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# Femoroacetabular Impingement Syndrome: Evaluating Postoperative Rehabilitation Progress and Return to Sport Readiness

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Health and Rehabilitation Sciences

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## Abstract

Femoroacetabular impingement syndrome (FAIS) is a common cause of non-arthritis hip pain and reduced physical activity in active young adults. It is defined as a motion-related disorder of the hip with a triad of symptoms, clinical signs, and imaging findings that represent symptomatic premature contact between the proximal femur and the acetabulum. There are two anatomical morphologies that can cause FAIS, cam, and pincer, but patients can present with a mixed pathology. Patients typically undergo hip arthroscopy to repair damage to the joint and recess the bone causing the impingement. These procedures can result in positive outcomes for the patient, like reduced pain and symptoms, but research continues to investigate the optimal methods of ensuring a patient can return to their desired level of function and sports performance after surgery.

Postoperative return to sport guidelines and their efficacy are highly variable. Guidelines are typically broken down to four, five, or six phases of rehabilitation, but return to sport criteria are also variable and based on criteria for other lower extremity injuries. Developing safe, effective, and reproducible guidelines for patients with FAIS after surgery is difficult because they lack clinical data and optimal methods for evaluating a return to sport readiness lack consensus.

Practicing physiotherapists and orthopaedic surgeons who work with patients with FAIS appear to rely heavily on their own level of professional experience when making a postoperative return to sport recommendations rather than an established protocol. Their methods and outcomes for evaluating a patient's functional progress at postoperative follow-up periods and return to sport readiness are highly variable depending on a clinician's type of practice.

Hip arthroscopy is an effective procedure to reduce impingement and improve a patient's quality of life. A safe, effective, and reproducible postoperative return to sport guideline has not been established. Future studies should assess the if recommended outcomes are suitable to evaluate return to sport

readiness and determine which prognostic factors can predict if a patient with FAIS can safely return to sport after surgery to ensure they can remain physically active throughout their life.

## **Summary for Lay Audience**

Mechanical hip impingement is a common cause of non-arthritic hip pain and reduced physical activity in active young adults. Hip arthroscopy is an effective procedure to reduce impingement and improve a patient's quality of life. These procedures can result in positive outcomes for the patient, like reduced pain and symptoms, but research continues to investigate the optimal methods of ensuring a patient can return to their desired level of function and sports performance after surgery. Safe, effective, and reproducible postoperative return to sport guidelines needs to be established because practicing physiotherapists and orthopaedic surgeons currently appear to base postoperative return to sport recommendations on their own expert opinion rather than evidence-based practices.

## Co-Authorship Statement

- Chapter 1 Trevor Day- Sole Author
- Chapter 2 Trevor Day- Sole Author
- Chapter 3 Trevor Day- Study Design, Search Strategy, Inclusion/Exclusion Criteria, Data Extraction, Manuscript Preparation, Manuscript Submission
- Nick Pasic, MD- Study Design, Search Strategy, Inclusion/Exclusion Criteria, Manuscript Review
- Laura Churchill, MPT/PhD- Search Strategy, Manuscript Review
- Ryan Degen, MD- Inclusion/Exclusion Criteria, Manuscript Review
- Dianne Bryant, PhD- Manuscript Review
- Chapter 4 Trevor Day- Study Design, Survey Distribution, Data Analysis, Manuscript Preparation, Manuscript Submission
- Greg Alcock, PT- Survey Review & Design, Manuscript Review
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- Dianne Bryant, PhD- Manuscript Review
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- Chapter 5      This study has been approved by ethics and is currently collecting data.

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# Chapter 1

## 1 Introduction

### 1.1 Background and Rationale:

Corrective hip arthroscopy procedures for femoroacetabular impingement syndrome (FAIS) and research investigating its pathoanatomy and management increased nearly five-fold from 2001 to 2011.<sup>1,2</sup> FAIS is a mechanical disorder of the hip with a triad of symptoms, clinical signs and imaging findings that represent symptomatic abnormal contact between the proximal femur and the acetabulum.<sup>3</sup> Two distinct patterns of FAIS exist: cam and pincer, but a mixed pattern with a cam predominance is most common.<sup>4</sup> These deformities can result in impingement within a physiologic range of motion causing pain and limitations in function.<sup>3</sup> Cam impingement is a femoral-sided problem, where there is an aspherical femoral head or decreased offset between the head and neck of the femur.<sup>5</sup> In contrast, pincer impingement is an acetabular-sided problem where there is anterosuperior acetabular over-coverage.<sup>5</sup> Recent data from a cohort study of 500 patients 20 to 49 years of age indicates cam and pincer morphologies are present in approximately 20.5% (Confidence Interval (CI): 14.1 to 26.9%) and 7.6% (CI: 3.9 to 11.4%) of Canadians, respectively.<sup>6</sup> Only 3% (CI: 1.5 to 4.5%) of patients with a cam or pincer deformity are clinically diagnosed with FAIS in Canada.<sup>6</sup>

Observational studies indicate that patients with symptomatic FAIS are typically highly active youth or young adults with a history of playing competitive sports.<sup>7-12</sup> Non-operative management, such as physiotherapy to improve hip stability, neuromuscular control, and movement patterns, is typically exhausted before surgeons recommend corrective hip arthroscopy.<sup>3</sup> Arthroscopic procedures repair any labral damage and resect the bone to eliminate any ongoing impingement.<sup>13</sup> Techniques like labral preservation, osseous resection or capsular repair can improve patient-reported outcome measures at short-to mid-term postoperative follow-up periods,<sup>14-19</sup> but consensus is lacking as to when patients can safely return to sport after surgery.

Postoperative return to sport guidelines and criteria for patients with FAIS are widely variable because the optimal methods to evaluate a patient's functional capabilities and readiness to return to sport lack consensus.<sup>20</sup> Some research suggests using clinical and functional outcomes postoperatively to evaluate a patient's ability to return to sport;<sup>14,21</sup> however, this evidence appears to lack consensus.<sup>22</sup> Recommended postoperative outcome measures, including patient-reported outcomes, physical exams, and performance-based measurements are also poorly reported, and most are not considered valid or reliable for patients with FAIS.<sup>20</sup> To ensure patients safely return to sport postoperatively, clinicians need return to sport criteria as well as valid and reliable outcome measures to evaluate their patients' functional progress and progress them safely to return to sport.

Some evidence indicates FAIS may increase an individual's risk of developing osteoarthritis (OA) of the hip.<sup>5,23,24</sup> Developing a safe and effective rehabilitation guideline for patients with FAIS and a postoperative protocol for return to sport could prevent or reduce a patient's risk of OA later in life, which may reduce future healthcare spending. To measure safety and efficacy, we first need to understand the outcome measures and return to sport criteria currently utilized in postoperative return to sport protocols for patients with FAIS. Next, the utility of these outcome measures must be established so that higher quality measures are adopted widely into practice, higher quality research can be conducted, and the interpretability of measures becomes more common place which may increase the uptake of new knowledge into practice. Finally, researchers and clinicians must identify factors predictive of successful return to sport so they can develop specific clinical prediction rules and better determine when patients are ready for return to sport after surgery. As a result, clinicians could tailor postoperative programs to suit their patient's specific needs, reduce the risk of reinjury, and deliver higher quality patient-centered care.

## **1.2 Objectives:**

The main objective of this thesis was to identify postoperative rehabilitation protocols and criteria clinicians currently use to evaluate readiness to return to sport. I will address these objectives in two

papers: 1) a scoping review summarizing published postoperative return to sport criteria and outcome measures to evaluate a patient's readiness to return to sport; 2) an international survey of physiotherapists and orthopaedic surgeons investigating current clinical practices and outcome measures used to measure postoperative recovery and readiness for return to sport in patients with FAIS. Lastly, I will present a protocol for a prospective observational cohort study to examine the postoperative functional recovery patterns of patients with FAIS aged 16 to 36 years, and identify prognostic factors for return to sport, and investigate the utility of common outcome measures.

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Tanzer M, and Noiseux N. Osseous Abnormalities and Early Osteoarthritis: The Role of Hip Impingement. *Clinical Orthopaedics and Related Research*. 2004;429: 170–177. doi: 10.1097/01.blo.0000150119.49983.ef.

## Chapter 2

### 2 Literature Review

The purpose of this chapter is to describe the history, etiology, epidemiology, and management of femoroacetabular impingement syndrome (FAIS), and post-operative rehabilitation guidelines. Lastly, I will summarize literature gaps related to FAIS, specifically, why current postoperative return to sport guidelines for FAIS patients need to be improved and the steps necessary to establish a safe, reliable, and effective RTS criteria for these patients following hip arthroscopy.

#### 2.1 Definition of FAIS:

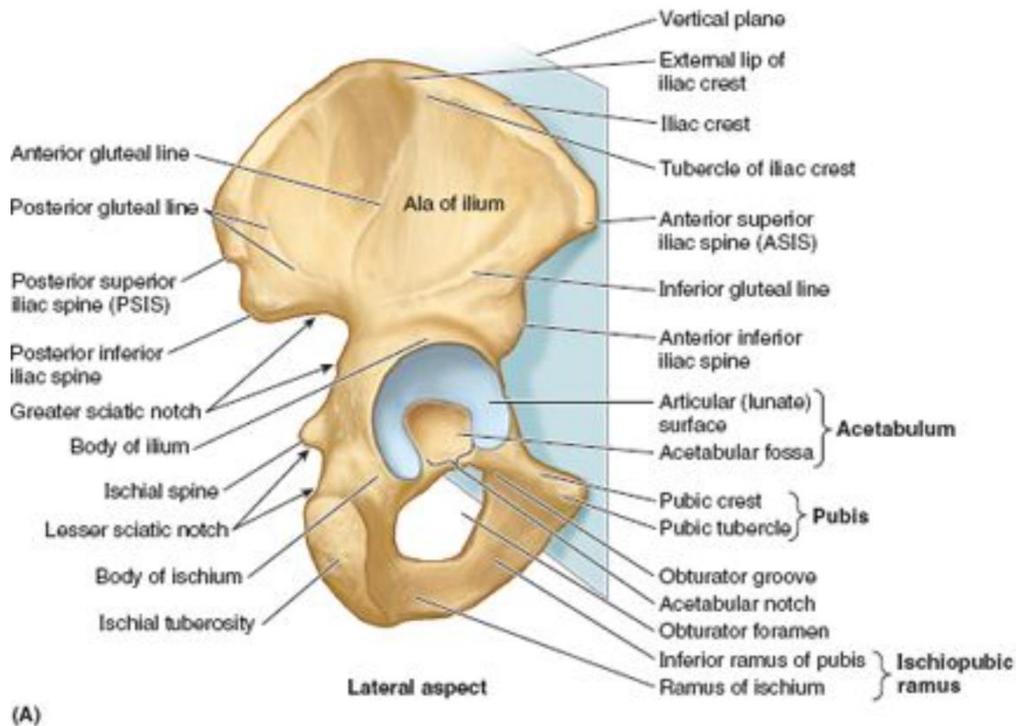
The concept of hip impingement was first described by Smith-Petersen in 1936, but the term femoroacetabular impingement was defined in 2003 in a paper describing its links to osteoarthritis (OA).<sup>1</sup> It was defined as a condition caused by abnormal contact between the head of the femur and the acetabulum due to abnormal morphologic features of the proximal femur or acetabulum.<sup>1</sup> A decade later, a new definition for FAI was proposed by researchers from the University of Pennsylvania highlighting five essential elements: 1) abnormal morphology of the femur and/or acetabulum; 2) abnormal contact between the two structures; 3) vigorous supraphysiological motion causing collision of the two structures; 4) excessive and repetitive ROM at the hip that causes pain; and lastly 5) the presence of soft tissue damage.<sup>2</sup> However, terms describing specific hip morphologies such as *asymptomatic FAI* or *radiological FAI*, commonly used throughout the literature,<sup>3-5</sup> made it difficult for clinicians and researchers to properly diagnose the disorder.<sup>6</sup> As a result, a consensus statement was published by a multidisciplinary team, consisting of a single patient, 22 expert clinicians and academics from nine different countries and five different specialties, called the Warwick Agreement.<sup>7</sup> This panel of experts strengthened previous definitions by emphasizing the need for a patient's symptoms to be included in a diagnosis. The Warwick Agreement has now been endorsed around the world by more than 25 clinical societies and defines “FAI syndrome” (FAIS) as, “a motion-related disorder of the hip with a triad of symptoms, clinical signs, and

imaging findings that represents symptomatic premature contact between the proximal femur and the acetabulum”.<sup>3</sup>

## 2.2 Anatomy

### 2.2.1 The Hip Joint:

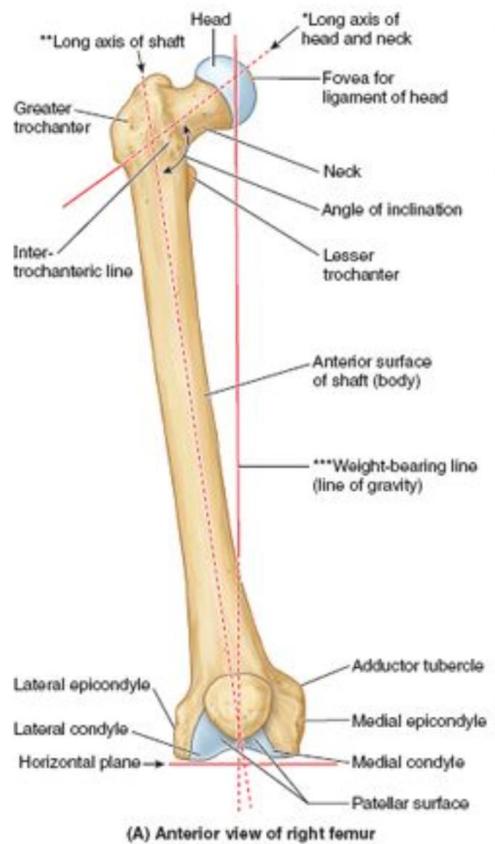
The hip joint is comprised of four bones -- the femur, the ilium, the ischium and the pubis -- and is a multiaxial ball and socket synovial joint that connects the lower limb to the pelvic girdle.<sup>8</sup> More specifically, the hemi-spherical head of the femur articulates within the lunate surface of the acetabulum, which sits within the non-articular acetabular fossa formed by the three pelvic bones.<sup>9</sup> The joint is designed for stability over a wide range of movement and supports the entire weight of the body during ambulation.<sup>9</sup> Similar to the glenohumeral joint in the shoulder, the hip joint is capable of flexion, extension, abduction, adduction, internal rotation, external rotation and circumduction.<sup>8,9</sup> It is also considered one of the most stable joints in the entire body due its complete ball and socket construction, joint capsule and surrounding musculature.<sup>8,9</sup>



**Figure 1.** Illustration depicting the bony pelvis and its associated bony landmarks that comprise the hip joint. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

### 2.2.2 The Femur:

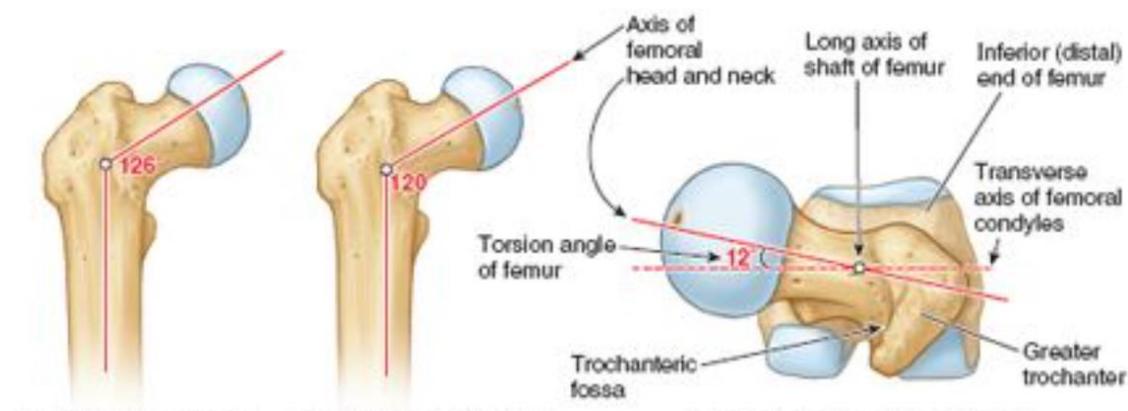
The femur is the longest bone in the body and makes up the “ball” of the hip joint. The bone has a neck, two trochanters and a head located at its proximal end, as well as a shaft and two condyles located at its distal end.<sup>8,9</sup> The head of the femur is normally spherical in shape, covered mainly in hyaline cartilage, except for the fovea, and is encompassed by the acetabulum.<sup>8,9</sup>



**Figure 2** Anatomical structures of the femur and its bony landmarks. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

The neck connects the head to the shaft of the femur and projects slightly forward and superomedial at approximately 125 degrees,<sup>9</sup> but it may range from 100 to 146 degrees depending on an

individual's sex, ethnicity, and body mass index (BMI).<sup>10</sup> The shaft also descends medially at approximately seven degrees with a normal torsion, or twist, that plays an important role in the stability and function of the hip.<sup>9</sup> The torsion angle of the femur is widely variable, and can be classified as anteversion or retroversion depending on the angle. Although the angle varies depending on an individual's sex, ethnicity and BMI, some evidence suggests it may have, on average, 14 degrees of anteversion.<sup>10,11</sup>



**Figure 3.** Typical Angles of the Femoral Neck and Head. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

### 2.2.3 The Acetabulum:

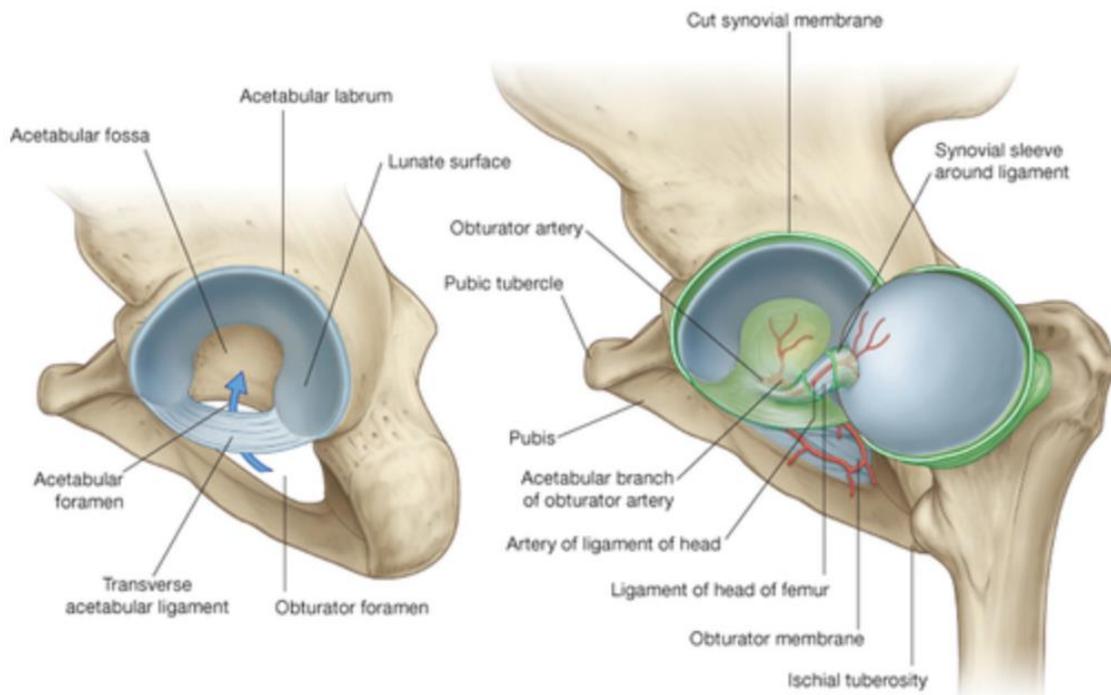
The acetabulum is a hemispherical concave hollow formed by the ischium, ilium, and pubis bones located on the lateral aspect of the hip bone and makes up the “socket” of the joint.<sup>8</sup> The semilunar articular surface of the acetabulum is covered in articular cartilage and is raised slightly by a fibrocartilaginous collar known as the acetabular labrum.<sup>9</sup> The two ends of the labrum form the acetabulum notch, which is converted into the acetabular foramen by the transverse acetabular ligament.<sup>9</sup>

The acetabular fossa is devoid of hyaline cartilage and serves as the origin for the ligamentum teres femoris (LTF) that inserts onto the fovea on the head of the femur, but does not contribute to the overall stability of the hip joint.<sup>8,9</sup> Within the fossa, the LTF is surrounded by a malleable synovial fat pad that can change shape to accommodate variations in the joint's congruity and movement.<sup>8,9</sup> The main

functions of the acetabular cartilage are to absorb shock, decrease friction and allow a free range of joint motion in all planes, and to dissipate the weight during weight-bearing activities of the lower extremity.

### 2.2.4 The Labrum:

The labrum creates suction on the femoral head, holding it within the acetabular fossa, which in turn contributes to the hip's overall stability.<sup>12</sup> The structure of the labrum also increases the joints surface area, perhaps by as much as 22%.<sup>13</sup> A greater surface area reduces contact stress and prevents damage to the articular surfaces by maintaining a layer of pressurized intra-articular fluid that ensures the joint is well lubricated during locomotion.<sup>12</sup> Although the three layers of the labrum dissipate the stress of loads across the hip joint, it makes the interface between the labrum, cartilage, and bony acetabulum vulnerable to shear forces.<sup>8,9</sup> Anatomical morphologies associated with conditions like FAIS and hip dysplasia often increase shearing forces that lead to injuries like labral tears.<sup>14</sup> Overall, the acetabular labrum deepens the socket of the hip joint, improves the hip's stability, and may help to prevent damage to the articular cartilage.

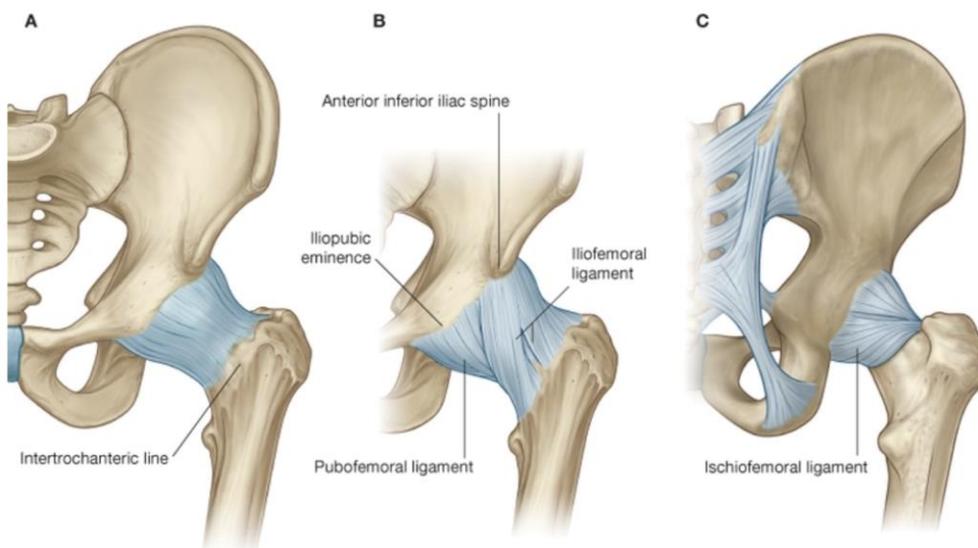


**Figure 4.** Anatomical illustration of the acetabulum, fossa, and surrounding structures of the hip. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

### 2.2.5 The Hip Joint Capsule:

The hip joint capsule plays a critical role in supporting the body's weight in upright postures and during locomotion. It is formed by a fibrous layer and synovial membrane that maintains functional mobility and joint stability.<sup>8</sup> The synovial membrane, located proximally along the femoral neck and edge of the head, lines the internal surfaces of the fibrous layer and any intracapsular bony surfaces that are devoid of articular cartilage.<sup>8,9</sup>

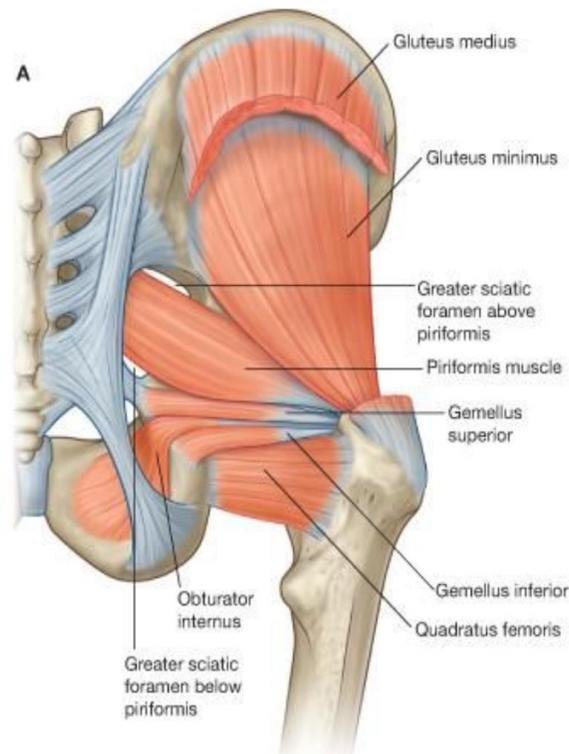
The fibrous membrane consists of three primary fibrous ligaments -- iliofemoral, ischiofemoral, and pubofemoral -- that enclose the hip, and contribute significantly to the joints stability along with the muscles of the gluteal region.<sup>9,15</sup> Multivariate analysis of data collected from a study involving 13 human cadavers demonstrated that the two arms of the iliofemoral ligament are stiffer and stronger than the posterior ischiofemoral ligament.<sup>16</sup> Another attempt to quantify the importance of the fibrous membranes in stabilizing the hip was done on cadaveric specimens and demonstrated that the zona orbicularis, a ligament on the neck of the femur, may contribute highly to the stability of the hip.<sup>17</sup>



**Figure 5.** Illustration depicting the anatomical ligaments and joint capsule of the hip. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

### 2.2.6 Supporting Musculature:

Muscles that surround and support the hip joint form the gluteal region of the body and are organized into two groups: superficial and deep.<sup>8,9</sup> The deep group of small muscles include the piriformis, obturator internus, gemellus superior, gemellus inferior and quadratus femoris; while the superficial group are larger and include the gluteus minimus, gluteus medius, gluteus maximus, and the tensor fasciae latae.<sup>8,9</sup> These muscles attach to bony landmarks on the pelvis and femur and work to stabilize the hip during ambulation and functional activities by effectively surrounding the joint. The muscles of the gluteal region act as lateral rotators of the thigh and stabilize the hip joint by working with the surrounding ligaments to steady the femoral head in the acetabulum.<sup>8</sup>

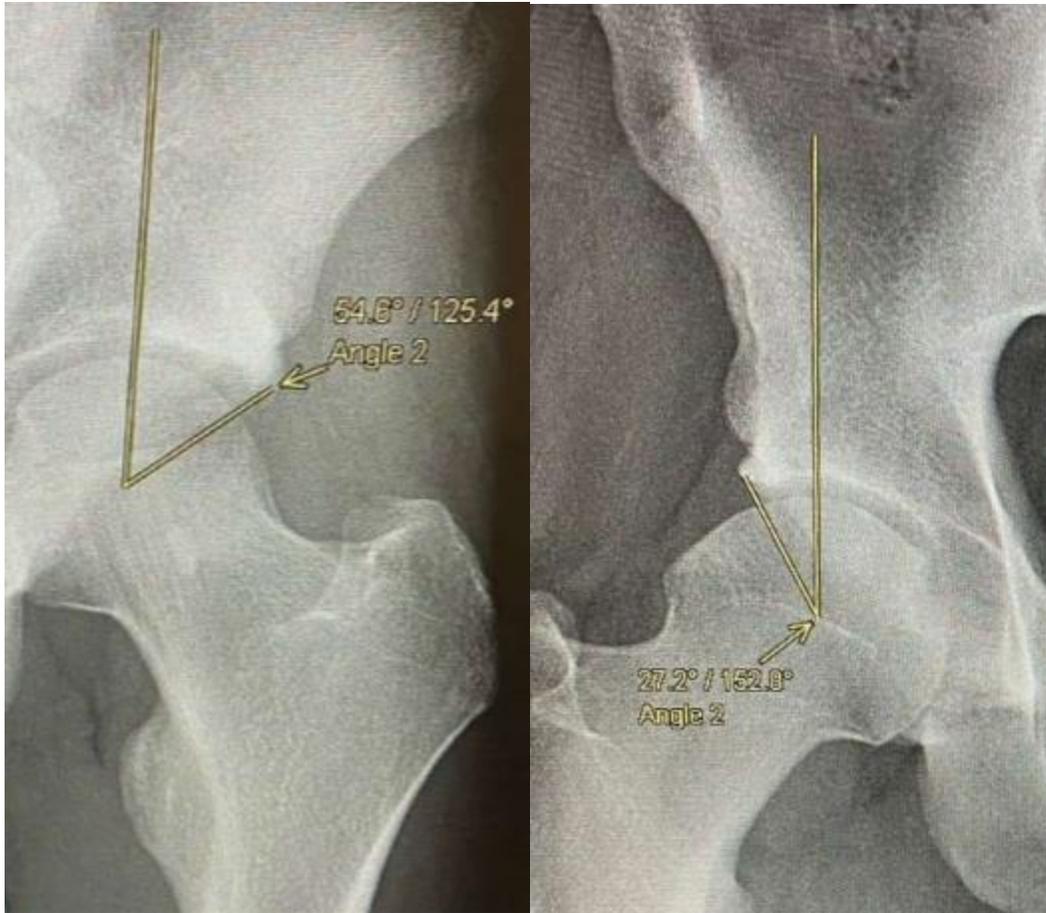


**Figure 6.** Illustration of the muscles in the gluteal region and surrounding the hip joint. Reproduced with permission from Elsevier Churchill Livingstone in the format of a dissertation/thesis.<sup>9</sup>

### **2.2.7 Joint Congruity:**

Congruity of the articular surfaces in the hip joint is important for transferring weight to the femur when standing. Anteriorly, the femoral head articulates mostly within the joint capsule and rarely is less than 40% of the head in contact with the acetabulum in any position.<sup>8,9</sup> The hip has the most congruity when it is flexed at 90 degrees, abducted five degrees, and externally rotated 10 degrees.<sup>8</sup>

Joint congruity and movement can decrease depending on the degree in which the acetabulum overlies the femoral head which is often determined radiographically.<sup>8,9</sup> The Wiberg lateral center edge angle (LCEA) and the Lequesne anterior center edge angle (ACEA) quantify the lateral and anterior acetabular coverage, respectively, and can be used to diagnose hip pathomorphology.<sup>18,19</sup> Historically, the pathological cut-off values are less than 20 degrees for the LCEA, and more than 12 degrees for the ACEA.<sup>18,19</sup> However, Werner et al.<sup>20</sup> estimated normative values for the LCEA and ACEA retrospectively by examining 1,226 anteroposterior pelvic radiographs (AP) from 2,452 hips. On average, the LCEA and ACEA were 33.6 degrees (95%CI 33.2 to 34.0) and 4.4 degrees (95%CI 4.1 to 4.7) respectively, and no clinically relevant differences between sexes or limbs were found.<sup>20</sup>

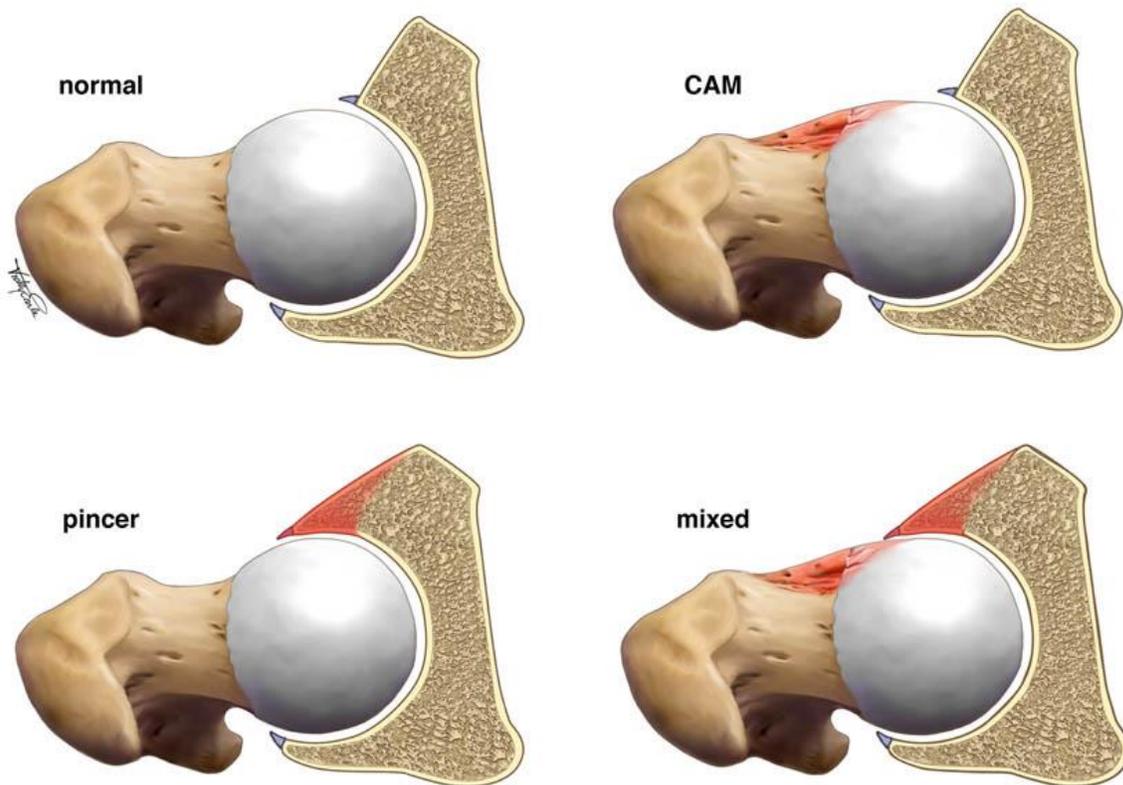


**Figure 7.** Left: AP radiograph of a left hip illustrating an abnormal Lateral center edge angle (LCEA) measuring 54.6° Right: AP radiograph of a left hip illustrating a normal Lateral Center Edge Angle (LCEA) measuring 27.2°

### 2.3 Etiology

The etiology of FAIS is not fully understood, but may be associated with developmental factors, genetics, pediatric hip diseases or surgical hip procedures.<sup>21,22</sup> It is believed that static or dynamic mechanical etiologies may cause anatomical morphologies, which in turn, can result in abnormal contact between the femur and acetabulum.<sup>1,17,23</sup> Static etiologies may include hip dysplasia, femoral anteversion, and femoral valgus, whereas dynamic etiologies include rim lesions and impingement.<sup>22</sup> According to Ganz et al.,<sup>1</sup> there are two main classifications of impingement: cam or pincer, each with a different pathomechanical explanation. During flexion, a cam morphology causes a non-spherically shaped femoral head to jam into the acetabulum and a pincer morphology causes linear contact at the acetabular rim and the femoral head-

neck junction. Patients often present with both entities, called mixed cam-pincer FAIS, and the cam morphology is often more predominant.<sup>1,14,25</sup> Both cam and pincer morphologies mechanically cause insufficient congruence between the articular surfaces of the hip joint, which can cause FAIS and could lead to asymmetric wear of cartilage on the acetabulum and femoral head, as well as associated injuries like labral tears.



**Figure 8.** Illustration of cam and pincer morphologies associated with femoroacetabular impingement syndrome. Copyright 2012-2013 Clinical Sports Medicine all rights reserved.

### **2.3.1 Developmental Factors:**

The majority of FAIS research has focused on the developmental factors in patients with cam-type morphologies. Some evidence suggests cam-type FAIS is the result of bony adaptations caused by excessive loading of the hip during adolescence when the growth plate is still open and which may continue until it is closed.<sup>26</sup> Recent findings hypothesize that frequently playing high intensity sports at a

young age may increase a patient's chances of developing a cam-type morphology.<sup>27</sup> Tak et al.<sup>28</sup> retrospectively examined 126 hip radiographs collected from 63 professional Dutch soccer players to determine if players who frequently played high intensity soccer when they were skeletally immature had a higher prevalence of cam morphologies. There was a higher prevalence of cam-type morphologies on Frog-leg lateral (FLL) radiographs in athletes who started playing before the age of 12 (64%) than among those who started after 12 years of age (40%).<sup>28</sup> Similar findings have also been found in several other retrospective and prospective studies.<sup>22</sup> Regardless of symptoms, when compared to non-athletes or controls, cam-type morphologies are reportedly more common in athletes.<sup>29,30</sup> Although the exact reason and loading pattern remains to be determined, cam-type morphologies may be more associated with larger growth plate extension towards the femoral neck and sports with repetitive hip flexion and hip rotation such as soccer, basketball and ice hockey.<sup>31</sup>

### **2.3.2 Genetic Factors:**

Developmental factors during adolescence may increase an individual's risk of developing anatomical morphologies in the hip. Some individuals may be more genetically predisposed to FAIS than others. Although one study found no statistically significant differences in genetic influences among patients with FAIS when compared to healthy individuals,<sup>32</sup> another study suggested that single nucleotide polymorphisms may be associated with the development of pincer-type morphologies.<sup>33</sup> Genetic factors may also make the cartilage in the hip more vulnerable to damage caused by abnormal hip morphologies.<sup>34</sup> Pollard et al.<sup>35</sup> compared 64 patients with FAIS to their siblings and a control group to examine the importance of genetic factors in the etiology of FAIS. Ninety-six siblings of patients treated for FAIS, and 77 controls were recruited and examined for clinical and radiographic evidence of FAIS. Siblings were more than two and a half times more likely to have symptoms and radiographic signs of a bilateral hip morphology (Relative Risk (RR) = 2.6). Cam morphologies were more prevalent in 46.9% of siblings compared to pincer morphologies. When compared to the control group, siblings of patients treated for FAIS were nearly 50% more likely to show signs and symptoms of a pincer morphology (RR

= 1.4).<sup>35</sup> However, strong methodological genetic studies are lacking and evidence at this time cannot attribute any genetic factors to a higher risk of developing an anatomical morphology or FAIS.<sup>21,22</sup>

### **2.3.3 Pediatric Disease:**

FAIS may develop due to pediatric hip diseases that alter the shape of the femoral head-neck contour or hip mechanics, like slipped capital femoral epiphysis (SCFE) or Legg-Calve-Perthes disease (LCPD). SCFE has been associated with growth spurts, obesity and endocrine disorders in youth between the ages of eight and 15.<sup>36,37</sup> It occurs in approximately 10.8 cases per 100,000 children<sup>36,37</sup> and causes bony changes of the femoral head that may contribute to the eventual development of anatomical morphologies, degenerative changes, and FAIS overtime.<sup>38,39</sup> When compared to patients with normal hips, several retrospective and observational cohort studies have identified a larger prevalence of cam-type morphologic characteristics, such as femoral head-neck junction bony prominences and reduced head-neck offsets, in patients with SCFE.<sup>40-42</sup> Evidence suggests SCFE may lead to the development of cam-type morphology, but more research is still needed to determine if the severity of SCFE is correlated to the development of FAIS later in life.<sup>22,41</sup> Although SCFE may lead to the development of FAIS, the relative contribution of LCPD is not completely understood. The results of a multi-center longitudinal study suggest the deformities associated with LCPD are complex, different, and radiographically diagnosing FAIS in these types of hips is exceedingly difficult.<sup>43</sup> Tannast et al.<sup>44</sup> retrospectively compared individuals diagnosed with FAIS to those with a history of LCPD using computed tomography (CT) and computerized 3-dimensional motion analysis. Inter-and extra-articular signs of impingement were more common in the LCPD hips on both the femur and acetabulum, but radiographically, the nature of the bony impingement did not appear to mimic the mechanisms associated with FAIS.<sup>44</sup> However, it is important to note several methodological concerns. First, the retrospective study lacks the scientific strength to determine a cause-and-effect relationship. Second, it was significantly underpowered and the LCPD group was over 50% smaller than the FAIS and control group. This is likely to have affected the internal validity and precision of these results. Therefore, the effects of LCPD on the development of anatomical

deformities that cause bony impingement in these types of hips, and how these deformities are related to the mechanisms associated with FAIS requires further investigation.

### **2.3.4 Direct Trauma & Surgical Procedures:**

Direct trauma, like femoral neck fractures, or surgical overcorrections for conditions such as hip dysplasia, could alter a patient's hip mechanics and lead to the development of FAIS later in life. A case series by Eihler, Myers and Ganz.<sup>45</sup> followed nine patients with a clinical history of a femoral neck fracture. Patients demonstrated on-going groin pain and were positive on anterior impingement tests. Eight patients underwent osteochondroplasty to correct a flat contour near the femoral head-neck junction that was determined to result from an insufficient reduction of the fracture. Intraoperatively, these patients also had anterior labral and adjacent acetabular cartilage lesions associated with FAIS.<sup>45</sup> Malunion of a femoral head-neck fracture may lead to the development of cam-type morphologies associated with FAIS if precise reduction of these fractures are not performed.

Corrective surgical procedures for acetabular deformities, like hip dysplasia, may lead to pincer-type FAIS if proper care is not taken by the surgeon. Yasunage et al.<sup>46</sup> recruited 104 patients (115 hips) with a mean age of 34.7 years who were undergoing rotational acetabular osteotomy for hip dysplasia. Patients were followed post-operatively for 13 years to investigate if surgical overcorrections for hip dysplasia can lead to the development of FAIS. Preoperatively, crossover signs were only observed in 7% of the hips, but postoperatively it was observed in 42.6% of the hips. A greater number of posterior wall signs were also observed postoperatively (63.5%) compared to preoperative findings (60.9%) but differences in pre and postoperative clinical or radiographic findings after 12 months were not observed.<sup>46</sup> However, these results are disputed by a longitudinal study conducted by Ziebarth et al.<sup>47</sup> Methodological differences, such as sample size, inclusion criteria, type of surgery, clinician experience and length of follow-up could have contributed to the different results from these studies. Although positive clinical impingement tests have been associated with postoperative radiographic crossover signs,<sup>46</sup> more research is still needed to determine if corrective hip surgeries lead to the development of pincer-type FAIS.

### **2.3.5 Summary:**

Factors contributing to the development of FAIS are not completely understood. Although several factors associated with the possible etiology of FAIS have been identified,<sup>21,22</sup> more longitudinal studies and randomized trials are needed to determine if they have a cause-and-effect relationship with the development of cam- or pincer-type morphologies.

## **2.4 Mechanism of Injury**

### **2.4.1 Cam-Type FAIS:**

The principal problem with Cam-type impingements is an anterior-to-anterolateral anatomical offset between the femoral neck and head junction or aspherical femoral head that resembles the shape of a ‘pistol grip’.<sup>24,25</sup> During flexion the anterosuperior aspect of the acetabulum becomes compressed by the non-spherical extension of the femoral head causing a shear stress at the junction between the labrum and the cartilage, and at the subchondral tidemark.<sup>24,25</sup> As a result, the labrum stretches and compresses the cartilage, pushing it centrally, and separating the two anatomical structures,<sup>24</sup> which commonly leads to an outside-in delamination of the anterosuperior acetabular cartilage and labral separation.<sup>24,25</sup>

### **2.4.2 Pincer-Type FAIS:**

In pincer-type FAIS, there is a linear impact of the acetabular rim against the head-neck junction on the femur as a result of general or focal acetabular overcoverage.<sup>24,25,48</sup> General over coverage can occur when the acetabular fossa or medial head of the femoral head overlaps with the ilioischial line medially, which is often referred to as Coxa profunda or acetabular protrusion, respectively.<sup>49,50</sup> In contrast, focal over coverage can occur due to acetabular retroversion such as crossover, posterior wall, or ischial spine signs.<sup>51</sup> Respectively, these signs are evident on AP radiographs when the superior aspect of the anterior acetabular wall crosses over the posterior wall to the lateral side, the center of the femoral head is located lateral to the posterior acetabular wall, or the shape of the ischial spine protrudes medially towards the pelvic rim.<sup>52</sup> Both types of over coverage result in a deep acetabulum that limits the ROM of the hip.<sup>24,25</sup>

Impingement often occurs at the anterosuperior rim of the acetabulum during flexion, internal rotation and abduction of the hip.<sup>24,25,48</sup> In this position the head of the femur begins to sublux posteriorly, increasing the pressure between the posteromedial aspect of the head and posteroinferior aspect of the acetabulum, which can often cause a contrecoup lesion.<sup>24</sup>

## **2.5 Associated Injuries**

Structural abnormalities in the hip joint can increase the biomechanical stress during upright posture, ambulation, and physical activity, resulting in reactive hip pain and mechanical injuries.<sup>25,51</sup> Over time the repetitive stress and trauma caused by FAIS can lead to labral tears, possible hip OA, chondral delamination, and detachment of the labrum.<sup>1,22,24,53</sup> FAIS primarily causes damage to the cartilage or an acetabular labral lesion, but chondral defects and degenerative arthritis have also been observed.<sup>1,24,53,54</sup> Labral lesions, or tears, can be classified by their location, morphology, or etiology.<sup>55</sup> Two distinct types of labral tears were observed by Seldes et al.<sup>56</sup> in cadavers and freshly frozen hips. The first type was a detachment between the labrum and the articular hyaline cartilage. These tears were observed in 89% of the specimens and commonly occurred perpendicular to the articular surface or subchondral bone. While the second type consisted of one or more ‘cleavage plane’ tears within the substance of the labrum. It commonly extended perpendicular to the labral surface in 11% of the specimens.<sup>56</sup> In patients with a mixed type of FAIS, labral tears are typically observed at the eleven, twelve and one o’clock positions, but posteroinferior lesions and cartilage damage can also occur.<sup>24</sup>

### **2.5.1 Long Term Effects:**

FAIS can also cause secondary damage to the acetabulum and femur-like chondral delamination, and possibly the development of OA in the hip later in life. A scoping review by Mella et al.<sup>57</sup> identified the secondary damage that can occur because of FAIS. Secondary damage occurs near the peripheral portion of the anterolateral region of the acetabulum where the mechanical impact of the femoral head typically occurs. Direct and repetitive impact to the joint surface in patients with pincer-type FAIS may lead to

degeneration of the labral and chondral surface. Comparatively, in cam-type FAIS, the impact of the femoral head-neck junction can cause chondrolabral disruption and progressive chondral delamination. Over time the mechanical stress on the joint increases, due to a limited chondrolabral junction, which damages the lunate surface and leads to secondary injuries such as cartilage delamination, full thickness chondral defects, diffuse thinning of the cartilage, osteophyte development, and damage to the chondral surface of the femoral head.<sup>57</sup>

Some research also suggests FAIS may predispose young and active populations to early arthritis.<sup>1,54,58</sup> This was first hypothesized when abnormal hip morphologies were first discovered by Stulberg et al.<sup>59</sup> and later suggested by Ganz et al.<sup>1</sup> when the authors presented their findings of early idiopathic arthritis in patients with FAIS. A 20-year longitudinal follow-up study of 1,003 women by Thomas et al.<sup>58</sup> discovered that cam-type FAIS may be associated with the development of radiographic OA in the hip. On average, for every one degree increase in the alpha angle above 65 degrees on FLL radiographs, women increased their risk of OA in the hip by 5% (Odds Ratio (OR) 1.05 [95% CI: 1.01-1.09]) and women with acetabular dysplasia had a lower risk of OA in the hip, on average, by 13% (OR 0.87 [95% CI 0.78-0.96]) for every one degree reduction in LCEA below 28 degrees.<sup>58</sup> Moreover, the results of a recent retrospective study involving 1,870 patients (mean age of 32.2 years) diagnosed with FAIS who had undergone hip arthroscopy between 2004 and 2013 and had no history of OA in the hip, found that 21.9% of patients were diagnosed OA in hip within two years after surgery.<sup>60</sup> However, these findings were based on diagnostic codes rendered by a medical provider, not radiographic evidence, and inferences in causality cannot be drawn due to methodological weaknesses in this study. As a result, the odds of developing OA in the hip may be significantly different if an alternative criterion to diagnose it, such as a radiograph, is considered and a stronger methodology is used. Therefore, although there may be a body of research suggesting that FAIS increases the risk of young active patients developing OA in the hip in the future, there is a lack of high-quality evidence in the form of randomized trials and systematic reviews to support this hypothesis.

### **2.5.2 Summary:**

While the pathomechanical patterns of injury associated with cam- and pincer-type FAIS may differ considerably, both can lead to abnormal wear-and-tear on the joint, such as cartilage or acetabular labrum lesions, chondral defects including delamination and detachment, and, possibly, OA in the hip in the future.

### **2.6 Diagnosis**

An accurate diagnosis of FAIS is made by combining the findings of a good history, a physical exam which can include specific provocative tests, and appropriate medical imaging. A clinical diagnosis of FAIS requires a morphologic assessment of the patient's hip using radiography and cross-imaging because a large portion of the general population can have a cam- or pincer-type morphology but be asymptomatic.<sup>7,30,61</sup> Hence, patients are diagnosed with FAIS only if they present with a triad of symptoms, radiographic and clinical evidence of an impingement.



**Figure 9.** Pathway of Management & Diagnosis for FAIS. Reproduced with permission from BMJ Publishing Group Ltd<sup>7</sup>

### 2.6.1 Symptoms:

Patients with FAIS complain of motion-related or position-related pain in the hip or groin and describe symptoms of clinking, catching, locking, stiffness, difficulty playing sports, and restricted ROM or feelings of giving way.<sup>1,7,23</sup> This pain is often described by patients with FAIS as severe and limiting in their everyday life.<sup>7</sup> Pain has also been reported in the lateral hip, lateral and posterior thigh, anterior thigh, buttock, knee, and lower back and is typically described as having an insidious onset.<sup>23</sup> In an observational cohort study by Philippon et al.<sup>62</sup> 71% of 301 patients treated for FAIS reported difficulty or an inability to participate in their sport, and 85% complained of moderate or marked pain. The most reported locations were the groin (81%), the greater trochanter (61%), deep posterior buttock (52%) and the sacroiliac joint (23%). Symptoms greatly limiting their activity such as stiffness, weakness, clicking or snapping, and feelings of instability, were also reported by 33%, 34%, 25% and 26% of patients,

respectively.<sup>62</sup> If a patient is symptomatic for FAIS a thorough history of incidence of trauma and exercise frequency should be taken along with a full physical examination of the lower back and abdomen to assess for alternate causes of anterior groin pain.<sup>7</sup>

### **2.6.2 Clinical Testing:**

Upon physical examination, patients with symptoms of FAIS often present with restricted ROM, abnormal movement patterns, positive hip provocation tests and muscle tenderness around the hip.<sup>7</sup> ROM of the injured hip, on average, is nine (95% CI: 6.7 to 10), four (95%CI: 2.9 to 5.3), three (95%CI: 2.0 to 3.6), four (95%CI: 2.7 to 5.4) and three (95%CI: 2.3 to 4.6) degrees less than the non-injured limb for hip flexion, abduction, adduction, internal and external rotation, respectively.<sup>62</sup>

Tijssen, van Cingel, Willemen & de Visser<sup>63</sup> systematically examined 21 studies describing the diagnostic accuracy and validity of physical tests used to diagnose FAIS. Only three tests were deemed appropriate for clinicians to clinically assess patients with FAIS: the anterior hip impingement test, the Patrick sign test, and the resisted straight leg raise test.<sup>63</sup> These tests are considered positive if the patient reports a reproduction of pain or if there is a decrease in ROM compared to the non-injured leg.<sup>63</sup>

The anterior impingement is performed by flexing, adducting, and internally rotating a patient's hip and referred to as the FADIR test.<sup>64,65</sup> Reiman et al.<sup>66</sup> systematically examined the results of 1335 patients across 21 studies to investigate the diagnostic accuracy of 11 different clinical tests for diagnosing FAIS. All 21 studies were at high risk for bias. Thirteen of these studies examined the FADIR test but only eight were included in the meta-analysis. Four of these studies (188 participants) compared the FADIR test to magnetic resonance arthrogram (MRA) and the other four (319 participants) compared the FADIR test to surgery. Results from this analysis demonstrate the FADIR test has a sensitivity (Sn) ranging from 0.90 to 0.97 and a specificity (Sp) ranging from 0.02 to 0.23 when compared to MRA. Compared to surgery, the Sn and Sp of the FADIR test ranges from 0.98 to 1.00 and 0.01 to 0.18, respectively.<sup>66</sup> When compared to surgery and MRA the FADIR test has excellent Sn and poor Sp.<sup>66</sup> This is clinically important because it means if a positive FADIR test does not accurately identify patients with

an injury associated with FAIS, but a negative test means they likely do not have one. A positive FADIR test has also been significantly associated with symptoms of hip joint pain, but not with the prevalence of cam or pincer morphology in the same hip.<sup>67</sup>

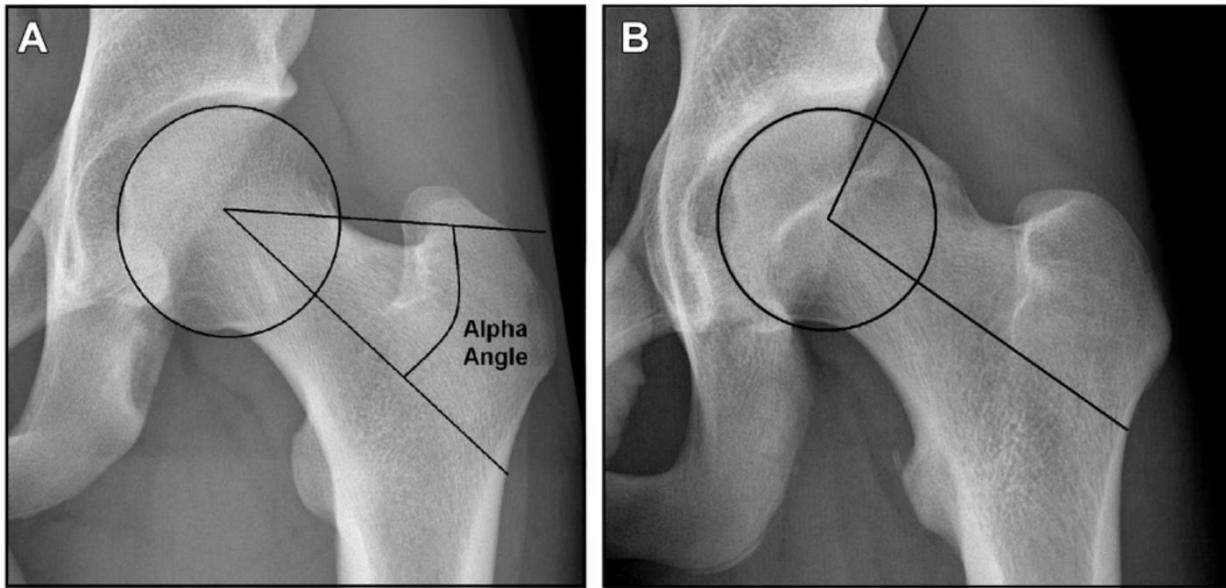
The Patrick sign is examined by flexing, abducting and externally rotating (FABER) a patient's hip and is also called the FABER test.<sup>64,65</sup> Three out of the 21 studies examined by Reiman et al.<sup>66</sup> compared the diagnostic accuracy of the FABER test to MRA and intra-articular injections. Results suggest the Sn and Sp of the FABER test is highly variable, ranging from 0.22 to 0.64 and 0.20 to 0.97 when compared to the MRA, respectively.<sup>66</sup> Published results are highly variable because they are underpowered. Larger cohort studies are needed to determine if the FABER test can accurately diagnose FAIS compared to MRA and surgery. Since both the FADIR and FABER tests cannot reliably diagnose FAIS in isolation, clinicians should support their findings with radiographic confirmation before making a diagnosis.<sup>7</sup>

### **2.6.3 Medical Imaging:**

Radiographic imaging is used to determine if a morphology is present and to rule out other potential causes for hip pain such as a fracture, acetabular dysplasia or OA.<sup>1</sup> Generally, AP radiographs of the pelvis are used to first identify and interpret the shape of the acetabulum.<sup>1,7,68</sup> A lateral orthogonal view of the symptomatic hip such as the cross-table lateral, Dunn or FLL is then taken to visualize and interpret the shape of the proximal femur and femoral neck.<sup>1,7,69</sup> Additionally, if surgical intervention is being considered for a patient with FAIS, clinicians should also consider ordering a computerized tomography (CT) or magnetic resonance imaging (MRI) to better characterize the type of morphology than radiographs can do alone.<sup>70,71</sup> Cross-sectional imaging of symptomatic FAIS hips can better assess femoral torsion, focal morphologies in the proximal femur and acetabulum, or any potential soft tissue lesions that may result in hip pain.<sup>7,71</sup> Clinicians interpret radiographic signs, such as alpha angles, crossover, and LCEA, to determine if an anatomic morphology is present in symptomatic and asymptomatic patients and, if so, identify its type.<sup>70,71</sup>

#### **2.6.4 Radiographic Signs:**

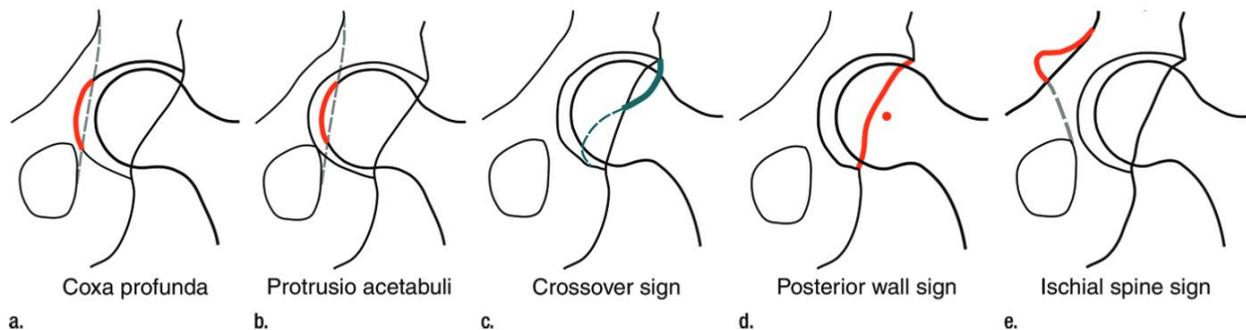
To identify the presence and size of a cam morphology, clinicians measure a patient's alpha angle. This is measured by drawing a line along the axis of the femoral neck to the center of the femoral head and a point where the head extends beyond the margin of a best-fit circle.<sup>70</sup> Two thresholds for alpha angle cut-off values for FAIS have been reported in orthopedic and radiologic literature. Although a cut-off threshold of 50 degrees has been reported throughout orthopedic literature,<sup>72,73</sup> 55 degrees commonly used because it is reported by both orthopedic and radiologic literature.<sup>71</sup> Interestingly, both groups cite the original study by Notzli et al.<sup>74</sup> who reported a maximal cut-off of 55 degrees and a minimum cut-off of 48 degrees, but a potential threshold of 50 degrees in the anterior position was also suggested. Larger alpha angles on lateral radiographs have been associated with larger acetabular rim chondral defects, as well as greater full thickness delamination of the acetabular cartilage and detachment at the base of the labrum.<sup>53</sup>



**Figure 10** The alpha angle quantifies the asphericity of the femoral head. A). A normal alpha angle of 41 is shown representing a spherical femoral head. B). An abnormal alpha angle of 98 is shown representing a cam deformity.

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In comparison, there are five morphologic signs of a pincer morphology on standard AP radiographs that represent either general or focal over coverage of the acetabulum: Coxa profunda, acetabular protrusion, crossover sign, posterior wall sign, and ischial spine sign.<sup>71</sup> Although the depth, orientation of the acetabulum, femoral-head neck profile, angle of the neck and torsion of the proximal femur can vary considerably within the general population,<sup>7,30,61</sup> an LCEA of 39 to 44 degrees indicates possible Coxa profunda, while an LCEA greater than 44 degrees could indicate protrusio acetabuli.<sup>50</sup>



**Figure 11.** Schematic of left hip as seen on anteroposterior views of pelvis demonstrate radiographic signs of (a, b) general over coverage of the acetabulum or (c–e) focal over coverage of the acetabulum due to acetabular retroversion. (a) Coxa profunda with floor of acetabular fossa (red line) overlapping ilioischial line (dashed line). (b) Protrusio acetabuli with medial aspect of femoral head (red line) overlapping ilioischial line (dashed line). (c) Crossover sign, also known as “figure of eight” sign. Superior aspect (solid green line) of the anterior acetabular wall (dashed green line) crosses over the posterior wall to the lateral side. (d) Posterior wall sign with center of femoral head (red dot) located lateral to posterior acetabular wall (red line). (e) Ischial spine sign with shape of ischial spine protruding medial of pelvic rim. Reproduced with permission from Radiological Society of North America (RSNA) in the format of a dissertation/thesis.<sup>71</sup>

### **2.6.5 Diagnostic Accuracy of Radiographic Signs:**

Several research studies have attempted to evaluate the diagnostic accuracy of interpreting radiographic signs of cam or pincer morphologies. Barton et al.<sup>72</sup> recruited 68 patients 17 to 60 years old with unilateral hip pain and an MRA of the symptomatic hip to determine the diagnostic accuracy of AP radiograph alpha angle measurements and reliability of Dunn view radiographs compared to MRA. AP, cross-table lateral and Dunn radiographs were all taken in the supine position and followed a standardized protocol. The Dunn view was taken with the patient supine with the symptomatic hip flexed at 90° and abducted 20° in neutral rotation. Radiographs and MRA images were interpreted by two blinded radiologists and alpha angles were measured using the method laid out by Notzli et al.<sup>74</sup> On average, alpha angles for the AP, cross-table, and Dunn radiographs were: 65 degrees (CI: 34 to 118), 63 degrees (CI: 32 to 101) and 61 degrees (CI: 35 to 94), respectively. Alpha angles had moderate to excellent inter- and intra-rater reliability values ranging from 0.75 to 0.99. When compared to MRI, alpha angles measured on Dunn view radiographs demonstrated the best diagnostic accuracy (0.90, CI: 0.80 to 0.96). The Dunn view had a high level of sensitivity and specificity running from 0.78 to 0.97 and 0.68 to 0.97, respectively while the AP view alone had the lowest sensitivity of 0.60 (CI: 0.44 to 0.75) and the cross-table lateral had the worst specificity of 0.63 (CI: 0.38 to 0.84).<sup>74</sup> Therefore, the Dunn view radiograph is better suited for measures and assessing a patient's alpha angle.

A smaller cohort study by Kutty et al.<sup>75</sup> recruited 46 patients to determine if the LCEA can correctly identify pincer morphologies in patients with symptomatic hip pain. Standard AP radiographs were taken and interpreted by two fellowship-trained radiologists. All FAIS radiographs were then assessed separately by two independent and blinded reviewers. Means and standard deviations (SD) of the LCEA for the pre-op, post-op and control groups were  $46.19 \pm 6.55$  degrees,  $38.34 \pm 5.71$  degrees and  $31.38 \pm 3.64$  degrees, respectively. The LCEA had a high pre- and postoperative inter- and intra-rater reliability of 0.96 and 0.98, respectively. An LCEA of  $\geq 40$  also had a Sn ranging from 0.62 to 0.95 and a Sp ranging from 0.94 to 1.00.<sup>75</sup> Additionally, Kappe et al.<sup>76</sup> examined if the crossover, posterior wall, or ischial spine sign could reliably detect a pincer deformity on 20 AP radiographs. Individually, all three signs demonstrated moderate inter-rater reliability of 0.51, 0.63 and 0.54, respectively. They also had moderate to substantial intra-rater reliability values of 0.73, 0.75 and 0.63.<sup>76</sup> The ischial spine sign has also demonstrated a Sn of 0.81, a Sp of 0.7, positive predictive value of 0.77, and a negative predictive value of 0.75 in cadaver hips.<sup>77</sup> The crossover, ischial spine and posterior wall signs are the least reliable and accurate radiographic signs to determine if a symptomatic patient suspected of FAIS has a morphology associated with pincer FAIS.

A more recent retrospective study by Ratzlaff et al.<sup>78</sup> examined the reliability and diagnostic accuracy of non-radiologists interpreting alpha angles, crossover signs, and the LCEA by randomly selecting 50 patients from a large longitudinal study involving 701 patients with hip pain. Twenty percent (10/50) of these patients were randomly selected from a single orthopedic practice in Vancouver, Canada, and were diagnosed with FAIS, arthroscopically, by the same orthopedic surgeon FAIS specialist. The three radiographic signs were interpreted independently by a blinded fellowship-trained musculoskeletal radiologist and 3rd year medical student with no prior experience scoring hip radiographs or FAIS. Prior to the study, the medical student was first trained by a non-participating radiologist on how to read digital radiographs of 25 hips obtained in patients who were not in the study cohort. The authors radiographically defined FAIS as either an LCEA  $> 40$  degrees, alpha angle  $> 55$  degrees, or the presence of a crossover sign. When compared to the trained radiologist, the 3rd year medical student had a Sn of 0.83 and a Sp of

0.87 using all three radiographic signs. Individually, the alpha angle (Sn: 0.87, Sp:0.85) and the LCEA (Sn: 0.92, Sp: 0.86) were the most accurate at radiographically diagnosing cam or pincer FAIS, respectively. To assess inter-rater reliability, the digital radiographs were re-randomized to a different order and re-assessed by the 3rd year medical student eight weeks after their initial assessment. Bland-Altman plots demonstrate overall intra-rater reliability values of 0.76 and a prevalence-adjusted bias-adjusted Kappa value of 0.72. Both the alpha angle and LCEA demonstrated good intra-rater reliability values of 0.97 and 0.87, but the crossover sign had a moderate to poor intra-rater reliability value of only 0.58.<sup>78</sup>

When compared to MRI, radiographic signs can be a valid and reliable tool for clinicians to determine the presence of a cam or pincer morphology. Evidence suggests the alpha angle and LCEA are the most reliable and accurate signs to evaluate on a patient's radiograph. Interpretation of radiographic signs are subject to human error and correct assessment of a patient's hip morphology depends on a clinician's experience identifying them, rather than their clinical years of experience.<sup>76</sup>

### **2.6.6 Summary:**

A wide range of physical, clinical, and radiographic tests are used by clinicians to diagnose FAIS and/or a labral pathology. Patients often present with hip pain in the anterior region of the hip and complain of being unable to participate in their chosen sport or activity. They will also have restricted range of motion in all planes of the hip and present with a compromised gait pattern or activity modification. A series of imaging techniques can be used to capture the anatomy of the joint and clinicians can interpret radiographic signs to determine if a patient has a cam or pincer morphology. However, thresholds for these signs lack consensus and most studies investigating the diagnostic accuracy of these signs lack methodological strength.<sup>63</sup> Interpretation of these radiographic signs appears to be highly variable depending on a clinician's experience interpreting them.<sup>71,76</sup> There is currently no single type of measurement capable of capturing the complex interaction between the anatomical structures of the hip

joint; hence, the presence of symptoms, clinical and radiographic signs must all be evident before a patient with symptomatic hip pain is clinically diagnosed with FAIS.<sup>7</sup>

## 2.7 Epidemiology

FAIS is a recognized cause of hip pain and reduced physical activity in adolescents and young adults aged 16 to 36 years of age but is more commonly diagnosed in younger and highly active populations.<sup>79-81</sup> Lee et al.<sup>82</sup> examined 362 hips in 338 consecutive patients (229 male and 109 female) with FAIS from July 2003 to May 2013. Most patients with FAIS were between the ages of 20 and 40 years of age (76.2%) and 48.3% of patients between the ages of 20 and 30 had either a cam, pincer, or mixed morphology. One hundred and fifty-six (43.1%) were involved in soccer (28.2%), baseball (23.1%) or taekwondo (22.4%) and 86 (55.1%), 43 (27.6%) and 27 (17.3%) of them had a cam, pincer, or mixed morphology, respectively.<sup>82</sup>

Certain types of sports and higher levels of competition may increase an individual's risk of developing FAIS. Among the patients recruited by Lee et al.,<sup>82</sup> one study found that highly competitive basketball players are 10-times more likely to have an alpha angle >55 degrees compared to age-matched volunteers who do not participate in competitive sports.<sup>83</sup> Additionally, semi-professional soccer players also have reportedly larger alpha angles than amateur players<sup>79</sup> and bony prominences are approximately 15% larger in youth soccer players during adolescence years over a mean follow-up of 2.4 years.<sup>82</sup> Furthermore, a prospective cohort study by Philippon et al.<sup>80</sup> aimed to determine the prevalence and size of alpha angles in youth hockey players and skiers aged 10 to 18 years of age. After grouping 61 youth hockey players and 27 youth skiers according to their USA classification, 75% of hockey players had an alpha angle >55 degrees compared to 42% of skiers. After adjusting for age, sex and level of competition, hockey players were also 4.5 times more likely to have an alpha angle >55 degrees on MRI than skiers.<sup>80</sup> It is possible that properties inherent to certain types of sports may place some athletes at a higher risk of developing FAIS than others.

It has been estimated that 10 to 15% of the general population who live with symptomatic hip pain may be clinically diagnosed with FAIS.<sup>54,85</sup> However, the recent study by Kopec et al.<sup>67</sup> indicates only 3% (95% CI: 1.5 to 4.5) of Canadians with symptomatic hip pain are diagnosed with FAIS. Data was obtained from 500 patients aged 20 to 49 years of age randomly selected from the metro Vancouver, Canada, area. Persistent or recurrent symptoms of hip joint pain were present in 28.1% (95% CI: 22.3 to 33.8) of the sample and 34.3% (95% CI: 27.6 to 41.1) had a positive FADIR test. A patient was deemed to have a cam or pincer morphology if they had an alpha angle >60 degrees on a Dunn radiograph or an LCEA >40 degrees on an AP radiograph. Within the sample, 20.5% (95% CI: 14.1 to 26.9) had a cam morphology and 7.6% (95% CI: 3.9 to 11.4) had a pincer morphology, but overall, 25.3% (95% CI: 18.7 to 31.9) had radiographic evidence of either a cam or pincer morphology. FAIS was more prevalent in men (3.4 % (95% CI: 1.3 to 5.4)) than females (2.7% (95% CI: 0.5 to 4.8)) regardless of age. Patients without symptoms of hip joint pain were 34% less likely to have a pincer or cam morphology after adjusting for age, sex, and BMI. However, patients with a positive FADIR test and symptomatic hip joint pain were four times more likely to be diagnosed with FAIS than those without symptoms (OR 3.98 (95% CI: 2.49 to 6.36) after adjusting for age, sex, and BMI.<sup>67</sup>

## **2.8 Management**

When considering different treatment options, clinicians should consider using a shared decision-making approach involving a multidisciplinary group of experts with the knowledge and ability to help patients make an informed decision.<sup>7</sup> Management strategies for patients diagnosed with FAIS include non-operative treatments, like rest, modifying activities, medications (oral or inter-articular injections) or physiotherapy, or surgical interventions like arthroscopy.<sup>7</sup>

### **2.8.1 Conservative Treatment:**

Conservative treatment for patients with FAIS is widely variable and poorly described but is often the first treatment of choice.<sup>7,86</sup> These can include education, activity modification, non-steroidal anti-

inflammatory drugs, intra-articular steroid injections, physiotherapy, or rest.<sup>7,87</sup> More research is needed to determine if conservative management strategies alone are effective for treating FAIS.<sup>7</sup>

### **2.8.2 Physiotherapy:**

The goal of physiotherapy treatment for patients diagnosed with FAIS is to improve a patient's hip stability, neuromuscular function, and movement patterns.<sup>7,87,88</sup> Physiotherapy led programs are based in part on the biomedical model of pain because a patients' symptoms often result from structural damage to the hip joint.<sup>87</sup> As a result, these programs may aim to correct any biomechanical deficiencies in patients with FAIS by improving their neuromuscular control and dynamic stability in the hip. More specifically, physiotherapy led programs may include exercises to strengthen muscles of the lower body, like the external rotators of the hip, hip flexors, hip abductors, and glutes, to improve a patients postural balance and dynamic stability of the hip joint.<sup>88</sup> Although there is a high degree of variability in the types of treatments physiotherapists can deliver, recent data demonstrates improvements in a patients passive range of motion, quality of life, and self-reported function.<sup>7,86,87,90</sup> Clinical guidelines appear to lack consensus, but physiotherapy can and should be considered initially for patients diagnosed with FAIS before undergoing corrective surgery.<sup>87,91,92</sup>

### **2.8.3 Surgery:**

When all nonoperative management strategies have been exhausted, a patient diagnosed with FAIS is considered a surgical candidate and will typically undergo arthroscopy, but in some cases open surgery is used.<sup>7</sup> Arthroscopic procedures use a series of portals, some located anterolaterally, anteriorly, and posterolateral, to visualize and correct bony abnormalities in the central and/or the peripheral compartments of the hip.<sup>93,94</sup> Arthroscopic techniques like acetabular rim trimming can be used to treat a pincer-type morphology and femoral osteochondroplasty to resect bone causing impingement can be used to correct a cam-type morphology.<sup>93,94</sup>

During open surgery, the Ganz technique is used to access the femoral head and acetabulum by safely dislocating the hip, which reduces the risk of avascular necrosis.<sup>95</sup> The Ganz technique is preferred when patients have a history of SCFE, LCPD, or clinical scenarios that are difficult to address arthroscopically such as Coxa profunda, complicated posterolateral cam lesions, or complex joint morphologies.<sup>94</sup> Contraindications for open surgery can include: extensive cartilage damage, anterior hip subluxation, and coup-contrecoup lesions.<sup>94</sup>. When surgical treatment for FAIS is necessary, the type of surgery performed often depends on the surgeon's preference, skill, and experience, but regardless, the goal is to reduce pain and improve the patient's level of function and ROM.<sup>94</sup>

#### **2.8.4 Non-Operative Management:**

Research is still uncertain as to when or why patients should be considered for an early surgical intervention and which form of treatment is the most effective.<sup>7</sup> Recently, three studies investigated whether conservative or surgical treatments of FAIS are more effective, but the findings are mixed. Physiotherapy could reduce a patient's symptoms for up to two years,<sup>87</sup> but two studies suggest patients treated arthroscopically may have better outcomes than if they are treated conservatively.<sup>96,97</sup> One additional study found no significant improvements or differences between the two forms of treatment.<sup>98</sup>

Griffin et al.<sup>90</sup> recruited and randomized 348 patients diagnosed with FAIS to receive either hip arthroscopy or a personalized hip therapy program and followed them for one year to determine which form of treatment was the most effective. After 12 months, both groups of patients showed improvements on the 33-question international hip outcome tool (iHOT-33), but higher scores were seen in patients who underwent hip arthroscopy. On average, iHOT-33 scores improved from 39.2 (SD: 20.9) to 58.8 (SD: 27.2) for patients in the hip arthroscopy group, and from 35.6 (SD: 18.2) to 49.7 (SD: 25.5) in the personalized hip therapy group. After adjusting for a patient's morphology type, sex, baseline scores and testing center, results indicated a mean difference (MD) in scores on the iHOT-33 of 6.8 (95%CI: 1.7 to 12.0) points in favor of patients in the hip arthroscopy group.<sup>90</sup> However, seven adverse events were

reported, and it was determined that five were related to the personalized hip program. Moreover, the absence of masking to treatment allocation biases these results.

Palmer et al.<sup>96</sup> also investigated the effectiveness of arthroscopy versus physiotherapy using a similar methodology. The authors recruited 222 patients with FAIS from seven secondary and tertiary care centers across England. Patients in the physiotherapy group received a goal-based program tailored to their individual needs, and eight physiotherapy treatments over five months. The active daily living subsection of the hip outcome score (HOS-ADL) was measured using a minimum clinically important difference (MCID) between groups of 9 points. Data from only 89% (100 patients) of participants from the hip arthroscopy group and 80% (88 patients) from the physiotherapy group was available for analysis after eight months. Among patients in the arthroscopic group, the mean HOS-ADL score was 78.4 (95% CI: 74.4 to 82.3), and 69.2 (95% CI: 65.2 to 73.3) for patients who received the physiotherapy program. When compared with the physiotherapy group, the mean HOS-ADL scores were also 10.0 (95% CI: 6.4 to 13.6) points higher in the arthroscopic group after adjusting for a patient's baseline score, age, sex, and study site. An MCID was achieved in 51% (95% CI: 41 to 61) of participants allocated to arthroscopic surgery and 32% (95% CI: 22 to 42) of those allocated to the physiotherapy programme.<sup>96</sup> It is important to note that the HOS-ADL is an aggregate score that can only be interpreted as part of the whole HOS and not individually as these results suggest. Moreover, although no adverse events were reported and the results indicate hip arthroscopy is more effective than physiotherapy, methodological concerns such as no intention to treat (ITT) analysis, loss of follow-up, and cross-over bias this evidence.

In comparison, the results of a randomized trial by Mansell et al.<sup>97</sup> investigating the effectiveness of arthroscopy and physiotherapy in 80 patients with FAIS found no significant differences in patient-reported outcome scores. One-hundred and four active and non-active members were eligible for this study, but only 80 participated. Patients were recruited from a single, large military hospital after being referred by a single orthopaedic clinic and 91.3% (73 patients) were active-duty members. After randomization, patients in the physiotherapy group received 12 treatments and were followed for a period of two years. Both groups demonstrated improvements on PROMs, but the results were not significant.

An MD of 3.8 (95% CI: -6.0 to 13.6); 1.8 (95% CI: -11.2 to 14.7); and 6.3 (95% CI: -6.1 to 18.7) were seen on the HOS-ADL, HOS sport specific (HOS-S) and iHOT-33, respectively. A median global rating of change (GRC) of zero ("felt about the same") was also reported in both groups after two years.<sup>97</sup>

Clinicians should use caution when interpreting the findings of this study because a number of methodological concerns, such as high rates of crossover, significantly underpowered analysis, and the inclusion of patients with less than two years of follow-up in the primary analysis,<sup>97</sup> biases these results and decreases the strength of this evidence. Therefore, more research is still needed to determine if conservative or surgical treatment is more effective at improving self-reported level of function and change in patients diagnosed with FAIS.

## **2.9 Prognosis**

The long-term prognosis of FAIS is still unknown,<sup>7</sup> but patients who do not receive proper treatment will likely become more symptomatic over time.<sup>98</sup> Patients diagnosed with FAIS and treated with physiotherapy or surgery can experience a gradual decrease in their symptoms and often see some improvement in their self-reported function,<sup>7</sup> but more research and long-term studies are still needed to determine the effectiveness of non-operative management strategies in isolation or when combined with surgery. Patients who undergo open surgery may experience long term benefits for up to 10 years,<sup>99</sup> but hip arthroscopy generally results in greater postoperative improvements in a patient's quality of life and self-reported level of function.<sup>100</sup> However, arthroscopic surgeons must use caution when performing certain procedures, like a femoral osteoplasty, because an inadequate resection of bone can result in revision surgery and a less desirable outcome for the patient.<sup>101,102</sup>

## **2.10 Prevention**

The role of preventive measures such as physiotherapy or surgical treatment for asymptomatic individuals is mixed. Although some research indicates that cam-type FAIS may be associated with hip OA,<sup>58,84,103</sup> it is still unknown if pincer-type morphologies are also associated with hip OA, or if treatments can prevent

the development of arthritis later in life.<sup>7</sup> There is currently no way to determine if asymptomatic patients with cam- or pincer-type morphologies will develop symptomatic FAIS, or how to prevent them from being diagnosed, and therefore no evidence to justify surgical interventions in asymptomatic individuals.<sup>7</sup>

## **2.11 Postoperative Rehabilitation**

Postoperative rehabilitation guidelines are highly variable depending on a therapist's experience, training, and knowledge. There are various types of postoperative rehabilitation programs following arthroscopic surgery for FAIS, but most of them outline four to six stages of rehabilitation and have a general timeline- or criteria-based progression protocol.<sup>80,104-107</sup> Generally, the goal postoperatively is to first protect the repairing tissues, maintain pain-free ROM, and then slowly progress patients to more sport-specific exercises and functional training at later stages in their rehabilitation.<sup>48,106,108,109</sup> Types of exercise can depend on the patient's preoperative abilities and the clinician's expertise, but often range from early weight-bearing, range of motion, and isometric-specific to specific concentric, eccentric and sport-related exercises like single-leg squats or plyometrics.<sup>48,106,108,109</sup> However, clinical data supporting the use of published postoperative rehabilitation guidelines are poorly and inconsistently reported, which has made it difficult to establish reproducible rehabilitation guidelines in this population.<sup>86</sup> More research is still needed to determine which postoperative outcome measures, exercises, and what types of programs should be used and how long they should be.

### **2.11.1 Patterns of Recovery:**

Postoperative improvements in patient-reported outcome measures following a criteria-based physiotherapy program have been commonly reported, but clinical outcome data is lacking.<sup>110</sup> Domb et al.<sup>106</sup> recruited and followed 738 patients diagnosed with FAIS to determine if defined, criteria-based postoperative rehabilitation protocols can improve patient-reported outcome measures following hip arthroscopy. The primary outcomes of interest were the modified Harris hip scores (mHHS), HOS-ADL, HOS-S, the non-arthritic hip score (NAHS), and visual analog scales (VAS) for pain. Only 500 patients

were available for follow-up at the 2-year point, but these patients' demonstrated improvements in self-reported measures of function and pain. Their mean age was 38 years (Range: 14.1 to 76.3), 61.7% (367 patients) were female and all the patients underwent either an acetabuloplasty (69.9%), femoroplasty (65.9%) or labral repair (59.2 %) arthroscopic procedure. On average, postoperative mHHS, HOS-S, HOS-ADL, NAHS, and VAS scores improved from 61.29 to 82.92, 40.96 to 70.07, 62.79 to 83.04, 57.97 to 80.41, and 5.86 to 2.94, respectively.<sup>106</sup> The precision and variability of these results cannot be determined because SD or CI for this data is not reported. Criteria-based rehabilitation programs have also been shown to improve a patient's hip ROM postoperatively in a few studies, but it is poorly reported, and it has not yet been determined if or when a patient achieves full-normal ROM postoperatively.<sup>109,111</sup> Furthermore, the postoperative functional recovery patterns of patients diagnosed with FAIS is unknown because data from recommended postoperative functional outcome measures has not been collected.<sup>110</sup>

## **2.11.2 Summary:**

Postoperatively, the goal is to protect the healing tissues and maintain pain-free ROM. Afterwards, postoperative guidelines are variable and progress patients based on a specific criteria or predefined timeline. Criteria-based rehabilitation programs have been shown to improve patient-reported outcome measures in FAIS patients postoperatively, but no clear guideline has been established due to a lack of data and consensus on the reported outcome measures. Therefore, a clear and concise way of determining how to measure a patient's progress throughout their rehabilitation program, when they should move to the next phase, or when they can safely return to sport has not been established.

## **2.12 Return to Sport**

### **2.12.1 Predictive RTS Factors:**

Several different types of athletes diagnosed with FAIS have been able to return to sport: basketball players, soccer players, football players, and skiers. Between 57%<sup>112</sup> and 94%<sup>113</sup> of patients recovering

from hip arthroscopy for FAIS return to sport postoperatively. It is estimated 30% of patients that do return to sport are able to return to their same, optimal or desired level of performance.<sup>112</sup> However, data from a systematic review and meta-analysis of 1634 athletes found that 74% returned to their same preoperative level of sport following hip arthroscopy.<sup>110</sup> A recent systematic review by Sogbein et al.<sup>114</sup> investigated the demographic and clinical predictors of positive and negative outcomes after hip arthroscopy in patients diagnosed with FAIS. Positive outcomes were defined as decreased hip pain or higher functional outcome scores; while an outcome was deemed negative if a patient's hip pain persisted, range of motion decreased, nonoperative treatments failed or if another operation like revision or total hip arthroplasty (THA) was elected. Of the 39 studies that met the inclusion criteria for this study, the mean follow-up for the 11 comparative and 28 noncomparative studies was 22.4 months (95% CI: 10 to 34) and 40.8 months (95% CI: 6 to 120), respectively. Younger age, male sex, preoperative intra-articular hip injections, and a BMI <24.5 kg/m<sup>2</sup> were predictive of positive outcomes, while surgical morphology, labral repair, poor ROM, and preoperative symptom duration were predictive of negative outcomes following surgery.<sup>114</sup> This review did not investigate if these factors are predictive of a patient's ability to return to sport, but rather if a patient experienced a positive or negative outcome. Therefore, more research is still needed on active or athletic populations undergoing hip arthroscopy for unilateral FAIS to identify if any of these factors can predict when and if these patients can safely return to sport.

### **2.12.2 Evaluating RTS Readiness:**

A recent systematic review by Grzybowski et al.<sup>115</sup> examined postoperative rehabilitation protocols reporting outcomes of hip arthroscopy. Only five of the eighteen protocols reported a specific criterion to clear a patient with FAIS to return to sport. Recommended clinical and functional outcome measures were poorly reported, but tests commonly utilized to evaluate readiness for return to sport include the vail-hip sports test (VHST), the star excursion balance test (SEBT), hand-held dynamometry (HHD), the Y-balance test (YBT) (also known as the modified SEBT), functional movement screening (FMS), the step-down test (SDT) and functional sports performance tests like the single leg hop test (SLHT) and drop

vertical jump (DVJ). The exact criteria for each of these outcome measures was not defined in these five studies, and rather tended to focus on clinical experience and subjective evaluation.<sup>115</sup> Furthermore, the utility of these tests is based on the measurement properties in populations with other lower extremity injuries such as anterior cruciate ligament (ACL),<sup>116,117</sup> knee OA,<sup>118</sup> and chronic patellar joint instability (CPI).<sup>119</sup> Although a wide range of postoperative functional outcome measures are recommended for patients with FAIS, consensus is currently lacking on the optimal methods of evaluating their readiness for return to sport or activity.<sup>86,110</sup> Recommended return to sport outcome measures are not deemed valid or reliable for patients diagnosed with FAIS. Future studies should therefore develop specific postoperative return to sport criteria for patients with FAIS using data collected from validated objective functional outcome measures.

### **2.12.3 Summary:**

If the goal postoperatively for a patient is to return to sport or their desired level of activity, valid and reliable objective physical and functional tests are needed to safely evaluate their ability to do so. Researchers must also determine which demographic or clinical factors can predict if or when a patient will be cleared to return to sport, and if they can return to their same or desired level of performance. If clinicians can identify the factors that predict successful return to sport or, contrastingly, increase the risk of reinjury, they could potentially modify these risk factors by tailoring a patient's postoperative rehabilitation programs.

### **2.13 Conclusion**

There is currently a lack of consensus on the optimum methods to evaluate post arthroscopic FAIS patients' readiness to return to sport. Recommended measurement tools and the exact return to sport criteria for post arthroscopic patients with FAIS have not been defined, and rather tend to be based mainly on clinical experience and subjective evaluation. More functional and clinical data on patients with FAIS is needed to determine if any of the recommended outcome measures are valid and reliable in this

population. The probability of FAIS patients' return to sport postoperatively, or which factors influence their ability to do so, is also not yet known. As a result, we cannot predict to what level, expected timeline, or if, patients should be cleared to return to sport postoperatively. It is critical that postoperative return to sport guidelines be established to ensure patients diagnosed with FAIS can safely and successfully return to competitive play, or to an active and healthy lifestyle following surgery. One of the first steps to developing a return to sport guideline for this population is to evaluate their functional recovery patterns. Next, valid, and reliable objective physical and functional tests should be established to evaluate their postoperative rehabilitative ability, so rehabilitation programs can be tailored to meet the patient's needs. Finally, a large prospective cohort study should be conducted to determine which demographic, clinical, or functional factors can predict when and if patients diagnosed with unilateral FAIS can return to sport following arthroscopy. Only after clinicians understand the functional recovery patterns, the predictive return to sport factors, and which functional outcome measures are valid and reliable in this population can a postoperative rehabilitation guideline be established.

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## Chapter 3

### Return to Sport and Physical Activity Criteria Following Hip Arthroscopy for Patients with Femoroacetabular Impingement Syndrome: A Scoping Review

#### 3 Abstract

**Purpose:** To identify the objective criteria and guidelines being utilized to determine if patients diagnosed with femoroacetabular impingement syndrome (FAIS) can safely return to sport or desired level of physical activity following hip arthroscopy. **Methods:** The electronic databases MEDLINE Ovid, EMBASE Ovid, and CINAHL were searched to identify eligible studies reporting on return to sport and physical activity criteria. Details of study design, sample size, primary diagnosis, and return to sport protocol, duration, and rate were collected by two reviewers, independently. **Results:** Sixty-two studies were selected for full text review of which 14 were included in the final analysis. Of these, nine were clinical commentaries and five were retrospective cohort studies. Eleven studies featured a four-phase return to sport protocol, one utilized a five-phase protocol, and two recommended a six-phase protocol. Thirteen studies provided objective return to sport criteria, but only four of fourteen studies reported return to sport rates, and timeframes. However, there was significant variability between pre and post operative data reported by included studies. Regarding return to sport criteria, the most commonly patient-reported outcome measure was the Hip Outcome Score (HOS) (5 studies). The most common physical exams were range of motion (11 studies) and gait assessments (10 studies). The most common performance-based outcomes were single- and double-leg squats (4 studies) and the Vail hip sports test (4 studies). Criteria across all three types of protocols was variable, but they all evaluated the same ICF constructs of body function and structure limitations as well as activity limitations. **Conclusions:** There is no consensus on the optimal methods of evaluating a patient's readiness to return to sport after undergoing hip arthroscopy, with most criteria focused on expert opinion. Performance-based return to sport outcome criteria is not clearly defined, and validated outcome measures are not being used for FAIS

patients post hip arthroscopy. Lastly, well-conducted prospective cohort studies using validated outcome measures and objective definitions of return to sport are needed to consistently identify signs that are prognostic of safe return to sport.

### **3.1 Introduction**

Femoroacetabular impingement syndrome (FAIS) is a common cause of hip pain and reduced physical activity in patients aged 16 to 36 years of age,<sup>1</sup> especially in athletes.<sup>2</sup> After nonoperative treatments like physiotherapy are exhausted, patients are commonly treated with hip arthroscopy to correct osseous impingement and associated labral pathology to reduce pain and restore function.<sup>3-5</sup> Over the last decade, hip arthroscopy procedural rates have significantly increased<sup>6,7</sup> and in some regions of the United States by nearly five-fold.<sup>8</sup> Arthroscopic techniques, with an emphasis on labral preservation, appropriate osseous resection and capsular repair, improve patient-reported outcomes at short-to mid-term postoperative follow-up periods.<sup>9</sup>

Postoperative rehabilitation programs aim to improve a patient's level of function by improving their hip stability, neuromuscular control, and movement patterns.<sup>3,10</sup> However, consensus on standardized rehabilitation programs is lacking, and physiotherapist-led programs vary depending on the clinician's experience or personal preferences.<sup>10</sup> As a result, reported durations of recovery and the rate of successful return to sport vary. If a patient's goal is to return to sport after surgery, clinicians should use the most efficacious, safe, and objective return to sport methods to evaluate their readiness to return to sport and reduce their risk of reinjury.

A wide range of evaluation tools are currently utilized to gauge return to sport readiness in patients with conditions such as chronic ankle instability and anterior cruciate ligament injuries.<sup>11,12</sup> However, these tools and the specific return to sport criteria for patients with FAIS postoperatively is unclear. Thus, the primary objective of this review is to summarize the types of published post arthroscopic return to sport guidelines, their objective return to sport criteria, and the currently recommended outcome measures for FAIS patients recovering from hip arthroscopy. Our secondary

objective is to determine which postoperative return to sport guidelines are the most efficient and effective at returning FAIS patients to sport by summarizing their reported return to sport timelines and success rates.

## **3.2 Methods**

### **3.2.1 Search Strategy:**

We conducted a comprehensive, systematic search of the online bibliographic databases MEDLINE Ovid, EMBASE Ovid, and CINAHL to identify eligible studies on RTS criteria following hip arthroscopy in patients with FAIS using the methodology described by Sucharew & Macaluso.<sup>13</sup> The search was conducted in August 2019 and included all studies up until that time. Three main headings were used in our search strategy: (1) diagnosis of intra-articular hip pathology, (2) hip arthroscopy, and (3) rehabilitation. A search of the MEDLINE Ovid database was performed using specific terms under the hip arthroscopy domain: ‘hip arthroscopy’, ‘labral tear’, ‘femoroacetabular impingement’, ‘FAIS’, and ‘hip dysplasia’, with the results for each term combined using the ‘OR’ command. Results of specific search terms related to rehabilitation including: ‘return to sport’, ‘return to activity’, ‘rehab’, ‘rehab protocol’, ‘physiotherapy’, ‘physical therapy’, ‘practice guideline’, ‘post-surgery rehab’, ‘post-surgery protocol’, ‘post-operative rehab’, and ‘post-operative protocol’ were also combined using the ‘OR’ command. Finally, the search results from each domain were combined using the ‘AND’ command. Remaining databases were searched using similar strategies. Results from each database were uploaded to Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia).

### **3.2.2 Study Selection:**

Titles and abstracts of articles found in our initial search strategy were reviewed and assessed for inclusion by reviewers (NSP and LKC), independently, using Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia). Conflicts were resolved by a third reviewer (RD). Studies were eligible for full-text review if they included all the following: 1) diagnosis of intra-

articular hip pathology, 2) operative intervention in the form of hip arthroscopy, 3) a return to sport rehabilitation protocol, and 4) objective outcome measures. A full-text review was then conducted by two reviewers (TD and NSP), independently, using Microsoft Excel (Microsoft Excel 2017; Microsoft, Redmond, WA). Studies were excluded if they: 1) did not include patients diagnosed with FAIS, 2) were unavailable for full-text review, 3) were not written in English, 4) did not describe the RTS protocol or activity criteria, and/or 5) did not use validated outcome measures. Any conflicts were resolved by a third reviewer (RD). Additionally, the reference list from each article was reviewed for any potentially relevant papers to ensure the completeness of our initial search.

### **3.2.3 Quality Assessment:**

A quality assessment of all eligible non-randomized studies was completed using the Robins-1 risk of bias tool and interpreted according to the Cochrane ROBIN-1 guidelines (Recommendation Statement Report, Cochrane Scientific Committee, 2017).

**Table 1: Quality Assessment of Retrospective and Prospective Cohort Studies**

Author (year)	ROBIN-1 ROB Category						
	Confounding	Participant Selection	Intervention Classification	Deviations from Interventions	Missing Data	Measurement of Outcomes	Reporting
Frank et al. (2017)	Serious	Moderate	Moderate	Serious	Low	Serious	Serious
Frank et al. (2018)	Serious	Moderate	Moderate	Serious	Low	Serious	Serious
Levy et al. (2016)	Moderate	Moderate	Moderate	Moderate	Low	Serious	Moderate
Saavedra et al. (2016)	Serious	Serious	Moderate	Serious	Serious	Serious	Critical
Shaw et al. (2017)	Serious	Serious	Low	Serious	Low	Serious	Moderate
Spencer-Gardner et al. (2014)	Serious	Serious	Serious	Serious	Not Indicated	Serious	Critical

Domb et al. (2016)	Serious	Critical	Low	Low	Serious	Serious	Critical
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### **3.2.4 Data Extraction:**

Study data was extracted in duplicate by two independent reviewers (NSP and TD) and compiled into tables in Microsoft Excel (Microsoft Excel 2017; Microsoft, Redmond, WA) using a form we developed and tested before conducting data extraction. Details of study design, sample size, primary diagnosis, return to sport protocol, protocol duration, return to sport rate and timeline were extracted. The types of patient-reported outcome measures, physical exams, and performance-based measurement tools, and any associated data were also extracted, along with any specific criteria or cut-offs utilized throughout each protocol.

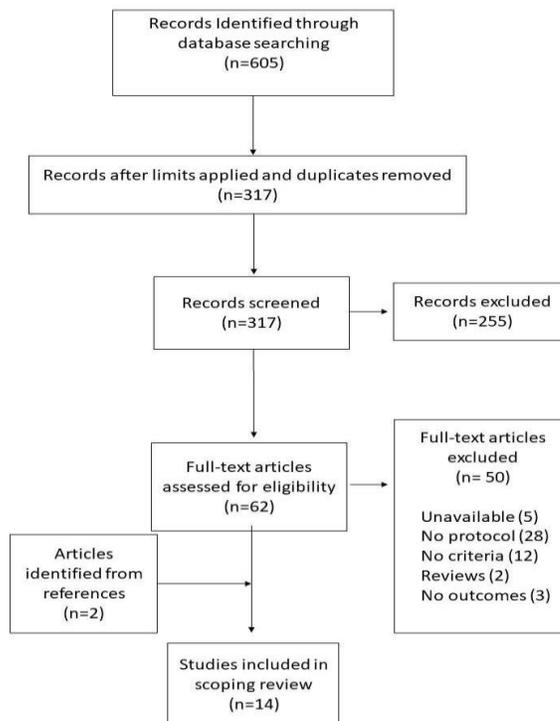
### **3.3 Data Analysis**

Citation information, along with the recruited sample size, type and level of sport or activity, reported outcome measures and the type of protocol used were summarized for each of the included articles. Any data were summarized as frequencies, rates, or arithmetic means with their standard deviation (SD) or 95% confidence intervals (CIs), where appropriate (Microsoft Excel 2017; Microsoft, Redmond, WA). After data extraction was complete, we used consensus to classify objective outcome measures as patient-reported, physical tests, or performance-based tools, and to identify the type of return to sport FAIS protocol used. Return to sport criteria were logically grouped according to the type of protocol used and recommended outcome measures used were grouped according to components of the international classification of function, disability, and health (ICF) model (body functions and structures, activities and participation, personal and environmental factors). Return to sport rates, timeframes, and recommended number of sessions were also summarized along with the type of protocol used. Lastly, mean differences (MDs) and SD of any reported pre- and post-intervention data were calculated and summarized, along with the 95% CIs when possible.

### 3.4 Results

The initial search yielded 317 studies for screening, 62 being selected for full text review, and 14 included in the final analysis (Figure 1). Of these 14 studies, nine were clinical commentaries and five were retrospective cohort studies. Postoperatively, patients could progress in one of three different types of criteria-based return to sport programs: 4-phase, 5-phase, or 6-phase. One 5-phase, two 6-phase and eleven 4-phase return to sport protocols are examined in this review (Table 2).

**Figure 1:** PRISMA Flow Diagram of Search Strategy



**Table 2: Summary of Included Studies Return to Sport Protocols**

Author (year)	Study Type	Sample Size	Population Type	Skill Level	Protocol Type	RTS Outcomes Measures			Data Collected
						Patient Reported	Physical Tests	Performance Based	
Frank et al. (2017)	RR	58	Cyclists	Rec	4 Phase	mHHS, HOS-ADL, HOS-S, NPRS	Active-ROM, Passive- ROM	Not Reported	Yes
Frank et al. (2018)	RR	42	Yoga	Rec	4 Phase	mHHS, HOS-ADL, HOS-S	Not Reported	Not Reported	Yes
Levy et al. (2016)	RR	51	Runners	Rec & Comp	4 phase	mHHS, HOS-ADL, HOS-S	Not Reported	Not Reported	Yes

Wahoff et al. (2014)	CC	Not Reported	Not Reported	Not Reported	6 Phase	HOS-ADL, HOS-S, VAS-Pain	Active-ROM, Passive-ROM, Gait Assessment, HHD, SDT, Side-Plank	SLHT, mTA, VHST, YBT, SLS, DLS, SEBT	No
Garrison et al. (2007)	CC	Not Reported	Not Reported	Not Reported	4 Phase	Not Reported	Active-ROM, Passive-ROM, Gait Assessment	SCT	No
Pierce et al. (2013)	CC	Not Reported	Hockey Players	Comp	6 Phase	Not Reported	Gait Assessment, Active-ROM, Passive-ROM, MMT	VHST	No
Wahoff & Ryan. (2011)	CC	Not Reported	Not Reported	Not Reported	4 Phase	Not Reported	Active-ROM, Passive-ROM, Gait Assessment	FHST	No
Saavedra et al. (2016)	RR	48	Not Reported	Not Reported	4 Phase	HHS, VHS	Active-ROM, Gait Assessment, HHD	VHST	Yes

Shaw et al. (2017)	CC	11	Military Personnel	Not Reported	4 Phase	HHS, HOS	Passive-ROM	SLBJ, APFT	Yes
Spencer-Gardner et al. (2014)	RR	52	Not Reported	Not Reported	5 Phase	mHHS, HOS-ADL, HOS-S	HHD, Active-ROM, Passive-ROM, Gait Assessment	FMS, YBT, DVJ, SLHT	Yes
Domb et al. (2016)	CC	595	Not Reported	Not Reported	4 Phase	mHHS, HOS-ADL, HOS-S, NAHS, VAS-Pain	Active-ROM, Passive-ROM, Gait Assessment, MMT	SLHT, SLS, DLS, DVJ, YBT	Yes
Kuhns et al. (2017)	CC	Not Reported	Not Reported	Not Reported	4 Phase	Not Reported	Active-ROM, Passive-ROM, Gait Assessment	SLS, VHST, Tuck Jump	No
Edelstein et al. (2012)	CC	Not Reported	Not Reported	Not Reported	4 Phase	Not Reported	Active-ROM, Gait Assessment, MMT, SDT	SLS, DLS	No

Malloy et al. (2013)	CC	Not Reported	Not Reported	Not Reported	4 phase	Not Reported	Active-ROM, Gait Assessment, SDT	DLS	No
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Notes: Table detailing the patient population, level of sport, type of sport, and type of return to sport protocol in each included study, as well as the specific types of outcome measures each recommends using to evaluate return to sport readiness.

Abbreviations: RTS; Return to Sport; Comp: Competitive Athletes; Rec: Recreational Athletes; RR: Retrospective Study; SR: Systematic Review; CC: Clinical Commentary; Hip Harris Score (HHS); Vail Hip Score (VHS); Hip Outcome Score-Sport (HOS-S); HOS- Active Daily Living (HOS-ADL); modified Hip Harris Score (mHHS); Hand-Held Dynamometry (HHD), Manual Muscle Testing (MMT), Vail Hip Sports Test (VHST); Sport Cord Test (SCT); Star Excursion Balance Test (SEBT); Non-Arthritic Hip Score (NAHS); Visual Analog Scale (VAS); Numeric Pain Rating Scale (NPRS); Range of motion (ROM); Single-Leg Squat (SLS); Double-Leg Squat (DLS); Gait Assessment: visually observing a patients walking pattern and ability without laboratory equipment; Single-Leg Hop Test (SLHT); 8" Step Down & Step-Up Test (SDT); Drop Vertical Jump (DVJ); Y-Balance Test (YBT); Functional Movement Screen (FMS); Functional Hip Sport Test (FHST); 2-mile Army Physical Fitness Test (APFT); Modified Agility T-Test (mTA); Single-Leg Broad Jump (SLBJ)

### **3.4.1 Outcome Measures:**

#### *Patient-Reported Outcomes*

Eight different patient-reported outcome measures were identified in fourteen protocols included in this review: the hip outcome score of the activities of daily living (HOS-ADL), HOS-sport (HOS-S), visual analog scales for pain (VAS-Pain), numeric pain rating scale (NPRS), non-arthritic hip score (NAHS), Vail hip score (VHS), Harris hip score (HHS) & the modified HHS (mHHS). Nine of fourteen (64%) recommended using patient-reported outcomes to evaluate rehabilitation progress and/or readiness to return to sport. Three patient-reported outcomes evaluate a mix of impairments of body function and activity limitations (HHS, mHHS, VHS, NAHS), two measured body function impairments (NPRS, VAS-Pain), one measured patients' capacity to perform activities (HOS-ADL), and one measured participation performance (HOS-SS).

#### *Physical Examination Tests*

Ten of the fourteen protocols examined used physical examination tests to evaluate progress and return to sport readiness (Table 2). Seven types were identified: active and ROM assessments, gait assessment, step tests, side planks, hand-held dynamometry (HHD), and manual muscle testing (MMT). Active and passive ROM and gait assessments the most used across all three types of protocols (Table 2). Of the seven, four measured body impairments (active and passive ROM, HHD, MMT) and three focused on activity limitations (gait assessment, step tests, side plank).

#### *Performance-Based Outcomes*

Fourteen performance-based outcomes were identified, and eleven of the fourteen studies recommend using them postoperatively, but only eight reported specific return to sport and progression criteria. These outcomes were: The Vail hip sport test (VHST), single-leg hop test (SLHT) single & double leg squats (SLS; DLS), modified agility T-test (mTA), Y-balance test (YBT), sport cord test (SCT), single-leg broad

jump (SLBJ), 2-mile army physical fitness test (APFT), functional movement screen, 10-second tuck jump, star excursion balance test (SEBT), drop vertical jump, and the functional hip sport test (FHST). These outcomes measure a patient's activity capacity and limitations. Among them, the VHST, SLS, DLS, and the YBT/SEBT were commonly recommended throughout all three types of return to sport protocol.

### **3.4.2 Return to Sport Criteria:**

Return to sport criteria was reported for thirteen of fourteen studies included in this review. Although, combinations of outcome measures and their recommended criteria varied across all three types of protocols, each of them included a balance of outcomes measuring body structure limitations and activity capacity limitations. The SEBT/YBT was the most used outcome to evaluate readiness to return to sport postoperatively, but criteria for only the anterior, posteromedial, and posterolateral vectors was reported. Progression and return to sport criteria for 4-phase, 5-phase, and 6-phase postoperative rehabilitation protocols are summarized in Table 3, Table 4, and Table 5, respectively.

**Table 3:** Summary of 4-Phase Postoperative Rehabilitation Progression and RTS Criteria

Author (Year)	Phase Progression				Return to Sport
	#1	#2	#3	#4	
Kuhns et al. (2017)			Not Reported		<u>NPRS</u> ≥ 2 Points Lower than Baseline  <u>Active-ROM</u> Full Symmetrical & Pain-Free  <u>Gait Assessment</u> Normal & Pain Free
Frank et al. (2017)			Not Reported		<u>VAS-Pain</u> ≥ 3 Points Lower than Baseline  <u>Gait Assessment</u> Normal & Pain Free  <u>No Trendelenburg Sign</u>

Domb et al. (2016)	Not Reported	<u>MMT</u> 4/5 in All Planes Except Extension	Not Reported	<u>MMT</u> 5/5 in All Planes	<u>Gait Pattern</u> Normal & Pain Free  <u>MMT</u> $\geq 4/5$ on $\geq 10$ Hip Abductions  <u>YBT:</u> Ant Vector LSI $< 4$ cm PM Vector LSI $\leq 6$ cm PL Vector LSI $\leq 6$ cm  <u>SLHT</u> LSI $\geq 90\%$  <u>DLS:</u> No Lateral Deviation of Hip or Lower Limb from Operated Side
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Wahoff & Ryan  
(2011)

Not  
Reported

Active-ROM  
Full Symmetrical  
& Pain-Free

Gait Assessment  
Normal  
& Pain Free

FHST  
Score 17/20  
Performing:

Lateral & Diagonal  
Agility for 100-  
seconds (1 Point for  
Every 20 second  
Completed)

Single Knee Bends  
for 3-minutes (1  
Point for every 30  
seconds completed)

Forward Box Lunges  
for 2-minutes  
(1 point for every 30  
seconds completed)

Malloy et al. (2013)	Not Reported	Not Reported	Not Reported	8" SDT Demo Multi Reps w/ No Dynamic Valgus at the Knee	<u>Active-ROM</u> Full Symmetrical & Pain-Free  <u>DLS</u> Max Depth w/ Adequate Kinematic Control
Garrison et al. (2007)	Not Reported	Not Reported	<u>Active-ROM</u> ≥ 75% of Contralateral Side	Not Reported	<u>Active-ROM</u> Full Symmetrical & Pain-Free  <u>Gait Assessment</u> Normal & Pain Free  <u>SCT</u> Good Neuromuscular Control w/:  SLS for 3-minutes  Lateral Bounding for 80 seconds  Fwd/Bwd Jogging for 2-minutes

Edelstein et al. (2012)	<u>MMT</u> 5/5 on Operated Leg	<u>Gait Pattern</u> Normal & Pain Free  <u>AROM</u> > 80% of Full Range	<u>SLS</u> Good Neuromuscular Control	<u>8" SDT</u> Good Neuromuscular Control	<u>8" SDT</u> ≥ 10 Reps w/ No Hip Drop, Fwd Trunk Flexion or Trunk Lean  <u>SLS</u> 10 Reps w/ Good Neuromuscular Control  <u>MMT</u> Score of ≥ 4/5 on ≥ 10 Hip Abduction Reps
Saavedra et al. (2016)			Not Reported		<u>No Trendelenburg Sign</u>  <u>Gait Pattern</u> Normal & Pain Free  <u>HHD</u> Hip Flexion LSI >85%
Levy et al. (2016)			Not Reported		Not Reported

Frank et al. (2018)	Not Reported	<u>Active-ROM</u> Full Symmetrical & Pain-Free	<u>Vas-Pain</u> > 3 points lower than baseline  <u>Gait Assessment</u> Normal & Pain Free  <u>No Trendelenburg</u> <u>Sign</u>
Shaw et al. (2017)	Not Reported		<u>SLBJ</u> ≤ 6 inches

Notes: Hip Harris Score (HHS); Vail Hip Score (VHS); Hip Outcome Score-Sport (HOS-S); HOS- Active Daily Living (HOS-ADL); modified Hip Harris Score (mHHS); Hand-Held Dynamometry (HHD) Gait Assessment: visually observing a patients walking pattern and ability without laboratory equipment; Sport Cord Test (SCT); Star Excursion Balance Test (SEBT); Non-Arthritic Hip Score (NAHS); Numeric Pain Rating Scale (NPRS); Visual Analog Scale (VAS); Range of Motion (ROM); Single-Leg Hop Test (SLHT); 8" Step Down & Step-Up Test (SDT); Drop Vertical Jump (DVJ); Y-Balance Test (YBT); Functional Movement Screen (FMS); Double-Leg Squat (DLS); Modified Agility T-Test (mTA); Single-Leg Broad Jump (SLBJ); Anterior (ANT); Posteromedial (PM); Posterolateral (PL); Limb Symmetry Index (LSI); Vail Hip Sports Test (VHST); Manual Muscle Testing (MMT); Single-Leg Squat (SLS); 2-mile Army Physical Fitness Test (APFT); Functional Hip Sport Test (FHST)

**Table 4: Summary of 5-Phase Postoperative Rehabilitation Progression and RTS Criteria**

**Recommended Outcome Measures**

Author (Year)	Phase Progression					Return to Sport
	#1	#2	#3	#4	#5	
Spencer-Gardner et al (2014)			Not Reported			<u>Gait Pattern</u> Normal & Pain Free  <u>No Trendelenburg Sign</u>  <u>HHD</u> LSL $\geq$ 90%  <u>YBT</u> Ant Vector: Satisfactory Score PM Vector: Satisfactory Score PL Vector: Satisfactory Score  Overall: LSI $\geq$ 90%

Notes: Hip Harris Score (HHS); Vail Hip Score (VHS); Hip Outcome Score-Sport (HOS-S); HOS- Active Daily Living (HOS-ADL); modified Hip Harris Score (mHHS); Hand-Held Dynamometry (HHD) Gait Assessment: visually observing a patients walking pattern and ability without laboratory equipment; Sport Cord Test (SCT); Star Excursion Balance Test (SEBT); Non-Arthritic Hip Score (NAHS); Visual Analog Scale (VAS); Range of Motion (ROM); Single-Leg Hop Test (SLHT); 8" Step Down & Step-Up Test (SDT); Drop Vertical Jump (DVJ); Y-Balance Test (YBT); Functional Movement Screen (FMS); Double-Leg Squat (DLS); Modified Agility T-Test (mTA); Single-Leg Broad Jump (SLBJ); Anterior (ANT); Posteromedial (PM); Posterolateral (PL); Limb Symmetry Index (LSI); Vail Hip Sports Test (VHST); Manual Muscle Testing (MMT); Single-Leg Squat (SLS); 2-mile Army Physical Fitness Test (APFT); Functional Hip Sport Test (FHST)

**Table 5:** Summary of 6-Phase Postoperative Rehabilitation Progression and RTS Criteria

Recommended Outcome Measures							
Author (Year)	Phase Progression						RTS
	#1	#2	#3	#4	#5	#6	
Pierce et al. (2013)			Not Reported				<u>Active-ROM</u> Full Symmetrical & Pain-Free  <u>MMT</u> 4/5 for External Rotation  <u>SLHT</u> LSI > 90%  <u>VHST</u> Score 17/20  <u>Gait Pattern</u> Normal & Pain Free  <u>No</u> <u>Trendelenburg</u> <u>sign</u>

								<u>HHD</u> LSI ≥ 90%
								<u>8" SDT</u> ≥ 10 Reps w/o Collapse
								<u>Side Plank</u> ≥60 Sec
								<u>YBT</u> Ant Vector: LSI < 4 cm
		<u>Active-ROM</u> ≥ 30 Prone Hip Extensions						<u>SEBT</u> Cumulative Score > 94%
Wahoff et al. (2014)	<u>Active-ROM</u> ≥ 10 Prone Hip Extensions	<u>SLS</u> Uncompensated Hip Flexion or Pelvic Rotation	<u>HOS-ADL</u> Score ≥ 89	<u>VHST</u> Score ≥ 10/20	<u>SLHT</u> LSI > 85%	<u>SLHT</u> LSI > 92%	<u>VHST</u> Score 20/20	<u>mTA</u> LSI < 10%
								<u>10 sec Tuck Jump</u> < 6 Errors or Biomechanical Flaws
								<u>HOS-ADL</u> Score ≥ 96
								<u>HOS-SS</u> Score ≥ 78

Notes: Hip Harris Score (HHS); Vail Hip Score (VHS); Hip Outcome Score-Sport (HOS-S); HOS- Active Daily Living (HOS-ADL); modified Hip Harris Score (mHHS); Hand-Held Dynamometry (HHD) Gait Assessment: visually observing a patients walking pattern and ability without laboratory equipment; Sport Cord Test (SCT); Star Excursion Balance Test (SEBT); Non-Arthritic Hip Score (NAHS); Visual Analog Scale (VAS); Range of Motion (ROM); Single-Leg Hop Test (SLHT); 8" Step Down & Step-Up Test (SDT); Drop Vertical Jump (DVJ); Y-Balance Test (YBT); Functional Movement Screen (FMS); Double-Leg Squat (DLS); Modified Agility T-Test (mTA); Single-Leg Broad Jump (SLBJ); Anterior (ANT); Posteromedial (PM); Posterolateral (PL); Limb Symmetry Index (LSI); Vail Hip Sports Test (VHST); Manual Muscle Testing (MMT); Single-Leg Squat (SLS); 2-mile Army Physical Fitness Test (APFT); Functional Hip Sport Test (FHST)

### **3.4.3 Return to Sport Protocols:**

The aim of each protocol was similar; to return an athlete to full-competition or their previous level of ability postoperatively. Generally, the purpose of phase 1 was to protect the healing tissues and perform pain-free ROM. Phase 2 focused on regaining full ROM and the strength required for pain-free ambulation. At phase 3, clinicians aimed to return the patient to preoperative functional levels, or better, in all planes of motion in the hip and ensure they can participate in recreational activities without pain or irritation. Afterward, protocols focused on building the power, speed, agility, and specific skills a patient requires to perform their level and type of sport.

Although the objectives and design of the first three phases are similar across 4-, 5-, and 6-phase protocols, two differences are the amount of time spent building strength, endurance, and functional ability in the latter phases and when patients are introduced to sport specific exercises or activities. Five and six phase protocols focus on gradually building on the patient's strength and endurance in phase four as well as continually restoring their sport specific skills to ensure they safely and effectively return to sport. The fifth and sixth phases of rehabilitation typically begin between twelve and sixteen weeks after surgery and can last between four to twelve weeks in length depending on the patient and their type of sport. Sport specific exercises also begin earlier and last long in five and six phase protocols. Although, duration and timing of each phase as well as when patients return to play may depend on the level and type of sport (Table 6).

Progression through each phase of a protocol was poorly reported. Seven of fourteen studies did not report their progression criteria. Criteria to progress to each phase of rehabilitation was only reported by two of fourteen studies: one six-phase and one four-phase protocol. Four-phase protocols used outcomes that measure a patient's body function and structure limitations to evaluate if they can progress through the first three stages, whereas six-phase protocols used activity and participation outcomes measure rehabilitation progress. No progression criteria were reported for the five-phase protocol.

A unique combination of different types of outcomes were also used to evaluate a patient's readiness to return to sport and the criteria varied across all fourteen studies. However, return to sport criteria in all three types of protocols focused on measuring a patient's body function and structure limitations as well as limitations to their activity limitations. Only one of fourteen measured participation performance limitations (HOS-SS) and a patient's contextual and environmental barriers were not listed as part of the criteria in any of the three types of protocols.

**Table 6: Return to Sport Rates, Time Frames, and the Type of Protocol**

<b>Author (year)</b>	<b>Protocol Type</b>	<b>RTS Phase Start (Weeks)</b>	<b>Protocol Duration (Weeks)</b>	<b># Of Sessions</b>	<b>RTS Time Frame (Weeks)</b>	<b>RTS Level /Rate (%)</b>
Frank et al. (2017)	4 Phase	$\geq 16$	$\geq 4$	Not Reported	18 (8.0, 28.0) <sup>#</sup>	Higher: 59 Same: 41
Frank et al. (2018)	4 Phase	$\geq 16$	$\geq 4$	Not Reported	20.8 (12.0, 29.6) <sup>#</sup>	Higher: 49 Same: 44 Lower: 8
Levy et al. (2016)	4 Phase	$\geq 16$	$\geq 4$	Not Reported	34 (17.2, 50.8) <sup>#</sup>	Comp: 100 Rec: 88
Pierce et al. (2013)	6 Phase	$4.5 \leq 16$	$8 \leq 16$	Min 4/ Phase	Not Reported	Not Reported
Wahoff et al (2014)	6 Phase	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported
Garrison et al. (2007)	4 Phase	$\geq 12$	$4 \leq 8$	Not Reported	Not Reported	Not Reported
Wahoff & Ryan. (2011)	4 Phase	Not Reported	$4 \leq 8$	Not Reported	Not Reported	Not Reported
Saavedra et al. (2016)	4 Phase	$\geq 12$	$\geq 4$	20 Total	Not Reported	Not Reported
Spencer-Gardner et al. (2014)	5 Phase	$12 \leq 16$	$\leq 12$	1-2 /week	$16 \leq 24$	Not Reported

Shaw et al. (2017)	4 Phase	$\geq 12$	Not Reported	Not Reported	Not Reported	Same: 73
Domb et al. (2016)	4 Phase	$\geq 12$	$4 \leq 8$	Not Reported	$24 \leq 36$	Not Reported
Kuhns et al. (2017)	4 Phase	$\geq 16$	$\leq 8$	Not Reported	Not Reported	Not Reported
Edelstein et al. (2012)	4 Phase	$12 \leq 20$	$4 \leq 16$	Not Reported	Not Reported	Not Reported
Malloy et al. (2013)	4 Phase	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported

#: Upper and Lower 95% Confidence Intervals (CIs) if it was reported by the authors

RTS: Return to Sport; Comp: Competitive Runners; Rec: Recreational Runners

### **3.4.3 Postoperative Outcome Improvement:**

Seven of fourteen studies, six 4-phase and one five phase protocol, reported postoperative improvements in ability to cycle, run, participate in yoga. Performance-based outcome data was not collected in any of these studies, and each study was at high risk of bias. Every study collected data from patient-reported outcomes (Table 7) and two measured range of motion before and after completing four-phase protocols (Table 8). Although data demonstrates 4- and 5-phase protocols may improve body function limitations (VAS-Pain, NAHS), body structure limitations (ROM), activity limitations (HOS) or a combination of these constructs (mHHS, VHS, HHS), there is a large amount of variability in the results.

**Table 7: Pre and Postoperative Changes in Patient-Reported Outcome Measurements**

Author (year)	Protocol Type	mHHS	HHS	HOS-ADL	HOS-S	VHS	VAS	NAHS
Saavedra et al. (2016) †	4 Phase	Not Reported	38.1 ± 0.86	Not Reported	Not Reported	30.6 ± 1.13	Not Reported	Not Reported
Domb et al. (2016) †	4 Phase	20.73	Not Reported	20.3	29.1	Not Reported	2.9	22.4
Shaw et al. (2017) *	4 Phase	Not Reported	34.28 ± 7.09	34.2 ± 9.22	37.1 ± 5.31	Not Reported	Not Reported	Not Reported
Frank et al. (2017) †	4 Phase	30.4 ± 1.96	Not Reported	22.6 ± 1.82	43.7 ± 2.27	Not Reported	63.4 ± 1.98 ¶	Not Reported
Frank et al. (2018) †	4 Phase	27.9 ± 2.61	Not Reported	23.9 ± 1.96	37.9 ± 2.38	Not Reported	4.87 ± 0.78 ¶	Not Reported
Levy et al. (2017) †	4 Phase	Rec: 25.1 ± 17.0 Comp: 16.3 ± 18.5	Not Reported	Rec: 27.3 ± 19.2 Comp: 17.4 ± 11.9	Rec: 38.4 ± 23.9 Comp: 34.0 ± 26.6	Not Reported	Not Reported	Not Reported
Spencer- Gardner et al. (2014) *	5 Phase	80.1 ± 19.9	Not Reported	83.6 ± 19.2	70.3 ± 27.0	Not Reported	Not Reported	Not Reported

\*: Mean Difference (MD) and standard deviation (SD) reported by the authors; †: Calculated MD and SD; ‡: Calculated MD; SD was not reported and could not be determined; ††: Likert scale ranged from 0 to 100; ‡: Likert scale ranged from 0 to 10

Note: mHHS Scores Range: 0-100; HOS-ADL Scores Range: 13.2-100; HOS-S Scores Range: 0-100; Hip Harris Score (HHS); Vail Hip Score (VHS); Hip Outcome Score-Sport (HOS-S); HOS- Active Daily Living (HOS-ADL); modified Hip Harris Score (mHHS); Non-Arthritic Hip Score (NAHS); Visual Analog Scale (VAS)

**Table 8: 4-Phase Pre-and Post Range of Motion Measurements**

Author (year)	Hip Flexion		Hip Extension	Internal Rotation		External Rotation		Hip Abduction	Hip Adduction
	Pre:	Post:		Pre:	Post:	Pre:	Post:		
Frank et al. (2017)	110.3° (98.9, 121.7)	118.1° (109.7, 126.5)	Not Reported	12.6° (2.7, 22.5)	21.0° (11.4, 30.6)	Not Reported	Not Reported	Not Reported	Not Reported
Frank et al. (2018)	111.8° (101.0, 122.6)	119.2° (111.1, 127.4)	Not Reported	19.2° (11.9, 26.5)	23.5° (17.9, 29.1)	39.2° (30.7, 47.7)	40.5° (29.4, 51.6)	Not Reported	Not Reported

### 3.5 Discussion

The main objective of this review was to summarize the return to sport criteria and outcomes currently used to safely evaluate if patients with FAIS can return to their desired level and type of sport following hip arthroscopy. Thirteen of fourteen studies described how to evaluate if a patient with FAIS can safely return to their desired level and type of sport postoperatively. We identified 29 different outcome measures used to evaluate postoperative rehabilitation progress and readiness to return to sport: eight patient-reported outcomes, seven physical exams, and fourteen performance-based outcomes. According to the ICF model, sixteen measure activity capacity (HOS-ADL, Tuck Jump, FHST, Gait Assessment, SDT, SLBJ, APFT, FMS, DVJ, SCT, VHST, YBT/SEBT, mTA, SLHT, SLS, DLS), five measure body structure limitations (active and passive ROM, HHD, MMT, Trendelenburg test), three measure body function limitations (VAS-Pain, NPRS, NAHS), three are mixed (HHS, mHHS, VHS), and only a single outcome measured limitations to participation performance (HOS-SS). The recommended criterion for several outcomes is not described, nor are minimal clinical important differences for any of the outcome measures used in any of the fourteen studies. Progression criteria was poorly reported and only fully described in two of fourteen studies. Return to sport criteria was variable across all studies, but they all focused on evaluating similar ICF constructs: body function and structure limitations as well as activity limitations and capacity.

Our secondary objective was to summarize the differences between established postoperative return to sport rehabilitation protocols. Our search strategy identified fourteen studies which each described either a: 4-phase, 5-phase, or 6-phase protocol. Quality assessment of all these studies revealed they have a high risk of bias, likely due to their methodological design. However, the aim of each protocol and the goal of the first three phases are identical to each other. Phases can last between four and twelve weeks and patients typically begin return to sport training between twelve and sixteen weeks postoperatively. However, we cannot determine the effectiveness and efficiency of these protocols because of the substantial variability in return to sport timelines and postoperative data.

Clinical data for recommended outcome measures in this population is also lacking, poorly reported, and has not yet been collected for performance-based outcomes. Only seven of fourteen studies collected this data, in the cohort. Although some data suggests 4- and 6- phase protocols are effective, clinicians should be cautious when considering the significant improvements reported by these seven studies because an intention to treat analysis was not conducted. Additionally, no clinical evidence supporting the validity and reliability of any of the recommended outcomes in this population was provided. Only a single study cited previous research to justify their criteria and rationale.<sup>22</sup> However, upon further review it appears the patient population referenced in this study was highly variable and included patients without FAIS.<sup>27</sup> This reduces the external validity of the authors' results, and more evidence is needed to support recommended return to sport and progression criteria. Outcomes designed to measure a patients participation limitations and performance within the context of their sport are under utilized and lacking. As a result, while several of the recommended outcome measures are considered valid for other lower extremity injuries,<sup>11,12</sup> more research is needed to support their use in this population and sport specific outcomes to evaluate a patients participation limitations and performance should be developed.

Although research on return to sport rehabilitation for patients with FAIS has recently expanded, we expected clinical outcomes in this population would already have been validated and supported by clinical data if they are utilized to clear patients to return to sport postoperatively. However, the results of this review suggest published postoperative return to sport guidelines appear to be based mainly on a clinician opinion, rather than objective evaluation criteria or evidence-based findings. Our results concur with recent findings of Reiman et al.<sup>29</sup> that indicate there is a lack of sufficient, high-quality clinical evidence on post arthroscopic FAIS patients making it difficult to establish and define clear, reproducible post-operative rehabilitation guidelines.<sup>29</sup> Therefore, we cannot be certain that current post-operative clinical rehabilitation practices are reliable, safe, and effective at returning patients to their desired type and level of sport.

It appears a patient's ability to return to sport after hip arthroscopy, or the time frame in which they do so, may depend on the type or level of sport, or which type of protocol is used. The type of clinical facility (private, public, specialized) as well a clinician's level of expertise may also be a contributing factor to a patient's successful return to sport. As a result, if a patient's goal postoperatively is to return to their same type and level of sport, future research should establish the validity and reliability of these recommended patient-reported, physical examinations, and performance-based outcome measures so clinicians can tailor postoperative rehabilitation programs to reduce the patient's risk of re-injury and safely determine if they can return to their sport. Additionally, more clinical data is needed to determine how effective and clinically reliable currently utilized rehabilitation guidelines are and identify prognostic factors that may affect a patient's ability to return to their sport after surgery.

### **3.6 Limitations**

While evaluation of the risk of bias is not mandatory for scoping reviews, 50% (7 of 14) of the studies in this review were non-randomized studies and collected data from a cohort of patients. Critical appraisal was conducted by a single reviewer (TD) using the ROBIN-1. Thus, the certainty as to the accuracy of this risk of bias assessment for these studies may have been improved if conducted in duplicate by independent reviewing pairs. Manual review of the reference lists of included studies were conducted to minimize publication bias, but it is possible some additional studies were not identified and captured by our search strategies. We did not attempt to synthesize the results and achieve consensus or to make recommendations for which type of protocol should be used. The aim of this study was to statistically summarize current postoperative return to study rehabilitation protocols, guidelines, criteria, and outcome measures used by clinicians to evaluate a patient's ability to progress to the next level of rehabilitation or return to sport. Thus, the results of this review should only be interpreted as a summary of the current postoperative guidelines and return to sport criteria for patients with FAIS.

### **3.7 Conclusion**

There is no consensus on the optimal methods of evaluating a patient's postoperative functional rehabilitation progress, ability, and readiness to return to sport. Postoperative return to sport criteria is not clearly defined and rely predominantly on performance-base outcomes to evaluate a patient's limitations to activity capacity and not limitations to their participation performance. Validated outcome measures have also not been established, and the efficiency and effectiveness of published return to sport protocols has not been determined because clinical data variable and lacking. Clinicians should proceed with caution before using any published return to sport guidelines to evaluate the postoperative functional progress of their patients and whether they can safely be cleared to return to their desired type and level of sport after corrective hip arthroscopy.

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## Chapter 4

### Postoperative Rehabilitation Outcome Measures for Patients with Femoroacetabular Impingement Syndrome (FAIS): An International Survey of Physiotherapists and Orthopedic Surgeons.

#### 4 Abstract

**Purpose:** Our primary objective was to determine which outcome measures practicing clinicians are using to evaluate progression through functional rehabilitation following arthroscopic treatment of femoroacetabular impingement syndrome (FAIS) and readiness to return to sport. Secondly, we aimed to examine the level of success clinicians have returning to sport patients with FAIS. **Methods:** We distributed an online survey consisting of 13 questions to physiotherapists and orthopaedic surgeons via a secure electronic survey portal. Surveys were completed electronically and anonymously, with invitations circulated to members of the Canadian Physiotherapy Association (CPA), Sport Physiotherapy Canada (SPC), Fowler Kennedy Sport Medicine Clinic (FKSMC) physiotherapists, former FKSMC orthopedic sport medicine fellows, and the Canadian Orthopedic Association (COA) between March 1st, 2020, and June 15th, 2020. **Results:** Our overall response rate was approximately 2% (152/6740). A total of 152 clinicians responded to our survey, but only 99 currently treat patients diagnosed with FAIS. Outcome measures varied considerably depending on a clinician's type of practice and postoperative follow-up period. The Western Ontario and McMaster Universities osteoarthritis index (WOMAC), visual analog scale for pain (VAS-Pain), walking assessments, range of motion (ROM) measurement, manual muscle testing (MMT), flexion abduction external rotation test (FABER), flexion adduction internal rotation test (FADIR), gait analysis testing, single-leg balance tests (SLS), and single-leg hop tests (SLHT) were the most utilized outcomes postoperatively by physiotherapists and surgeons. Almost 70% of clinicians (39/52) do not use a currently established hip-focused rehabilitation program for their patients. Most clinicians indicated their clinical recommendations and practices are based mainly on their

expert opinion (13/52). Most clinicians reported successfully returning patients with FAIS to their preoperative type and level of sport 66% of the time. Median rates were reportedly higher for orthopaedic surgeons than physiotherapists. The most frequently reported return to sport time frame amongst clinicians was 26 weeks after surgery but was six weeks longer for physiotherapists than orthopaedic surgeons. **Conclusion:** Postoperative clinical evaluation of readiness to return to sport in patients with FAIS varies among physiotherapists and orthopaedic surgeons. Recommended outcome measures are unique to each clinician but measure similar constructs of function, disability, and health such as, body functions, body structures, activity, and participation. Criteria to progress to the next stage of rehabilitation or readiness to return to sport is based on a clinician's experience rather than evidence-based hip-focused rehabilitation protocols.

## 4.1 Introduction

Femoroacetabular impingement syndrome (FAIS) is a common cause of non-arthritis hip pain in active young adults.<sup>1-3</sup> Cohort studies estimate 10 to 15% of patients in America,<sup>4,5</sup> and 3% of patients in Canada<sup>6</sup> with symptomatic hip pain are diagnosed with FAIS every year. While physiotherapy can be effective at improving pain and function, many patients with persistent symptoms are treated arthroscopically to manage their impingement and concomitant labral pathology.<sup>7</sup> It is estimated that between 57%<sup>8</sup> and 94%<sup>9</sup> of FAIS patients return to sport (RTS) postoperatively, depending on their type of activity or level of sport. Current rehabilitation programs and RTS criteria are highly variable because insufficient clinical data on post arthroscopic FAIS patients makes it difficult to establish and define clear, reproducible post-operative guidelines.<sup>10</sup>

Various postoperative rehabilitation guidelines recommend using patient reported outcomes to evaluate functional progress or RTS readiness,<sup>11</sup> but threshold criteria are variable<sup>12-15</sup> and their ceiling effects could result in missing functional deficits or limitations in postoperative patients with FAIS.<sup>16-17</sup> Current return to sport guidelines for patients with FAIS are ill-defined and include various combinations of outcomes that are patient-reported, performance-based, or based on the results of physical exams

manoeuvres or tests. Common patient-reported outcomes include pain scales, the hip outcome score, and Harris hip score. Common physical tests used are range of motion, impingement tests, and gait assessments. Performance-based outcomes such as the vail hip sport test, single-leg or double-leg squats, the star excursion balance test or Y-balance test, and hop testing are also commonly used to measure progress and readiness to return to sport after surgery. Optimal methods for evaluating the functional progress and return to sport readiness in patients with FAIS postoperatively are lacking. Consensus is essential so that scientists and clinicians can improve their postoperative decision-making.

Therefore, the purpose of this study was to determine which outcome measures practicing clinicians are currently using to evaluate readiness for progression through functional rehabilitation and their readiness to return to sport following surgery. Secondly, we aimed to ask clinicians about their perceived level of success in returning patients with FAIS to sport after hip arthroscopy and examine any differences.

## **4.2 Methods**

This study followed a cross-sectional design using an online international survey. We developed an electronic online survey using the web based Qualtrics XM Software (Version 4.02, © 2014 Qualtrics, LLC) for physiotherapists and orthopaedic surgeons to capture their relevant perspectives on recommended outcome measures used to evaluate the rehabilitation progress of patients with FAIS postoperatively and their ability to return to sport. To assess the face validity of this survey, it was reviewed by a practicing orthopedic surgeon and two physiotherapists from the Fowler Kennedy Sport Medicine Clinic (FKSMC). We distributed the survey by email to members of the Canadian Physiotherapy Association (CPA), Sport Physiotherapy Canada (SPC), the FKSMC alumni orthopedic fellows, practicing physiotherapists at FKSMC, and the Canadian Orthopedic Association (COA) between March 1st, 2020, and June 15th, 2020. Only practicing clinicians who have or currently work with postoperative FAIS patients were eligible to participate. Clinicians were excluded if they were not currently registered, retired, or have not worked with postoperative FAIS patients. Reminder emails were

sent out by the participating organizations every two weeks and attempts to contact members were not made after six weeks. This study was granted ethics approval by the Western University Health Science Research Ethics Board (Ref#: 115014) on January 23<sup>rd</sup>, 2020.

The survey contained 13 questions regarding clinician experience, number of patients treated each year, type of practice, treatment preferences, return to sport, and currently utilized postoperative outcome measures. To determine which types of outcomes clinicians, use postoperatively, a matrix of 10 outcomes grouped according to their type, either patient-reported, physical examinations, or performance-based measurements. Clinicians were asked to select preferences at each postoperative follow-up visit (Table 1). Questions pertaining to the types of outcomes a clinician used were coded to allow for them to select more than one outcome measure and/or outcomes we may have missed.

**Table 1.** Clinical Outcome Measure Decisions at Postoperative Follow-up Periods

<b>Follow-Up Periods</b>	<b>Type</b>	<b>Outcome Measure Options</b>
2-Weeks	Patient-Reported	WOMAC, VAS-Pain, NPRS, NAHS, LEFT, iHOT, HOS, HOOS, HHS, GRC, None
6-Weeks 3-Months	Physical Examination Tests	Walking Assessments, ROM Testing, Ober, Modified Trendelenburg, MMT, Log Roll, Imaging, FADIR, FABER, None
6-Months 1-Year	Functional/ Performance	DVJ, FMS, Gait, SEBT, SLHT, SLS, T-Agility Test, Tuck Jump, VHST, YBT, None

Abbreviations: Western Ontario and McMaster Universities osteoarthritis index (WOMAC); Visual analog scale for pain (VAS-Pain); Numeric pain rating scale (NPRS); Non-arthritic hip score (NAHS); Lower extremity functional score (LEFS); International hip outcome tool (iHOT); Hip disability and osteoarthritis outcome score (HOOS); Harris hip score (HHS); Global rate of change score (GRC); Range of motion (ROM); Manual muscle testing (MMT); Flexion adduction internal rotation (FADIR); Flexion abduction external rotation (FABER); Drop vertical jump (DVJ); Functional movement screen (FMS); Star excursion balance test (SEBT); Single-leg hop test (SLHT); Single-leg balance (SLS); Vail hip sport test (VHST); Modified Y-Balance test (YBT).

### **4.2.1 Sample Size:**

Our sample size calculations were based on the finite population of physiotherapists who were members of the organizations we had access to during the data collection period. This constituted approximately 5,000 orthopedic physiotherapists from the CPA, 99 members of the SPC, 16 physiotherapists at FKSMC, 125 orthopedic fellows of the FKSMC, and 1,500 members of the COA. A required sample size of 91 orthopaedic surgeons and 94 physiotherapists was calculated based on 95% confidence intervals (CI), a 5% margin of error, and the most conservative estimation of survey response parameters (50%).

### **4.2.2 Statistical Analysis**

We planned to analyze data as it was collected, assuming a low percentage of missing and was normally distributed. If data is not normally distributed, we will first summarize participant demographics based on their type of practice (physiotherapist or surgeon) and then calculate the median return to sport times, success rates, and the number of patients a clinician treats per year. Outcome measures will also be grouped by the construct they measure according to the international classification of functioning, disability, and health (ICF) model (Function, Structure, Activity, Participation or Mixed) according to how they are defined. We will also record the frequencies each outcome is selected, as well as the frequencies each construct is measured at the six follow-up time periods (2-weeks, 6-weeks, 3-months, 4.5-months, 6-months, 1-year).

## **4.3 Results**

Thirteen orthopaedic surgeons and 39 physiotherapists completed the survey. Due to the method of survey distribution, requesting the societies to distribute the survey invitation via email to their members, we are unable to determine the percentage of respondents from those who may have received the invitation. Although, 65% (99/152) of responses were from practicing clinicians, data from only 52 surveys were complete. Most of these responses (39/52) were from physiotherapists, practicing in Canada only, and 13 orthopaedic surgeons within North America completed our survey. Our data was not

normally distributed. Our sample varied by province/state, country of practice, and the specific outcome measures and type used postoperatively (Table 2).

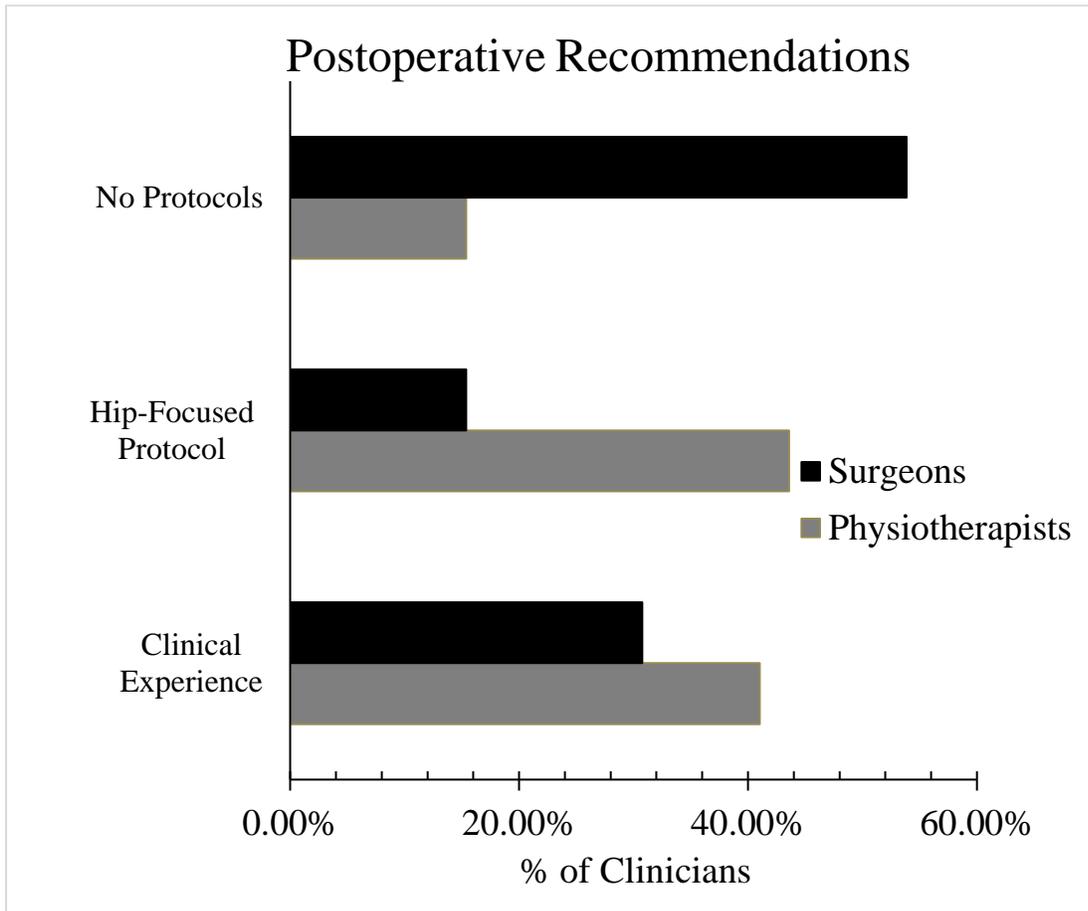
**Table 2:** Clinician Summaries and Demographics

<b>Type of Practice</b>	<b>Median (SD) or N (% of Respondents)</b> <b>Registered Physiotherapists</b>	<b>Median (SD) or N (% of Respondents)</b> <b>Orthopaedic Surgeons</b>
<b>Patients /year</b>	5	85
<b>Region (State/Prov)</b>		
<b>Canada:</b>	39 (100.0)	4 (30.8)
BC	1 (2.6)	-
AB	5 (12.8)	1 (7.7)
MB	2 (5.1)	1 (7.7)
ON	23 (59.0)	2 (15.4)
QB	2 (5.1)	-
NS	5 (12.8)	-
NFL	1 (2.6)	-
<b>USA:</b>		9 (69.2)
UT	-	1 (7.7)
CA	-	1 (7.7)
TX	-	3 (23.1)
MA	-	1 (7.7)
NY	-	1 (7.7)
MI	-	1 (7.7)
KA	-	1 (7.7)
<b>Recommended # of PT Sessions/week</b>	2	2
<b>RTS (Weeks)</b>	30	24
<b>RTS Success Rate (%)</b>	60(21)	80(17.5)

Abbreviations: SD= Standard deviation, CI= confidence interval, PT= Physiotherapy, RTS= Return to sport.

### Current Clinical Practices

The median number of patients treated by orthopaedic surgeons each year was substantially larger than physiotherapists. Most responses from clinicians (39/52) suggests they base decision-making on their opinion rather than an evidence-based hip-focused rehabilitation protocol. In total, seven of thirteen orthopaedic surgeons and six of thirty-nine physiotherapists indicated they do **not** use an established hip-focused rehabilitation protocol in their practice (Figure 1).



**Figure 1.** Orthopaedic Surgeons and Physiotherapists Preferred Postoperative Clinical Decision-Making Tools

Note: Hip-focused protocols included the Steadman-Hawkins FAIS protocol, Fowler Kennedy Sport Medicine Clinic FAIS protocol, and postoperative recommendations from the University of Pittsburgh Medical Center.

Reported return to sport success rates for patients with FAIS postoperatively were variable. Orthopaedic surgeons reported higher success rates than physiotherapists and were reportedly higher in the United States than in Canada (Table 2). Although estimated median return to sport time frames by

physiotherapists were longer, there was more variability than orthopaedic surgeons (Table 2), the most frequently report time frame among both types of clinicians was 26 weeks. Regardless of a clinician's type or country of practice, the median return to sport rate for patients with FAIS following hip arthroscopy was 66%, but orthopaedic surgeons more frequently reported higher rates than physiotherapists.

### *Postoperative Outcome Measurements*

The specific types of progression and return to sport outcomes used by clinicians after hip arthroscopy is variable, but some similarities were identified (Figure 2). We considered the Harris Hip Score,

A variety of outcome that measure body function, body structure, and activity limitations are used by physiotherapists and orthopaedic surgeons to progress a patient through their rehabilitation program or clear them to return to sport (Figure 3). Body function outcomes, like pain scales, were not as frequently reported six weeks after surgery as outcomes measuring body structure and activity limitations and between three and six months after surgery by both types of clinicians. However, physiotherapists reported using activity outcomes postoperatively than orthopaedic surgeons. The Harris Hip Score, Vail hip Score, and modified Harris Hip Score were considered 'mixed' outcomes, that measure more than one construct based on the ICF model definitions. Orthopaedic surgeons reported using more 'mixed' outcomes, than physiotherapists. Specific outcomes to measure 'participation' were not reported or described by practicing clinicians for any of the six follow-up time periods.

2A

**Physiotherapists**

**Surgeons**

- GRC
- LEFS
- NPRS

- WOMAC
- VAS Pain Scales

- HOS
- iHOT
- HHS

2B

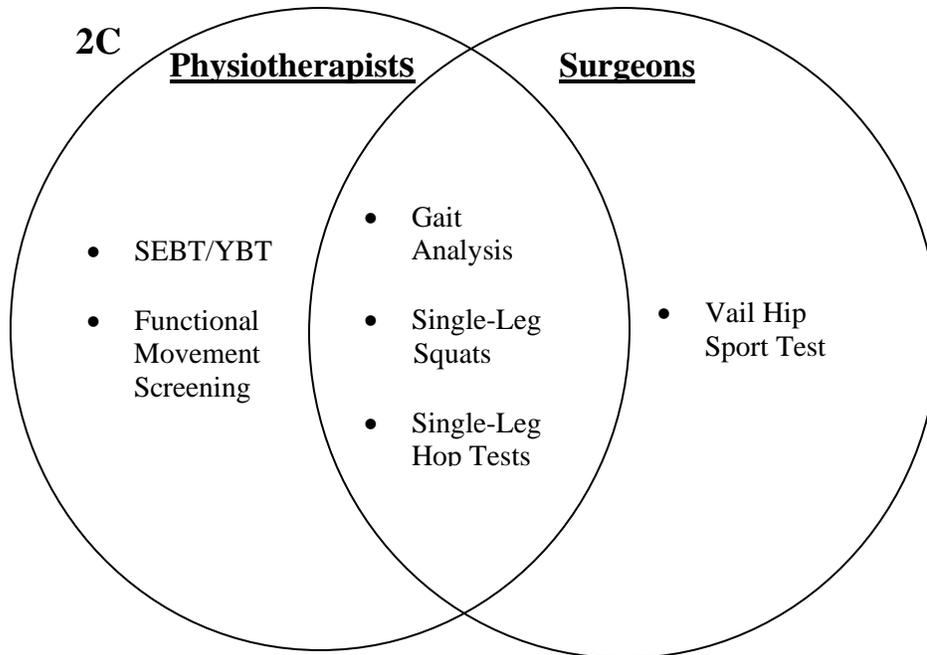
**Physiotherapists**

**Surgeons**

- Trendelenburg
- Ober

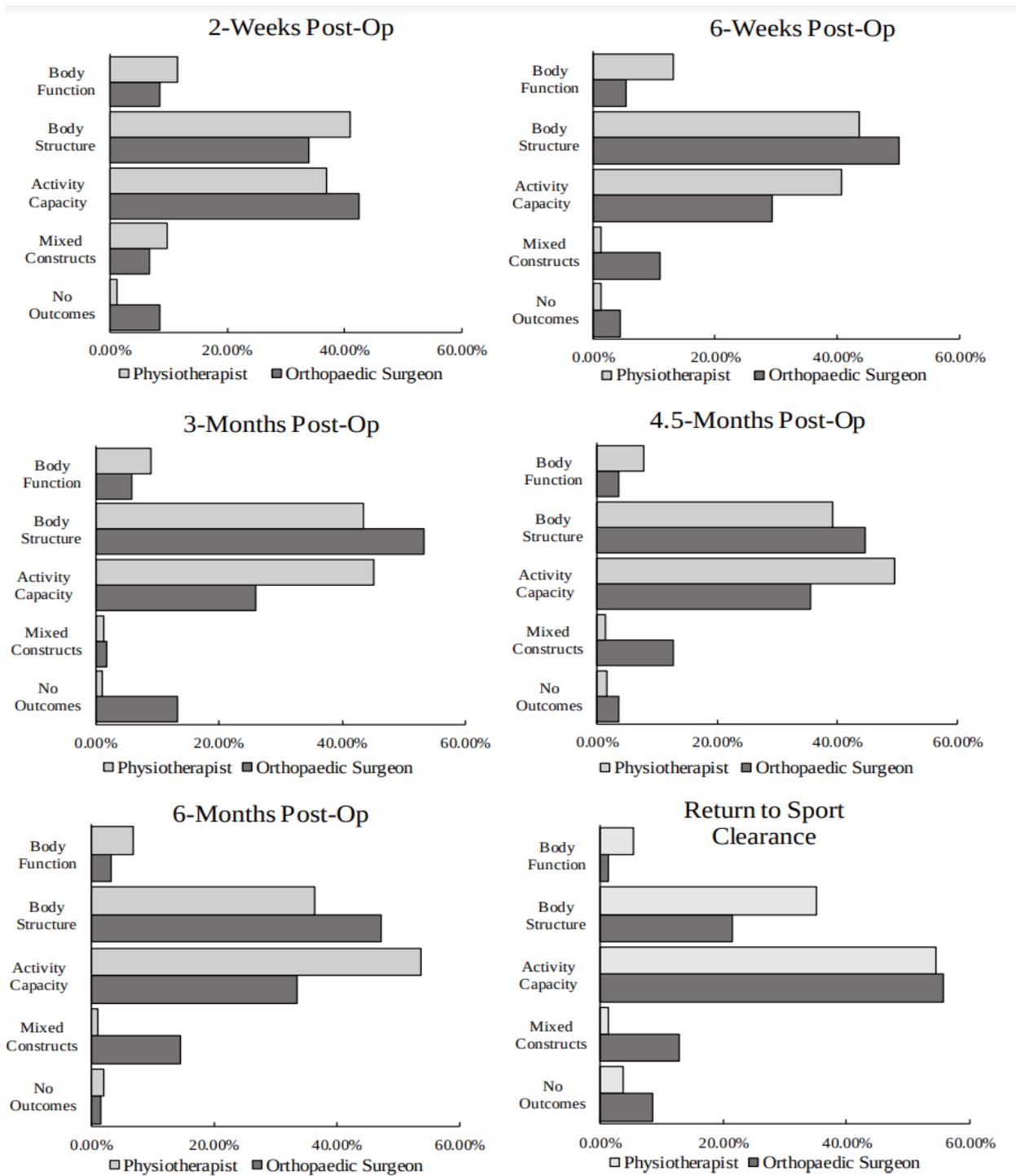
- Gait Assessments
- ROM Testing
- FABER/FADIER
- MMT

- Log Roll



**Figure 2:** Outcome Measures Used by > 25% of Clinicians Postoperatively for Patients with FAIS. **2A)** Patient Reported Outcomes; **2B)** Physical Examinations; **2C)** Performance-Based Outcomes.

Abbreviations: Western Ontario and McMaster Universities osteoarthritis index (WOMAC); Visual analog scale for pain (VAS-Pain); Numeric pain rating scale (NPRS); Non-arthritic hip score (NAHS); Lower extremity functional score (LEFS); International hip outcome tool (iHOT); Harris hip score (HHS); Global rate of change score (GRC); Range of motion (ROM); Manual muscle testing (MMT); Flexion adduction internal rotation (FADIR); Flexion abduction external rotation (FABER); Star excursion balance test (SEBT); Modified Y-Balance test (YBT).



**Figure 3:** International Classification of Functioning, Disability, and Health Constructs Measured in Patients with FAIS at Common Postoperative Follow-Up Time Periods.

## 4.4 Discussion

### *Outcome Measures*

The main objective of this survey was to identify the specific types of outcome measures clinicians are currently using to evaluate the functional progress and readiness for return to sport for patients with FAIS who are postoperative. Surgeons and physiotherapists use a wide variety of outcomes; the most common patient-reported outcome for orthopaedic surgeons were those measuring pain whereas for physiotherapists it was the Lower Extremity Functional Scale. The most common physical examination tests used by orthopaedic surgeons and physiotherapists were gait assessments, range of motion measurements, muscle strength tests, and hip impingement tests. Although a variety of performance-based outcome measures were selected by clinicians, most used the single-leg squats, hop tests, and computer-based gait analysis. The specific types of outcome measures to evaluate readiness to return to sport varied, but performance-based ‘activity’ outcomes were the most widely selected amongst clinicians. No clinicians reported using outcomes that measure ‘participation’ limitations.

Approximately 45% of physiotherapists and 15% of orthopaedic surgeons indicated they use a dedicated post-operative FAIS rehabilitation protocol. However, approximately 70% of our respondents indicated their current postoperative practices and recommendations are based mainly on their own opinion. Interestingly, some respondents did not select any of the outcome measures listed in our survey and did not list additional outcomes that they prefer to use postoperatively. Thus, we do not know if these clinicians formally evaluate their patients’ progress or readiness to return to sport.

Some of our findings appear to support those of a systematic review by Grzybowski et al.<sup>11</sup> that investigated rehabilitation guidelines following hip arthroscopy. Eighteen studies (2,092 subjects; 52% male, mean age  $35.1 \pm 10.6$  years, mean follow-up  $3.2 \pm 1.0$  years) were included. They concluded that there was a high degree of variability in postoperative outcomes and guidelines. Clinical data and parameters such as weight-bearing, range of motion, strengthening, and return to sport are poorly reported.<sup>11</sup> Unpublished data from our recent scoping review of postoperative return to sport guidelines

and criteria for patients with FAIS also concludes clinical data is lacking. Clinical timelines, objective return to sport criteria, and the specific types of outcome measures used by clinicians postoperatively were also variable.

The number of patients treated each year and reported return to sport success rates were substantially higher for orthopaedic surgeons than physiotherapists. Because we had a low number of respondents, our estimates may be inaccurate. It is also possible that rates of success are higher for clinicians who treat larger volumes of patients with FAIS every year.

Similarly, the findings of this survey indicate there is significant heterogeneity amongst clinicians as to which outcome measures to use postoperatively. It is possible that currently practicing clinicians recognize that published postoperative return to sport guidelines and criteria lack the methodological strength necessary for them to change their clinical practice.<sup>10</sup> Clinical practice often lags behind what is suggested by research because only 57% of patient care and recommendations for orthopaedic pathologies are based on the best available research evidence.<sup>18</sup> Promisingly, a consensus statement was recently published in 2016 outlining how to clinically diagnose and treat FAIS, bringing together the opinions of clinicians, academics, and clinical researchers.<sup>7</sup> However, the validity and reliability of commonly used outcomes measures has only been established for other lower extremity injuries, not for patients with FAIS. It seems reasonable to believe practicing clinicians might be more inclined to change their clinical practice if researchers determine which outcomes are most valid for FAIS patients. Hence, more research is needed before a safe, reliable, and reproducible postoperative return to sport guideline is established for these patients. We recommend researchers determine the utility of currently recommended postoperative outcome measures if the goal is to improve postoperative clinical practices and support higher quality studies, like randomized control trials.

### *Postoperative Clinical Practices*

The secondary objective of our survey was to determine how successful current clinical practices are at returning FAIS patients to sport after hip arthroscopy. Canadian practicing clinicians had a lower median return to sport success rate than clinicians practicing in the United States higher among orthopaedic surgeons than physiotherapists. Overall, the median return to sport success rate and time frame was 66% and 26 weeks, respectively, regardless of clinicians' type of practice. Previously estimated return to sport success rates between 57%<sup>8</sup> and 94%<sup>9</sup>, have been estimated, it is believed roughly 30% return to their same type and level of sport.<sup>8</sup>

### *Limitations*

There are several limitations to this study. Firstly, we had a disproportionate rate of responses from physiotherapists and surgeons, with a larger proportion of PT responses. Additionally, most surgeons were practicing in the US and physiotherapists were all practicing in Canada. Therefore, our findings represent only a subset of the clinical practices of all PTs and orthopaedic surgeons who currently work with FAIS patients and differences between the public and private health care systems may have influenced the differences between clinicians.

Response rates were lower than previously reported surveys of specialty physicians and clinicians. However, survey response rates from specialty physicians are often quite low in health-related fields because of time constraints and the cumbersome nature of survey research.<sup>19,20, 21</sup> Our sample of clinicians performing hip arthroscopy, and correspondingly sample of physiotherapists working to rehabilitate these patients with FAIS was small.

Our list of available outcome measures and protocols was also not exhaustive. Outcomes and protocols were chosen based on currently published guidelines for return to sport, the 2016 consensus statement,<sup>7</sup> and our earlier research on published criteria for readiness to return to sport.

Recommendations from our focus group of PTs, academics, and surgeons supported the surveys' face

validity. The survey did not undergo reliability or validity testing. However, it was intended to be an informative questionnaire for on-going research into the postoperative rehabilitation guidelines for patients with FAIS. Survey questions did not address the level or types of athletes' clinicians currently treat. We also did not ask clinicians to describe the treatment goals for their patients. As a result, variability in success rates for return to sport may be explained by unique factors specific to a patient's level or type of sport that were not accounted for in our survey design.

#### **4.4.1 Future Directions**

Clinicians are currently relying on their own, expert, opinion, rather than an established postoperative FAIS protocol when evaluating their patient's readiness to return to sport because current guidelines lack consensus. Development studies are needed to determine how clinicians can or should evaluate postoperative readiness to return to sport. More data should also be collected using currently recommended or preferred outcome measures so their efficacy and measurement properties for patients with FAIS can be determined.

#### **4.5 Conclusion**

Postoperative clinical practices appear highly variable, with differing recommendations regarding the use of patient-report, physical examination tests, and performance-based outcome measures. The most used outcome measures postoperatively measure activity capacity and included the SEBT/YBT, hop tests, single-leg squats, and computer-based gait analysis. Surprisingly, some practicing clinicians do not use a formal guideline or outcome measures to determine readiness to return to sport. More research is needed to determine a more precise estimate of return to sport success rates, time frames and the psychometric properties of outcome measures used by physiotherapists and orthopaedic surgeons.

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## Chapter 5

### Postoperative Functional Recovery Patterns in Unilateral FAIS Patients Returning to Sport: A Prospective Observational Study Proposal

#### 5 Introduction & Rationale

Femoroacetabular impingement syndrome (FAIS) is a commonly diagnosed cause of hip pain and reduced physical activity in highly active young adults.<sup>1-3</sup> Cohort studies estimate 10 to 15% of patients in America,<sup>4,5</sup> and 3% of patients in Canada with symptomatic hip pain are diagnosed with FAIS every year.<sup>6</sup> FAIS occurs when there is abnormal contact between the femur and acetabulum due to a pincer or cam-type deformity.<sup>7,8</sup> Higher levels of competitive sports like soccer,<sup>1</sup> basketball,<sup>9</sup> hockey and downhill skiing,<sup>10</sup> may increase an individual's risk of developing FAIS.<sup>3</sup>

Patients are often treated arthroscopically to repair damage to the labrum and resect excessive bone after non-operative treatments like physiotherapy are exhausted without satisfactory improvement.<sup>11</sup> Unpublished data from our summary of postoperative return to sport guidelines suggest a criteria or graded approach to rehabilitation often represented in phases.(Chapter 3).

Researchers and clinicians estimate between 57%<sup>12</sup> and 94%<sup>13</sup> of patients recovering from unilateral FAIS arthroscopy will return to the same level of sport, but only 30% may ever achieve their previous, desired, or optimal levels of function.<sup>12</sup> If a patient's goal postoperatively is to return to the same level of sport at their desired performance level, valid and reliable functional tests are needed to evaluate their progress and risk of reinjury.

Our results from chapter three indicate optimal methods of evaluating a patient's ability to progress to other phases of treatment or readiness to return to sport lack consensus. Our recent survey of practicing clinicians who treat patients with FAIS suggests they recommend using several combinations of patient-reported, clinical, and functional outcome measures such as: the hip outcome score (HOS), the Vail hip sports test, the star excursion balance test (SEBT), hand-held dynamometry (HHD), Y-balance

tests (YBT), functional movement screening (FMS), step down test (SDT), and the single leg hop test (SLHT) (Chapter 4). The utility of outcome measures commonly used in clinical practice should be established so researchers and clinicians can determine which are best to evaluate functional progress and readiness to return to sport in patients with FAIS postoperatively.

To ensure patients with FAIS have the best chance of successfully returning to the same type and level of sport, clinicians should use the most effective and efficient postoperative rehabilitation guidelines and objective evaluation criteria. However, published return to sport guidelines and progression criteria currently lack evidence and should not be considered as evidence-based practice.<sup>14,15</sup>

Identifying risk factors and functional deficits that can predict whether a patient can return to their same level of sport at their desired performance level or, contrastingly, be reinjured, would allow clinicians to focus their rehabilitation protocols to potentially mitigate these risk factors. For instance, the SLHT and SEBT are used to predict return to sport outcomes and risk of reinjury in patients with other lower extremity injuries.<sup>16-19</sup>

Additionally, demographic, and clinical predictors of positive and negative postoperative outcomes for patients with FAIS were recently identified by Sogbein et al.<sup>20</sup> at follow-up periods ranging from 22.4 to 40.8 months. Positive outcomes were defined as a decrease in hip pain or higher outcome measure scores, whereas negative outcomes were defined as persistent hip pain, decreased range of motion (ROM), refractory to nonsurgical treatment, revision, or total hip arthroplasty (THA). Predictors of positive outcomes were younger age, male sex, a positive response to preoperative intra-articular hip injections, and lower body mass index (BMI) ( $<24.5 \text{ kg/m}^2$ ). Comparatively, surgical morphology, labral repair, poor range of motion, and longer preoperative symptoms predicted negative outcomes postoperatively.<sup>20</sup>

A similar study needed to determine whether additional variables, such as level and type of sport, duration of physiotherapy treatment, or if commonly recommended outcome measures like the SEBT and SLHT, can successfully predict if patients with FAIS can successfully return to sport following hip

arthroscopy. A postoperative clinical prediction tool developed and validated for FAIS patients is critical before an efficient, safe, and effective postoperative return to sport guideline and criteria for FAIS patients can be established.

Thus, the main purpose of this study is to observe functional recovery patterns in patients 16 to 36 years of age following corrective hip arthroscopy for unilateral FAIS. Secondly, we will determine the proportion of patients who 1) return to their same type of sport; 2) return to their same level of sport, and 3) the proportion of patients who are cleared to return to sport by their surgeon postoperatively at each follow-up period. Lastly (4), nested within this prospective cohort study, we will evaluate the psychometric properties of patient-reported outcomes, physical examination tests, and performance-based measures used in this cohort after surgery.

## **5.1 Hypotheses**

### **5.1.1 Main Objective:**

Our first hypothesis is that patients will demonstrate improvements in postoperative outcomes that are correlated to changes indicated on the global rating of change over time. Secondly, change scores in outcomes measuring ‘body function and structure’ limitations will improve but will plateau within three months postoperatively while those measuring ‘activity’ limitations will plateau after six months.

### **5.1.2 Secondary Objectives:**

#### *RTS Success*

We hypothesize the majority of our patients will return to their same type and level of sport between six months and one year after surgery which is similar to other cohort studies.<sup>12,13</sup> A larger proportion of male patients, with lower BMIs, who participate in sports with higher mechanical demands, like hockey, and higher than varsity levels, will return to same type and level of sport after surgery than women and men with larger BMIs who participate in lower levels of sport and have less mechanical demand on the hip.

### *Prediction*

First, we hypothesize a patient's type of FAIS, preoperative level of sport and type, body structure and function, single-leg balance, dynamic hip strength, and previously identified positive postoperative outcome factors will predict when a patient returns to their same level and type of sport after surgery. Secondly, preoperative performance-based outcome scores on the star excursion balance test and hop tests will predict whether a patient returns to the same type and level of sport postoperatively. Lastly, we will evaluate the validity of a simplified risk score for predicting whether a patient will return to their same level and type of sport following surgery.

#### **5.1.3 Third Objective:**

First, the test-retest reliability of the Star Excursion Balance Test (SEBT) will have ICC values like those previously reported for lower extremity reported values for other lower extremity injuries<sup>21,22</sup> and the HOS-Activities of Daily Living (ADL) and Sports Subscale (SS), international Hip Outcome Tool (iHOT-33), modified Harris Hip Score (mHHS), and the four-item pain scale (P4), will have moderate to good ICC values. in FAIS patients.

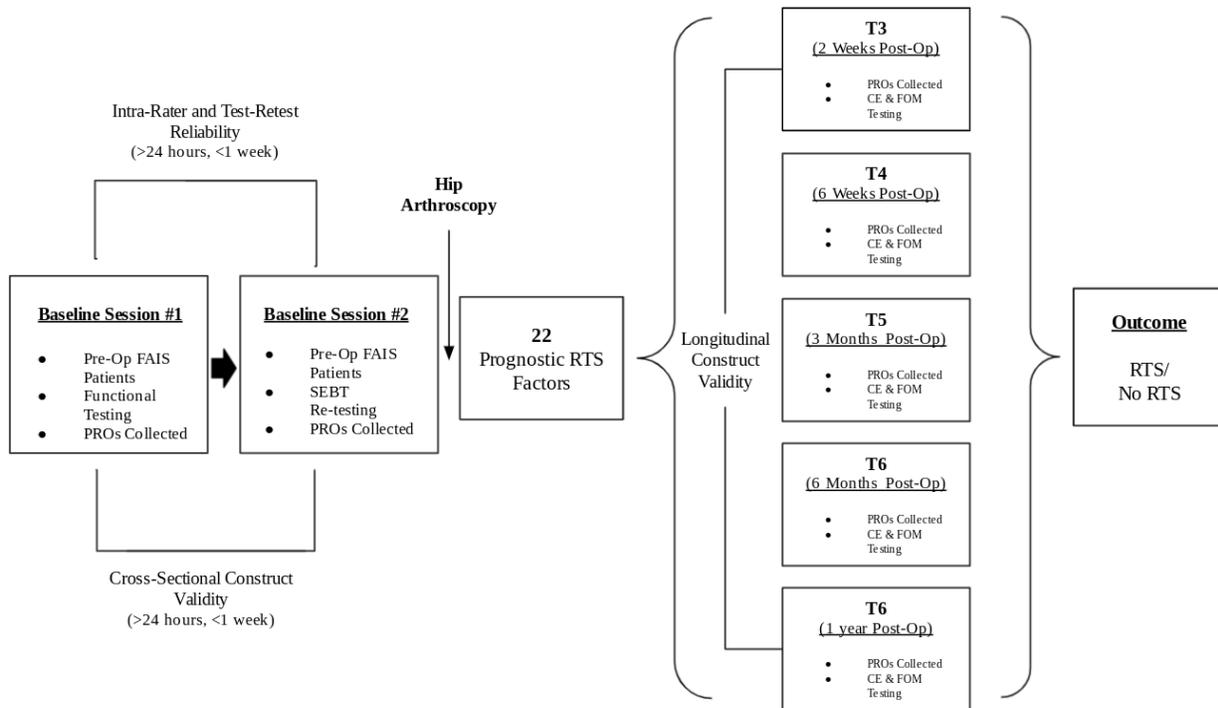
Second, the SEBT, HOS-ADL, HOS-SS, iHOT-33, and mHHS will demonstrate excellent cross-sectional validity.

Third, for longitudinal construct validity and sensitivity to change we expect the SEBT, hop test, HOS-ADL, HOS-SS, iHOT-33, and mHHS will demonstrate excellent longitudinal construct validity and sensitivity to change at 6-weeks, 3-months, 6-months, and 1-year. While the double-leg squat, hurdle step-, and step-down test will demonstrate poor longitudinal construct validity and sensitivity to change 3-months, 6-months, and 1-year. We estimate the MCID for the SEBT, hop test, HOS-ADL, HOS-SS, iHOT-33, and mHHS from preoperative to each postoperative period.

## **5.2 Methods**

### **5.2.1 Study Design:**

This study is a prospective, observational cohort study with repeated measures over time that uses methodology to identify factors that are prognostic of outcome. Local ethics approval was obtained from the Western University Health Sciences Research Ethics Board (REF#: 114897) (Figure 1).



**Figure 1.** Study design: Testing procedures for assessing measurement properties of the star excursion balance test and patient-reported outcomes in patients with FAIS.

### 5.2.3 Setting:

Eligible patients referred to the Fowler Kennedy Sport Medicine Clinic (FKSMC), located on the campus of Western University in London, Ontario, Canada, which specializes in physiotherapy, orthopaedic, primary sport medicine care, will be recruited between November 1<sup>st</sup>, 2020, and August 31<sup>st</sup>, 2026. Patients will complete first and second baseline data collection visits preoperatively, T1 and T2, respectively. Data collection will continue when patients attend standard surgical follow-up visits with their surgeon at two weeks, six weeks (T3), three months (T4), six months (T5), and one year (T7) after surgery.

### 5.2.3 Participant Eligibility Criteria:

Patients will be eligible to participate if they are: 1) between 16-36 years of age; 2) participate in non-organized, recreational, competitive, varsity or elite sports; 3) clinically diagnosed with unilateral FAIS;

4) undergoing hip arthroscopy to correct impingement and associated injuries; and 5) willing to travel to FKSMC for follow-up appointments. Patients will be approached after consenting to hip arthroscopy.

Patients will not be eligible to participate if they: 1) have radiographic evidence, history, or diagnosis of arthritis in the hip; 2) are clinically diagnosed with bilateral FAIS; 3) have a major neurological disorder; 4) are unable to read or speak English; or 5) have had prior hip surgery or a concomitant lower limb injury within the past two months.

Participants will be consecutively recruited from the clinic of two orthopaedic surgeons (Dr. Ryan Degen and Dr. Kevin Willits) at the FKSMC.

### **5.3 Variables of Measurement**

Outcome measures were chosen based on currently published rehabilitation protocols and our prior research. Outcome measures will include: the HOS, mHHS, iHOT-33, P4, FABQ, GRC, a pre and postoperative questionnaires that measures sport participation, a form that records rehabilitation progress and experience, active and passive range of motion of the hip (flexion, abduction, adduction, extension), the SEBT, the 90° double-leg squat and hurdle step components of the functional movement screen (FMS), an eight-inch lateral step-down test, and a single-leg hop test (SLHT)

#### **5.3.1 Patient Reported Outcomes:**

All PROs including the: HOS-Activities of Daily Living (ADL) and Sports Subscale (SS); iHOT-33, mHHS, and the four-item pain scale (P4), will be collected online using EmPOWER software (Empower Health Research Inc, 2009). Research has recently demonstrated that arthroscopy can significantly improve a patient's self-reported level of function and pain. On average, preoperative HOS-ADL, HOS-S, mHHS, and iHOT scores significantly improve in FAIS patients two years after undergoing hip arthroscopy, but minimal clinically important differences (MCIDs), substantial clinical benefits (SCB), and a patient acceptable symptomatic state (PASS) for PROs appear to be time-dependent.<sup>23</sup> Results demonstrate that 97.6% of FAIS patients undergoing hip arthroscopy achieved an MCID of 14.8 points

for pain, 66.4% achieved a PASS pain threshold of 21.6 points, and 71.2% achieved an SCB pain threshold of 25.5 points two years postoperatively.<sup>23</sup> However, more research is needed because these results were only collected from a single, fellowship-trained, practicing orthopedic surgeon.

More recently, Nwachukwu et al.<sup>24</sup> administered the mHHS, iHOT-33, and HOS to 719 FAIS patients undergoing hip arthroscopy. Multi-factor regression analysis adjusting for age, sex, sagittal and coronal center edge angle (CEA) demonstrates the probability of a patient achieving an MCID, SCB or PASS varies depending on the PRO and follow-up period. Patients achieved an MCID on the mHHS, HOS-ADL, HOS-SS, and iHOT-33, 70.4%, 62.8%, 52.2% and 76%, of the time, respectively, six months postoperatively. These probabilities increased to 83.5%, 72.2%, 74.6%, and 93.6%, for each PRO two years postoperatively.<sup>24</sup> Patients are more likely to achieve an MCID or SCB for PROs at six-month follow-up postoperative visits but may continue to see improvements two years after surgery. Younger patients with lower BMI, a smaller alpha angle, a higher mHHS score, and lower pain scores preoperatively may also be more likely to achieve an MCID, SCB or PASS before their two-year follow-up.<sup>23,24</sup>

### *Hip Outcome Score*

The HOS is a patient-administered questionnaire with a scoring system composed of two subscales, active daily living (ADL) and sport specific (SS). The HOS-ADL contains 19 items that evaluate tasks like putting on socks, standing and sitting, to more demanding activities like squatting, twisting and pivoting on the symptomatic leg.<sup>25</sup> Whereas the HOS-SS is composed of nine items that evaluate an individual's ability to perform specific tasks related to sport like starting and stopping quickly, as well as lateral and cutting motions.<sup>25</sup> The responses for each item range from zero, indicating “extreme difficulty”, to four, indicating “no difficulty at all”. The HOS has demonstrated validity and responsiveness in patients with higher levels of physical ability and has been utilized during the early stages of rehabilitation, as well as in return to sport protocols for patients recovering from arthroscopy FAIS.<sup>25-28</sup> Kemp et al.<sup>29</sup> recruited 45 patients with FAIS and related injuries undergoing arthroscopy. Test-

retest reliability for the HOS-ADL (ICC 0.95 (95%CI: 0.92 to 0.97)) and HOS-SS (ICC 0.96 (0.92 to 0.98)) was excellent across a span of seven to eight days. The ADL and SS had a minimal detectable change (MDC) of nine and 13 points, respectively, as well as a standard error (SEM) of three and four points, respectively, in FAIS patients 12 to 24 months after surgery. Lastly, the two subscales demonstrated low to moderate correlations to the global rating of change (GRC) ( $r$ : 0.35 to 0.47) and a minimal important change (MIC) of five and six points, respectively.<sup>29</sup>

### *Modified Hip Harris Score*

The mHHS was derived from the Harris Hip Score (HHS), and consists of eight items: pain, limp, support, distance walked, stairs, shoes/socks, sitting, and public transportation. The HHS is scored on a 100-point scale, with each answer receiving a specific number of points, and interpreted as: <70 = poor; 70–80 = fair, 80–90 = good, and 90–100 = excellent.<sup>30</sup> However, the mHHS only includes the pain and functional constructs derived from the HHS. Hence, the maximum score of 91 is multiplied by 1.1 to give a total score out of 100.<sup>31</sup> The mHHS is a commonly used PRO in hip arthroscopy to evaluate the subjective functional ability of the hip joint in patients with known pathologies such as total hip replacement,<sup>32</sup> pre-trochanteric fractures,<sup>33</sup> and FAIS.<sup>29</sup> The mHHS subscales of pain and physical function have good construct validity with the 36-item short form survey (SF-36) having Pearson correlation coefficients ranging from 0.71 to 0.85.<sup>34</sup> It has also demonstrated excellent test-retest reliability (ICC > 0.9 (95%CI: 0.84 to 0.95)) between seven and nine days, an SEM of four points, and an MDC of 12 points in FAIS patients 12 to 24 months postoperatively.<sup>29</sup> However, the mHHS has demonstrated ceiling effects of 24% in postoperative patients 12 to 24 months after surgery.<sup>29</sup>

### *International Hip Outcome Test*

The international hip outcome tool (iHOT-33) is a quality-of-life measurement tool developed for active aged patients presenting with a variety of symptomatic hip pathologies, including FAIS.<sup>35</sup> The questionnaire consists of 33 items relating to a patient's symptoms, functional limitations, sport and recreation activities, job, and lifestyle concerns. It evaluates a patient's ability to return to an active

lifestyle as well as their emotional and social health status.<sup>35</sup> Patients mark their perceived level of ability on a visual analog scale between “significantly impaired” and “no problems at all.” The iHOT-33 has been deemed a valid and reliable tool that is responsive to change in hip arthroscopy patients. It has demonstrated face, content, and construct validity ( $r = 0.81$ ) with the non-arthritic hip score (NAHS).<sup>35</sup> On average, test-retest reliability has an ICC of 0.93 (95%CI: 0.87 to 0.96) and an SEM of six points.<sup>29</sup> It has also demonstrated an MDC of 16 points and an MIC of 10 points.<sup>29</sup>

### *Pain*

The P4 is a four-item questionnaire that evaluates a patient’s level of pain over the past two days. The patient reports the level of pain they experience in the morning, afternoon, evening and during any type of physical activity. Each item consists of ten responses that range from 0 (no pain) to 10 (worst pain). The maximum score a patient can achieve is 40 and is calculated as a sum of each item's individual score. The P4 has been shown to be a valid and reliable instrument for assessing change in pain intensity in patients receiving physiotherapy for various musculoskeletal injuries.<sup>36</sup> The P4 has demonstrated significantly greater test-retest and longitudinal validity when compared to the 24 hour (ICC = 0.57 to 0.63) and 48 hour (ICC = 0.56 to 0.61) numeric pain rating scale (NPRS).<sup>36</sup> It also has an estimated MDC of nine points, compared to three and three and a half points for the 48-hour and 24-hour NPRS, respectively.<sup>36</sup> Test-retest reliability is estimated to have an ICC of 0.78 (95%CI: 0.72 to 0.83) and an SEM of 3.9 points (95%CI: 3.6 to 4.4).<sup>36</sup> However, measurement properties in patients with FAIS have not been investigated.

### *Fear Avoidance Behavior*

The FABQ assesses a patient's fear avoidance beliefs regarding physical activity. It is based on a fear-avoidance model of exaggerated pain perception that was developed to understand why patients with acute back pain develop chronic back pain.<sup>37</sup> It consists of two subscales: (1) 7-item work scale (range 0 to 42 points); (2) a 4-item physical activity scale (range 0 to 24 points). Patients rate their level of agreement, 7-point ordinal Likert scale, with their degree of physical activity or work avoidance due to

their fear of experiencing pain. The maximum score possible is 96 and a higher score indicates a stronger fear avoidance belief. In this study the FABQ will be modified to make that questionnaire more usable for patients with hip injuries: “back” will be replaced with “hip”. Modified versions of the FABQ for diagnosed lower extremity pathologies, like chronic ankle instability (CAI),<sup>38</sup> and knee-related injuries<sup>39</sup> are correlated to measures of self-reported function and dynamic balance. Evidence suggests identifying the reliability, validity, internal consistency, responsiveness, and cut-off scores for modified FABQs would inform clinical rehabilitation practices.<sup>38,39</sup> Therefore we will create and use a modified FABQ specific for FAIS patients and investigate its measurement properties in this cohort.

### *Global Rating of Change*

A recent systematic review by Bobos et al.<sup>40</sup> found the GRC is more commonly measured on a 15-point scale ranging from -7 (much worse) to +7 (much better) scales, but other scales; 29, 11 and 9-points, have been reported.<sup>40</sup> It clinically quantifies if a patient's condition has gotten worse, better, or stayed the same following a course of treatment by capturing their self-reported level of change. Linear regression modelling has demonstrated the GRC does not adequately or consistently correlate functional change scores in the hip and ankle across varying lengths of follow-up due to a high level of recall bias and bias towards functional outcome scores at discharge.<sup>41</sup> The GRC has demonstrated fair-to-good test-retest reliability (ICC = 0.61) in patients with lumbar spine disorders and a moderate inter-rater reliability between patient and clinician ( $r = 0.63$ ).<sup>40</sup> It has also been shown to be responsive to change on an 11-point scale (MDC = 0.45 points) with an MIC ranging from 2.0 to 2.5 points.<sup>40,42</sup> It is therefore recommended that future studies investigating responsiveness to treatment use the GRC in combination with other outcome measures to mitigate recall bias because evidence for its validity ranges from very weak to weak.<sup>40</sup> Although its psychometric properties have been debated, the GRC is a simple, easy to administer, interpret, and applicable to a wider range of different patient populations.<sup>42</sup> In this study the GRC will be tailored to patients with FAIS and used to measure patient-rated change in combination with other patient-reported outcomes since their last postoperative follow-up visit.

### *Duration of Treatment*

In this study we will use a rehabilitation experience and progress (PER) form developed in Empower to evaluate the quality and amount of physiotherapy treatment a patient receives postoperatively. The PER asks patients to answer a series of questions related to the progress of rehabilitation exercises and protocols they have completed. The PER also records the amount of treatment a patient is receiving including the duration of each session. If a patient has stopped attending physical therapy, they are asked to answer a series of follow-up questions to determine why, such as cost, lack of insurance, scheduling conflicts, personal beliefs, or quality of care.

### *Sport Participation*

For this study two specific pre and postoperative return to sport questionnaires were developed and will be used to capture data pertaining to the patient's level of sport. We will define levels of sport and group types of sport according to Parvaresh et al. (2020). We will define types of sport as games, activities, or competition requiring physical skill that is played or conducted according to rules, against other players or teams and will **not** include only working out, lifting weights, jogging etc. There are five categorical levels of sport: elite, varsity, competitive, recreational, or non-organized. We define categories of sport the same in both questionnaires. “Elite” is defined as playing the highest level of professional sport such as the Olympics, world games, professional (ex. National Hockey League) or any of their amateur affiliated organizations (ex. Ontario Hockey League). “Varsity” is defined as playing for a team that represents a college or university. A sport is deemed “competitive” if the individual plays in a competitive league. “Recreational” sport is defined as regularly playing for a beginner or social league. Lastly, in this study we define non-organized sport as any activity that involves not playing in a league; or as playing irregularly with friends or family. For both questionnaires, patients are instructed to check “Yes” next to the sport(s) that they participated in prior to their injury and indicate the “level of sport” at which they participate for those sport(s) only. The preoperative questionnaire is designed just to record the type and level of sport a patient participates in. Whereas the postoperative return to sport

questionnaire records if the patient has fully or partially returned to the preoperative level of sport(s) they participated in prior to their injury. If not, patients are asked to indicate the reason(s) for why they have not returned, such as fear, lack of confidence, lack of interest, pain, lack of function, or re-injury.

### **5.3.2 Physical Examinations:**

#### *Goniometry*

Range of motion (ROM) refers to the hip joint's ability to move through its degrees of flexion, extension, abduction, adduction, and circumduction measured with a goniometer. It is measured by placing the stationary arm at the joint's axis and movement arm then moving along the axis of rotation to measure the joint's angle in degrees.<sup>43</sup> There are two types: active- ROM and passive- ROM. Active- ROM requires the patient to move the joint without any assistance to the muscles or joint. In comparison, during passive-ROM a health professional, like a physiotherapist, manually moves the joint through its applicable planes of movement with no effort from the patient. ROM measurements are valid and reliable when a goniometer is used by trained professionals.<sup>43</sup> In this study, ROM will be measured using a goniometer by a trained member of the research team who is a registered kinesiologist with more than 10-years of experience.

#### *FABER/FADIR*

The Flexion, Adduction, Internal Rotation (FADIR) and Flexion, Abduction, External Rotation (FABER) physical examinations evaluate the irritability of hip movements and mobility of the hip joint. The FABER test requires the examiner to place the patient's leg in a figure-4 position with the lateral ankle resting on the contralateral thigh proximal to the knee.<sup>44</sup> The examiner stabilizes the opposite side of the pelvis at the anterior superior iliac spine, then applies an external rotation, abduction and posterior force to the ipsilateral knee until the end range of motion is achieved.<sup>44</sup> A positive test reproduces painful symptoms or identifies a limited range of movement.<sup>44</sup> The FADIR test requires the patient to lay with the testing hip on top. The clinician applies downward pressure while moving the hip into flexion, adduction, and internal rotation.<sup>44</sup> A positive FADIR test occurs when pain is reproduced.<sup>45</sup> The FABER test has

good inter-rater reliability 0.63 (95% CI: 0.43 to 0.83),<sup>46</sup> while the FADIR test has moderate reliability 0.58 (95 CI: 0.29 to 0.87).<sup>46</sup> The FADIR test has an estimated sensitivity (Sn) and specificity (Sp) of 0.75 (95% CI: 0.19, 0.99) and 0.43 (95% CI: 0.18, 0.72).<sup>46</sup> Unfortunately, the diagnostic accuracy of the FABER test is highly variable. Sn and Sp is estimated to range from 0.22 to 0.64 and 0.20 to 0.97,<sup>47</sup> respectively, and an estimated positive predictive value of 0.46 (95% CI 0.28-0.65).<sup>48</sup> These clinical examinations will be performed by a patient's orthopedic surgeon, associated orthopedic resident or fellowship-trained physicians preoperatively and postoperatively.

### **5.3.3 Performance-based Outcome Measures:**

#### *Functional Mobility*

To prevent injuries and improve performance, an important factor to quickly identify fundamental movement deficits are mobility and stability.<sup>49</sup> One tool that can assess fundamental movement patterns is the Functional Movement Screen (FMS), which consists of seven movements that challenge the body's ability to use its kinetic linking system. Scores on the FMS range from zero to three, with three being the best possible score. If the patient experiences pain anywhere in the body during the test a score of zero is recorded and the painful area is noted. A score of one is recorded if the patient is unable to complete the movement or assume the correct position of the movement while a score of two is recorded if the patient must compensate in some way to complete the movement. Clinical documentation for why a patient received a score of one or two should be recorded and any limitations should be obtained by using standardized goniometric measurements of the hip joint. A score of three is only recorded if the movement is performed correctly without any compensation. Functional mobility in this study will be assessed using two fundamental movement patterns performed in the FMS: the 90° double-leg squat and the hurdle step.

The squat position should be performed with the patient's feet shoulder width apart, heels on the floor, head and chest facing forward, with the shoulders flexed, abducted, and elbows extended over head with hands holding a wooden dowel. If the criteria for a score of three is not achieved, the athlete is then

asked to perform the test with a 2x6 block under their heels.<sup>49</sup> To perform the hurdle step, a patient starts by first placing their feet together and toes touching the base of the hurdle. The hurdle is then adjusted to the height of the athlete's tibial tuberosity. The patient positions a dowel across their shoulders just below the neck. While maintaining the single stance leg in an extended position, the patient is then asked to step over the hurdle touching the heel to the floor and returning to the starting position. Patients should maintain a stable torso, and not lock their knees. Evaluators should score the leg stepping over the hurdle and try not to interpret the score during the test. As many as three repetitions for each assessment should be performed bilaterally, but if one repetition meets the criteria above, a score of three is recorded.<sup>49</sup> These fundamental movements are assessed to determine if a patient can perform essential movement patterns. To our knowledge, the measurement properties of these tests in patients recovering from unilateral FAIS surgery have not yet been reported in the literature.

### *Dynamic Balance*

The Star Excursion Balance Test (SEBT) is an inexpensive method of measuring a patient's single-leg dynamic balance by observing their maximal reach in eight different directions, spaced 45 degrees apart, extending outwards from a center point.<sup>50,51</sup> The patient places their stance leg with the middle of the foot on the center of the star with the non-stance limb beside it. Using the non-stance limb, the patient reaches out as far away as possible and taps a line without bearing any weight; the distance is recorded, and the patient returns to their starting position. A complete trial requires the patient to reach in all eight directions using both legs without losing their balance and moving their stance leg, or the attempt is voided.<sup>50,51</sup> Reach distances are normalized to limb length by dividing them by the patient's leg length, measured from the anterior superior iliac crest to the medial malleolus of the ankle.<sup>51</sup> Normalized reach distances are calculated for each of the eight vectors and higher scores indicate better dynamic balance. Although previous authors have recommended six practice trials of the SEBT in each direction to achieve good reliability,<sup>52,53</sup> evidence indicates a total of only four in each direction are necessary to account for any practice or learning effects.<sup>54</sup>

The measurement properties of the SEBT in healthy and injured patients has been investigated extensively throughout the literature. It can differentiate between injured and non-injured limbs in these populations as well as between injured and healthy controls. Patients with chronic ankle instability (CAI) have demonstrated normalized reach deficits (3 to 5%) when compared to the non-injured limb and healthy controls.<sup>55</sup> Moderate to excellent test-reliability (ICC = 0.84 to 0.93) has been observed for all eight directions of the SEBT in healthy populations.<sup>16,56</sup> Research has also shown it has moderate to excellent inter-rater reliability (ICC = 0.78 to 0.96)<sup>53,57</sup> but poor to excellent intra-rater reliability (ICC = 0.35 to 0.93) in healthy populations.<sup>53</sup> Performance deficits on the SEBT may also be able to predict lower extremity injuries in healthy and injured athletic populations.<sup>16,17,18,58</sup> It is estimated that healthy basketball players may be up to 6.5 times more likely to sustain a lower body injury throughout the season if the sum of their normalized reach distances in the anterior (ANT), posteromedial (PM) and posterolateral (PL) directions of the SEBT has a limb symmetry index (LSI) lower than 94%.<sup>16</sup>

The SEBT is also valid, reliable, sensitive and responsive to change in patients with various lower extremity injuries including; patellofemoral pain syndrome (PFPS),<sup>59</sup> chronic patellar instability (CPI),<sup>21</sup> knee osteoarthritis (OA),<sup>22</sup> and anterior cruciate ligament injuries (ACL).<sup>60,61</sup> Data collected by Firth et al.<sup>21</sup> on patients with CPI indicates the SEBT has cross-sectional validity and the ANT, PL, lateral (LAT) and anterolateral (AL) directions were the most responsive to change; 3.7%, 16.3%, 22.3%, and 12.0%, respectively. The standardized response means (SRM) also never exceeded one and were small to moderate ranging from 0.22 to 0.81 for all eight directions and the MDC ranged from 11% to 20.5% of leg length in all eight directions. Test-retest reliability was estimated to be fair to good (ICC 0.66 to 0.83) and agreement between scores were lowest in the LAT and AL directions (ICC 0.66). On average, the SEM ranged from 4.0 to 7.5% (95CI, 7.86 to 14.50) of leg length for all eight vectors.<sup>21</sup> The results of this study were severely underpowered, and more data is currently being collected to determine the longitudinal validity and the MDIC in this population. In patients with knee OA, results from Kanko et al.<sup>22</sup> indicate the SEBT has good to excellent test-retest reliability (ICC 0.70 to 0.94), and, on average, measurements can vary between 2.82 to 6.30% of a patient's leg length depending on the vector. Low-to-

moderate associations ( $r=0.24$  to  $0.48$ ) on both legs were found between composite normalized change scores on the SEBT, the knee injury osteoarthritis outcome score (KOOS) and 40-meter walk times. An MDC of 8.72% of leg length was estimated for patients with knee OA.<sup>22</sup>

Clinicians have proposed a modified and more streamlined version of the SEBT called the Y-balance test (YBT)<sup>16,17,62-64</sup> which only measures the ANT, PM, and PL vectors and is commonly used as in return to sport rehabilitation protocols because it requires less time and space to administer.<sup>65</sup> It has also demonstrated construct validity and can differentiate between patients with and without FAIS. Johansson and Karlsson<sup>66</sup> investigated the validity of the YBT by comparing scores in symptomatic FAIS patients to matched participants without FAIS. The Copenhagen hip and groin outcome score (HAGOS) was significantly correlated to the PL and PM vectors ( $r = 0.56, 0.75$ ) and moderate correlations between the chair stand test and the PM and PL vectors ( $r = 0.5$  to  $0.6$ ) were also observed. Overall, when compared to patients with FAIS, patients without FAIS demonstrated 22% larger median YBT scores, while distances in the PM vector were 9% and 8% greater on the injured and non-injured leg, respectively. There was also a significant within-group difference of 4.8% in median YBT scores in the PL direction between injured and non-injured legs in patients with FAIS.<sup>66</sup>

However, reach distances captured on the SEBT may not be transferable to the YBT and greater hip displacements in the ANT direction have been observed on the YBT than on the SEBT.<sup>64</sup> Additionally, the YBT may not capture important information because reach deficits on the SEBT have been demonstrated with several different lower extremity injuries.<sup>60,61,67</sup> Therefore, we will collect data from all eight vectors of the SEBT because its psychometric properties in patients with FAIS has yet to be determined and the YBT may miss important information in this cohort.

### *Single Leg Hop Test*

The single-leg hop test (SLHT) requires a patient to stand on one-leg with their toes on a predefined mark on the floor and perform: (1) a single hop for distance; (2) a triple hop for distance; (3) a timed 6-m hop; and, (4) a crossover triple hop for maximum distance while swinging their arms freely

and landing on the same leg.<sup>19,68</sup> Maximal distance is scored for each leg by measuring from the starting position to the heel of the foot and each hop is measured bilaterally. A trial is considered successful if the patient sticks their landing on the same leg they took off from and maintains balance till the distance is recorded, except for the timed 6-m hop. Three attempts on each leg are recorded and a limb symmetry index (LSI) is then calculated for all hop tests as well as the total distance of the 3 hop tests ( $LSI = \text{injured leg/uninjured leg} \times 100$ ). The SLHT has demonstrated longitudinal validity and test-retest reliability in patients undergoing ACL reconstruction (ACLR). Estimated ICC values vary depending on the specific hop test, but indicate good to excellent test-retest reliability ranging from 0.82 to 0.93 with an SEM between 3.04 and 5.59%.<sup>68</sup> A patient's individual score can vary between 5.72% and 9.17%, and the MDC, between 8.09% and 12.96% depending on the specific hop test performed.<sup>68</sup> Poor to moderate correlations ranging from 0.26 to 0.58 have been demonstrated between LSI scores and patient-reported outcome measures, but the GRC is more strongly correlated in patients undergoing ACLR.<sup>68</sup> The SLHT is a commonly used return to sport outcome in postoperative patients with FAIS,<sup>68</sup> but its measurement properties have not yet been examined in this population.

### *Lateral Step-Down Test*

The lateral step-down test (SDT) is often clustered with other single-leg or double-leg tests like the SLHT. Specifically, the test assesses deviations in the hip, pelvis, and trunk performance in patients with hip related pain or a lower extremity injury.<sup>69</sup> Patients should wear shorts so evaluators can observe their knee position throughout the assessment. Patients begin by standing barefoot with both legs shoulder width apart and parallel to each other on a standardized step 20-25 cm high. They then must transition to a single leg-stance on the unaffected leg with the non-stance knee extended out from the step with foot in dorsiflexion. Patients are instructed to bend their stance knee until the heel of the contralateral leg touches the floor while maintaining an upright posture. They then perform one squat every two seconds, without weight bearing on their heel, and return to the starting position every repetition until three squats on each leg are performed on each leg. Each repetition is graded as “positive” or “negative” based on five criteria:

1) arm strategy; 2) trunk alignment; 3) pelvic plane; 4) knee position; and 4) steady stance. A repetition is considered successful if 4 out of the 5 criteria are negative. Points are awarded to each criterion to a maximum of seven and a higher score indicates less function. The SDT is a valid and reliable assessment for biomechanical deficiencies and lower extremity strength in patients with non-arthritic hip pain,<sup>70</sup> but its measurement properties for this population have not yet been determined.

## 5.4 Data Sources/Management

All baseline characteristics, and demographics will be collected immediately after a patient has given their consent. We will then fully explain the purpose of each outcome measure and demonstrate each of them twice before collecting pre-and-postoperative data (Figure 2).

	1 <sup>st</sup> Baseline	2 <sup>nd</sup> Baseline	2 Weeks Post	6 Weeks Post	3 Months Post	6 Months Post	1 Year Post
HOS*	X	X	X	X	X	X	X
MHHS*	X	X	X	X	X	X	X
IHOT-33*	X	X	X	X	X	X	X
P4*	X	X	X	X	X	X	X
FABQ*	X	X	X	X	X	X	X
PER*	X		X	X	X	X	X
Pre-Op* RTS	X						
Post-Op* RTS			X	X	X	X	X
GRC*		X	X	X	X	X	X
FABER*	X				X	X	X
FADIR*	X				X	X	X
PROM*	X				X	X	X
AROM*	X				X	X	X
SEBT	X	X	X	X	X	X	X
Deep Squat	X			X	X	X	X
Hurdle Step	X			X	X	X	X
SDT	X			X	X	X	X
SLHT	X					X	X

\*: Indicates blinding to the data collector.

**Figure 2.** Outcomes collected at baseline and postoperative follow-up visits.

Data collection will take place on site at the FKSMC in the physiotherapy or research department. If a patient has consented over the phone or is unable to attend a preoperative visit, we will collect data on their surgery date at the London Health Sciences Surgery Center, in London, Ontario, Canada. At the first baseline visit (T1), we will collect preoperative data from: 1) six patient-reported outcomes (Hip Outcome Score (HOS), International Hip Outcome Tool (iHOT-33), modified Harris Hip Score (mHHS), a four-item pain questionnaire (P4), the Fear Avoidance Belief Questionnaire (FABQ), a preoperative return to sport questionnaire) using Empower Health Research; 2) pain provoking impingement assessments on the patients symptomatic hip; 3) four passive and active goniometer assessments on the patients symptomatic hip; 4) four practice trials of the star excursion balance test (SEBT) on each leg and four complete trials on each leg; 5) three double-leg squat assessments past 90°; 6) three hurdle steps per leg; 7) three lateral step-down tests per leg; and lastly, if capable, a five minute warm-up on a stationary bike and one complete single leg hop test (SLHT). Patients will then complete a second baseline (T2) visit within one week of their first visit to assess the test-retest reliability of collected patient-reported outcome measures and the SEBT preoperatively. We will collect data from the same six patient-reported outcomes from the first baseline visit, four complete trials of the SEBT per leg, and a global rating of change scale (GRC) to ensure patients has not changed since their last visit.

Data collection protocols two-weeks (T3), six-weeks (T4), three months (T5), six months (T6) and one year postoperatively follow the same guidelines for each outcome measure at T1. Six patient reported outcomes, a GRC, and a postoperative RTS questionnaire will be collected after the patient has completed their postoperative follow-up visit with there surgeon. We will then collect performance-based measurements based on postoperative FKSMC protocol for patients with FAIS at each follow-up visit.

## 5.5 Potential Sources of Bias:

All patients will undergo hip arthroscopy by one of two, orthopaedic specialists with sport medicine and arthroscopy fellowship experience. Both surgeons are experts in their field and perform over 100 hip arthroscopies every year.

Research assistants will be trained to conduct and score physical examinations and performance-based outcome measures by clinical experts in kinesiology and physiotherapy sport medicine. Research assistants will be blinded to a patients' patient reported outcome data at each follow-up visit until all physical examinations and performance-based measurements have been collected to reduce potential detection bias.

Physical examinations and performance-based assessments will be administered in a standardized order and research assistants will always assess a patient's asymptomatic hip first and alternated back and forth to reduce any potential sources of performance bias or effects of fatigue.

We will attempt to reduce attrition bias by collecting patients full contact information and alternative contact after the they have consented so we can contact them to remind them of an upcoming appointment or follow-up with them if they drop out of the study. We also ensure patients have their next appointments booked prior to commencing any data collection and send a reminder email a week before their upcoming appointment. If a patient misses a follow-up appointment, we contact them by phone and email to reschedule their appointment within the data collection window. We will collect all relevant outcome data if another appointment can be scheduled within the visit window. Study visits also align with standard surgical follow-up visits with the patient's orthopaedic surgeon.

Lastly, patients will complete all patient reported outcome measures online through Empower Health Research ([www.empowerhealthresearch.ca](http://www.empowerhealthresearch.ca)) to reduce the time a patient is required to be in the clinic and ensure adherence to COVID-19 policies. Paper copies of patient reported outcomes will only be provided if a patient does not have access to internet accessible devices like a phone, tablet, or laptop. However, we will provide with a tablet to complete any necessary forms in clinic when possible

## **5.6 Sample Size:**

We calculated our sample size based on our primary objective to identify predictors of successful RTS using logistic regression. Logistic regression requires a minimum of 10 events per predictor<sup>71</sup> and we chose to include 22 prognostic predictors of return to sport [age, sex, BMI, active and passive range of motion (Ext, Flex, Abduction, Adduction), positive impingement tests, fear, pain, single leg balance, limb symmetry, body functional and structural mobility (deep squat, hurdle step), dynamic hip strength (step-down test, hop test), surgical morphology (cam/pincer/mixed), length of rehabilitative treatment, amount of physical activity preoperatively per week, and level of sport (same/higher or lower)]. We used a conservative rate of 43%<sup>12</sup> and accounted for a 20% loss to follow-up rate in the calculation. As a result, we will aim to recruit 615 participants for this study.

## **5.7 Data Analysis Plan**

All data analyses will be performed using Stata (Version 17, 2021 StataCorp LLC).

### **5.7.1 Main Objective:**

#### *Postoperative Patterns of Recovery*

We will first calculate mean postoperative change scores for each outcome measure with 95% CIs, standard errors, and p-values for each follow-up visit. Change scores for each outcome will then be plotted over time and interpreted separately using locally weighted smoothing (LOWESS) curves. Similarly, outcomes will be categorized according to the ICF model and plotted over time (ICF Checklist, 2021). We will determine if change scores for performance-based measurements are correlated to changes in patient-reported outcome scores by calculating and interpreting Pearson correlation coefficients.

### **5.7.2 Secondary Objectives:**

#### *Predictive Factors of Successfully Returning to Same Type and Level of Sport*

For our second objective, we will first fit a multivariable logistic regression model with RTS as our outcome variable and the 22 predictive factors we selected based on clinical hypotheses. We will use a two-sided p-value  $<0.05$  to indicate statistical significance. Any potential confounding variables will be addressed by including any that are statistically significant in our predictive models and performing a sensitivity analysis to determine how much coefficient estimates would change if outliers were not excluded from our final model. We will handle missing data by attempting to contact the patient and understand the reason. If we cannot recover the missing data, we will use multiple imputation methods to arrive at an aggregated score for that person. Statistical assumptions of linearity, model adequacy, and identify outliers or influential points for our model will be examined both graphically and statistically. We will determine the area under the receiver operating characteristic curves (ROC-AUC) for our model using a forward conditional test for removal. We will then conduct a sensitivity analysis to determine how much coefficient estimates would change if outliers were not excluded from our final model. To make our model more user friendly, we will use the ROC-AUC to identify cut-off values for each of the predictive factors to develop a simplified risk score for clinicians by assigning one point to any identified independent predictor, but we will not attempt to validate this simplified risk score to avoid risk of overfitting. We hypothesize there will be an absolute difference of less than 0.05 between the ROC-AUC of the predictive model and our simplified risk score.

#### *Postoperative Return to Sport Proportions and Time Frames.*

Prior hypotheses and predictive factors identified in our logistic model will be used to fit a multivariable Cox proportional hazards model to estimate hazard ratios (HRs) and 95% CIs of a patient being cleared to return to the sport by their surgeon at each of the follow-up visits. We will perform Kaplan-Meier analysis and generate life tables with 95% CIs using centered mean values for each factor to estimate a cumulative return to sport success rate as a function of time. Secondary subgroup Kaplan-Meier analyses will also be performed based on prior hypotheses to determine how these factors individually affect a patient's ability to return to the same level of sport using cluster sampling techniques. A positive coefficient will indicate a worse prognosis and a negative coefficient will indicate the variable

has a protective effect on its associated outcome. Assumptions of log-linearity, proportional hazard assumptions, and influential or outlier data points for our model will be examined graphically and then statistically. Like our logistic regression analysis, any outlier data points identified will be removed and a sensitivity analysis performed to determine if estimated HRs change.

### **5.7.3 Third Objective:**

#### *Measurement Properties of Postoperative Return to Sport Outcomes*

#### **Reliability**

We will use an anchor-based approach to investigate the measurement properties of performance-based and patient-reported outcomes commonly used in this cohort postoperatively. Test-retest reliability of the Star Excursion Balance Test (SEBT) and patient-reported outcome measures will be calculated using only the baseline scores from T1 and T2 from patients who answered ‘no change’ or ‘certainly nothing important’ on the global rating of change scale (GRC) because they will be deemed to have remained stable between time points. Intra-rater reliability of the SEBT will be calculated by using baseline scores from all eight vectors collected at T1 and T2 by the same rater. Maximum reach distances for patients will be normalized to leg length by calculating the mean reach distance for each vector and dividing it by the patient's leg length. An intra-class correlation coefficient (ICC) will be used to estimate the absolute agreement between scores and a standard error of measurement (SEM) equation will be used to calculate with a 95% CI's individual scores for both test-retest and intra-rater reliability. We will also provide 95% CI's around both the parameter estimates and interpret ICC's according to Coppieters et al:<sup>72</sup> <0.40 = poor, 0.40-0.70 = fair, 0.70-0.90 = good, 0.90 = excellent. First, we hypothesize all the patient-reported outcomes will have good to excellent test-retest reliability in this cohort. Secondly, will have ICC values like other reported lower extremity injuries between 0.66 and 0.96 for test-retest reliability<sup>21,22</sup> and between 0.78 and 0.96 for intra-rater reliability over a seven-day period.<sup>16,53,57</sup>

#### **Validity**

Cross-sectional construct validity of the SEBT in this cohort will be determined by calculating the association between the normalized composite baseline score at T1 and scores from validated patient-reported outcomes collected at T2. Magnitudes of association will be evaluated using Cohen's interpretations of 'd': >0.5= large, 0.3-0.5= medium, 0.1-0.3 = small.<sup>73</sup> Longitudinal construct validity will be calculated for performance-based outcomes including the SEBT, by grouping postoperative mean

change scores of patients with their responses on a GRC at the follow-up time points they are collected and where we expect to see incremental increases in change scores, such as T3 to T4, T5 to T7, or T6 to T7. Outcome measures will be considered to have excellent cross-sectional and longitudinal construct validity if greater than 75% of our hypotheses are supported by data that is within one classification of magnitude and identical in direction.

### **Sensitivity to Change**

Sensitivity to change will be determined by calculating the postoperative mean change scores for each of the outcome measures from T3 to T4, T5, T6 and T7. A standardized response mean (SRM) will be calculated by averaging the difference between the two means at each time point, then dividing it by the standard deviation of the change. We will then calculate the minimal detectable change (MDC) and associated 95% CI for each outcome using the SEM calculated from test-retest reliability (Base 1, Base 2). We will use the MDC for each outcome and follow-up visit to determine whether change has in fact occurred since their previous visit.

### **Responsiveness to Change**

Responsiveness of the double-leg squat, hurdle step and lateral step-down test will only be calculated from T4 to T5, T6, and T7, while only T6 to T7 will be used for the single-leg hop test. We will consider participants who answer a two (a little better or a little worse, but large enough to be important) on the GRC to have experienced a minimally clinically important change (MCID). We will conduct similar analysis from T3 to T4, and again from T3 to T5, T6 and T7 for the Star Excursion Balance Test and patient-reported outcome measures because the MCID may change over time.

## **5.8 Perceived Barriers and Mitigation Strategies:**

Policies and procedures at London Health Sciences Center (LHSC) are constantly evolving due to COVID-19 pandemic and may present some barriers to our recruitment and data collection. To mitigate some of these barriers we will ensure research assistants and personnel are sufficiently trained to recruit and collect any data at follow-up windows. As a result, it is possible some data may be collected by

different personnel at different follow-up visits, which could present a problem with the consistency in measurements. We will attempt to overcome this barrier by taking a proactive approach to training. All personnel will be trained by an expert kinesiologist specializing in return to sport testing and we will create a procedural manual that will outline the steps to take from recruitment to booking and how to score and measure each test. We will also draft a phone script and follow-up emails to ensure that research personnel are informing patients correctly and appropriately following up with them. Additionally, if recruitment is unable to take place in person, we will contact patients over the phone once they have consented to surgery and book patients in with the trained kinesiology on staff to collect baseline or follow-up data. Lastly, to mitigate any potential loss of patients due to drop out we have aligned visit windows to align with a patient's postoperative follow-up appointments with their orthopaedic surgeon to make data collection as convenient to the patient, and staff, as possible.

All testing will also be conducted on the non-injured hip first and data collectors will alternate between limbs to reduce any potential effects of fatigue and ensure patients have both consistent and enough time to recover between performance-based tests. We will also hold weekly meetings with research assistants review and discuss potential patients the following week, any staff and patient scheduling issues, follow-up appointments, or feedback and concerns around the logistics of arranging adequate testing space.

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## Chapter 6

### 6 Conclusion

The main objective of this thesis was to investigate current postoperative RTS criteria and clinical practices for patients with FAIS so safer, and more effective, guidelines may be developed in the future. Chapter three summarizes the types of postoperative RTS protocols and objective criterion currently utilized to evaluate a patient's RTS readiness. While 14 different protocols were identified, RTS criteria was poorly described and evidence to support their clinical use is lacking. Consensus is therefore lacking on the optimal methods for evaluating a patient's postoperative functional progress, abilities, or RTS readiness. As a result, current postoperative rehabilitation protocols and RTS criteria for patients with FAIS appear to be based more on expert opinion rather than evidence-based practice.

We further investigated this hypothesis in chapter four by conducting an international survey of practicing orthopedic surgeons and physiotherapists. Clinicians were asked a series of 12 questions relating to their postoperative clinical practice and RTS criteria for patients with FAIS. Responses were highly variable, but the most utilized outcome measures to evaluate functional progress and RTS readiness postoperatively in patients with FAIS by surgeons and physiotherapists were the SEBT/YBT, SLHT, single-leg balance tests and gait analysis. Surprisingly many respondents indicated they do use any of the recommended outcome measures summarized in chapter 3. Although RTS success rates were highly variable, our data on expected RTS timeframes for patients postoperatively were not only similar for both surgeons ( $\mu=25.6 \pm 10.3$  weeks) and physiotherapists ( $\mu=29.4 \pm 11.5$  weeks), but also supported by similar findings and data within the published literature.

Our evidence and observational data suggest the utility of currently recommended postoperative RTS criteria and protocols for patients with FAIS is lacking and appears to be based on expert opinion rather than evidence-based practices. Therefore, more research is needed to ensure patients safely, and efficiently, RTS after surgery. As a result, this research will inform futures clinical studies, beginning with an observational cohort study seeking to identify the functional rehabilitation patterns of patients

aged 16 to 36 recovering from corrective hip arthroscopy for FAIS. This study will also aim to examine the utility of outcome measures currently utilized by clinicians and determine how effective they are at identifying when or if a patient will safely RTS.

## Appendices

### Appendix A: Abbreviations List

#### Outcome Measures

##### Patient-Reported

**FABQ:** Fear Avoidance Belief Questionnaire

**GRC:** Global Rating of Change

**HAGOS:** Copenhagen Hip and Groin Outcome Score

**HHS:** Hip Harris Score

**HOS-S:** Hip Outcome Score-Sport

**HOS-ADL:** HOS- Active Daily Living

**HOOS:** Hip Disability and Osteoarthritis Outcome Score

**HOS:** Hip Outcome Score

**iHOT-33:** 33-Item International Hip Outcome Score

**LEFS:** Lower Extremity Functional Score

**KOOS:** Knee Injury and Osteoarthritis Outcome Score

**mHHS:** modified Hip Harris Score

**NAHS:** Non-Arthritic Hip Score

**NPRS:** Numeric Pain Rating Scale

**VAS:** Visual Analog Scale

**VHS:** Vail Hip Score **P4:** 4-Item Pain Questionnaire

**PER:** Patient Experience with Rehabilitation Form

## **Physical Examinations**

**AROM:** Active Range of Motion

**DLS:** Double-Leg Squat

**HHD:** Hand-Held Dynamometry

**MMT:** Manual Muscle Testing

**PROM:** Passive Range of Motion

**ROM:** Range of Motion

**SCT:** Sport Cord Test

**SLS:** Single-Leg Squat

## **Performance-Based Measurements**

**APFT:** 2-mile Army Physical Fitness Test

**DVJ:** Drop Vertical Jump

**FHST:** Functional Hip Sport Test

**FMS:** Functional Movement Screen

**mTA:** Modified Agility T-Test

**SDT:** 8" Step Down & Step-Up Test

**SLBJ:** Single-Leg Broad Jump

**SLHT:** Single-Leg Hop Test

**VHST:** Vail Hip Sports Test

**YBT/SEBT:** Y-Balance Test/Star Excursion Balance Test

**AL:** Antrolateral Vector

**AM:** Anteromedial Vector

**Ant:** Anterior Vector

**Lat:** Lateral Vector

**PL:** Posterolateral Vector

**PM:** Posteromedial Vector

**Post:** Posterior Vector

## **Clinical Terminology**

**ACEA:** Anterior Center Edge Angle

**ACL:** Anterior Cruciate Ligament

**ACL:** Anterior Cruciate Ligament Reconstruction

**ADL:** Active Daily Living

**AP:** Anterior posterior Pelvic Radiograph

**BMI:** Body Mass Index

**CAI:** Chronic Ankle Instability

**CE:** Clinical Examinations

**CEA:** Center Edge Angle

**CPI:** Chronic Patellar Instability

**CPA:** Canadian Physiotherapy Association

**COA:** Canadian Orthopaedic Association

**CT:** Computerized Tomography

**FABER:** Flexion Abduction External Rotation

**FADIR:** Flexion Adduction Internal Rotation

**FAI:** Femoracetabular Impingement

**FAIS:** Femoracetabular Impingement Syndrome

**FOM:** Functional Outcome Measure

**FKSMC:** Fowler-Kennedy Sport Medicine Clinic

**FLL:** Frog Leg Lateral Radiograph

**LCEA:** Lateral Center Edge Angle  
**LCPD:** Legg-Calve-Perthes Disease  
**LSI:** Limb Symmetry Index  
**LTF:** Ligamentum Teres Femoris  
**MRA:** Magnetic Resonance Angiography  
**MRI:** Magnetic Resonance Imaging  
**OA:** Osteoarthritis  
**PA:** Physical Activity  
**PFPS:** Patellar Femoral Pain Syndrome  
**PRO:** Patient Reported Outcomes  
**PT:** Physiotherapist  
**RCT:** Randomized Control Trial  
**RTS:** Return to Sport  
**ROB:** Risk of Bias  
**SCFE:** Slipped Capital Femoral Epiphysis  
**SPC:** Sport Physio Canada  
**THA:** Total Hip Arthroplasty  
**US:** United States

## **Statistical Terminology**

**CI:** Confidence Interval  
**ICC:** Interclass Correlation  
**HR:** Hazard Ratio  
**ITT:** Intention to Treat  
**LOWESS:** Locally Weighted Smoothing Curves  
**MD:** Mean Difference

**MDC:** Minimal Detectable Change

**MCID:** Minimal Clinically Important Difference

**MIC:** Minimal Important Change

**OR:** Odds Ratio

**SEM:** Standard Measurement Error

**SD:** Standard Deviation

**Sn:** Sensitivity

**Sp:** Specificity

**SRM:** Standardize Response Mean

**RR:** Relative Risk

**ROC-AUC:** Receiver Operator Curves Area Under the Curve

## Appendix B: Image Permissions

**Figure 1-6:** Drake RL, Vogl, WA, and Mitchel A. *Greys Anatomy for Students*. Third ed. 2014: Elsevier Churchill Livingstone.

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## Appendix C: Chapter 4 Western Research Ethics Approval



**Date:** 5 February 2020

**To:** Dr Ryan Degen

**Project ID:** 115014

**Study Title:** Post-operative outcome measures to evaluate the rehabilitation progress of patients with unilateral Femoroacetabular Impingement (FAI): A Survey of Physiotherapists and Orthopedic Surgeons

**Application Type:** HSREB Initial Application

**Review Type:** Delegated

**Full Board Reporting Date:** February 25, 2020

**Date Approval Issued:** 05/Feb/2020

**REB Approval Expiry Date:** 05/Feb/2021

---

Dear Dr Ryan Degen

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

**Documents Approved:**

Document Name	Document Type	Document Date	Document Version
Qualtrics Surbey Study Protocol V2 Dec18th2019	Protocol	18/Dec/2019	Version #2
RTS Qualtrics Survey Final Email	Email Script	18/Dec/2019	Version #1
RTS Qualtrics Survey Questions Document for Ethics Submission	Online Survey	14/Jan/2020	2
RTS Qualtrics Survey Second Email	Email Script	18/Dec/2019	Version #1
RTS Survey Letter of Information and Consent V3	Written Consent/Assent	14/Jan/2020	3
RTS Survey Recruitment First Email	Email Script	28/Nov/2019	Version #1

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

*Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).*

## Appendix D: Chapter 4 Clinician Qualtrics Survey

**Western UNIVERSITY · CANADA**

**Letter of Information and Consent**

**Project Title:** Post-operative outcome measures to evaluate the rehabilitation progress of patients with unilateral Femoroacetabular Impingement (FAI): A Survey of Physiotherapists and Orthopaedic Surgeons.

**Principal Investigator:** Dr. Ryan Degen

**Co-investigator:**  
Trevor Day, RKin, MSCHRS (Student)  
Dr. Dianne Bryant, PhD  
Dr. Trevor Birmingham, BScPT, PhD  
Greg Alcock, MScPT, FCAMPT

**Invitation to Participate in Research:**  
You are invited to participate in a graduate student's research project. This study aims to inform clinical practice guidelines by determining what outcome measures are currently being used to evaluate the progress of a patient's rehabilitation program. All practicing orthopaedic surgeons and physiotherapists holding a membership with the Canadian Orthopaedic Association (COA), and/or International Society for Hip Arthroscopy (ISHA), the Canadian Physiotherapists Association (CPA), Sport Physiotherapy Canada (SPC), the American Orthopaedic Society for Sports Medicine (AOSSM) and/or belong to the Fowler Kennedy Fellows Alumni (FKFA) are eligible to participate. We anticipate the participation of 500 physiotherapists and orthopaedic surgeons across Canada.

12:29

**Western UNIVERSITY · CANADA**

**Letter of Information and Consent**

**Project Title:** Post-operative outcome measures to evaluate the rehabilitation progress of patients with unilateral Femoroacetabular Impingement (FAI): A Survey of Physiotherapists and Orthopaedic Surgeons.

**Principal Investigator:** Dr. Ryan Degen

**Co-investigator:**  
Trevor Day, RKin, MSCHRS (Student)  
Dr. Dianne Bryant, PhD  
Dr. Trevor Birmingham, BScPT, PhD  
Greg Alcock, MScPT, FCAMPT

**Invitation to Participate in Research:**  
You are invited to participate in a graduate

**Study Information:**

This is a survey-based study. Questions have been designed to identify which patient reported, clinical and functional outcome measures should be used to evaluate a patient's post-operative rehabilitation progress. Survey responses will help us describe current opinion and practice trends among orthopaedic surgeons and physiotherapists internationally and across Canada.

**Participation:**

Participation in this research is voluntary. There are no anticipated risks and/or benefits to your involvement.

Should you choose to participate, the survey will require 5-10 minutes to complete. Submitted responses cannot be changed or revoked. The software uses adaptive questioning to ensure the questions pertain specifically to you. Blank responses are not allowed, but you may answer "not applicable" or "none of the above" if a question no longer pertains to you or if you do not wish to provide an answer.

You will receive two emails, at weekly intervals from your affiliated organization(s) that will serve as reminders of your invitation to participate in this study. There will be no further attempts to contact you thereafter.

**Compensation:**

There is **no compensation** for your participation in this research

**Confidentiality:**

Your email invitation has been generated by the COA, ISHA, CPA, SPC and/or the Fowler Kennedy Fellows Alumni. Your contact information has not been shared with members of the research team and **will** remain confidential.

All survey responses will be processed in aggregate to ensure anonymity and all data will be used for scholarly purposes only. Gathered data will be stored securely for a period of 15 years. Data will not contain personal identifiers and will not be shared with any third parties not involved in the study at all.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to study-related documents to oversee the ethical conduct of this study.

Representatives of Lawson Quality Assurance Education Program may require access to study-related documents to ensure that proper laws and guidelines are followed.

**If you have questions about your rights as a participant or about ethical issues related to this study, you can talk to someone who is not involved in the study at all by contacting the Patient Relations Office at LHSC**

All survey responses will be processed in aggregate to ensure anonymity and all data will be used for scholarly purposes only. Gathered data will be stored securely for a period of 15 years. Data will not contain personal identifiers and will not be shared with any third parties not involved in the study at all.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to study-related documents to oversee the ethical conduct of this study.

Representatives of Lawson Quality Assurance Education Program may require access to study-related documents to ensure that proper laws and guidelines are followed.

**If you have questions about your rights as a participant or about ethical issues related to this study, you can talk to someone who is not involved in the study at all by contacting the Patient Relations Office at LHSC**

Warm Regards,

**Ryan Degen, MD, MSc, FRCSC**

**\*\*Consent\*\***

*You do not waive any legal rights by consenting to this study.*

*By starting the survey, you agree that you have read the Letter of Information and agree to participate in our research.*

1) Are you a practicing Physiotherapist or Orthopedic Surgeon who treats active patients who have undergone surgery for hip impingement, commonly known as femoroacetabular impingement (FAI)?

Yes

No

12:29

MEASURES SHOULD BE USED TO EVALUATE a patient's post-operative rehabilitation progress. Survey responses will help us describe current opinion and practice trends among orthopaedic surgeons and physiotherapists internationally and across Canada.

**Participation:**

Participation in this research is voluntary. There are no anticipated risks and/or benefits to your involvement.

Should you choose to participate, the survey will require 5-10 minutes to complete. Submitted responses cannot be changed or revoked. The software uses adaptive questioning to ensure the questions pertain specifically to you. Blank responses are not allowed, but you may answer "not applicable" or "none of the above" if a question no longer pertains to you or if you do not wish to provide an answer.

You will receive two emails, at weekly intervals from your affiliated organization(s) that will serve as reminders of your invitation to participate in this study. There will be no further attempts to contact you thereafter.

**Compensation:**

There is **no compensation** for your participation in this research

12:29

**to this study, you can talk to someone who is not involved in the study at all by contacting the Patient Relations Office at LHSC**

Warm Regards,

**Ryan Degen, MD, MSc, FRCSC**

**\*\*Consent\*\***

*You do not waive any legal rights by consenting to this study.*

*By starting the survey, you agree that you have read the Letter of Information and agree to participate in our research.*

1) Are you a practicing Physiotherapist or Orthopedic Surgeon who treats active patients who have undergone surgery for hip impingement, commonly known as femoroacetabular impingement (FAI)?

Yes

No

**Western**  
UNIVERSITY · CANADA

2) What is your current profession?

Orthopedic Surgeon  
 Physiotherapist

3) Approximately how many arthroscopic surgeries do you perform, or post-operative patients do you see, per year with FAI?

0 10 20 30 40 50 60 70 80 90 100  
Patients with Femoroacetabular Impingement (FAI)

Number of Hip Arthroscopies Per Year

4) If a patient's goal is to return to sport or play post-operatively, how many physical therapy sessions per week would you typically recommend or prescribe?

0 1 2 3 4 5 6 7  
Amount of Sessions Per Week

12:29

**Western**  
UNIVERSITY · CANADA

2) What is your current profession?

Orthopedic Surgeon  
 Physiotherapist

3) Approximately how many arthroscopic post-operative patients do you see, per year with FAI?

0 10 20 30 40 50  
Patients with Femoroacetabular Impingement (FAI)

Number of Hip Arthroscopies Per Year

4) If a patient's goal is to return to sport or play post-operatively, how many physical therapy sessions per week would you typically recommend or prescribe?

5) Which post-operative rehabilitation protocol or guideline best reflects your current practice or clinical recommendations?

Fowler Kennedy Sports Medicine Clinic (FKSMC)  
 University of Pittsburgh Medical Center (UPMC)  
 The Steadman Clinic (formerly Steadman-Hawkins)  
 Clinical Experience/General post-operative guidelines  
 None of the above

6) Based on your clinical experience, approximately how many weeks does it take your patients to return to play or sport after they undergo arthroscopic hip surgery for FAI?

0 10 20 30 40 50 60 70 80 90 100  
Number of weeks to return to sport or activity

7) What percentage of your patients return to the same or higher preoperative level of sport/activity without restrictions?

0 10 20 30 40 50 60 70 80 90 100  
Percentage of patients that return to unrestricted sport or activity

8) Which of the following assessment tools do you use to evaluate the progress of a patient recovering from FAI between 0 weeks and 2 weeks post arthroscopic surgery?

12:29

5) Which post-operative rehabilitation protocol or guideline best reflects your current practice or clinical recommendations?

Fowler Kennedy Sports Medicine Clinic (FKSMC)  
 University of Pittsburgh Medical Center (UPMC)  
 The Steadman Clinic (formerly Steadman-Hawkins)  
 Clinical Experience/General post-operative guidelines  
 None of the above

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

9) Which of the following assessment tools do you use to evaluate the progress of a patient recovering from FAI between 2 weeks and 6 weeks post arthroscopic surgery?

12:29

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

Hip disability and Osteoarthritis Outcome Score (HOOS)

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

10) Which of the following assessment tools do you use to evaluate the progress of a patient recovering from FAI between 6 weeks and 3 months post arthroscopic surgery?

12:29

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

Hip disability and Osteoarthritis Outcome Score (HOOS)

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

11) Which of the following assessment tools do you use to evaluate the progress of a patient recovering from FAI between 3 months to 4.5 months post arthroscopic surgery?

12:29

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

Hip disability and Osteoarthritis Outcome Score (HOOS)

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

12) Which of the following assessment tools do you use to evaluate the progress of a patient recovering from FAI between 6 months and 1 year post arthroscopic surgery?

12:29

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

Hip disability and Osteoarthritis Outcome Score (HOOS)

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

13) Which of the following measures do you believe is/are the most critically important for determining if an athlete can be cleared to return to play or sport without restrictions?

12:29

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

Hip disability and Osteoarthritis Outcome Score (HOOS)

Select All that Apply:

Patient Reported Outcomes	Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)	Lower Extremity Functional Scale (LEFS)	Pain Visual Analog Scale (VAS)	Numeric Pain Rating Scale (NPRS)	Hip disability and Osteoarthritis Outcome Score (HOOS)	Hip Outcome Score (HOS)	Hip Harris Score (HHS)	Non-Arthritic Hip Score (NAHS)	International Hip Outcome Tool (iHOT)	Global Rating of Change (GRC)	None of the Above
Clinical Examinations	Walking Examination	Modified Trendelenburg Test	Active Range of Motion (AROM)	Passive Range of Motion (PROM)	FADIR Test	FABER Test	Log Roll Test	Manual Muscle Testing	Ober Test	Medical Imaging	None of the Above
Functional/ Performance Assessments	Computer Gait Analysis	Vail Hip Sports Test	Star Excursion Balance Test (SEBT)	Y-Balance Test	Single Leg Stance Test	T-Agility Test	Single Leg Hop Tests	Tuck Jump Test	Drop Vertical Jump Test	Functional Movement Screen	None of the Above

13) Which of the following measures do you believe is/are the most critically important for determining if an athlete can be cleared to return to play or sport without restrictions?

Select All that Apply:

Patient Reported Outcomes

Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC)

Lower Extremity Functional Scale (LEFS)

Pain Visual Analog Scale (VAS)

Numeric Pain Rating Scale (NPRS)

## Appendix E: Chapter 5 Western Research Ethics Approval



**Date:** 16 July 2020

**To:** Dr Ryan Degen

**Project ID:** 114897

**Study Title:** Post-Operative Functional Recovery Patterns in Unilateral FAI Patients Returning to Sport: A Prospective Observational Study.

**Application Type:** HSREB Initial Application

**Review Type:** Full Board

**Meeting Date / Full Board Reporting Date:** 16/Jun/2020

**Date Approval Issued:** 16/Jul/2020

**REB Approval Expiry Date:** 16/Jul/2021

Dear Dr Ryan Degen

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

### Documents Approved:

Document Name	Document Type	Document Date	Document Version
P4	Paper Survey	20/Jan/2020	1
SEBT	Non-Participant Observation Guide	20/Jan/2020	1
Qualitative Analysis for Single Leg Loading Functional Tests	Non-Participant Observation Guide	27/Jan/2020	1
Demographics sheet	Paper Survey	25/May/2020	2
mHHS Sheet	Paper Survey	25/May/2020	2
IHOT-33 Sheet	Paper Survey	25/May/2020	2
HOS Sheet	Paper Survey	25/May/2020	2
GRC Sheet	Paper Survey	25/May/2020	2
Patient Experience Sheet	Paper Survey	25/May/2020	2
Pre-Op RTS Sheet	Paper Survey	25/May/2020	2
Post-Op RTS Sheet	Paper Survey	25/May/2020	2
Functional FAI Patters Study Propsoal Version 5	Protocol	24/Jun/2020	5
Letter of Info and Consent Version 2	Written Consent/Assent	19/Jun/2020	2

### Documents Acknowledged:

Document Name	Document Type	Document Date	Document Version
References	References	19/May/2020	4
Empower_Master TSA_FE_FY17	Technology Review document	06/Feb/2017	1
Flow Diagram	Flow Diagram	27/Jan/2020	2

**Documents Acknowledged:**

Document Name	Document Type	Document Date	Document Version
References	References	19/May/2020	4
Empower_Master TSA_FE_FY17	Technology Review document	06/Feb/2017	1
Flow Diagram	Flow Diagram	27/Jan/2020	2

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

Page 1 of 2

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Patricia Sargeant, Ethics Officer (psargean@uwo.ca) on behalf of Dr. Joseph Gilbert, HSREB Chair

*Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).*

# Appendix F: Case Report Forms



## Contact Information

Database ID:

Randomization ID:

Date:     -   -    
YYYY MM DD

My ethics board will not allow this information to be collected.

**Do not complete this form for patients not giving consent or patients who are not eligible for participation**

**Patient:** \_\_\_\_\_  
(please print) Last Name Given Names

Home Phone \_\_\_\_\_ Work Phone \_\_\_\_\_  
Cell Phone \_\_\_\_\_ Ext.

Email: \_\_\_\_\_  Patient has agreed to complete forms online

### Alternative Contact 2 (Family Physician)

This patient does NOT have a family physician.

(please print) \_\_\_\_\_  
Last Name Given Names

Work Phone    -    -      
Ext.

### Hospital Patient Identification Number (PIN)

\_\_\_\_\_



8. Occupation: Specify: \_\_\_\_\_

- Classify using the following criteria:  Repetitive activity involving walking  
 Desk job  
 Other specify: \_\_\_\_\_  
 N/A

1

Version #1: May 25<sup>th</sup> 2020

9. Type of employment:

- Full-time       Part-time       Volunteer  
 Retired       Student       Stay-at-home parent/spouse  
 Social Assistance       Other specify: \_\_\_\_\_

10. Have you had to reduce your hours of work because of your hip problem?

- Yes       No       N/A

11. Have you had to modify your duties at work because of your hip problem?

- Yes       No       N/A

12. Check this box if you are off work for reasons unrelated to your hip problem

If you checked the box, please describe the reason:

\_\_\_\_\_



- Pain killers (e.g. Tylenol)
- Anti-inflammatories (e.g. Naproxen, Advil)
- Corticosteroid injection
- Non-steroid injection (e.g. Synvisc, Durolane, NeoVisc)
- Physical Therapy    Duration:  0-6 weeks     6-12 weeks     >12 weeks
- Surgery    (please specify): \_\_\_\_\_
- Other    (please specify): \_\_\_\_\_



### Pre-Op RTS Form

#### RTS FAI Recovery

Date:  
Database ID:

Randomization ID:

Visit: Baseline

#### Return to Sport (Pre-Operative)

##### DEFINITIONS

- Sport: A game or competition requiring physical skill that is played according to rules, against other players or teams. This **does not** include working out, lifting weights, jogging, etc.
- Elite Sport: Playing at the highest level of professional competition (Olympics, World Games)
- Varsity Sport: Playing for a team representing a college or university
- Competitive Sport: Playing for a competitive league
- Recreational Sport: Playing for a beginner or social league
- Non-Organized Sport: Not playing for a league; playing casually with friends or family

**1. What sport did you participate in prior to your injury? Check all that apply.**

Check here if you did not participate in any sports prior to your injury. ***This form is complete.***

***Instructions:*** check the “Yes” checkbox next to the sport(s) that you participated in prior to your injury, and fill out the right column for those sport(s) only. For sports that you did not participate in prior to your injury, please check the “No” checkbox.

**Prior to my injury, I participated in...**

<input type="checkbox"/> Yes	<input type="checkbox"/> No	<b>1. Soccer</b>
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<input type="checkbox"/> YES <input type="checkbox"/> NO	<p>If yes, what is the highest level of soccer that you were participating in prior to your injury?</p> <p><input type="checkbox"/> Elite</p> <p><input type="checkbox"/> Varsity</p> <p><input type="checkbox"/> Competitive</p> <p><input type="checkbox"/> Recreational</p> <p><input type="checkbox"/> Non-Organized</p>
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**Pre-Op RTS Form**

<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>2. Basketball</b></p> <p>If yes, what is the highest level of basketball that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>3. Rugby</b></p> <p>If yes, what is the highest level of rugby that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized

<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>4. Football</b></p> <p>If yes, what is the highest level of football that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
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**Pre-Op RTS Form**

<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>5. Volleyball</b></p> <p>If yes, what is the highest level of volleyball that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>6. Tennis/Squash</b></p> <p>If yes, what is the highest level of tennis/squash that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized

**Pre-Op RTS Form**

<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>7. Downhill Skiing</b></p> <p>If yes, what is the highest level of downhill skiing that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
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<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>8. Other Sport (please specify):</b> _____</p> <p>If yes, what is the highest level of this sport that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
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<input type="checkbox"/> Yes <input type="checkbox"/> No	<p><b>9. Other Sport (please specify):</b> _____</p> <p>If yes, what is the highest level of this sport that you were participating in prior to your injury?</p> <input type="checkbox"/> Elite <input type="checkbox"/> Varsity <input type="checkbox"/> Competitive <input type="checkbox"/> Recreational <input type="checkbox"/> Non-Organized
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## Resume & Curriculum Vitae

**Name:** Trevor Day

**Post-Secondary  
Education and  
Degrees:** University of Alberta, Bkin (Hons)  
Edmonton, Alberta, Canada  
2016-2019

Western University, MScHRS  
London, Ontario, Canada  
2019-2021.

Western University, MPT/PhD  
London, Ontario, Canada  
May 2021-Present

**Honours and  
Awards:** Top PhD and MSc Presenter in Clinical and MSK  
Rehabilitation Sciences Award, Western University, 2021

Undergraduate Degree with Distinction  
University of Alberta. 2019

The Dr. Erwin and Gerda Bako Memorial Scholarship  
University of Alberta, 2018

Coca-Cola Leadership and Academic Achievement Award  
University of Alberta, 2017

Undergraduate Scholarship. University of Alberta. 2017

Deans Honour Roll. University of Alberta. 2016-2019

**Related Work  
Experience:**

Registered Kinesiologist  
Canadian Back Institute  
London, Ontario  
Aug 2019-Present

Kinesiology Clinical Training & Education Lead  
Canadian Back Institute  
London, Ontario  
May 2021-Present

Research Assistant to Dr. Ryan Degen, MSc, MD, FRCSC  
Fowler Kennedy Sports Medicine Clinic  
London, Ontario  
Sept 2019-Present

Graduate Course Organizer  
Faculty of Health and Rehabilitation Sciences  
Western University  
2020-April 2021

Teaching Assistant  
HS 1002B, KIN 3222B, AHCP 9600  
Western University,  
January 2020-Present

MCISc Research Project Leader and Coordinator  
Faculty of Health and Rehabilitation Sciences  
Western University, Aug 2020-July 2021

Practicing Kinesiologist  
West Edmonton Fit Body Boot Camp  
& The Steadward Centre  
Edmonton, Alberta, Canada  
2016-2019

**Publications:**

Day T, Pasic N, Churchill L, Degen R, Bryant D. (2021). Return to Sport and Physical Activity Criteria Following Hip Arthroscopy for Patients with Femoroacetabular Impingement Syndrome. *The Physician and Sports Medicine*. (Accepted & Awaiting Publication).

Day T, Alcock G, Degen R, Bryant D. (2021). Postoperative Rehabilitation Outcome Measures for Patients with Femoroacetabular Impingement Syndrome (FAIS): An International Survey of Physiotherapists and Orthopaedic Surgeons. Under review

Day T. (2021). Femoroacetabular Impingement Syndrome: Evaluating Postoperative Rehabilitation Progress and Return to Sport Readiness. Thesis. (Accepted & Awaiting Publication)

**Presentations:**

Poster Presentation: Postoperative Functional Recovery Patterns in Patients with Femoroacetabular Impingement Syndrome.

Health and Rehabilitation Sciences Research Day, Western University, London, ON, 2020

Poster Presentation: Return to Sport and Physical Activity Criteria Following Hip Arthroscopy for Patients with Femoroacetabular Impingement Syndrome.

Health and Rehabilitation Sciences Research Day, Western University, London, ON, 2021

Poster Presentation: Postoperative Rehabilitation Outcome Measures for Patients with Femoroacetabular Impingement Syndrome (FAIS): An International Survey of Physiotherapists and Orthopedic Surgeons. Health and Rehabilitation Sciences Research Day, Western University, London, ON, 2021