Best Practice & Research Clinical Rheumatology 33 (2019) 66–87

Contents lists available at ScienceDirect

Best Practice & Research Clinical Rheumatology

journal homepage: www.elsevierhealth.com/berh

5

Current trends in sport and exercise hip conditions: Intra-articular and extra-articular hip pain, with detailed focus on femoroacetabular impingement (FAI) syndrome

Joanne Kemp [a, *], Alison Grimaldi [b], Joshua Heerey [a], Denise Jones [a], Mark Scholes [a], Peter Lawrenson [c], Sally Coburn [a], Matthew King [a]

[a] Latrobe Sport and Exercise Medicine Research Centre, La Trobe University, Plenty Road, Bundoora, Vic, 3086, Australia
[b] Physiotec, 23 Weller Rd, Tarragindi, Qld, 4121, Australia
[c] University of Queensland, St Lucia, Queensland, Australia

Keywords:
Hip pain
Femoroacetabular impingement syndrome
Rehabilitation
Assessment
Exercise

A B S T R A C T

Musculoskeletal conditions, such as hip pain are leading causes of pain and disability. Hip pain is the second most common cause of lower limb musculoskeletal pain, and is commonly seen in active individuals. Hip and groin pain may have intra-articular and extra-articular causes. Femoroacetabular impingement (FAI) syndrome and the associated pathologies are common intra-articular causes of hip and groin pain in active individuals. There are also a number of extra-articular causes of pain, which include musculotendinous conditions, extra-articular impingements and the clinical entities of groin pain described in the Doha agreement. This chapter will describe these, with a detailed focus on FAI syndrome. Specifically, it addresses: 1. What is and what causes FAI syndrome; 2. How do I diagnose FAI syndrome; and 3. What is the evidence-based approach to managing FAI syndrome?

* Corresponding author.
E-mail addresses: j.kemp@latrobe.edu.au (J. Kemp), info@physiotec.com.au (A. Grimaldi), j.heerey@latrobe.edu.au (J. Heerey), d.jones@latrobe.edu.au (D. Jones), m.scholes@latrobe.edu.au (M. Scholes), p.lawrenson@uq.edu.au (P. Lawrenson), s.coburn@latrobe.edu.au (S. Coburn), m.king@latrobe.edu.au (M. King).

https://doi.org/10.1016/j.berh.2019.02.006
1521-6942/

Introduction

Musculoskeletal conditions, such as hip pain, are leading causes of pain and disability in the community and the second largest global contributor to years lived with disability [1], affecting one in five people [1]. Hip pain is the second most common cause of lower limb musculoskeletal pain. While most studies focus on musculoskeletal pain affecting the elderly (e.g. osteoarthritis (OA)) there is compelling and increasing evidence that hip pain in younger adults (e.g. aged 18–50) creates a substantial burden. Hip and groin pain is commonly seen in active individuals. For example, hip and groin injuries account for up to 16% of all football injuries [2].

Hip pain can be associated with both intra-articular and extra-articular pathologies and mechanisms. There are many potential extra-articular sources of nociception in the hip region, and often coexistence of intra and extra-articular sources [3]. Acute muscular or musculotendinous injuries occur most frequently in the gluteal, hip flexor and groin regions. Pathologies of the gluteus medius and minimus, hamstrings, iliopsoas and adductor tendons and adjacent bursal or fascial structures may also be implicated in the development of hip pain in these regions. Extra-articular impingements have been described: ischiofemoral impingement of the quadratus femoris muscle, anterior inferior iliac spine or subspine impingement of the direct head of rectus femoris and Iliocapsularis, and impingement of the iliopsoas tendon against the acetabular rim, adjacent labrum and iliopectineal bursa [4]. It is also possible for the greater trochanter to impinge painfully into the superior [5] or posterior soft tissues [6]. Neuralgic pain may be referred from impingement of lumbar nerve roots at the spine or arise from impingement of various nerves as they transit through the hip and pelvic region, most frequently the sciatic, cluneal, pudendal and lateral femoral cutaneous nerves [7]. Amongst this multitude of extra-articular problems, pain associated with pathologies in the lateral hip and groin regions are two of the most common presentations, both with substantial impact on sport or exercise participation.

Lateral hip pain has been reported to affect up to 23.5% of post-menopausal women and 8.5% of men between the ages of 50 and 79, amounting to between 10% and 25% of the general population [8]. It is anticipated that the prevalence of lateral hip pain in athletes, particularly in women, will continue to rise in association with trends of increased participation of women over 40 years in long distance running and triathlon [9]. Traditionally attributed solely to trochanteric bursitis, the more recent recognition of tendinopathy of the gluteus medius and/or minimus tendons (gluteal tendinopathy) as the primary pathology associated with pain in the trochanteric region [10,11] has paved the way for greater understanding of the presentation, clinical diagnosis and management of this condition. Typical of other tendinopathies, trochanteric pain associated with gluteal tendinopathy is load-responsive, provoked by tasks where the gluteal tendons are under tensile and/or compressive load, such as standing on one leg to dress, walking or running (particularly long distance or high speed), uphills or upstairs and side lying positions involving direct tendon compression [12]. Apart from direct palpation, a cardinal element of clinical diagnosis, pain provocation tests that have been shown to be most useful in predicting presence of gluteal tendon pathology have involved either an active contraction and/or passive stretch of the abductor mechanism [13,14].

Recent evidence regarding impairments associated with gluteal tendinopathy has emerged, revealing targets for remediation in abductor muscle atrophy [11], weakness [15] and kinematic, kinetic and muscle recruitment alterations that result in loss of normal load-sharing throughout the abductor mechanism [16,17]. These advances in our understanding are likely to underpin the successes recently reported in two randomised clinical trials (RCTs), both employing load management education and targeted exercise as a primary management strategy [18,19]. Mellor and colleagues (2018) reported relative success rates for education and exercise, corticosteroid injection and wait-and-see of approximately 80%, 60% and 30% in the short-term with the advantages of education and exercise maintained at 12 months and no difference in success between injection and wait-and-see in the longer term, in 204 people (82% women) aged 35–70 years [18]. While there remains much to be established regarding the optimal and perhaps minimal dose of physical intervention required, and how best to apply such interventions economically across differing settings, substantial progress has been made in our understanding and management of lateral hip pain.

Recent advances have also been made with respect to groin pain in athletes. One notable problem disrupting communication and interpretation of data within both clinical and scientific fields has been the lack of a common language around groin pain terminology. In one review of 72 papers, 33 different diagnostic labels were used to denote variations of groin pain presentations [20]. The Doha agreement was a consensus publication following consensus meeting by international experts in athletic groin pain. This agreement subsequently outlined a 'clinical entities model' that recommends definition via clinical presentation: adductor-related, iliopsoas-related, pubic-related, or inguinal-related groin pain [21]. This has made an impact, with most publications now better clarifying the nature of the presentation studied. However, there remain difficulties in bridging the divide between clinical and imaging findings. Clinical tests for the Doha entities have been shown to be useful for predicting imaging findings in acute [22], but not long-standing adductor-related groin pain [23], not useful for iliopsoas-related groin pain [20] and untested or inadequately defined in the other two entities. Clinical tests then may be more useful, particularly in long-standing groin pain, for defining a clinical presentation and monitoring progress than in the diagnosis of a painful structure.

Impairments associated with groin pain remain under-investigated, although there is consistency in the presence of adductor weakness in identifying those with or at risk of developing groin pain [24]. The only exercise approach tested under RCT rigour places a particular focus on addressing this impairment in athletes with adductor-related groin pain [25,26]. The initial protocol that included 24–36 physiotherapy sessions provided good success with returning athletes to sport [26] [reference?]. In this study, 68 male athletes aged 18–50 years were randomised to one of two groups, the active adductor strengthening group, or the passive treatment (stretching massage and electrotherapy) [26]. The authors of the later study however, reported that the same exercise intervention supplied over three physiotherapy sessions and a home programme, was not 'very effective'. A more recent philosophy suggests that positive findings on hip adductor loading tests reflect global distress of the anterior pubic region, rather than a localised adductor deficit [23]. These authors have published a large prospective cohort study (n = ?) reporting promising outcomes from a protocol that focussed on optimising load transfer across the groin via exercise and athletic drills designed to improve intersegmental kinematic control, linear running and change of direction mechanics [27]. Such a protocol is yet to be tested under RCT conditions but provides direction for future research.

One of the most common intra-articular causes of hip pain is femoroacetabular impingement (FAI) syndrome, and will be the focus of this chapter. FAI syndrome is a foremost cause of hip pain in adults, evident in 49% of people with hip pain [28]. It is also a primary cause of chronic hip pain [21] and impaired physical function [29]. People with FAI syndrome are typically younger adults (usually aged 18–50), with unacceptable levels of hip-related pain, poor quality of life (QOL) and difficulty with sports and physical activity participation. The burden of FAI syndrome is amplified by the high daily physical demands (e.g. occupational, childcare responsibilities) encountered by younger adults. FAI syndrome may cause hip and groin pain in active individuals due to extra bone formation at the femoral head-neck junction, which can create aberrant joint forces during hip movements and damage to the intra-articular structures of the joint. Consequently, FAI syndrome is associated with an increased risk of total hip arthroplasty [30].

Femoroacetabular impingement (FAI) syndrome

pathology & pathoetiology (what is it and what causes it?)

What is FAI syndrome?

FAI syndrome is a cause of hip and groin pain in active young adults. It is considered a movement disorder, where particular hip morphology results in abutment of the femoral head against the acetabulum, resulting in pain. It is currently unclear if pain relates to abnormal morphology, or associated changes to intra-articular soft tissues. There are three types of morphology associated with FAI syndrome: cam morphology, which refers to extra bone formation on the femoral head neck junction; pincer morphology, which refers to a deep or retroverted acetabulum (and subsequent over coverage of the anterior/superior femoral head); or mixed morphology where both cam and pincer impingement are present [31]. FAI syndrome has been recently defined as a triad of symptoms, clinical signs and imaging findings [31]. Put simply, if a person is asymptomatic, they do not have FAI syndrome, even if they have imaging findings typically seen in FAI syndrome.

What causes FAI syndrome?

The majority of research examining the development of FAI syndrome is focussed on cam morphology. There is increasing evidence suggesting that cam morphology development is a bony adaptation to vigorous hip loading when the growth plate is still open [32]. Cam morphology can begin to develop in early adolescence and continues until the growth plate closes [32]. During skeletal maturation, there may be a dose response relationship between the intensity of sports practice and the development of a cam morphology [33]. The exact loading pattern that causes cam morphology to develop remains to be determined, although it is possibly related to loading in hip rotation and flexion [34]. This is supported by recent systematic reviews that explored the prevalence of cam morphology in athletes compared to controls [28,35]. Cam morphology was identified on imaging in around one in four asymptomatic non-athletes [28,35]. Comparatively, one in two symptomatic non-athletes was found to have cam morphology [28]. In athletes, cam morphology was present in two of three athletes, regardless of symptoms [28,35] (Fig. 1).

No completed cohort studies have examined the natural history, and therefore causative relationship, between cam morphology and associated intra-articular pathology in individuals with FAI syndrome. A large cohort study is underway, which aims to determine risk factors for structural deterioration of the hip [36]. It hypothesises that structural deterioration will be associated with larger cam morphology, higher hip joint force, lower muscle strength, and reduced joint range [36]. It will also explore whether worsening QoL occurs with hip joint structural deterioration [36]. This study has completed recruitment of 185 individuals with hip –related pain, with 50% completing 12-month follow-up and loss to follow up of less than 10%.

The prevalence of intra-articular soft tissue pathologies thought to be associated with FAI syndrome have been reported in a recent review [37]. Pooled data indicate that labral tears were observed in 62% (95% confidence interval (CI) 47%–75%) of symptomatic individuals and 54% (95%CI 41%–66%) of asymptomatic individuals. In contrast, cartilage defects were reported in 64% (95%CI 25%–91%) of symptomatic individuals, compared with only 12% (95%CI 7%–21%) of asymptomatic individuals (Fig. 2). Bone marrow lesions and ligamentum teres tears were more prevalent in people with symptoms, whereas paralabral cysts and herniation pits were prevalent in both symptomatic and

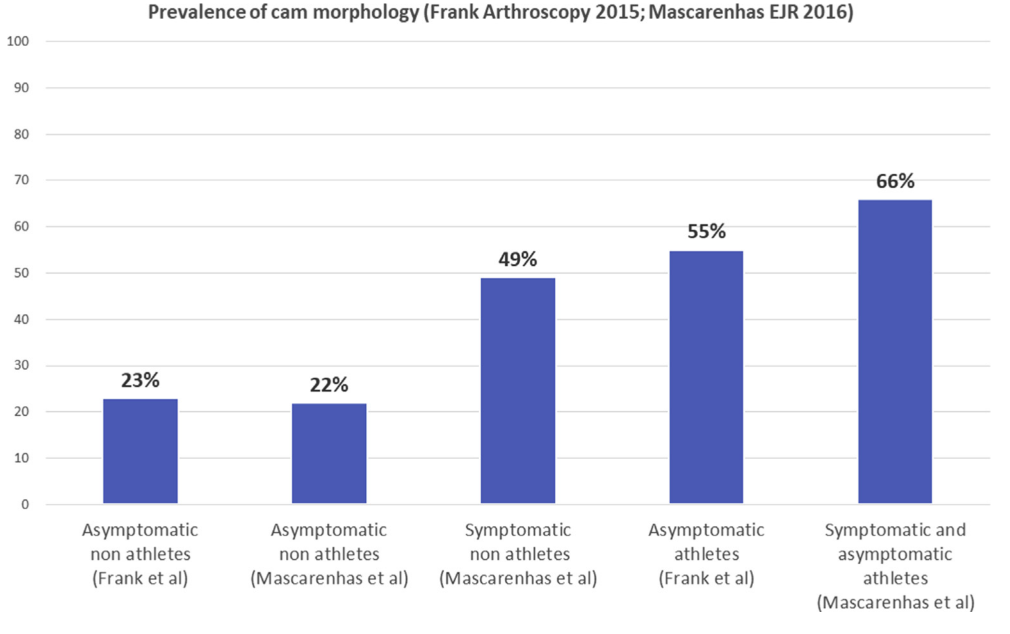


Fig. 1. The prevalence of cam morphology.

asymptomatic people. This review suggests that pain might be associated with some intra-articular structures more than others [37]. Based on a limited, emerging evidence base, articular cartilage pathology may be a stronger driver of hip pain than labral pathology, and may be related to the onset of early hip OA. However, further research is required to support this hypothesis. It is important to note from this review that the prevalence of intra-articular hip pathologies appears highly variable in symptomatic and asymptomatic populations (confidence intervals range from 7% to 91%). When deciding on appropriate treatment options, the clinician must understand the intra-articular pathology associated with FAI syndrome, factors that contribute to intra-articular pathology, and its ability to cause pain.

Diagnosis

A comprehensive clinical assessment can greatly assist in the diagnosis of FAI syndrome. A flow chart of clinical assessment of hip and groin pain is indicated in Fig. 3.

When developing an evidence-based assessment of hip pain, the role of subjective, physical and imaging findings should be considered. These are outlined below.

Presentation – subjective

An evidence-based subjective examination can provide the practitioner with vital information to assist in the clinical decision making process, prior to undertaking physical examination or imaging [38].

Particular questions related specifically to the patient with hip pain include:

- Symptom specific
  - Duration: people with FAI syndrome may have had symptoms for three years or more.
  - Clicking, locking, catching, giving way and pain on twisting may suggest the presence of labral or chondral pathology.
  - Pain at rest and at night may indicate the presence of synovitis.
  - Length of time sitting, and whether this is an aggravating factor. Conditions like FAI syndrome may be aggravated by prolonged periods of hip flexion.

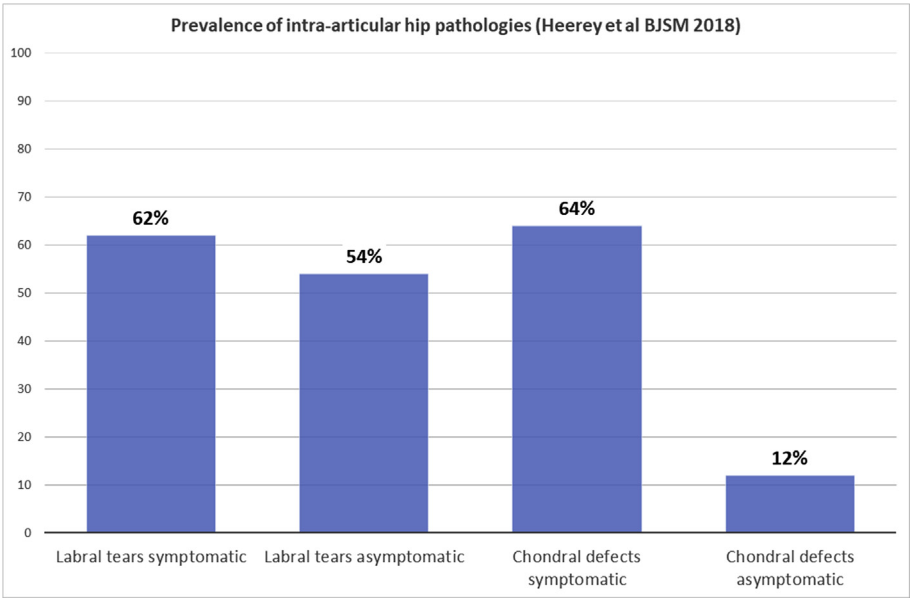


Fig. 2. The prevalence of intra-articular hip pathology.

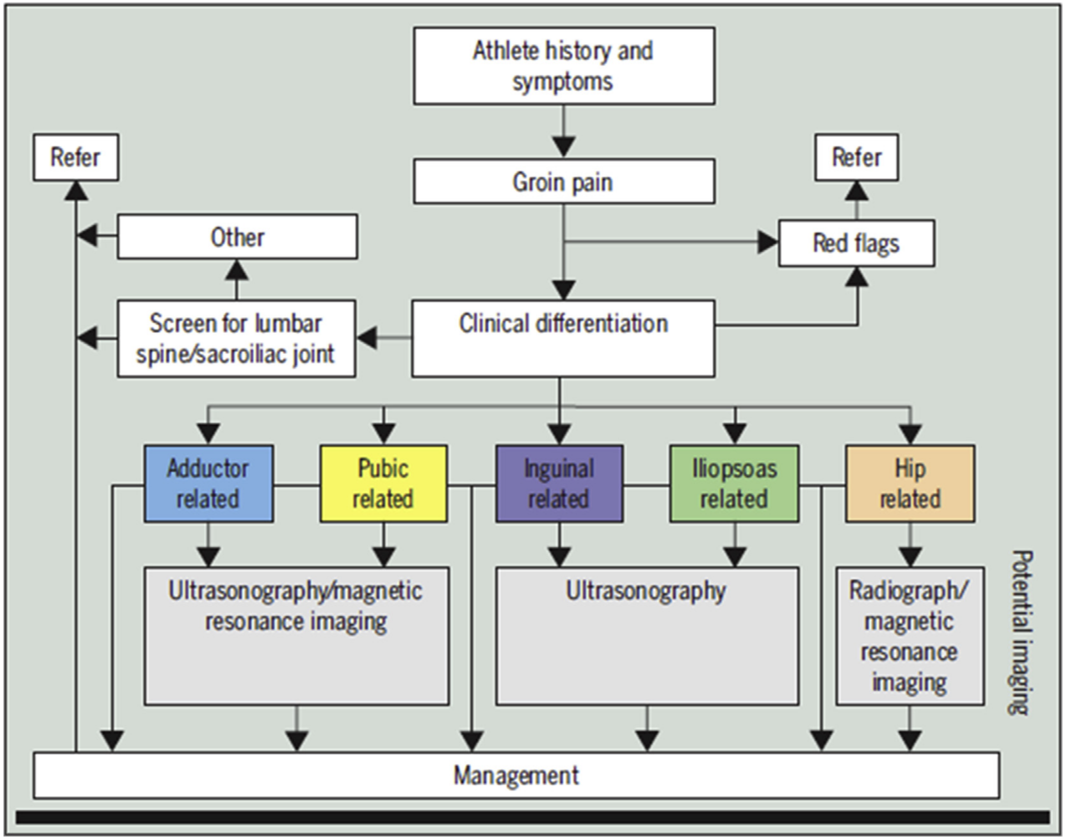


Fig. 3. Flow chart of clinical assessment of patient with hip and groin pain (from Thorborg et al. JOSPT 2018) [38].

- Patient specific
  - Age and sex, as the male pelvis may be skeletally immature until 25 + years; apophyses of the ASIS, AIIS, and pubic ramus may be seen
  - Age, as non-arthritic hip pain is more likely in people aged 20–30 years, while hip osteoarthritis (OA) may be seen in people 35 + years of age.
  - Previous history of hip pain, especially conditions such as slipped capital femoral epiphysis (SCFE), or developmental dysplasia of the hip (DDH).
- Sports specific
  - Type of sport: it has been suggested that kicking sports are a more common cause of hip pain, while sports, such as long distance running, gymnastics and dance may cause stress fractures.
  - Specific current sporting/activity load: this should include the frequency, intensity and duration of activity, and its relationship with symptoms. Loading may also provide information about possible overload injuries, including stress fractures. Adolescent sporting history is particularly important, given the above-mentioned relationship between load during growth and cam morphology.
- Questions to assist in screening for red flags
  - History of cancer (prostate, breast and gynaecological cancers can all metastasise to hip)
  - Female sex (to rule out gynaecological causes of pain, ask about monthly cycle)
  - Unexplained weight loss (can be an indication of cancer, as outlined above)
  - Burning with urination can indicate a urinary tract infection (UTI)
  - Change in bowel habits can indicate cancer or other bowel disease
  - Alcohol abuse can result in avascular necrosis (AVN)
  - Corticosteroid exposure can result in AVN or stress fractures
  - Acute pain with fever can indicate infection
- Administration of an appropriate hip-related patient-reported outcome measure (PROM). PROMs are considered the gold standard when evaluating outcomes in a clinical population but when choosing a PROM, the psychometric properties of all possible PROMs should be considered, specific to the patient. The most commonly administered PROMs and their clinical utility are contained in Table 1.

Diagnostic tests

There are a number of commonly used clinical diagnostic tests for hip pain; however, a thorough understanding of the diagnostic utility and limitations of these tests is important to ensure accurate diagnosis (Table 2). Notably, almost no tests have adequate specificity or positive likelihood ratios to

Table 1
Commonly administered hip-related patient-reported outcome measures (Table adapted from Brukner and Khan's Clinical Sports Medicine [39]).

Questionnaire	Recommended	Patient group best suited for	Validity	Responsiveness	SEM	MIC	Test/retest reliability ICC
HAGOS	Yes	Patient with hip and groin pain, hip arthroscopy	Yes	Yes	6-12 points	6-10 points	0.82–0.91
HOOS	Yes	Hip arthroscopy, Hip OA, Intra-articular cause of hip pain	Yes	Yes	3-6 points	6-11 points	0.93–0.96
HOS	Yes	Hip arthroscopy	Yes	Yes	3-5 points	5-6 points	0.95–0.96
iHOT-33	Yes	Hip arthroscopy, Intra-articular cause of hip pain	Yes	Yes	5 points	6 points	0.78
MHHS	No	None	No	No	5 points	8 points	0.91
NAHS	No	None	Yes	NR	NR	NR	0.87–0.95

Each questionnaire in this table has been commonly used in patients with hip and groin pain. Each has a maximum score of 100 points which is the best possible score. HAGOS = Copenhagen Hip and Groin Outcome Score; HOOS = Hip Dysfunction and Osteoarthritis Outcome Score; HOS = Hip Outcome Score; iHOT-33 = International Hip Outcome Tool Hip score; MHHS = Modified Harris Hip Score; NAHS = Non-Arthritic Hip Score; SEM = Standard Error of Measurement; MIC = minimal important change (also called minimal clinically important difference/change); ICC = intra-class correlation coefficient.

Table 2
Diagnostic accuracy of commonly used clinical tests for FAI syndrome (Table adapted and expanded with permission from Brukner and Khan's Clinical Sports Medicine [39]).

Assessment Finding	What is a positive finding?	Sn (95% CI)	Sp (95% CI)	LR-	LR+
History					
Labral tear					
Painful clicking in hip(41)	Clicking	100	85	0.00	6.7
Special Tests					
FAI syndrome					
FADDIR (vs MRA)(40)	Pain	0.94(0.90-0.97)	0.09(0.02-0.23)	1.02	0.45
FADDIR (vs surgery)(40)	Pain	0.99(0.98-1.00)	0.05(0.01-0.18)	1.04	0.14
Flexion/IR(40)	Pain	0.96(0.81-0.99)	0.25(0.01-0.81)	1.28	0.15
Intra-articular pathology (not specific)					
FABER(40, 42)	Pain	0.42-0.60	0.18-0.75	0.73-1.70	0.72-2.2
Scour test(40, 43)	Pain	0.50(0.26-0.74)	0.290.12-0.51)	0.70	1.72
IR with overpressure(40, 43)	Pain	0.91(0.68-0.99)	0.18(0.05-0.40)	0.5	1.1
Labral tear					
FADDIR (vs MRA)(40)	Pain	0.94(0.90-0.97)	8	0.48	1.02
FADDIR (vs surgery)(40)	Pain	0.99(0.98-1.00)	0.05(0.01-0.18)	0.15	1.06
Flexion IR(40)	Pain	0.96(0.81-0.99)	0.25(0.01-0.81)	0.27	1.12
Thomas test(40, 44)	Pain & reduced range	0.89(0.73-0.97)	0.92(0.75-0.99)	0.12	11.1

Sn = Sensitivity; Sp = Specificity; LR- = Negative likelihood ratio; LR+ = Positive likelihood ratio; - = not available

Green = Large change in likelihood (LR- <0.1, LR+ >10)

Red = Rarely important change in likelihood (LR- >0.5, LR+ <2.0)

accurately confirm a diagnosis [40]. Similarly, while some tests have high levels of sensitivity, which may assist in ruling out a diagnosis, the negative likelihood ratios for all tests are poor [40]. Moreover, the quality of studies examining these tests is not high, reducing confidence in their use [40]. A positive Thomas test can assist with diagnosing labral tear as the source of pain, while a negative FADDIR or Flexion/IR test can help rule out FAI syndrome and labral pathology. The absence of painful clicking can assist in ruling out a diagnosis of a labral tear. However, when using these tests in clinical practice, the treating clinician must remain aware of their limited diagnostic utility, and combine these test findings with the overall clinical picture by using a comprehensive clinical reasoning process.

Screening of the lumbar spine and pelvis is an important component of the diagnostic examination of the hip [38]. The diagnostic utility of tests to rule out the lumbar spine and pelvis as the source of hip pain include:

- Walking with limp (seven times more likely to indicate hip rather than spine pathology) [45].
- Pain in groin/anterior hip (seven times more likely to indicate hip rather than spine pathology) [45].
- Reduced hip internal rotation (IR) range of motion (ROM) compared to other side (14 times more likely to indicate hip rather than spine pathology) [45].
- No change in symptoms with repeated lumbar movement (sensitivity 92% ruling out lumbar spine) [38].
- Negative extension/rotation through lumbar spine (sensitivity 100% ruling out lumbar spine) [38].
- Negative straight leg raise (sensitivity 97% ruling out lumbar spine) [38].
- Negative slump test (sensitivity 87% ruling out lumbar spine) [38].
- Negative thigh thrust (sensitivity 82% ruling out sacro-iliac joint) [38].

Imaging

Imaging is used to evaluate the presence of intra-articular hip conditions, including the morphology and associated intra-articular pathology seen in FAI syndrome. As outlined above, the prevalence of hip morphology and labral tears is similar in symptomatic and asymptomatic people. Given the likelihood of these entities co-existing, it is vital that clinicians understand the complex relationship between pathology seen on imaging and the presence of pain [37] to recommend appropriate treatment. The clinical utility of commonly used imaging techniques is outlined in Table 3.

Table 3
Clinical utility of commonly used imaging techniques for FAI syndrome (Table adapted and expanded with permission from Brukner and Khan's Clinical Sports Medicine [39]).

Assessment Finding	Sn	Sp	LR-	LR+
Imaging				
Labral tear				
Ultrasound(47)	0.66 (0.48-0.81)	0.65 (0.38-0.86)	0.56	1.86
CTA(47)	0.91 (0.83-0.96)	0.89 (0.74-0.97)	0.11	6.28
MRI(1.5T)(47)	0.71 (0.63-0.78)	0.60 (0.35-0.82)	0.78	1.18
MRI(3.0T)(47)	0.72 (0.62-0.80)	0.76 (0.57-0.89)	0.51	2.03
MRA(1.5T)(47)	0.88 (0.85-0.92)	0.59 (0.50-0.68)	0.20	1.91
MRA(3.0T)(47)	0.89 (0.82-0.95)	0.79 (0.61-0.92)	0.15	3.21
Cartilage				
CT(48)	0.88	0.82	0.15	4.89
MRI(49)	0.76 (0.65-0.85)	0.72 (0.57-0.84)	0.33	2.71
MRA(49)	0.75 (0.69-0.80)	0.79 (0.73-0.85)	0.32	3.57
Cam morphology				
AP pelvis X-ray[a(50)]	0.60	0.81	0.49	3.15
AP pelvis X-ray[b(51)]	0.50	0.82	0.61	2.78
Cross-table X-ray[a(50)]	0.74	0.63	0.41	2.0
Cross-table X-ray[b(51)]	0.40	0.82	0.73	2.22
Dunn 45 X-ray[b(51)]	0.80	0.36	0.55	1.25
Dunn 45 X-ray[a(52)]	0.96	0.90	0.04	9.60
Dunn 90 X-ray[a(50)]	0.91	0.88	0.10	7.58
Frog-leg lateral X-ray[b(51)]	0.47	0.91	0.58	5.22
AP pelvis + Dunn X-ray[b(51)]	0.87	0.36	0.36	1.36
MRA(53)	1.00	1.00	NR	NR

Sn = Sensitivity; Sp = Specificity; LR- = Negative likelihood ratio; LR+ = Positive likelihood ratio; CTA = computed tomography arthrography; CT = computed tomography; MRI = magnetic resonance imaging; MRA = magnetic resonance arthrography; T=Tesla
Green = Large change in likelihood (LR- <0.1, LR+ >10)
Red = Rarely important change in likelihood (LR- >0.5, LR+ <2.0)
**dGEMRIC not listed as not commonly used in clinical practice
[a] = MRA reference standard
[b] = CT reference standard

Known impairments

Range of motion

Despite frequent reports of reduced hip flexion, adduction and internal rotation ROM in the literature, a recent systematic review found limited and conflicting evidence with regard to ROM deficits in patients with FAI syndrome [53].

Muscle strength

Significant differences in hip strength measures are consistently identified in patients with FAI syndrome when compared with healthy controls [37]. Hip muscle strength in all planes of movement (adduction, abduction, extension, flexion, external rotation and internal rotation) is significantly reduced in people with FAI syndrome compared with controls, but adduction strength has been shown to demonstrate the greatest deficit [53]. Deficits in hip extension rate of force development (RFD) have also been identified in patients with FAI syndrome; however, this phenomenon has been scarcely investigated [43]. Exercise interventions to address strength deficits in patients with FAI syndrome have been shown to significantly improve measures of pain, function and QoL [54,55], highlighting the important link between strength impairments and symptoms.

Function

Functional task performance may be affected in patients with FAI syndrome; however, the cross-sectional nature of studies to date does not confirm a causal relationship. In a post-surgical cohort, patients with FAI syndrome demonstrated poorer performance during functional tasks including single leg hop distance, side bridge endurance and the single-leg rise test when compared to healthy control participants [53]. Furthermore, dynamic balance appears reduced during a single leg squatting task [53] and star excursion balance test [56]; however, static balance is unaffected when compared to healthy populations [53]. Future studies are required to examine the relationships between these known functional deficits and the deterioration of hip joint disease, to identify appropriate treatment targets. In addition, a greater understanding of the relationship between functional task performance and athletic performance might assist clinicians aiming to rehabilitate athletes to return to sport and optimal performance.

Biomechanics

Table 4 outlines hip joint biomechanics of two commonly investigated functional tasks in FAI, walking and a double leg squat, compared with control populations. The hypothesised mechanisms for observed differences include compensatory movements to reduce pain and hip joint contact forces during certain aspects of the task (especially during walking) [57]. A lesser squat depth with a similar peak hip flexion angle in people with FAI syndrome compared with controls may indicate the presence of poor motor programming, or fear of moving into a potentially painful position [57].

Muscle size

There is limited knowledge of changes in muscle size in populations with FAI syndrome specifically. Given our understanding of deficits in hip muscle strength, changes might be seen in the hip abductors, adductors, flexors, extensors and rotators. There is no difference in muscle size seen in populations with acetabular labral tears [58], while there is a decreased ratio of iliocapsularis to rectus femoris size seen in pincer morphology [59]. This is an important emerging area of research in people with FAI syndrome. If significant changes in muscle size are identified in these patients, changing muscle size through targeted muscle strength programs could become an important treatment target. However, further research is required to determine whether this is the case.

Muscle activation

To understand the role of muscular contribution to clinical signs and symptoms in FAI syndrome, recent studies have investigated static and dynamic tasks. Altered coordination of deep posterior hip

Table 4
Hip biomechanics in people with FAI syndrome during walking and double leg squatting (Table adapted from King et al., 2018 [58]).

Task and plane of movement	Variable	FAI Syndrome vs. comparator	Comparator
Walking (Stance Phase)			
Sagittal Plane			
Angles	Peak hip flexion	=	Controls
	Peak hip extension	↓	Controls
	Total ROM	↓	Controls
External joint torques	Peak hip flexion	=	Controls
	Peak hip extension	=	Controls
Frontal Plane			
Angles	Peak hip adduction	=	Controls
	Peak hip abduction	=	Controls
	Total ROM	=	Controls
External joint torques	Peak hip adduction	=	Controls
	Peak hip abduction	=	Controls
Transverse Plane			
Angles	Peak hip internal rotation	↓	Controls
	Peak hip external rotation	=	Controls
	Total ROM	=	Controls
External joint torques	Peak hip internal rotation	=	Controls
	Peak hip external rotation	↓	Controls
Double Leg Squat	Squat depth	<*	Controls
Sagittal Plane			
Angles	Peak hip flexion	=	Controls
	Total ROM	=	Controls
External joint torques	Peak hip flexion	=	Controls
Frontal Plane			
Angles	Peak hip adduction	=	Controls
	Total ROM	=	Controls
External joint torques	Peak hip adduction	=	Controls
Transverse Plane			
Angles	Peak hip internal rotation	=	Controls
	Total ROM	=	Controls
External joint torques	Peak hip internal rotation	=	Controls
	Peak hip external rotation	↓	Controls

* indicating people with FAI syndrome squat to a lesser depth (not as deep) compared with controls.

muscle activity during walking is evident during early swing phase of gait [60]. Investigation of more superficial hip musculature demonstrates increased amplitude of gluteus maximus activity in FAI syndrome when compared to asymptomatic controls, and increased amplitude of medial hamstrings compared to lateral hamstrings in unilateral FAI syndrome [61]. The implications of these findings are not yet clear as they are from a small number of studies, of short duration, with gait not generally considered a provocative activity in FAI syndrome. Investigation of more provocative tasks, such as squatting, failed to show any significant difference in muscle activity, although a tendency for increased rectus femoris activity during squatting descent and decreased gluteus maximus activity during ascent was evident [62]. Further studies in larger cohorts of people with FAI syndrome are required, particularly in tasks that cause pain in symptomatic cohorts, such as cutting and direction change manoeuvres, deep flexion tasks, and single leg dynamic tasks [36].

What can be assessed in the clinic?

Muscle strength, range of motion and function. With the consistent identification of hip strength deficits in patients with FAI syndrome [53] and the reported improvements in pain and function following strengthening interventions [54,55], reliable clinical measurement of hip strength is an important clinical tool to guide the accurate prescription and monitoring of exercise programs. Clinically, the use of hand-held dynamometry to measure isometric peak force has been shown to have good intra-rater and inter-rater reliability [63]. In conjunction with strength, reliable assessment of functional performance might also be completed in the clinical setting. However, clinicians must remember the lack of known clinical utility of functional performance tests, and only include these tests as part of a battery of physical assessment tools, without placing excessive emphasis on the ability of such tests to predict outcomes. A summary of strength and functional assessments is contained in Table 5.

Physical activity and return to sport measures. Physical activity encompasses occupational activities, leisure, planned sport and exercise. In assessing physical activity and return to sport, it is important to consider the dimension to be captured (such as quantifying the type, duration or intensity of activity or qualifying the degree of difficulty undertaking a particular activity). No single outcome measure will effectively capture all dimensions.

Table 6 identifies a selection of PROMs used to measure physical activity. Some established hip scores, such as the HOOS, HOS and HAGOS have relevant subscales that may be used, rather than the entire score. PROMs that quantify physical activity are not specifically validated for populations with FAI syndrome, but this should not preclude their use. Physical and psychological readiness are required to successfully return to sport and PROMs can assist in monitoring this aspect of recovery [72]. The Hip Return to Sport Index (Hip-RSI) was recently published, and while its psychometric properties are unknown, it may prove to be a promising score in the future to measure psychological readiness to return to sport [73].

Treatment

Common treatments

Treatment for FAI syndrome includes surgical and non-surgical options, such as physiotherapist-led interventions. In recent years, arthroscopic surgery has become a favoured treatment option for the management of hip pain. However, this type of surgery is associated with significant cost, inherent risks, and its efficacy is uncertain. In light of these factors, and evident from clinical guidelines for OA and low back pain, non-surgical approaches should always be the first line options for musculoskeletal pain conditions. Physiotherapist-led interventions have potential as an effective, low risk and cost-saving alternative to surgery to reduce the symptoms of FAI in active individuals.

Evidence regarding value of different treatments and practical guide for evidence-based management

Physiotherapist-led interventions. Physiotherapist-led interventions should always be considered prior to any surgical treatment for FAI syndrome. High-quality, high-value physiotherapist-led interventions

Table 5
Clinical assessment of strength and function.

Test	Identified difference in FAI syndrome when compared to healthy control?	Reliability/Validity	Recommended using in FAI syndrome patients?	Recommendations
Hand Held Dynamometry Abduction Adduction Flexion Extension Internal rotation External rotation	Yes [53]	Intra-rater = 0.77–0.96 [63] 0.74–0.95 [64] Inter-rater = 0.82–0.95 [64] 0.82–0.91 [65]	Yes	Isometric make test. Standardise testing procedure and instructions. Record pain score.
Manual Muscle Testing As above	No	N/A	No	Use when HHD not available.
Single leg rise	Yes [66]	NR	Yes	Standardise testing procedure and instructions.
Side bridge	Yes [66]	Intra-rater = 0.87[10] Inter-rater = 0.86[10]	Yes	Standardise testing procedure and instructions.
Hop for distance	Yes [67]	Intra-rater = 0.98 [63] Inter-rater = 0.99 [68]	Yes	Standardise testing procedure and instructions.
Star excursion balance	Yes [69]	Intra-rater = 0.67–0.96 [70] Inter-tester = 0.35–0.84 [70] Good validity in FAI [69]	Yes	Young, physically active individuals[5]. Posterolateral and posteromedial most valid in patients with FAI[5].
Single leg standing balance	No [67]	Intra-rater (device) = 0.81 Inter-rater (device) = 0.77	No	Using Wii Balance Board [71]

should include exercise programs of sufficient dose and progression to address strength, and be designed to target known impairments [53,90]. Additionally, interventions should focus appropriately on activity limitations, incorporating a graduated, progressive return to sport and physical activity plan [72]. Known impairments include (i) reduced hip muscle strength, particularly hip adduction [53]; (ii) reduced trunk strength bilaterally [53]; reduced dynamic single-leg balance [53]; and reduced functional task performance [53].

The key components of a high-value physiotherapist-led intervention for FAI syndrome include:

Hip muscle strengthening. Hip muscle strengthening exercises are a key component of physiotherapist-led interventions for FAI syndrome. They should be targeted to the individual's impairments, and should be appropriately dosed to maximise strength gains. Strength and conditioning principles that ensure appropriate strength gains include number of repetitions and sets, rest between repetitions and sets, applied load, time under tension, ROM through which the exercise is performed, and frequency of exercise sessions [89,91]. Progressive strength programs can advance from safe, low load positions, to challenging, high load positions, as the individual gains capacity and confidence with strength training.

Hip adduction, abduction and extension strength should be targeted in programs for the majority of patients with FAI syndrome. Examples of progressive hip strength programs are outlined in Figs. 4 and 5. It is important to note that while these impairments are most often reported, the strength program should be tailored to the individual's own impairments.

Trunk muscle strengthening. Trunk muscle strength is an important target for people with FAI syndrome. It is reduced in people post-arthroscopy [66] and when reduced, can increase acetabular retroversion and impingement [92]. It is likely that trunk strength is an important treatment target, given its important role in controlling the pelvis (which contains the acetabulum). Given that acetabular position may alter impingement, in patients with FAI syndrome this

Table 6
Summary of questionnaires used to measure physical activity and return to sport.

Name of PROM	Subscale	Scoring	MIC	Recall	Psychometric properties established for hip	Recommended populations
Ability to perform physical activity						
Hip Disability and Osteoarthritis Outcome Score (HOOS) [74]	HOOS - sport and recreational activity	Separately scored subsection (%). 0 = extreme disability; 100 = no symptoms	10/100	Previous week	Yes	Adults with hip disability with/without OA.
Hip Outcome score (HOS) [74]	HOS -sports sub-scale (HOS-SS)	Separately scored subsection (%). 0 = unable to do; 100 = no difficulty at all	6/100	Previous week	Yes	Adults – labral tear. Arthroscopy
Hip and Groin Outcome Score (HAGOS) [74]	HAGOS - sport and recreation	Separately scored subsection (%). 0 = extremely problematic; 100 = no problems	9/100	Previous week	Yes	Active adults (young-middle aged) with hip and groin pain. Arthroscopy
	HAGOS - physical activity		12/100			
Patient specific functional scale (PSFS) [75]	Patient nomination of activity	For each activity 0–10 scoring (0 = unable to perform activity; 10 = able to perform at pre-injury level)		Current status	No	Adults – musculoskeletal conditions
Activity level						
Hip sports activity scale HSAS [76]	9 sports activity levels, no sport to elite sport participation.	Single score 0 = no sport; 8 = elite (highest hip load)		Current status	Yes	FAI syndrome
Quantifying physical activity						
Nord-Trøndelag Health Study questionnaire for assessment of moderate to vigorous activity (HUNT 1 PA-Q) [77].	Physical activity intensity, frequency and duration (3 items)	Single summary score, 0–15 (15 being most active)			No	Adults
International physical activity questionnaire - short form (IPAQ-short) [78]		Duration spent undertaking different levels of activity – [walking, moderate, vigorous]. Total score = Median METs min/week		Previous week	No	Adults [15–69]
Psychological preparedness						
Hip-return to sport index (short) (HIP-RSI Short)	Whole scale (6 items)	Single composite score (0 = extremely negative psychological responses; 100 = no negative psychological responses)		Current status	No (underway)	(Arthroscopy)

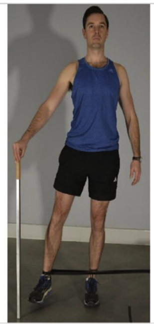
Movement	Early Stage	Middle Stage	Advanced Stage
Hip Adduction			
Hip Abduction			

Fig. 4. Progressive hip adductor and abductor strength examples. Exercise program should be progressed on an individual basis. Progression to the next level can be determined by successful completion of the previous level (VAS <20 mm and Borg Rate of Perceived Exertion ≤5 (moderate)). Exercises dosage can be targeted to improve strength hypertrophy (three sets of 6–8 repetitions, at 6–8 RM).

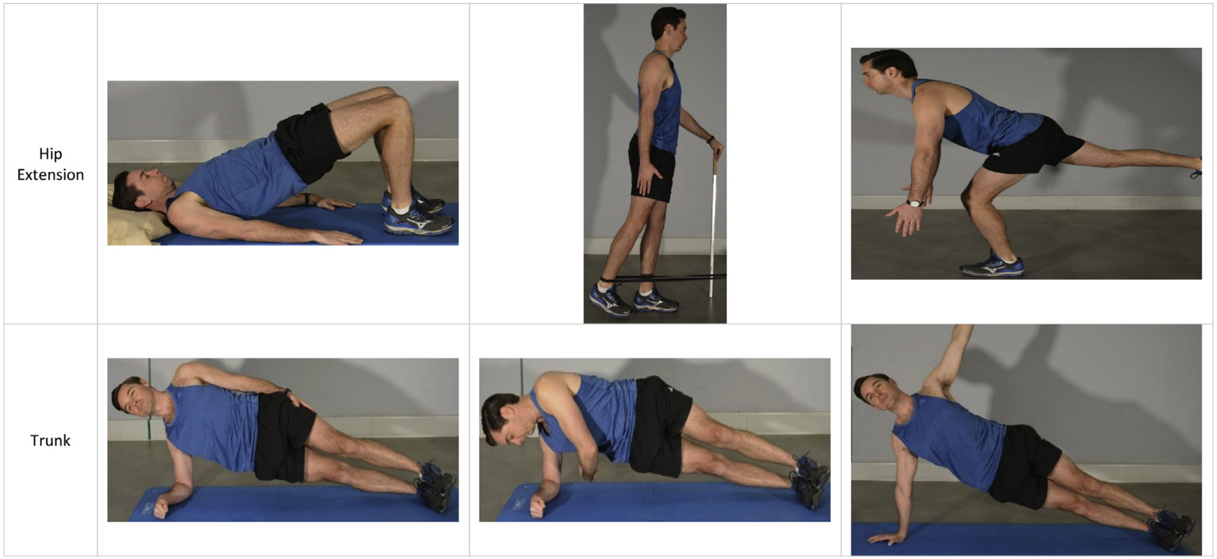


Fig. 5. Progressive hip extensor and trunk strength examples. Exercise program should be progressed on an individual basis. Progression to the next level can be determined by successful completion of the previous level (VAS <20 mm and Borg Rate of Perceived Exertion $\leq$5 (moderate)). Exercises dosage can be targeted to improve strength hypertrophy (three sets of 6–8 repetitions, at 6–8 RM).

should always be considered. It is important to avoid increasing hip pain and impingement when performing trunk muscle strengthening exercises. Examples of a progressive trunk strength program are outlined in Fig. 5.

Functional retraining. Functional retraining is probably a key component of rehabilitation for people with FAI syndrome, although clinicians must recognise the limitations in knowledge of functional performance as a causative factor in patients with hip pain. Normalising gait biomechanics, performance and endurance could begin early in treatment, be progressed in a graded fashion and include running, direction change and cutting manoeuvres specific to functional demands. Patients with hip pain often have a reduced step length to avoid increased joint loading seen at end range hip extension [57]. Any modification to gait should not significantly increase the individual's hip pain.

Lower limb control during functional tasks requires strength of the hip abductors and adductors, balance and trunk strength. Increased femoral adduction movement during single leg tasks may result in increased impingement [93], prolonging the individuals' symptoms. Individuals with specific strength deficits of the trunk, hip abductors and hip adductors should address these in targeted strength programs as well as functional and balance retraining. Adequate control during single leg tasks is something to be considered before an athlete can return to sport, especially when fatigued.

An example of a progressive functional retraining program (including balance) is outlined in Fig. 6.

Balance retraining. Dynamic single-leg balance is reduced bilaterally in people with FAI syndrome [56] and post-hip arthroscopy [67]. Reduced hip adduction and abduction strength is associated with poor balance [56]. Balance retraining should be undertaken bilaterally and concurrently with hip adduction and abduction strengthening. Retraining of balance should begin immediately in low-impact dynamic functional tasks, and be progressed as symptoms and performance allows. Examples of progressive balance retraining are included in Fig. 6 (functional retraining).

Range of motion optimisation. Hip joint range of motion (ROM) can be reduced in people with FAI syndrome [53,94] and better hip ROM is associated with better outcomes [95]. In addition, hip joint ROM can affect load within the hip. Hip flexion [96] and extension [96] increase load on the anterior [96] and superior [97] regions of the hip. This suggests that ROM may be limited if movement at the end of range provokes pain. Techniques to improve ROM may include soft tissue manual therapy techniques around the hip, as well as hip joint mobilisations. However, these techniques have not been tested in a clinical trial and have little evidence to support their use.

Individualised return to sport/physical activity including graded loading program. Returning to pre-injury sport and activity is important to young and middle-aged people with hip pain, and is often the reason they seek surgical and non-surgical treatment [31,88]. Only two studies have been published that included a specific return to sport/return to physical activity component within the physiotherapist-led program [55,85]. A study examining patients post-hip arthroscopy found that only 17% of people returned to optimal performance and full participation 33 ± 16 months post-surgery [88]. Given the importance of returning to sport in this active patient group and the disappointing rates of returning to optimal performance reported [88], it is imperative that physiotherapist-led treatments incorporate and commence key patient-specific sporting and functional components early in the rehabilitation process [72].

Education. When managing someone with FAI syndrome, many key points should be addressed to improve their understanding of the condition.

- Based on contemporary understanding of the morphology and associated pathology seen in FAI syndrome, these patients may have early hip OA and should be treated according to OA guidelines [98]. Aspects of treatment based on these guidelines may include weight loss if appropriate, management with exercise programs, and education [98].
- Flares of pain are common in people with FAI syndrome and probably do not relate to structural deterioration of the joint. Exercise programs can be adapted but should not be stopped due to pain. Patients should be encouraged to continue to exercise with an acceptable level of pain, as it is likely that ongoing exercise will reduce pain severity [99].
- All patients with musculoskeletal conditions should aim to achieve recommended physical activity guidelines. People with FAI syndrome should be encouraged to find a cardiovascular activity

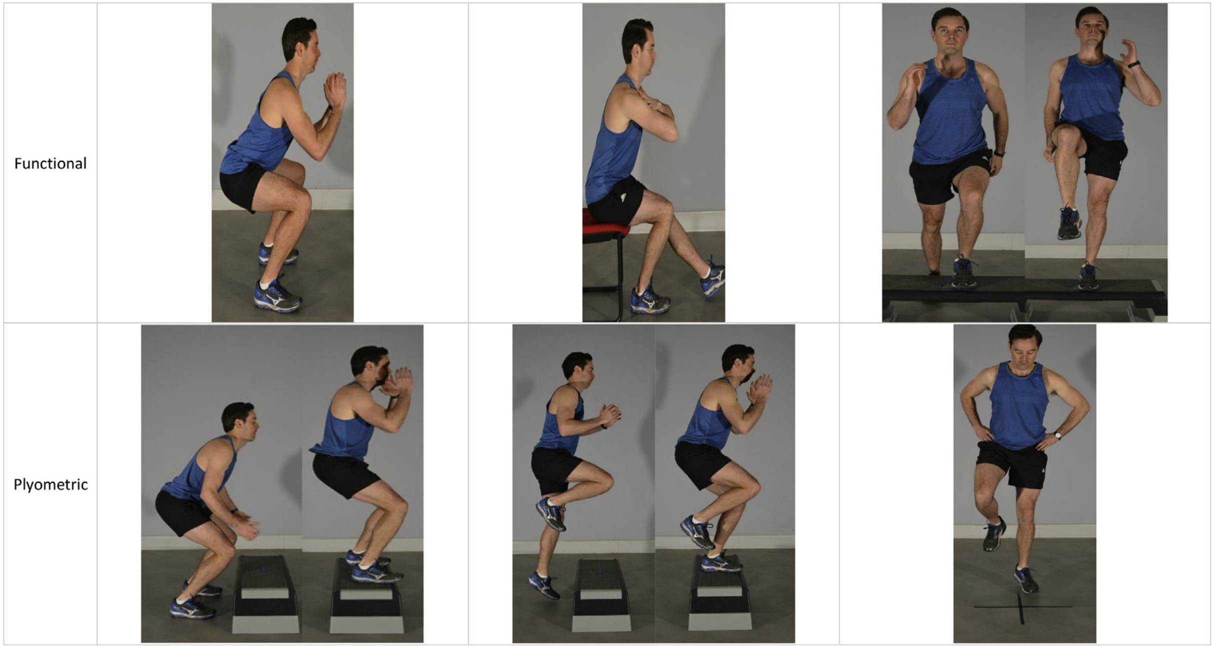


Fig. 6. Progressive hip functional strength and plyometric examples. Exercise program should be progressed on an individual basis. Progression to the next level can be determined by successful completion of the previous level (VAS <20 mm and Borg Rate of Perceived Exertion $\leq$5 (moderate)). Exercises dosage can be targeted to improve strength hypertrophy (three sets of 6–8 repetitions, at 6–8 RM).

(walking, cycling, swimming and dancing as examples) that they enjoy and they feel confident doing. Clinicians may need to work with individuals already undertaking physical activity to find alternative activities that do not significantly exacerbate symptoms, but still allow them to achieve recommended physical activity guidelines. In addition, clinicians may need to adjust the duration, intensity and frequency of activity to achieve this aim.
- As FAI syndrome is a chronic musculoskeletal condition, people must be prepared for a maintenance program that includes key components outlined above. Clinicians must be prepared to 'coach' their patients to enable the ongoing changes to behaviour that are necessary for adherence to a maintenance program.
- While people with FAI syndrome will probably improve with treatment, it is unlikely they will have outcomes the same as a healthy age-matched control, regardless of treatment undertaken [54,55,100].

Hip arthroscopy surgery and post-operative rehabilitation. Indications for arthroscopic surgery in the hip may include both intra- and extra-articular pathology [79], aiming to possibly prevent progression to end stage joint disease [80]. Recent systematic reviews concluded that early-onset hip OA is associated with worse outcomes after hip arthroscopy [81], and that people with severe hip OA at arthroscopy will progress to total hip arthroplasty (joint replacement surgery) within two years of hip arthroscopy [82]. In the United States, the rate of hip arthroscopy increased by 600% between 2006 and 2010 [83].

Two recent randomised controlled trials (RCTs) compared hip arthroscopy surgery to physiotherapist-led interventions for FAI syndrome [54,84]. In the largest of the two, there was a very small between-group difference in hip-related quality of life at 12-months that favoured the hip arthroscopy group [IHOT-33 standardised mean difference (SMD) 95% confidence interval) 0.21 (0.19–0.23)] [54]. The second, smaller RCT showed a similar very small difference favouring surgery for hip-related daily or sporting activity between the groups at 24-months follow-up [HOS ADL 0.20 (0.27–0.13); HOS Sport 0.07 (0.00–0.14)] [84]. Given the greater expense of surgery, and inherent risk of surgical complications, these small between-group effects support the implementation of non-surgical treatments, such as high quality physiotherapist-led treatments, prior to undertaking any surgical procedure.

The quality of post-operative rehabilitation programs is vital if surgery is to be successful. Although several pilot RCTs exploring post-arthroscopy rehabilitation have been published [85–87], it remains unclear what optimal post-arthroscopy rehabilitation programs should include. Post-hip arthroscopy impairments in strength, functional performance and balance are evident [53,67], and less than 17% of patients return to an 'optimal level of sports performance.' [88] Post-surgical outcomes can be enhanced if post-operative rehabilitation programs are targeted to impairments, contain exercise programs that are adequately progressed, and include comprehensive return-to-sport planning [89].

Summary

Hip pain is a common cause of lower limb musculoskeletal pain seen in active individuals. Hip and groin pain may have intra-articular and extra-articular causes. Extra-articular causes include musculotendinous conditions, such as gluteal, hamstring, iliopsoas and adductor tendinopathy; and extra-articular conditions, such as ischiofemoral impingement of the quadratus femoris muscle, anterior inferior iliac spine or subspine impingement of the direct head of rectus femoris and Iliocapsularis, and impingement of the iliopsoas tendon against the acetabular rim, adjacent labrum and iliopectineal bursa. Femoroacetabular impingement (FAI) syndrome and its associated pathologies (chondral pathology, labral pathology) are common intra-articular causes of hip and groin pain. FAI syndrome is a clinical diagnosis comprising symptoms, signs and imaging findings and should be diagnosed using an evidence-based subjective examination, physical examination, and use of imaging. Young active individuals with FAI syndrome can be treated with physiotherapist-led interventions or, as a secondary option, surgical interventions. As with many musculoskeletal conditions, non-surgical interventions should always be undertaken prior to surgery. Physiotherapist-led interventions should comprise hip and trunk muscle strengthening, functional and plyometric retraining, range of motion optimisation, education and return to sport planning.

Practice points

- Hip pain in active individuals may have intra-articular or extra-articular causes, or both.
- FAI syndrome is a common clinical diagnosis based on symptoms, signs and imaging findings.
- Pain must be present for a diagnosis of FAI syndrome.
- An understanding of the clinical utility of a subjective examination, physical examination, and use of imaging can assist in the accurate diagnosis of FAI syndrome.
- Treatment of FAI syndrome should always start with non-surgical treatments, before surgery is considered.
- Non-surgical treatments for FAI syndrome should primarily consist of exercise-based interventions, and should also focus on returning the individual to sport or physical activity as desired.

Research agenda

- Future full-scale RCTs are required to determine the efficacy of physiotherapist-led interventions for hip pain and FAI syndrome.
- Further RCTs are required to determine the efficacy of hip arthroscopy surgery for FAI syndrome, and help identify patients who will respond positively to surgical interventions.
- Consistency in methods used to measure physical impairments in people with FAI syndrome is required.
- Further large-scale cross-sectional studies in non-surgical patients will help to identify the prevalence of physical impairments in patients with FAI syndrome.

Conflicts of interest

There are no conflicts of interest to declare.

Acknowledgments

Dr Joanne Kemp is funded by a NHMRC Early Career Research Fellowship, Australia (grant number 1119971).

References

[1] Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380(9859):2163–96.
[2] Werner J, Hägglund M, Waldén M, Ekstrand J. UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. Br J Sports Med 2009;43(13):1036–40.
[3] Battaglia PJ, D'Angelo K, Kettner NW. Posterior, lateral, and anterior hip pain due to musculoskeletal origin: a narrative literature review of history, physical examination, and diagnostic imaging. J Chiropr Med 2016;15(4):281–93.
[4] Bardakos NV. Hip impingement: beyond femoroacetabular. J Hip Preserv Surg 2015;2(3):206–23.
[5] de Sa D, Alradwan H, Cargnelli S, Thawer Z, Simunovic N, Cadet E, et al. Extra-articular hip impingement: a systematic review examining operative treatment of psoas, subspine, ischiofemoral, and greater trochanteric/pelvic impingement. Arthrosc J Arthrosc Relat Surg 2014;30(8):1026–41.
[6] Kivlan BR, Martin RL, Martin HD. Defining the greater trochanter-ischial space: a potential source of extra-articular impingement in the posterior hip region. J Hip Preserv Surg 2016;3(4):352–7.
[7] Martin R, Martin HD, Kivlan BR. Nerve Entrapment in the hip region: current concepts review. Int J Sports Phys Ther 2017; 12(7):1163–73.
[8] Williams BS, Cohen SP. Greater trochanteric pain syndrome: a review of anatomy, diagnosis and treatment. Anesth Analg 2009;108(5):1662–70.

[9] Fields KB. Running injuries - changing trends and demographics. Curr Sports Med Rep 2011;10(5):299–303.

[10] Long SS, Surrey DE, Nazarian LN. Sonography of greater trochanteric pain syndrome and the rarity of primary bursitis. AJR Am J Roentgenol 2013;201(5):1083–6.

[11] Woodley SJ, Nicholson HD, Livingstone V, Doyle TC, Meikle GR, Macintosh JE, et al. Lateral hip pain: findings from magnetic resonance imaging and clinical examination. J Orthop Sports Phys Ther 2008;38(6):313–28.

[12] Grimaldi A, Mellor R, Hodges P, Bennell K, Wajswelner H, Vicenzino B. Gluteal tendinopathy: a review of mechanisms, assessment and management. Sports Med 2015;45(8):1107–19.

[13] Ganderton C, Semciw A, Cook J, Pizzari T. Demystifying the clinical diagnosis of greater trochanteric pain syndrome in women. J Wom Health 2017;26(6):633–43.

[14] Grimaldi A, Mellor R, Nicolson P, Hodges P, Bennell K, Vicenzino B. Utility of clinical tests to diagnose MRI-confirmed gluteal tendinopathy in patients presenting with lateral hip pain. Br J Sports Med 2017;51(6):519–24.

[15] Allison K, Vicenzino B, Wrigley TV, Grimaldi A, Hodges PW, Bennell KL. Hip abductor muscle weakness in individuals with gluteal tendinopathy. Med Sci Sports Exerc 2016;48(3):346–52.

[16] Allison K, Salomoni SE, Bennell KL, Wrigley TV, Hug F, Vicenzino B, et al. Hip abductor muscle activity during walking in individuals with gluteal tendinopathy. Scand J Med Sci Sports 2018;28(2):686–95.

[17] Ganderton C, Pizzari T, Harle T, Cook J, Semciw A. A comparison of gluteus medius, gluteus minimus and tensor facia latae muscle activation during gait in post-menopausal women with and without greater trochanteric pain syndrome. J Electromyogr Kinesiol–Off J Int Soci Electrophysiol Kinesiol 2017;33:39–47.

[18] Mellor R, Bennell K, Grimaldi A, Nicolson P, Kasza J, Hodges P, et al. Education plus exercise versus corticosteroid injection use versus a wait and see approach on global outcome and pain from gluteal tendinopathy: prospective, single blinded, randomised clinical trial. BMJ 2018;361:k1662.

[19] Ganderton C, Semciw A, Cook J, Moreira E, Pizzari T. Gluteal loading versus Sham exercises to improve pain and dysfunction in postmenopausal women with greater trochanteric pain syndrome: a randomized controlled trial. J Wom Health 2018;27(6):815–29.

[20] Serner A, Weir A, Tol JL, Thorborg K, Roemer F, Guermazi A, et al. Characteristics of acute groin injuries in the hip flexor muscles - a detailed MRI study in athletes. Scand J Med Sci Sports 2018;28(2):677–85.

[21] Weir A, Brukner P, Delahunt E, Ekstrand J, Griffin D, Khan KM, et al. Doha agreement meeting on terminology and definitions in groin pain in athletes. Br J Sports Med 2015;49(12):768–74.

[22] Serner A, Weir A, Tol JL, Thorborg K, Roemer F, Guermazi A, et al. Can standardised clinical examination of athletes with acute groin injuries predict the presence and location of MRI findings? Br J Sports Med 2016;50(24):1541–7.

[23] Falvey ÉC, King E, Kinsella S, Franklyn-Miller A. Athletic groin pain (part 1): a prospective anatomical diagnosis of 382 patients—clinical findings, MRI findings and patient-reported outcome measures at baseline. Br J Sports Med 2016;50(7):423–30.

[24] Whittaker JL, Small C, Maffey L, Emery CA. Risk factors for groin injury in sport: an updated systematic review. Br J Sports Med 2015;49(12):803–9.

[25] Weir A, Jansen JA, van de Port IG, Van de Sande HB, Tol JL, Backx FJ. Manual or exercise therapy for long-standing adductor-related groin pain: a randomised controlled clinical trial. Man Ther 2011;16(2):148–54.

[26] Holmich P, Uhrskou P, Ulnits L, Kanstrup IL, Nielsen MB, Bjerg AM, et al. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. Lancet 1999;353(9151):439–43.

[27] King E, Franklyn-Miller A, Richter C, O'Reilly E, Doolan M, Moran K, et al. Clinical and biomechanical outcomes of rehabilitation targeting intersegmental control in athletic groin pain: prospective cohort of 205 patients. Br J Sports Med 2018;52(16):1054–62.

[28] Mascarenhas VV, Rego P, Dantas P, Morais F, McWilliams J, Collado D, et al. Imaging prevalence of femoroacetabular impingement in symptomatic patients, athletes, and asymptomatic individuals: a systematic review. Eur J Radiol 2016;85(1):73–95.

[29] Kemp JL, Beasley I. 2016 International consensus on femoroacetabular impingement syndrome: the Warwick Agreement-why does it matter? Br J Sports Med 2016;50(19):1162–3.

[30] Agricola R, Waarsing J, Arden N, Carr A, Bierma-Zeinstra SMA, Thomas GE, et al. Cam impingement of the hip—a risk factor for hip osteoarthritis. Nat Rev Rheumatol 2013;9:630–4.

[31] Griffin DR, Dickenson EJ, O'Donnell J, Agricola R, Awan T, Beck M, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. Br J Sports Med 2016;50(19):1169–76.

[32] Agricola R, Bessems JHJM, Ginai AZ, Heijboer MP, Van Der Heijden RA, Verhaar JAN, et al. The development of cam-type deformity in adolescent and young male soccer players. Am J Sports Med 2012;40(5):1099–106.

[33] Tak I, Weir A, Langhout R, Waarsing JH, Stubbe J, Kerkhoffs G, et al. The relationship between the frequency of football practice during skeletal growth and the presence of a cam deformity in adult elite football players. Br J Sports Med 2015;49(9):630–4.

[34] Roels P, Agricola R, Oei EH, Weinans H, Campoli G, Zadpoor AA. Mechanical factors explain development of cam-type deformity. Osteoarthritis Cartilage 2014;22(12):2074–82.

[35] Frank JM, Harris JD, Erickson BJ, Slikker 3rd W, Bush-Joseph CA, Salata MJ, et al. Prevalence of femoroacetabular impingement imaging findings in asymptomatic volunteers: a systematic review. Arthrosc J Arthrosc Relat Surg–Off Publ Arthrosc Assoc North Am Int Arthrosc Assoc 2015;31(6):1199–204.

[36] Crossley KM, Pandy MG, Majumdar S, Smith AJ, Agricola R, Semciw AI, et al. Femoroacetabular impingement and hip OsteoaRthritis Cohort (FORCe): protocol for a prospective study. J Physiother 2018;64(1):55.

[37] Heerey JJ, Kemp JL, Mosler AB, Jones DM, Pizzari T, Souza RB, et al. What is the prevalence of imaging-defined intra-articular hip pathologies in people with and without pain? A systematic review and meta-analysis. Br J Sports Med 2018;52(9):581–93.

[38] Thorborg K, Reiman MP, Weir A, Kemp JL, Serner A, Mosler AB, et al. Clinical examination, diagnostic imaging, and testing of athletes with groin pain: an evidence-based approach to effective management. J Orthop Sports Phys Ther 2018;48(4):239–49.

[39] Kemp JL, Crossley KM, Agricola R, Schache AG, Pritchard M. Hip-related pain. In: Brukner PD, Bahr R, Blair S, Cook JL, Crossley KM, McConnell J, et al., editors. Brukner and Khan's clinical sports medicine. Sydney: McGraw Hill; 2017. p. 510–44.
[40] Reiman MP, Goode AP, Cook CE, Hölmich P, Thorborg K. Diagnostic accuracy of clinical tests for the diagnosis of hip femoroacetabular impingement/labral tear: a systematic review with meta-analysis. Br J Sports Med 2015;49(12):811.
[43] Maslowski E, Sullivan W, Forster Harwood J, Gonzalez P, Kaufman M, Vidal A, et al. The diagnostic validity of hip provocation maneuvers to detect intra-articular hip pathology. PM & R–J Inj Funct Rehabil 2010;2(3):174–81.
[45] Reiman MP. Orthopedic clinical examination 1ed. USA: Human Kinetics Publishers; 2016.
[53] Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. Br J Sports Med 2016;50(19):1180.
[54] Griffin DR, Dickenson EJ, Wall PDH, Achana F, Donovan JL, Griffin J, et al. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomised controlled trial. Lancet 2018;391(10136):2225–35.
[55] Kemp JL, Coburn SL, Jones DM, Crossley KM. The physiotherapy for femoroacetabular impingement rehabilitation study (physioFIRST): a pilot randomized controlled trial. J Orthop Sports Phys Ther 2018;48(4):307–15.
[56] Freke M, Kemp J, Semciw A, Sims K, Russell T, Singh P, et al. Hip strength and range of movement are associated with dynamic postural control performance in individuals Scheduled for arthroscopic hip surgery. J Orthop Sports Phys Ther 2018;48(4):280–8.
[57] King MG, Lawrenson PR, Semciw AI, Middleton KJ, Crossley KM. Lower limb biomechanics in femoroacetabular impingement syndrome: a systematic review and meta-analysis. Br J Sports Med 2018;52(9):566–80.
[58] Mendis MD, Wilson SJ, Hayes DA, Watts MC, Hides JA. Hip flexor muscle size, strength and recruitment pattern in patients with acetabular labral tears compared to healthy controls. Man Ther 2014;19(5):405–10.
[59] Haefeli P, Steppacher S, Babst D, Siebenrock K, Tannast M. An increased iliocapsularis-to-rectus-femoris ratio is suggestive for instability in borderline hips. Clin Orthop Relat Res 2015;473:3725–34.
[60] Diamond LE, Van den Hoorn W, Bennell KL, Wrigley TV, Hinman RS, O'Donnell J, et al. Coordination of deep hip muscle activity is altered in symptomatic femoroacetabular impingement. J Orthop Res 2017;35:1494–504.
[61] Rutherford DJ, Moreside J, Wong I. Differences in hip joint biomechanics and muscle activation in individuals with femoroacetabular impingement compared with healthy, asymptomatic individuals: is level-ground gait analysis enough? Orthop J Sports Med 2018;6(5). 2325967118769829.
[62] Lamontagne M, Ng KCG, Mantovani G, Catelli DS. Biomechanics of femoroacetabular impingement. In: Doral MN, Karlsson J, editors. Sports injuries: prevention, diagnosis, treatment and rehabilitation. Berlin, Heidelberg: Springer Berlin Heidelberg; 2015. p. 783–95.
[63] Kemp JL, Schache AG, Makdissi M, Sims K, Crossley KM. Greater understanding of normal hip physical function may guide clinicians in providing targeted rehabilitation programmes. J Sci Med Sport/Sports Med Aust 2013;16:292–6.
[64] Thorborg K, Petersen J, Magnusson SP, Hölmich P. Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sports 2010;20(3):493–501.
[65] Thorborg K, Bandholm T, Schick M, Jensen J, Hölmich P. Hip strength assessment using handheld dynamometry is subject to intertester bias when testers are of different sex and strength. Scand J Med Sci Sports 2011:n/a-n/a.
[66] Kemp JL, Risberg MA, Schache AG, Makdissi M, Pritchard MG, Crossley KM. Patients with chondrolabral pathology have bilateral functional impairments 12 to 24 Months after unilateral hip arthroscopy: a cross-sectional study. J Orthop Sports Phys Ther 2016;46(11):947–56.
[67] Hatton AL, Kemp JL, Brauer SG, Clark RA, Crossley KM. Dynamic single-leg balance performance is impaired in individuals with hip chondropathy. Arthritis Care Res 2014;66(5):709–16.
[68] Lewis CL, Sahrmann SA, Moran DW. Effect of hip angle on anterior hip joint force during gait. Gait Posture 2010;32(4):603–7.
[69] Johansson A, Karlsson H. The star-excursion balance test: criterion and divergent validity on patients with femoral acetabular impingement. Man Ther 2016;26:104–9.
[70] Gribble P, Hertel J, Pliskey P. Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train 2012;47(3):339–57.
[71] Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M. Validity and reliability of the nintendo wii balance board for assessment of standing balance. Gait Posture 2010;31(3):307–10.
[72] Ardern CL, Glasgow P, Schneiders A, Witvrouw E, Clarsen B, Cools A, et al. 2016 consensus statement on return to sport from the first world congress in sports physical therapy, bern. Br J Sports Med 2016;50(14):853–64.
[73] Wörner T, Thorborg K, Stålman A, Webster K, Olsson HM, Eek F. 5 Return to sport and psychological readiness following hip arthroscopy. a cross-sectional study covering return-rates 3–39 months after femororacetabular impingement surgery. Br J Sports Med 2018;52(Suppl. 1):A2-A.
[74] Thorborg K, Tijssen M, Habets B, Bartels E, Roos E, Kemp JL, et al. Patient-reported outcome questionnaires for young to middle-aged adults with hip and groin disability: a systematic review of the clinimetric evidence. Br J Sports Med 2015. In press.
[75] Stratford PW, Binkley J, Solomon P, Gill C, Finch E. Assessing change over time in patients with low back pain. Phys Ther 1994;74(6):528–33.
[76] Naal FD, Miozzari HH, Kelly BT, Magennis EM, Leunig M, Noetzli HP. The hip sports activity scale (HSAS) for patients with femoroacetabular impingement. Hip Int 2013;23(2):204–11.
[77] Kurtze N, Rangul V, Hustvedt B-E, Flanders WD. Reliability and validity of self-reported physical activity in the Nord-Trøndelag Health Study (HUNT 2). Eur J Epidemiol 2007;22(6):379–87.
[78] Craig CL, Marshall AL, Sjorstrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35(8):1381–95.
[79] Medicine ACoS. ACSM's guidelines for exercise testing and prescription. 10th ed. Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins; 2017.
[80] Toigo M, Boutellier U. New fundamental resistance exercise determinants of molecular and cellular muscle adaptations. Eur J Appl Physiol 2006;97(6):643–63.

[81] Heerey J, Risberg MA, Magnus J, Moksnes H, Ødegaard T, Crossley K, et al. Impairment-based rehabilitation following hip arthroscopy: postoperative protocol for the HIP ARThroscopy International Randomized Controlled Trial. J Orthop Sports Phys Ther 2018;48(4):336–42.
[82] Ross JR, Nepple JJ, Philippon MJ, Kelly BT, Larson CM, Bedi A. Effect of changes in pelvic tilt on range of motion to impingement and radiographic parameters of acetabular morphologic characteristics. Am J Sports Med 2014;42(10): 2402–9.
[83] Charlton PC, Bryant AL, Kemp JL, Clark RA, Crossley KM, Collins NJ. Single-leg squat performance is impaired 1 to 2 years after hip arthroscopy. PM&R 2016;8(4):321–30.
[84] Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. Br J Sports Med 2015;49(4):230–42.
[85] Kemp JL, Makdissi M, Schache AG, Finch CF, Pritchard MG, Crossley KM. Is quality of life following hip arthroscopy in patients with chondrolabral pathology associated with impairments in hip strength or range of motion? Knee Surg Sports Traumatol Arthrosc 2015:1–7.
[86] Lewis CL, Sahrmann SA, Moran DW. Effect of position and alteration in synergist muscle force contribution on hip forces when performing hip strengthening exercises. Clin Biomech 2009;24(35–42).
[87] Correa T, Crossley K, Kim H, Pandy M. Contributions of individual muscles to hip joint contact force in normal walking. J Biomech 2010;43:1618–20.
[88] Ishoi L, Thorborg K, Kraemer O, Holmich P. Return to sport and performance after hip arthroscopy for femoroacetabular impingement in 18- to 30-year-old athletes: a cross-sectional cohort study of 189 athletes. Am J Sports Med 2018. 363546518789070.
[89] Bennell KL, Spiers L, Takla A, O'Donnell J, Kasza J, Hunter DJ, et al. Efficacy of adding a physiotherapy rehabilitation programme to arthroscopic management of femoroacetabular impingement syndrome: a randomised controlled trial (FAIR). BMJ Open 2017;7(6).
[90] Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines. Osteoarthritis Cartilage 2008; 16(2):137–62.
[91] Sandal LF, Roos EM, Bogesvang SJ, Thorlund JB. Pain trajectory and exercise-induced pain flares during 8 weeks of neuromuscular exercise in individuals with knee and hip pain. Osteoarthritis Cartil 2016;24(4):589–92.
[92] Thorborg K, Kraemer O, Madsen A-D, Hölmich P. patient-reported outcomes within the first year after hip arthroscopy and rehabilitation for femoroacetabular impingement and/or labral injury: the difference between getting better and getting back to normal. Am J Sports Med 2018, 0363546518786971.
[93] Wright JG, Einhorn TA, Heckman JD. Grades of recommendation. JBJS 2005;87(9):1909–10.
[94] Jordan MA, Van Thiel GS, Chahal J, Nho SJ. Operative treatment of chondral defects in the hip joint: a systematic review. Curr Rev Musculoskelet Med 2012;5(3):244–53.
[95] Kemp JL, Collins NJ, Makdissi M, Schache AG, Machotka Z, Crossley K. Hip arthroscopy for intra-articular pathology: a systematic review of outcomes with and without femoral osteoplasty. Br J Sports Med 2012;46(9):632–43.
[96] Kemp JL, MacDonald D, Collins NJ, Hatton AL, Crossley KM. Hip arthroscopy in the setting of hip osteoarthritis: systematic review of outcomes and progression to hip arthroplasty. Clin Orthopaed Relat Res 2015;473(3):1055–73.
[97] Bozic KJ, Chan V, Valone FH, Feeley BT, Vail TP. Trends in hip arthroscopy utilization in the United States. J Arthroplast 2013;28(8):140–3.
[98] Mansell NS, Rhon DI, Meyer J, Slevin JM, Marchant BG. Arthroscopic surgery or physical therapy for patients with femoroacetabular impingement syndrome: a randomized controlled trial with 2-year follow-up. Am J Sports Med 2018 May;46(6):1306–14.
[99] Grant LF, Cooper DJ, Conroy JL. The HAPI 'Hip Arthroscopy Pre-habilitation Intervention' study: does pre-habilitation affect outcomes in patients undergoing hip arthroscopy for femoro-acetabular impingement? J Hip Preserv Surg 2017; 4(1):85–92.
[100] Kemp JL, Moore K, Fransen M, Russell TG, Freke MD, Crossley KM. A pilot randomised clinical trial of physiotherapy (manual therapy, exercise and education) for early-onset hip osteoarthritis post-hip arthroscopy. Pilot Feasibility Stud 2018;4(16).