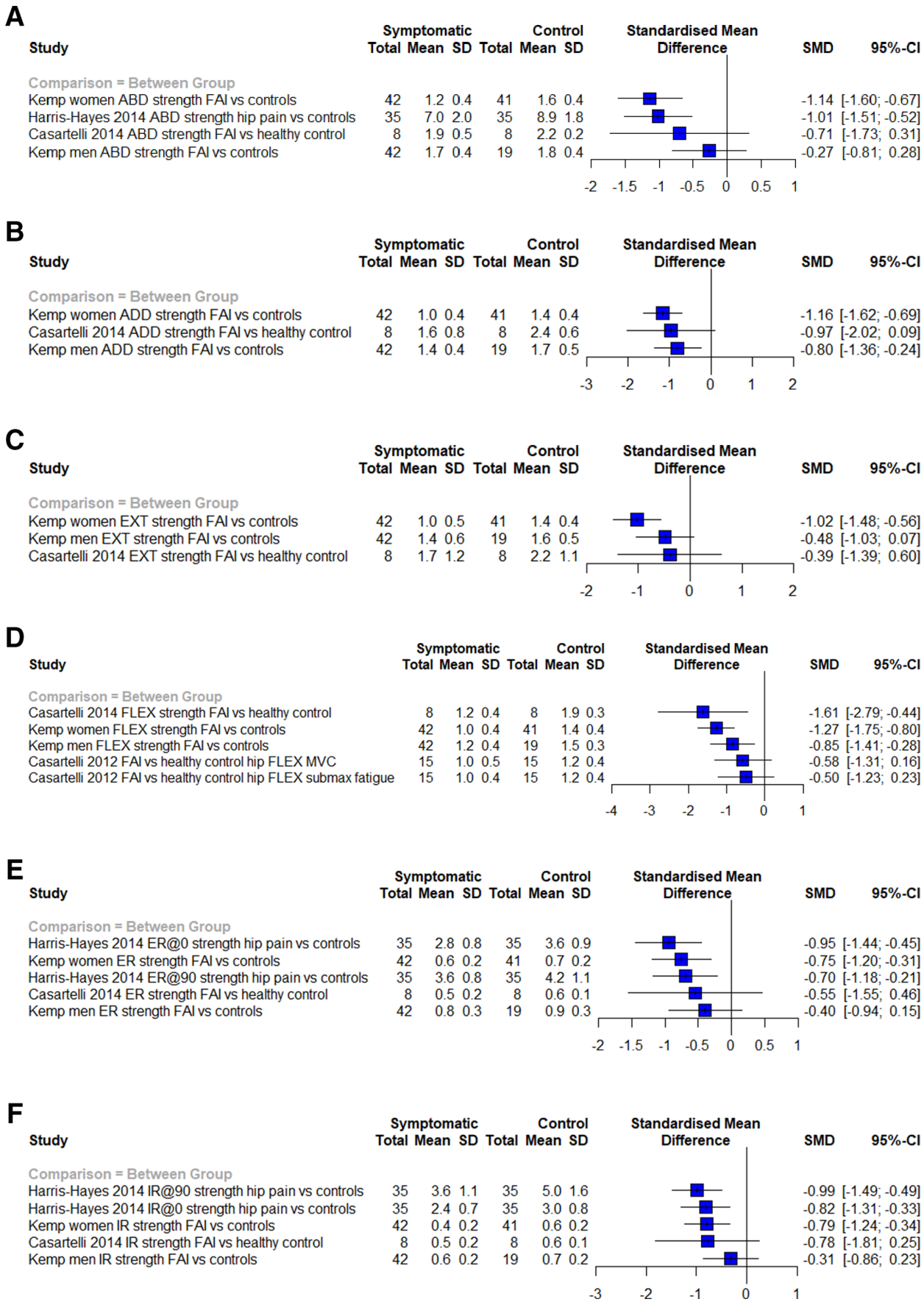

Figure 4 (A–F) Between-group SMDs for hip muscle strength (based on only case–control studies, no randomised controlled trials (RCT) were found). Significant positive SMDs indicate greater strength in the hip group. ABD, abduction; ADD, adduction; ER, external rotation; EXT, extension; FAI, femoroacetabular impingement; FLEX, flexion; IR, internal rotation; MVC, maximal voluntary contraction; SMD, standardised mean difference.

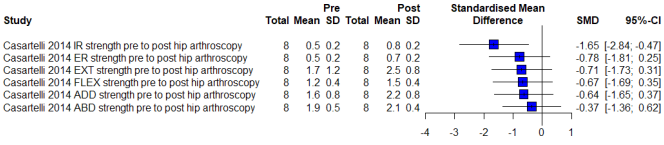

Figure 5 Within-group SMDs for hip muscle strength. Significant positive SMDs indicate greater strength at the postintervention time point. ABD, abduction; ADD, adduction; ER, external rotation; EXT, extension; FLEX, flexion; IR, internal rotation; SMD, standardised mean difference.

was of moderate quality and reported no differences in number of strides.[32]

DISCUSSION

This systematic review included 22 studies (16 case–control studies—level III evidence, 1 cross-sectional comparison—level IV evidence, 5 case series—level IV evidence) to establish whether people with symptomatic FAI demonstrated physical impairments and/or functional limitations compared with people without symptomatic FAI. No RCTs were found. Four of the studies evaluated the 'within group' effects of surgical and conservative intervention on ROM (three studies) and muscle strength (one study). This review found limited evidence that people with symptomatic FAI have significant differences in hip muscle function in both 'between group' (favouring the control group) and 'within group' (favouring postintervention) studies. There was limited, conflicting evidence to suggest ROM and functional deficits exist when compared with individuals without symptomatic FAI or for postintervention using 'within group' comparisons.

Reduced hip ROM into flexion, IR and adduction[3 20 29 31 33 42–46] is commonly reported in FAI research. In the current review, these restrictions were only significant for abduction and flexion. The five between-group studies with sufficient data for SMD calculations[3 19 25 29–31 33 34] were limited in quality, and demonstrated mixed findings for measures of hip ROM. This suggests that while cam abnormalities may be associated with increased bony impingement/abutment and soft tissue damage,[47] it is unclear whether symptomatic FAI is associated with lower hip ROM. It is possible that computer simulations or X-ray studies that rely on direct bone contact to predict impingement may be unrealistic.[48] It might also reflect that some studies evaluated participants after surgery, which may have influenced the results. Surgical interventions had no significant effect on hip ROM. Evaluation of 'within group' studies describing surgical intervention to remove the cam abnormality[29 31] indicated no significant changes to ROM. Surgery to restore hip ROM should be questioned in light of these findings. Thus, while further high-quality studies are clearly needed, the best available evidence for impairments in ROM in people with symptomatic FAI is limited

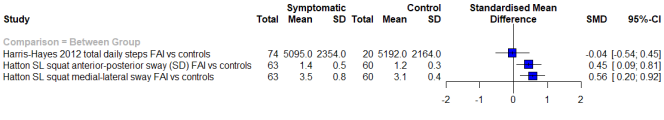

Figure 6 SMDs for functional tasks (based on only case–control studies, no randomised controlled trials (RCT) were found). Significant positive SMDs indicate greater functional task performance in the hip group. FAI, femoroacetabular impingement; SL, single leg; SMD, standardised mean difference.

in quality, and may not be the most appropriate primary target for treatment regimes.

Hip muscle function was somewhat impaired in those with FAI, although the evidence was limited by the small number and overall low quality of included studies. The six studies where SMD could be calculated[19 26–28 30 49] indicated mixed results, with limited evidence for hip flexion strength, and moderate and conflicting evidence for adduction and ER strength favouring the control group. While the overall results were mixed, in a single high-quality case–control study, women were impaired in all hip muscle strength measures, whereas men were only impaired in flexion and adduction strength.[19] This suggests that future research should consider examining hip muscle function for men and women separately. One study showed significant difference in hip flexor EMG activity in people with FAI compared with controls.[27] However, the EMG amplitude in this study was not normalised to a submaximal or maximal contraction reference value and the validity of comparing raw EMG signals between groups is not considered valid because it can be affected by factors such as adiposity, position of electrodes and skin impedance.[50] The impingement pain induced by symptomatic FAI[3 43] may play a role in inhibiting muscle contraction around the hip. Studies have shown experimentally induced knee joint pain reduces flexion and extension muscle strength by 5%–15% compared with the control conditions[51] and patients suffering with knee OA reported 20%–40% less quadriceps strength than healthy controls.[52] For sufferers of knee OA, resistance training may increase strength by 5%–71%[52] and has been shown to be beneficial for sufferers of hip OA.[53] The strength deficits noted in this study suggest that programmes to improve strength may provide a positive rehabilitation intervention for both presurgical and postsurgical symptomatic FAI sufferers. There are no studies comparing temporal EMG measures such as muscle contraction onset, offset and duration. Further studies are required to investigate strength and muscle activity in people with symptomatic FAI across all movement directions and should include asymptomatic control groups that have been imaged to ensure absence of cam abnormalities. These studies may include measuring preoperative muscle strength and progress to follow muscle strength changes through postoperative rehabilitation programmes.

Functional task performance was not impaired in people with symptomatic FAI. While there was no difference in static balance on one leg with eyes closed between people after hip arthroscopy compared with controls, the same patients demonstrated reduced balance via increased medial-lateral sway and worse anterior-posterior control during a dynamic single leg squat task.[24] The control groups used were only age, sex and physical activity matched for one study.[24] One study had low numbers of controls significantly older than the symptomatic group and defined only by age,[32] the remaining study matched only by age and body mass.[41] A lack of consistency in the control groups makes it difficult to have confidence in the validity of between-group differences reported. These findings are similar to those in a recent study by Charlton *et al* that reported patients' posthip arthroscopy having increased frontal plane hip adduction and knee valgus compared with controls.[54] The authors suggested that this may perpetuate impingement load in the hip during single leg functional tasks and called for targeted rehabilitation programmes to improve lower limb control during these tasks.[54] Biomechanically, some studies suggest that symptomatic FAI affects walking by reducing speed[55] and limiting ROM in the sagittal and frontal planes[55–57] as well as reducing peak hip extension, abduction,[56 57] adduction and IR during the stance

Table 4 Summary of included case–control studies evaluating the effect of FAI and associated pathologies on functional task

Paper (total score using modified Downs and Black appraisal)	Study characteristics			Sample characteristics				Results			
	Inclusion pathology	Outcome measured	Method measured	Level of evidence	Sample size	Gender	Age (years) *	(Between-group) Hip group mean (SD)	(Between-group) Control group mean (SD)	Standardised mean difference (SMD) magnitude (95% CI)	Overall main findings
Harris-Hayes *et al*[32] (11/17)	Unilateral FAI (clinical and radiological diagnosis)	TDS including % time spend doing no activity; low activity (15–40 strides/min); medium activity (41–75 strides/min); high activity >75 strides/min)	Stride activity monitoring	Cross sectional	74 hip groups/ 20 controls	36 M/38 W	32 (11)	TDS 5095 (2354); % time at no activity 73.2 (9.4); % time at low activity 17.7 (6.5); % time at medium activity 7.7 (3.8); % time at high activity 1.4 (1.6)	TDS 5192 (2164); % time at no activity 72.3 (8.8); % time at low activity 18.3 (6.3); % time at medium activity 8.0 (3.9); % time at high activity 1.4 (1.4)	**TDS FAI versus controls** −0.04 (−0.54 to 0.45)	
Hatton *et al*[24] (13/17)	Chondropathy at arthroscopy	12–24 months after arthroscopy— balance during SL stance eyes closed and SL squat eyes open. Specific outcomes=COP Path velocity; AP range; AP SD, ML range, ML SD	Wii balance board	Cross sectional	63 hip groups/ 60 controls	27 M/36 W	36 (10)	SL squat—COP 6.92 (1.77); AP=6.8 (2.33); AP SD=1.37 (0.47); ML=3.5 (0.77); ML SD=0.65 (0.15); SL stance eyes closed COP=11.39 (3.13); AP=8.11 (2.51); AP SD=1.57 (0.46); ML=5.73 (2.35); ML SD=1.33 (0.39)	SL squat—COP=6.3 (1.2); AP=6.25 (1.4); AP SD=1.19 (0.31); ML=3.14 (0.45); ML SD=0.69 (0.87); SL stance eyes closed COP=11.21 (5.41); AP=8.31 (5.64); AP SD=1.51 (0.54); ML=5.52 (4.62); ML SD=1.21 (0.45)	**SL squat versus controls** COP 0.41 (0.05 to 0.76), AP 0.28 (−0.07 to 0.64), AP SD 0.45 (0.09 to 0.81), ML 0.56 (0.20 to 0.92), ML SD −0.06 (−0.42 to 0.29) **SL stance versus controls** COP 0.04 (−0.31 to 0.39), AP −0.05 (−0.40 to 0.31), AP SD 0.12 (−0.24 to 0.47), ML 0.06 (−0.30 to 0.41), ML SD 0.28 (−0.07 to 0.64)	Additional findings to between-group difference: in patients with chondropathy, greater ER 90 ROM (r=0.353, p=0.005), greater total hip ROM (0.296, 0.020), greater hip IR (0.265, 0.039) and Abd strength (0.290, 0.023) were correlated with greater ML range in SL squat eyes open task
Ng *et al*[41] (13/17)	Cam deformity (clinical and radiological diagnosis)	Squat depth and sagittal pelvic ROM	Vicon	Cross sectional	43	50 M/0 W	33 (7)			**Squat depth versus asymptomatic** −0.77 (−6.43 to 4.89) **Squat depth versus controls** −0.53 (−6.18 to 5.13) **Pelvic ROM versus asymptomatic** 0.7 (−1.56 to 2.96) **Pelvic ROM versus control** 0.7 (−1.56 to 2.96)	

No randomised clinical trials were available to include in this review. Significant positive SMDs indicate greater functional performance in the hip group.
*Mean (SD).
AP, anterior/posterior; Abd, abduction; COP, centre of pressure; ER, external rotation; FAI, femoral acetabular impingement; IR, internal rotation; M, male; ML, medial/lateral; ROM, range of movement; SL, single leg; TDS, total daily strides; W, woman.

phase of gait.[55] These findings contradict the conclusions of this review where evidence for ROM differences between individuals with symptomatic FAI and normal controls was limited and mixed. It should also be noted that normal gait does not require hip joint motion to end of range so non-significant ROM reductions should not affect gait by restricting movement. More studies are required in functional limitations in individuals with symptomatic FAI.

This review enhances the body of literature examining the physical impairments and functional limitations within sufferers of symptomatic FAI. When reviewing the physical impairments and activity limitations in people with FAI impingement, Diamond *et al*[12] reported decreased ROM into directions of hip joint impingement, altered sagittal and frontal plane hip ROM during gait, altered sagittal plane hip ROM during stair climbing and decreased hip adductor and flexor muscle strength. The conclusions of this paper differed. While 9 out of the 14 papers cited by the Diamond study were included in this review, five were excluded as not having clinically useable measures of strength and ROM. The current review included evidence gained from an additional 13 papers; these data resulted in a different conclusion regarding the effect of symptomatic FAI on ROM and function. The utilisation of effect size measures has allowed an unbiased appraisal of existing literature to clarify physical examination findings that can be expected during the objective assessment of individuals presenting with symptomatic FAI. However, we acknowledge the limitations of utilisation of effect sizes only based on case–control studies, not based on RCTs (as there are no RCTs within this topic). These important findings can be used to develop rehabilitation programmes for both conservative management and postsurgical rehabilitation. Emara *et al*[22] suggest modifications to those activities of daily living that may be exacerbated by FAI and maintaining function within 'safe range of movement' as a means of improving function and reducing symptoms. Other modifiable impairments such as greater hip flexion range and adduction strength have been associated with higher quality-of-life patient-reported outcome scores in patients with chondrolabral pathology 12–24 months after hip arthroscopy.[8] Programmes targeted at improving these specific impairments as well as other strength and functional movement patterns around the hip may help improve functional outcomes for those with symptomatic FAI.

This review was able to use 22 articles in an area of rapidly expanding research, some with conflicting observations. Studies were eligible for inclusion if they contained human participants with symptomatic FAI assessed using preoperative diagnostic imaging techniques or hip arthroscopy; had at least five participants; and examined physical impairments of the hip. In an effort to make this paper clinically relevant, only papers including measures of ROM and strength were reviewed. Despite meeting these criteria, some of the inclusions may have suffered from relatively small sample sizes and poorly described methodology. As 15%–29% of the population[58–61] have asymptomatic cam-type abnormalities, their potential inclusion within the control group may have affected results. When examining the evidence for the effect of symptomatic FAI, all papers containing 'impingement related pathology' were included. Restricting searches to the English language may have potentially omitted studies that could have been included in this review and the findings should be interpreted in light of these limitations. It is recommended that future populations studied need more specific diagnostic labelling to be able to examine the differences between specific patient groups. There is an urgent need for RCT designs to address questions related to differences between groups for different types of interventions. Future research should also examine the relationship between symptoms and impairments in symptomatic FAI.

The strengths of this review include using a thorough search strategy, comprehensive evaluation of multiple databases and usage of the Downs and Black checklist to appraise the methodological quality of included studies.[15] This has adequate reliability and validity for assessing non-randomised studies. This review also included the calculation of SMDs, ensuring an unbiased evaluation of effect sizes, taking into account sample sizes and variability of data within individual studies. Areas for future research should aim at providing a better understanding of the ROM, strength and functional limitations encountered by sufferers of symptomatic FAI. These studies should include age, weight, sex and activity matching of controls and participants as well as radiographic screening to prevent the inclusion of asymptomatic cam abnormalities among the controls which may potentially compromise the normal data.

In conclusion, people with symptomatic FAI demonstrate some deficits in hip muscle strength when compared with a control population, as well as reduced dynamic balance on one leg. However, no RCTs have evaluated the effect of different types of interventions for symptomatic patients with symptomatic FAI. Furthermore, the evidence for hip joint ROM deficits in people with symptomatic FAI to control subjects was mixed. In the papers assessed, there was no other compromise of function in squatting, total daily strides or static balance. Further research is needed to determine whether symptomatic FAI affects other aspects of functional performance; and to evaluate whether targeted strength training or skill acquisition interventions can improve hip muscle strength and physical function in symptomatic FAI.

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Contributors All nominated authors fulfilled the *BJSM* criteria as follows: made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; and assisted in drafting the work or revising it critically for important intellectual content; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Kate Croft (Queensland and School of Health and Rehabilitation Sciences, University of Queensland, Australia) assisted in reviewing the quality of papers included in this manuscript.

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Correction: *Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence*

Freke M, Kemp JL, Svege I, *et al*. 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

Due to a formula error, the authors have re-run the correct confidence in intervals with the following changes noted: all figures re-drawn; all tables amended; reflection of corrections shown in the text. The corrections are now showing online.

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