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THE ROLE OF PSYCHOSOCIAL FACTORS ON PRE AND POSTOPERATIVE PAIN IN
PATIENTS WITH FEMORAL ACETABULAR IMPINGEMENT

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Health Sciences
at the University of Kentucky

By

Kate Nichole Jochimsen

Lexington, Kentucky

Co-Directors: Dr. Cale A. Jacobs, Director of Orthopaedic Research
and Dr. Carl G. Mattacola, Associate Dean for Academic and Faculty Affairs

Lexington, Kentucky

2018

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ABSTRACT OF DISSERTATION

THE ROLE OF PSYCHOSOCIAL FACTORS ON PRE AND POSTOPERATIVE PAIN IN PATIENTS WITH FEMORAL ACETABULAR IMPINGEMENT

Femoral acetabular impingement (FAI) is a bony hip condition that often results in tears to the acetabular labrum. Patients with FAI experience pain, decreased function, and quality of life. FAI and its' sequela are treated definitively with hip arthroscopy. Hip arthroscopy is being performed with increasing frequency, and while most patients respond favorably, a subset of 10-20% of patients have suboptimal outcomes.

Previous research suggests that mental status may be a primary driver in the way patients with FAI respond to and feel pain. Measures of mental status include the presence of mood disorders and psychosocial patient reported outcomes (PROs). Psychosocial constructs that have yet to be examined in patients with FAI include self-efficacy, kinesophobia, and pain catastrophizing. The Pain Self-Efficacy Questionnaire (PSEQ) gauges an individual's confidence, or self-efficacy, in their ability to complete tasks despite their current pain. Previous research has established that a patient's self-efficacy is an important determinant of long-term success following orthopedic surgery. Kinesophobia, measured via the Tampa Scale for Kinesiophobia (TSK), is a measure of movement-related fear. In contrast to self-efficacy, fear of movement has been identified as a predictor of early success following orthopedic surgery. Lastly, pain catastrophizing is a set of maladaptive behaviors including ruminating on pain, feeling helpless to overcome painful situations, and magnifying the circumstances surrounding the painful experience. Catastrophizing behaviors, measured via the Pain Catastrophizing Scale (PCS), have been repeatedly linked to increased pain and decreased functionality in a variety of orthopedic populations. To date, the relationship between these psychosocial variables and pain has not been examined in patients with FAI.

The primary aim of this dissertation was to evaluate the role of psychosocial factors on pre and postoperative pain in patients with FAI undergoing hip arthroscopy. To accomplish this aim we performed a series of three studies. The first study was a retrospective chart review to determine the prevalence of mental health disorders and compare preoperative clinical presentation between patients with and without mental health disorders. The second was a cross-sectional study designed to determine if any psychosocial variables could predict preoperative hip pain. The final study utilized a longitudinal, cohort design. Patients were tested preoperatively and at 12-weeks postoperative. The primary outcomes measured were self-efficacy, kinesophobia, pain

catastrophizing, and hip pain at rest and during activity measured via a visual analog scale (VAS). The purpose of this study was to determine the effect of preoperative psychosocial variables on postoperative pain, and to determine if these variables were predictive of persistent postoperative pain three months following hip arthroscopy.

Based on the results from these studies we can conclude the following: 1) Mental health disorders are more common in patients with FAI than other orthopedic populations, and self-reported pain and function are worse in this subset of patients, but neither symptom chronicity nor the severity of joint deformity differs; 2) Low self-efficacy is predictive of worse preoperative pain in patients with FAI; and 3) Patients with high preoperative pain catastrophizing or low self-efficacy are more likely to have increased postoperative pain. Low preoperative self-efficacy is predictive of persistent hip pain during activity three months following hip arthroscopy, while low self-efficacy and mental health disorders are predictive of persistent hip pain at rest. Future studies are necessary to develop and implement interventions targeting low self-efficacy and elevated catastrophizing in patients undergoing hip arthroscopy to improve patient outcomes for this high-risk group.

KEYWORDS: femoral acetabular impingement, hip arthroscopy, patient reported outcomes, pain catastrophizing, self-efficacy

Kate N. Jochimsen
Student's Signature

November 16th, 2018

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“It is not the critic who counts; not the man who points out how the strong man stumbles, or where the doer of deeds could have done them better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood; who strives valiantly; who errs, who comes short again and again, because there is no effort without error and shortcoming; but who does actually strive to do the deeds; who knows great enthusiasms, the great devotions; who spends himself in a worthy cause; who at the best knows in the end the triumph of high achievement, and who at the worst, if he fails, at least fails while daring greatly, so that his place shall never be with those cold and timid souls who neither know victory nor defeat.”

Theodore Roosevelt, April 23rd, 1910

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Femoral acetabular impingement (FAI) is a hip condition in which there is incongruence between the femoral head and acetabulum. This incongruence can be resultant of extra bone growth on the femoral neck, known as a CAM lesion, extended bone off the acetabulum, known as a pincer lesion, or the combination of the two creating a “mixed” morphology. Regardless of the type, FAI can result in pain, functional limitations, and decreased quality of life.⁴ One common sequela of FAI is tears to the acetabular labrum, a wedge shaped fibro-cartilaginous structure that helps maintain joint lubrication and pressure homeostasis by creating a suction seal between the acetabulum and femoral head.

Clinical and radiologic signs of FAI are common and are more prevalent in active populations^{5,6} setting patients up for higher functional expectations than other similar pathologies such as hip osteoarthritis. It is estimated that one in three healthy, asymptomatic people have radiographic evidence of FAI^{7,8}, and two in three asymptomatic adults has a labral tear.⁹ Athletes are more likely to develop FAI than their peers.¹⁰ At the professional level greater than nine in ten male soccer players has radiographic evidence of FAI¹¹, and nearly 95% of patients seeking treatment for hip pain have abnormal labral findings.¹² This evidence along with a growing body of literature may suggest that FAI can be propagated by participation in athletic activity. Irrespective of the etiology, when conservative treatment fails, definitive treatment for symptomatic FAI is hip arthroscopy. Hip arthroscopies have increased dramatically over the past 20 years. From 1999 to 2009, the number of hip arthroscopies performed annually in the United States increased 18-fold.¹³

Outcomes following hip arthroscopy are generally good with 86% of patients reporting satisfaction¹⁴ and a recent meta-analysis demonstrating all patient reported

outcomes (PROs) improving pre- to post-operation.⁴ However, there is a subset of patients with less than ideal outcomes. For example, 10.5% of patients undergoing hip arthroscopy have a poor outcome as defined as a Modified Harris Hip Score (mHHS) score of < 70 at a two year follow-up.⁴ Approximately 85% of athletes are able to return to the same level of play¹⁵, and only 80% of military members return to full duty.¹⁶ Most grimly, Levy et al identified that only 25% of patients are meeting the patient acceptable symptomatic state (PASS) for the Hip Outcome Score (HOS)- activities of daily living (ADL) and 30% for the HOS-sport specific (SS).¹⁷

Regardless of the measure it is clear that based on the available evidence there is a subset of patients with suboptimal outcomes following hip arthroscopy. As such, researchers have begun to examine factors influencing these outcomes. Both non-modifiable and modifiable factors have been identified. The literature has identified the following non-modifiable factors leading to poorer outcomes: female sex¹⁸, decreased joint space¹⁹, and older age²⁰. Though one could argue patient selection could mitigate the effects of decreased joint space and older age, these are not factors that treatment seeking patients can control. In contrast, potentially modifiable factors that have been identified include a longer duration of symptoms²¹, smoking²⁰, and higher BMI²⁰.

Though the above factors have been identified, more recent evidence suggests that mental coping may be an important driving factor in hip arthroscopy outcomes. In fact, the Veteran's Rand-12 (VR-12) mental component score (MCS) has demonstrated a stronger relationship with preoperative pain and function than other traditional orthopedic markers including joint status and self-reported function.^{22,23} Psychological distress^{24,25} and depressive symptoms^{26,27} have also been highlighted in patients with symptomatic FAI as they are related to worse postoperative self-reported pain and function. It is clear from this group of studies that mental status is driving pre- and

postoperative symptoms in patients with symptomatic FAI; however, these measures are fairly nonspecific making identifying appropriate treatment interventions challenging.

Following the fear avoidance model (FAM) of chronic pain, more sensitive psychosocial measures such as pain catastrophizing, pain self-efficacy, and kinesiophobia warrant examination. The FAM appropriately portrays the outcome trajectories for patients with musculoskeletal pain, with or without these psychosocial constructs.²⁸ Pain catastrophizing is a negative mental state and set of behaviors that are adopted in response to actual or anticipated pain.²⁹ Pain catastrophizing is broken into three sub-categories: rumination “I think about my pain all the time”, magnification “my pain interferes with my daily activities”, and helplessness “there is nothing I can do to improve my pain”.²⁹

Pain catastrophizing is measured via the Pain Catastrophizing Scale (PCS). Scores range from 0-52 with 19 routinely used as a threshold to identify patients with catastrophizing behaviors as it is the 50th percentile in patients with chronic pain.²⁹ In acute pain populations, catastrophizing behaviors fluctuate situationally with tissue insult.³⁰ However, in chronic pain, patients’ catastrophizing behaviors can be either a state or trait.³¹ State catastrophizing involves a hyper-response to a situational pain stimulus. It involves the specific mindset of the patient in that moment or on that day. Conversely, trait catastrophizing is stable and more attune to a personality disposition. Trait catastrophizing can allow for more accurate predictions across time. Either way, catastrophic thinking is maladaptive to successful rehabilitation. Pain catastrophizing has repeatedly been shown to be predictive of poor outcomes such as increased pain intensity³²⁻³⁴, increased disability^{33,35}, persistent pain^{36,37}, increased opioid use^{38,39}, and increased pain interference⁴⁰. Currently there is only one published study that reported PCS scores in patients with FAI (mean 23.7 ± 11.8).⁴¹ Notably, this score is above the treatment threshold for high-risk catastrophizing behaviors.

Self-efficacy and kinesiophobia have never been reported in patients with symptomatic FAI. The Pain Self-Efficacy Questionnaire (PSEQ) gauges how confident a person is in completing tasks in spite of their current pain. Previous research has found self-efficacy to be an important moderator between pain and disability⁴² as well as long-term success following orthopedic surgery.⁴³ Kinesiophobia, an exaggerated, debilitating fear of movement⁴⁴, is measured via the Tampa Scale of Kinesiophobia (TSK). The TSK, a 17-item survey that gauges patients fear during specific exercise and movement scenarios. Following with the FAM, when patients display high levels of kinesiophobia pain is viewed as a threat resulting in worse postoperative pain and function.⁴⁵

The examination of the psychosocial constructs of pain catastrophizing, self-efficacy, and kinesiophobia is warranted in patients undergoing hip arthroscopy based on the evidence that all three are associated with a variety of poor postoperative outcomes in patient's following orthopedic surgery, and previous literature demonstrates global measures of mental health are currently driving pre- and postoperative symptoms in patients with symptomatic FAI.

1.2 PROBLEM STATEMENT

As hip arthroscopy has increased dramatically over the past 20 years, focus on patient outcomes has as well. Currently the literature suggests there is a subset of 10-20% of patients having suboptimal postoperative outcomes, and there is evidence suggesting that mental coping strategies, or lack of, may be playing an important role. Though pain catastrophizing, low self-efficacy, and kinesiophobia have been linked to poor outcomes in other orthopedic populations, to date there is no evidence examining these variables as they relate to patients with symptomatic FAI or outcomes after hip arthroscopy.

1.3 SIGNIFICANCE/PURPOSE

The primary purpose of this study is to determine the effect of preoperative pain catastrophizing on postoperative pain in patients with symptomatic FAI undergoing hip arthroscopy. Secondly, the effect of preoperative self-efficacy and kinesiophobia on postoperative pain in patients with FAI undergoing hip arthroscopy was examined.

1.4 SPECIFIC AIMS

Specific Aim 1: Identify the preoperative prevalence of mental health disorders in patients undergoing hip arthroscopy and examine if the prevalence of mental health disorders differs between patients that have a short duration of symptoms (>6 months) and a long duration of symptoms (<6 months).

Hypothesis 1: We hypothesized that consistent with previous osteoarthritis and total hip arthroplasty literature, mental health disorders would be present in approximately 20% of patients undergoing hip arthroscopy, and that those patients with mental health disorders would present with a longer duration of symptoms (DOS) and worse self-reported pain and function.

Specific Aim 2: Compare pain catastrophizing, self-efficacy, and kinesiophobia between patients with and without mental health disorders and determine if these variables were predictive of preoperative pain in patients with FAI.

Hypothesis 2: We hypothesized that preoperative pain would be predicted by low pain self-efficacy and high kinesiophobia and pain catastrophizing. More specifically, we expected pain catastrophizing to be the primary predictor of preoperative pain. Further we hypothesized that these behaviors would be more severe in patients with mental health disorders.

Specific Aim 3: Determine the effect of preoperative pain catastrophizing on postoperative pain in patients with FAI undergoing hip arthroscopy.

Hypothesis 3: We hypothesize that patients with high preoperative pain catastrophizing will have worse postoperative pain.

Overview: This dissertation is organized in the following order: Chapter 2 is a literature review on FAI, hip arthroscopy outcomes, pain perception and processing specifically as they relate to postoperative outcomes. Chapter 3 is a retrospective chart review identifying the preoperative prevalence of mental health disorders in patients with symptomatic FAI. Chapter 4 is a cross-sectional study determining if preoperative pain catastrophizing, self-efficacy, and kinesiophobia are predictive of preoperative hip pain in patients with FAI undergoing hip arthroscopy. Chapter 5 is prospective, longitudinal study determining the effect of preoperative pain catastrophizing on postoperative pain in patients with symptomatic FAI undergoing hip arthroscopy. Finally, Chapter 6 is a review of findings, discussion, and future research directions.

1.5 OPERATIONAL DEFINITIONS

- Patient reported outcome (PRO): Self-reported outcome measure completed directly by the patient.
- Postoperative pain: Defined as equal to or greater than 3 on a visual analog scale (VAS) where 0 equates to no pain at all and 10 represents the worse pain imaginable. A VAS score of 3 was selected because is consistently used as the threshold score for unacceptable or persistent, unresolved pain.^{46,47}
- Pain catastrophizer: A pain catastrophizer will be defined as any patient with a score of 19 or greater on the Pain Catastrophizing Scale (PCS). A score of 19 is the 50th percentile in patients with chronic pain.²⁹
- Low self-efficacy: A threshold on the Pain Self Efficacy Questionnaire of 40 can be used to decipher between patients with healthy levels of self-efficacy, and

those with low self-efficacy. A score of below 40 will be used to categorize patients as having low self-efficacy in this series of studies.⁴⁸

- High kinesiophobia: High and low levels of fear will be dichotomized using the cut-off score of 37. This cut-off score was identified in patients with chronic low back pain. A score of above 37 will be used to categorize patients as having high levels of movement related fear.⁴⁹

1.6 ASSUMPTIONS, LIMITATIONS, DELIMITATIONS

Assumptions:

1. Patients completed all patient reported outcomes honestly.

Limitations:

1. The order of patient reported outcomes was not randomized.
2. Blinding was not possible due to one researcher collecting all data.

Delimitations:

1. All participants in this study were treatment-seeking patients with symptomatic FAI, and were all treated by a single, fellowship-trained surgeon.

CHAPTER 2: LITERATURE REVIEW

The following review will be separated into eleven distinct sections to address all facets of the dissertation research projects. The hip joint, hip pathology and femoral acetabular impingement, treatment options and outcomes, and postoperative pain in the context of both normal and abnormal recovery will be discussed. The literature review will conclude with a short summary and overall purpose of the dissertation research projects.

2.1 CLINICAL EXAMINATION OF THE HIP JOINT

The hip, or coxofemoral, joint is a multi-axial ball-and-socket joint comprised of two segments. The proximal end of the femur forms the first, and the socket, or acetabulum, created by the ilium, ischium, and pubis, forms the second. The anterior rim of the acetabulum is a continuation of the superior pubic ramus, and the posterior rim is a continuation of the inferior pubic ramus. The ilium, ischium, and pubis fuse during adolescence to form the pelvis. The proximal head of the femur creates a convex surface articulating with the concave articulation of the acetabulum. The articulating surface of the femoral head is 180 degrees in diameter providing motion in all three planes.

Range of motion

The bony anatomy of the hip provides limited range of motion, but increased stability compared to other ball-and-socket joints such as the glenohumeral joint. The shallow acetabulum in the glenohumeral joint, or shoulder, provides increased ranges of motion, but decidedly less stability. Normal bony hip anatomy provides motion in six directions, two directions in each of the three planes. Hip motion is almost entirely caused by rotation between the head of the femur and acetabulum. Very little translation between the two segments occurs.

To accomplish normal movement patterns for activities of daily living approximately 120° of hip flexion, 20° of hip abduction, and 20° of hip external rotation are required.⁵⁰ Normally reported range of motion values for the hip can be found in Table 2.1 along with end feels, minimal clinically important difference (MCID), and standard error of measurement (SEM).⁵¹ A MCID is the smallest change that is viewed as beneficial by the patients.^{52,53} For example, a patient comes in for therapy visit one and has 100° of passive hip flexion measured via standard goniometry. One week later the patient comes back for visit two and via standard goniometry you measure 104° of hip passive flexion. Because the MCID for hip flexion is 5.5° this change of 4° is not considered clinically meaningful to the patient.

Another consideration when taking measurements via standard goniometry is the SEM. The SEM is the difference between the current clinical measurement and the theoretical true score.⁵⁴ For example, a patient comes in for their therapy visit and you measure their passive hip flexion with a standard goniometer to be 120°. Taking into account the SEM of 3.5°, the patient's true passive hip flexion would fall between 116.5° and 123.5°. Established SEMs for hip goniometry vary between 3.1° and 4.7°.⁵⁵ When gauging a patient's progression or establishing motion restrictions MCIDs and SEMs should be considered.

Recent evidence suggests that true coxofemoral flexion, to the point of bony contact between the femoral head-neck junction and acetabulum, is much lower than commonly reported. Using healthy males and ultrasound visualization, researchers established passive hip flexion to be $96^\circ \pm 6^\circ$ ⁵⁶ which contrasts the normally reported 120° of hip flexion. Terminal motion at the hip joint is ultimately limited by bony contact between the femur and acetabulum. Any additional motion is a result of pelvic movement instead of rotation between the femoral head and acetabulum. In a non-weight bearing position the pelvis contributes 13.1-35.3% of hip flexion.⁵⁷ Greater contributions from the

pelvis correspond with the knee in the extended position and shorter hamstring length.⁵⁷ While weight bearing pelvic motion is responsible for approximately 18% of hip flexion.⁵⁸ In order to limit accessory motions the pelvis can be secured with a belt. By placing one hand under the sacrum clinicians can feel for any lift, tilt, or rotation that would indicate motion is no longer coming from the hip joint.

Hip flexion is also affected by the position of the knee joint. When the knee is extended hip flexion will be dependent on the tightness of the hamstring muscles as they cross both the knee and hip joints.⁵⁹ With the knee flexed, tension on the hamstring muscles is eliminated.⁵⁹ As hip flexion is limited by bony contact or hamstring tension, hip extension (ranging from 10-15°) is always limited by soft tissue. The iliofemoral ligament, anterior capsule, rectus femoris, and iliopsoas limit hip extension.⁵⁹

Internal and external rotation at the hip can be measured in three positions: the patient short sitting with the knee and hip to 90°, the patient supine with the hip and knee flexed to 90°, or with the patient prone with the hip in neutral and the knee bent to 90°. In any of these scenarios it is important to use a belt or another clinician to stabilize the pelvis. Measuring rotation in supine has demonstrated excellent inter- and intra-rater reliability (0.75-.091),⁶⁰ while measuring rotation in the seated position is less reliable (0.64-0.82).⁶⁰ Studies comparing patient positioning have found that ROM values differ significantly from one position to another due to stiffness or laxity in ligaments surrounding the hip joint. When the hip is flexed these ligaments are significantly more lax resulting in increased rotatory motion. As such, consistency in measurement methods, including patient positioning, is extremely important in the clinical setting.

Similar to the pelvic accessory motion seen during hip flexion, motion at the tibiofemoral joint, especially in women, may contribute to inflated hip internal and external range of motion values.⁶¹ When the tibiofemoral joint is properly stabilized the arch of rotation at the hip significantly decreases. This difference is only seen in

women.⁶¹ As such, it can be hypothesized that increased motion is caused by ligamentous laxity.⁶¹ In order to stabilize the tibiofemoral joint rotation can be measured in supine where the femur is rotated without using the tibia as a lever.

When evaluating rotation at the hip it is important to consider the total arch of motion instead of isolated internal and external rotation. Similar to shoulder rotation, some athletes develop more rotation in one direction and limited rotation in the other. For example 42% of professional baseball pitchers have a bilateral difference of greater than 10 degrees for hip external rotation.⁶² Normal arch of motion has been reported to be between 73 and 83 degrees.⁶²⁻⁶⁴

Understanding the potential for inflation to affect hip range of motion is of the utmost importance to clinicians. Consistency of measurement among one clinician and between multiple clinicians is imperative to a patient's progress and diagnosis. Some hip pathology presents with increased or decreased ranges of motion and accurate measurements are critical to making these diagnoses. When measuring hip range of motion via a standard goniometer always keep patient positioning consistent, secure the pelvis with a strap or support from another clinician, watch for compensations such as pelvic rotation via the anterior superior inferior spine lifting on the contralateral side, and compare bilaterally.

Bony and ligamentous anatomy

In order to thoroughly assess bony anatomy of the hip there are multiple angulations that must be considered. One is the angle of inclination. The angle of inclination is the angle between the femoral shaft and neck in the frontal plane. A normal value is approximately 125° allowing the greater trochanter to lie at the center of the femoral head therefore appropriately aligning the joint surfaces. An angle of inclination greater than 125° is called coxa valga, and an angle smaller than 125° is called coxa vara. At birth the angle of inclination is approximately 150°; however, due to

the stresses of walking during development this angle decreases to the normal adult value of $125 \pm 5^\circ$.⁶⁵ Physicians generally measure the angle of inclination via x-ray or MRI. Each variation has unique clinical implications resulting from changes in the length of the lever arm. This lever arm spans the distance from the greater trochanter to the center of the hip joint. Lengthening or shortening of this lever arm results in a change in the length of the abductors.

For example, in coxa valga the distance between the greater trochanter to the center of the hip joint has increased. Thus, the hip abductors have to produce less power because of a longer lever arm. Conversely in coxa vara the lever arm between the greater trochanter and the center of the hip joint has been shortened placing the greater trochanter nearly level with the center of the hip joint. In this scenario the abductors are working in a more optimal length for force production and therefore don't have to work as hard to stabilize the joint.⁶⁶

An additional variation to the bony anatomy is version. In the hip joint the femoral head and/or acetabulum can be anteverted or retroverted. Each variation carries with it its' own set of clinical and biomechanical implications. In a healthy hip the acetabulum should sit slightly anteverted. Femoral version is measured via the angle of torsion. The angle of torsion is the angle between the femoral head and femoral shaft in the transverse, or axial plane and a normal value is 12° to 14° .⁵⁹ As this angle increases the mechanical advantage of the gluteus maximus increases and that of the abductors decreases.⁶⁶

The angle of torsion can be measured clinically via Craig's Test to measure the angle of torsion. The patient lies prone with the involved knee flexed to 90° . The clinician will internally and externally rotate the femur palpating the greater trochanter. The clinician will align the greater trochanter parallel with the horizontal. Then the clinician then uses a standard goniometer to measure the angle between the tibial shaft

and the vertical. Craig's Test has moderate inter-rater reliability .6, and good intra-rater reliability .8-.9.⁶⁷

Femoral retroversion is defined as an angle of torsion less than 10°, while femoral anteversion is defined as an angle of torsion greater than 20°. Often patients with femoral retroversion will walk with a toe-out gait, and patients with femoral anteversion with a toe-in gait. This is a natural compensatory behavior adapted to align the middle of the head of the femur in the socket as the body attempts to attenuate joint forces by internally or externally rotating the femur. In other words, the body is seeking stability and joint congruity.⁶⁸

In addition to bony articulations, a complex arrangement of ligamentous, muscular, and cartilaginous structures comprises the hip joint. The acetabular labrum is a wedge-shaped fibro-cartilaginous structure that helps maintain joint lubrication and pressure homeostasis by creating a suction seal between the acetabulum and femoral head. Additionally, it increases the depth of the acetabulum providing additional stability especially in shallow or dysplastic hips. In cadaveric studies it has been shown that the labrum increases the joint depth by ~21%.⁶⁹ Though many assume the labrum circles the entire acetabulum it is in fact incomplete inferiorly.

Researchers and surgeons often refer to the labrum as a clock; 12 o'clock corresponding to the most superior portion of the labrum. Tears to the labrum typically occur in the antero-superior portion (9 to 12 o'clock on the left hip and 12 to 3 o'clock on the right hip respectively). Deep hip flexion and rotation put particular stress on the antero-superior portion of the labrum while an axial load in mid range flexion is more likely to stress the posterior labrum. Labral tears are common. Approximately 70% of asymptomatic adults have a labral tear.⁹ It is not clear what variables make one individual symptomatic and another asymptomatic. The following five etiologies cause acetabular labral tears: trauma, femoral acetabular impingement (FAI), dysplasia,

capsular laxity/hypermobility, and degeneration.⁶⁹ Research has shown that symptomatic labral tears secondary to FAI are more common in active people and athletes.¹⁶ Many athletic demands place additional stress on the antero-superior labrum. Some of the sports with the highest incidence of labral repairs are hockey, American football, and baseball.

Similar to meniscal tears in the knee, tears to the labrum in the hip have very limited healing potential because the majority of the labrum is avascular. There are four zones that comprise the acetabular labrum, IA, IB, IIA, and IIB. Zone I is more vascular than zone II as it is closer to the joint capsule, and zone IB is the most vascular.⁷⁰ Due to the anatomic location of the zones, labral tears are rarely isolated to zone IB meaning surgical intervention is often a required treatment to repair, reconstruct, or debride symptomatic tears.

The capsule surrounding the hip joint is bi-layered originating on the acetabular rim and inserting on the anterior and proximal posterior intertrochanteric lines. The fibers of the superficial capsule run longitudinally while the fibers of the deep capsule run circularly. The purpose of this bi-layered system is to increase joint stability. Though bi-layered the capsule is thinner posteriorly, thereby providing more stability anteriorly. Thinning of the posterior capsular, in-part explains the disproportionate amount of posterior hip dislocations in comparison to anterior dislocations. In addition to less capsular support the posterior joint also has significantly less ligamentous support.

Acetabular retroversion can also anatomically predispose a patient to a posterior hip dislocation due to the lateral rotation of the socket. In a hip with a retroverted acetabulum the anterior wall of the acetabulum provides a bony block preventing an anterior dislocation. With a retroverted acetabulum the femoral head is positioned further posteromedial. This positions the femoral head toward the weakest part of the joint capsule, and a force in that direction can more easily dislocate the joint. One common

mechanism for a posterior hip dislocation is a car accident. This injury is sometimes referred to as the “dashboard injury” because the force of the dashboard slamming into the front of the knees shoves the femur posteriorly and can result in a posterior hip dislocation.

In terms of the ligamentous support in the hip the most notable structure is the iliofemoral ligament, also referred to as the “y-ligament”. This ligament originates on the anterior inferior iliac spine (AIIS) and splits to insert on the distal and proximal aspects of the anterior intertrochanteric line; creating the shape of an upside down “y”.⁶⁷ The iliofemoral ligament is one of the strongest ligaments in the human body reinforcing the anterior joint capsule, preventing hip extension, and resisting anterior translation of the femur inside the acetabulum.⁶⁷ The iliofemoral ligament along with the anterior joint capsule serves as the primary restraints against anterior hip dislocations.

Other ligamentous structures surrounding the hip joint include the ischiofemoral and the pubofemoral ligaments. Each ligament is named by combining the names of the bones it connects. The primary purpose of the pubofemoral ligament is to reinforce the joint inferiorly and limit hip abduction. Likewise, the ischiofemoral provides support to the capsule posteriorly and limits hip internal rotation and extension. Connecting the three primary hip ligaments, the ilio-, ischio-, and pubofemoral ligaments, is the ligamentum obicularis. As discussed earlier, the labrum does not surround all 360° of the acetabula. The transverse acetabular ligament, or TAL, is an inferior continuation of the labrum serving to connect the anterior and posterior surfaces of the acetabulum.

The ligamentum teres, or ligament of the head of the femur, attaches the head of the femur and acetabulum intra-articularly. The functionality of the ligamentum teres is heavily debated but proposed functions include stability, proprioceptive input, blood supply to the femoral head, and nociception.⁷¹ The lateral branches of the medial femoral circumflex artery provide the majority of the blood supply to the head of the

femur. If the femoral head suffers an axial load strong enough this blood supply can be cut off causing necrosis to the head of the femur.

Vascular supply

Additional vascular supply to the hip begins with the femoral artery, the main contributor of blood into the lower extremities. The femoral artery branches from the profunda femoris (deep femoral artery) and it can be located in the femoral triangle. When examining the hip the femoral triangle is an anatomic location to become extremely familiar due to the important structures it contains. The borders of the triangle are Sartorius (laterally), inguinal ligament (superiorly), and the adductor longus (medially). Located within these borders are (from lateral to medial) the femoral nerve, femoral artery, femoral vein, and lymph nodes.

Branching from the femoral artery are the medial and lateral circumflex arteries. The medial and lateral circumflex arteries serve the proximal femur and surround musculature. As previously discussed the lateral branches of the medial circumflex artery along with the inferior gluteal artery provide the majority of the blood supply to the proximal femur and femoral head. When performing a clinical examination, the vascular supply to the hip can be assessed by finding the pulse in the femoral artery. Any trauma to the upper thigh including femoral fractures and dislocations are a medical emergency due to the proximity of the femoral artery to these structures.

Muscular anatomy

The primary purpose of the hip joint is to support the head, trunk, and upper extremities in an upright position. Functionally, the hip serves to transmit forces between the axial skeleton and the lower extremities and is a primary component in locomotion, working simultaneously with the foot, ankle, and knee.

The 21 muscles crossing the hip joint provide triplanar motion.⁶⁸ In addition to motion these muscles reinforce stability between the femur and acetabulum. As a

reminder the three planes of motion are the sagittal in which the hip can flex and extend, the transverse where the hip internally and externally rotates, and lastly the frontal or coronal plane where the hip abducts and adducts. These muscles can be grouped by primary action as seen in Table 2.2.

During a clinical evaluation assessing the musculature surrounding the hip includes testing range of motion, evaluating strength in isolated muscles or muscle groups when isolation is not possible, palpating for tenderness and/or deformity, and testing for functionality. Manual muscle testing (MMT) can be an excellent clinical tool for screening and assessing gross muscular function; however it lacks the sensitivity necessary to rehabilitate active individuals, and accuracy to evaluate bilateral strength deficits.⁷²

If available, a better way to assess strength is via hand held dynamometry. Movement using MMT is graded on a zero to five scale where zero represents no contraction, one represents there was a visible contraction but no movement, two represents either movement through limited ROM against gravity or movement through the full gravity-free ROM, three represents full ROM against gravity, four represents full ROM against gravity and moderate resistance, and lastly five represents full ROM against gravity and full resistance. When performing MMT be aware of compensations. For example, if the patient internally rotates their femur when you are performing iliopsoas MMT they are attempting to compensate with their tensor fascia latae. Conversely, if they roll into external rotation they are compensating with their sartorius.

For a clinical examination it is important to know the location of the muscles surrounding the hip. Starting most medial and working laterally on the proximal anterior side of the hip the superficial muscles are the gracilis, adductor magnus, adductor longus, adductor brevis, and pectineus. To identify the adductor longus have the patient think about adducting their leg. You will feel the slightest contraction over the adductor

longus muscle belly. Likewise, by having them think about flexing the hip will help you identify when you move from the adductor group to the pectineus which is both a hip flexor and adductor.

The muscle belly of the adductor magnus can be palpated more easily with the patient prone. The posterior head of the adductor magnus is a hip extensor. In fact, it has the greatest moment arm of all the hip extensors.⁶⁸ The gluteus maximus and adductor magnus also have the greatest cross sectional area of the primary extensors.⁶⁸ To differentiate between the adductor magnus and other medial hip extensors, the semimembranosus and semitendinosus, have the patient adduct the hip in prone and then extend the hip with the knee straight. The adductor magnus should fire in both these scenarios.

The semimembranosus and semitendinosus will contract when you have the patient extend the hip with the knee straight and with the knee bent, as they are hip extensors and knee flexors. It is important to note that the semitendinosus tendon lies on top of the semimembranosus tendon. On the lateral posterior thigh lies the biceps femoris. This primary hip extensor and knee flexor has two origins: the ischial tuberosity (long head) and proximal femur (short head). Both the long and short head of the biceps femoris insert on the styloid process of the head of the fibula. In addition to hip extension and knee flexion, the biceps femoris is also a secondary external or lateral hip rotator. Compared to other muscle groups, the hip extensors produce the most torque across the hip joint.⁶⁸ This torque is demonstrated during explosive motions such as rapid acceleration and rising from a deep squat.

In some terminal motions hip muscles can reverse their actions due to their orientation to the center of rotation (i.e. the femoral head). For example, the piriformis, gluteus minimus (posterior fibers), and gluteus maximus (anterior fibers) all become internal rotators in deep hip flexion. In anatomic position (0° of hip flexion) the piriformis

is a primary hip external rotator with an external moment arm of 2.9 cm. Beyond $\sim 90^\circ$ of hip flexion, it becomes an internal rotator with an internal rotation moment arm of 1.4 cm. This happens when the line of pull flips superior to the greater trochanter of the femur. The exact point in hip flexion where the piriformis switches to an internal rotator is not completely understood and may vary based on an individual's anatomy.⁶⁸

Traditionally it was thought that the primary external rotators of the hip were the six short external rotators. These six muscles are the piriformis, gemellus superior, obturator internus, gemellus inferior, obturator externus, and the quadratus femoris; however, cadaveric studies have shown that the obturator externus does not produce enough torque to be considered a primary external rotator. This is because obturator externus has a line of force so close to the longitudinal axis of rotation it cannot develop substantial torque.⁶⁸ Therefore, it is classified as a secondary external rotator. The primary external rotators of the hip are the piriformis (below $\sim 90^\circ$ of hip flexion), obturator internus, gemellus superior, gemellus inferior, quadratus femoris, and the gluteus maximus. In addition to producing movement, the short external rotators also compress the femoral head into the acetabulum adding dynamic stability to the femoroacetabular joint.⁶⁸ This mechanical stability is similar to that provided by the infraspinatus and teres minor on the glenohumeral joint.

Normal hip mechanics allow forces to properly transmit from the distal joints, the ankle and knee, through the hip and into the trunk. The hip is responsible for mitigating ground reaction forces and allows for bipedal gait. The literature has demonstrated that during a single leg stance two to three times a person's body weight are transferred through the hip joint. During gait that load increases to two to four times a person's body weight. The greatest load is applied through the hip joint at mid-stance. The majority of the stress moving through the hip is transferred directly through the superior and anterior acetabular surfaces. One common abnormality to hip mechanics is called a

Trendelenberg gait. In this gait pattern patients shift their trunk over involved side due to gross abductor weakness.

Patients with symptomatic FAI present with impairments such as weak external rotators and abductors, tight anterior joint structures, and limited hip flexion and rotation motion.⁷³ Biomechanical analyses have demonstrated that patients with symptomatic FAI have significantly lower peak abduction during walking secondary to weak abductors and external rotators. Additionally, these patients demonstrate a trend toward decreased motion in the sagittal plane during a walking task. This decrease was not due to decreased hip extensor strength. Instead the authors hypothesized reduced sagittal plane motion was likely due to tight anterior structures such as the iliofemoral ligament and joint capsule.⁷⁴

Intra-articular disorders

Clinical assessment can be 98% reliable at detecting the presence of a hip joint problem; however, the exam may be poor at defining the exact nature of the intra-articular disorder.⁷⁵ According to a recent systematic review there is an equal (50%) distribution between intra-articular and extra-articular pathologies resulting in surgery.⁷⁶ Over 80% of cases were attributed to one of five pathologies: femoral acetabular impingement (FAI), sports hernia/athletic pubalgia, adductor-related pathology, inguinal pathology, or an acetabular labral tear.⁷⁶

In the remaining pages of the chapter we will provide a brief overview of the common intra-articular pathologies affecting the hip joint. The first pathology we will address is developmental dysplasia of the hip (DDH). DDH is a broad term used to categorize alignment abnormalities to the femoral head and acetabulum. Acetabular dysplasia is characterized primarily by an under developed acetabulum which provides insufficient coverage to the femoral head. Following Wolff's Law which states that adaptive changes in the structure and biomechanical properties of bone occur in

accordance with functional demands⁷⁷, the femoral head may then under develop as the acetabulum is not providing appropriate, healthy stress.

Ultrasound is the preferred screening method in children under six months of age; however, following ossification of the femoral head and maturing of the cartilage portions of the acetabulum and femur radiographs can be used. Eighty percent of children affected by DDH are female.⁷⁸ Most cases of DDH will resolve in the first few months of life; however, if DDH does not resolve and carries on to skeletal maturity there may be long-term ramifications. These ramifications according to a recent Cochrane review include delayed walking, leg length discrepancy, chronic hip pain, avascular necrosis (AVN), and osteoarthritis.⁷⁹ The most commonly recommended treatments in infants include bracing and casting to avoid the motions of hip extension and abduction, giving the hip time to properly develop while limiting risk of dislocation.

Early symptoms of DDH adolescence and adults include poor exercise tolerance with muscle pain secondary to muscle fatigue of the hip's abductor muscles, and diffuse hip pain in the groin, buttocks, anterior thigh, or over the area of the greater trochanter. Treatment options for skeletally mature patients with DDH are more limited, but in the absence of osteoarthritis a periacetabular osteotomy (PAO) may be considered.

Secondary to DDH patients may present with a hypertrophic acetabular labrum. This hypertrophy is a compensatory mechanism aimed at deepening the hip socket and providing stability.⁸⁰ Labral tears are a common intraarticular hip pathology in young, active adults. These patients present clinically complaining of clicking, locking, or catching deep within the hip. Unusual sounds and/or sensations can be helpful in making a clinical diagnosis. Snapping/popping coming from the hip can be incidental or clinically significant. Popping coming from deep inside the hip is both sensitive (100%) and specific (85%) for an acetabular labral tear.⁸¹ Pain patterns can vary however the most common locations for pain are the groin and anterior thigh.⁸² Not all labral tears are

symptomatic. In fact, 70% of people have an asymptomatic labral tear.⁹ Symptomatic labral tears often correlate with abnormal hip morphology including DDH and femoral acetabular impingement (FAI).

Additional pathologies that present in children with insidious hip and groin pain are legg-perthes disease and slipped capital femoral epiphysis (SCFE). Legg-perthes disease is five times more common in obese (32%) and overweight (16%) boys and is significantly more common in Caucasians.⁸³ In legg-perthes disease ischemia, or a lack of blood supply, to the femoral head causes the articular cartilage to become necrotic and flatten. It is hypothesized that genetic and/or environmental factors may play a role in the incidence and progression of legg-perthes disease. Genetic factors may increase the susceptibility to the disruption of the blood supply to the capital femoral epiphysis, whereas environmental factors may trigger the disease. Environmental factors would include excessive activity causing mechanical overload and repeated micro-trauma.

The average age at presentation is generally between 4 and 8 years old.⁸³ Children with legg-perthes disease will report their pain gets worse as the day progresses and gets better with rest. Seventy-five percent of cases of legg-perthes disease will present with a limp, and if the femoral head has collapsed they will have a leg length discrepancy with the involved limb being shorter. To measure true leg length, the actual difference in length of the femur or tibia bones, measure from the anterior superior iliac spine (ASIS) to the ipsilateral medial malleolus. The minimal detectable change (MDC) for a true leg length discrepancy is 10-20mm.⁶⁷ Clinically, weakness in the hip abductors, a positive Trendelenberg gait, and decreased abduction and internal rotation may also be noted. There are multiple treatment options for legg-perthes disease described in the literature. Non-weight bearing for a period of six to eight weeks has been suggested, but results are conflicting. Surgical treatment options are quite invasive including pelvic and/or femoral osteotomies.

Slipped capital femoral epiphysis (SCFE) is the most common hip condition in adolescents.⁸⁴ SCFE is idiopathic; however it has been suggested that growth hormones (specifically testosterone), or obesity, which increases the sheer forces on the growth plate may play a role.⁸⁴ Like in legg-perthes disease, SCFE is also most commonly seen in young obese boys. Contrary to legg-perthes disease SCFE is more common in children a bit older (mean age 12 ± 1.8), and is more common in blacks or Hispanics than Caucasians.⁸⁴ On radiographs SCFE presents with the femoral head shifted inferior and posterior.

Patients with SCFE will clinically present with excessive external rotation and nearly no internal rotation.⁸⁴ Due to the slip of the femur these children will likely present with a leg length discrepancy and moderate to severe limp. Ninety percent of SCFE cases are stable⁸⁴, however if suspected patients should be placed on crutches until they have a thorough exam by a physician including radiographs. Bilateral SCFE cases occur in approximately 60% of children.⁸⁴ SCFE is always treated surgically, inserting a pin between the femoral head and femoral neck to stabilize the epiphysis.

Femoral neck stress fractures are rare, and treatment is highly dependent on the location of the stress fracture. If the stress fracture is located on the tension side of the femoral neck is it a higher risk injury than if it is located on the compression side. Treatment for tension side femoral neck stress fractures is screw fixation, whereas treatment for compression side femoral neck stress fractures is much more conservative. Generally, compression side stress fractures will respond to treatment with non-weight bearing. Coxa vara, previously discussed, is a decreased femoral neck-femoral shaft angle, can be a risk factor because it increases the bending moment across the tension side of the femoral neck, placing it at risk of femoral neck fracture. If a stress fracture is suspected during a clinical examination, it is not recommended to do additional stress testing.

The hip, or coxofemoral joint, is a complex arrangement of bony, muscular, ligamentous, and cartilaginous structures. This complexity can make clinical diagnosis and treatment challenging. Understanding muscles acting on the hip joint as well as bony variations can assist clinicians in making a thorough diagnosis.

2.2 FEMORAL ACETABULAR IMPINGEMENT

The coxofemoral joint, described in detail above, provides triplanar motion. Functioned with providing support to the head, trunk, and upper extremities in an upright position and transmitting forces between the axial skeleton and the lower extremities, the hip is a primary component in locomotion, working simultaneously with the foot, ankle, and knee. The acetabular labrum is a fibrocartilage rim surrounding the acetabulum. The primary purpose of the acetabular labrum is to create a suction seal maintaining intraarticular joint pressure, though in dysplastic hips it can also be functioned with increasing joint depth.

Injuries to the hip joint are common. Femoral acetabular impingement (FAI) is one common source of non-arthritic hip pain. FAI occurs from a morphologic incongruence between the femoral head, acetabulum, or both. There are three types of FAI. The first is characterized by extra bone growth on the femoral neck, known as a CAM lesion. On radiograph, an aspherical femoral head, and therefore a decreased femoral head-neck offset, is found in patients with CAM lesions. (Image 2.1) The second type, a pincer lesion, is extended bone off the acetabulum or an ossification of the labral tissue. Sometimes a pincer lesion is referred to as coxa profunda, or a deep socket. (Image 2.2) Lastly, patients may present with a combination of the two lesions creating a “mixed” morphology. Clinical and radiologic signs of FAI are more common in athletic populations.^{5,6} Clinically, patients often present reporting their pain with a “c sign”. The “c sign” is displayed when a patient cups their hand around their affected hip to describe pain deep within the joint.

Similar to DDH, FAI can result in tears to the acetabular labrum. Instead of the labrum becoming hypertrophic, the labrum is pinched by the bony overgrowth in positions such as hip flexion and internal rotation. Over time this repetitive trauma can result in a tear. Whether caused by FAI, DDH, capsular laxity/hypermobility, or degeneration treatment options for acetabular labral tears are the same. First line treatment includes an intra-articular cortisone injection and physical therapy. In addition to providing patients pain relief, intra-articular cortisone injections have a high sensitivity (1.0) and specificity (0.88) in diagnosing intra-articular hip pathologies.⁸⁵ A decrease in symptoms following an intra-articular injection suggests the pain generator is intra-articular. Intra-articular injections are 90% accurate when compared to arthroscopic findings.⁷⁵ This diagnosing capability is important as it can be clinically challenging to differentiate the true generator of hip pain. Hip pain may be referred from a number of locations including the sacroiliac (SI) joint, lumbar spine, pelvic floor (including insertion of the hip adductors), and extra-articular hip structures (iliotibial band, trochanteric bursa, gluteal tendons). A definitive diagnosis is key in treating hip pathology. If an intra-articular cortisone injection and physical therapy fails to improve symptoms for an acetabular labral tear surgical intervention can include labral debridement or removing the portion of the labrum that is torn, labral repair, or labral reconstruction. Patients that undergo labral repair generally report less pain and higher function in the years following surgery.^{86,87}

Radiographic prevalence of FAI is common; however, radiographic evidence of FAI is not always correlated with symptoms. In 2017, Thier et. al. measured lateral center edge angles (LCEAs) (Image 2.2), a measure of pincer deformity, on standard anterior-posterior (AP) pelvis radiographs, and alpha angles, a measure of CAM deformity (Image 2.1), on lateral view radiographs in 110 asymptomatic patients.⁷ They found indications for pincer deformity (LCEA > 40°) in 13% of patients, and for CAM

deformity (alpha angle > 50°) in 41% of patients.⁷ Unfortunately, radiographic measures of impingement have limited reliability. In 2009 five hip specialists and one fellow performed blinded radiograph evaluations. They concluded that standard radiograph hip parameters are unreliable and not reproducible.⁸⁸ In 2018 the Thier et. al study was replicated using a more sensitive measure, 3D models developed from CT scans.⁸ Using this method 31% of healthy, asymptomatic volunteers presented with a CAM deformity.⁸ Though one in every three healthy patients may have a CAM deformity, labral tears are even more common. In 2012 Register et. al. performed MRIs on 45 patients with no history of hip pain, symptoms, injury, or surgery and found 69% had a labral tear.⁹

Clinical and radiologic signs of FAI are identified with a higher prevalence in athletic populations. For example, in 2018 Falotico et al. used radiographs to calculate measures of bony impingement in 60 professional male soccer players and 32 healthy male controls. 92.5% of the soccer players displayed signs of FAI (21.7% CAM, 33.3% pincer, 45% mixed), while only 28.1% of controls displayed signs. Additionally, the alpha angle positively correlated with the duration of the soccer career ($p=.03$) and negatively correlated with the age at which the career began ($p<.01$).¹¹ In younger populations this is also true. Youth ice hockey players are 15 times more likely to develop a CAM lesion than their age-matched peers.¹⁰ Similarly, 94.3% of hips in the National Football League (NFL) have radiographic indicators of FAI.⁸⁹ Labral damage seems to mirror bony impingement. Kivlan et. al. demonstrated that 93.3% of patients seeking treatment for hip pain had abnormal labral findings.⁸²

Treatment seeking patients with FAI are generally physically active, as previously discussed, or females in their mid-thirty's according to recent epidemiology data.⁸² They present with the primary complaints of pain with sitting (45%) and sporting activity (45%). Pain patterns typically consist of groin (40%) and anterior hip pain (24%).⁸² Upon clinical examination 62% of patients with FAI will test positive on the anterior impingement test,

or internal rotation overpressure (IROP), and will have passive motion limitations primarily in flexion and rotation.¹²

Patients with symptomatic labral tears present clinically with pain, clicking, locking, or catching deep within the hip. Pain patterns can vary however the most common locations for pain are the groin and anterior thigh.⁸² As discussed above, symptomatic labral tears often correlate with abnormal hip morphology. CAM and pincer lesions often create differing damage patterns to the labral tissue. CAM lesions result in focal tears to the anterosuperior labrum while pincer lesions result in circumferential labral ossification.⁹⁰ There is evidence to suggest that the previously described labral tears and impingement patterns are a causative factor in the accelerated development of hip osteoarthritis (OA).^{90,91}

Diagnosing symptomatic FAI and associated labral tears is challenging as a variety of pathologies throughout the low back and pelvis can refer pain to the hip. Intra-articular cortisone injections are one method of differentiating the pain generator. Cortisone injections have a high sensitivity (1.0) and specificity (0.88) in diagnosing intra-articular hip pathologies.⁸⁵ A decrease in symptoms, primarily pain, following an intra-articular injection suggests the pain generator is intra-articular. Intra-articular injections are 90% accurate when compared to arthroscopic findings.⁷⁵

Secondary to challenges in diagnosis, treatment-seeking patients with symptomatic FAI often have an extended duration of symptoms. The average duration of symptoms is approximately 28 months⁹², with 40% of patients reporting having pain for longer than 24 months.⁸² Consequences of such an extended duration of symptoms include worse pain and symptoms at preoperatively.²¹

2.3 CONSERVATIVE TREATMENT OF FAI

The current state of conservative treatment for FAI is moderately effective at best. Based on the five available studies that examine physical therapy as a treatment

for symptomatic FAI we can conclude in general, at least half of patients will continue on to surgical intervention⁴¹, and those patients may be more active⁹³ and/or have worse hips (i.e. greater severity of impingement) at baseline.⁹⁴ The overarching goal of conservative rehabilitation is to target impairments such as weak external rotators and abductors and limited hip flexion and rotation motion.⁷³

The first of the five studies to examine rehabilitative therapy to improve symptoms and function in patients with symptomatic FAI was a 2012 prospective observational study. In total, 52 patients presenting with symptomatic FAI were recruited into and completed the study. Following 3 months of conservative rehabilitation those with continued limitations proceeded to surgical intervention. The results demonstrated moderate success with conservative treatment with 44% of patients satisfied with their improvement, and 56% choosing to have surgery. Those that went on to surgery were more active at baseline (Baecke total score surgical group 8.4 ± 1 , nonsurgical group 7.4 ± 1 , $p=.02$).⁹³ Further information regarding types of activities was not provided.

The second study was a randomized control trial involving 80 (91% active) military members. Patients were randomized into one of two groups: hip arthroscopy or 12 sessions of physical therapy (conservative treatment). There were no significant differences between groups at baseline. Following treatment, 70% of those in the conservative treatment group went on to surgery, and at 2 years post-operation there were no differences between groups in terms of self-reported pain and function. No predictors of success or failure were provided. Regardless of group, 33% of patients were no longer medically fit for duty at the two year timepoint.⁴¹

A 2018 study examined the success of conservative treatment in patients with hip pain caused by FAI. In this multicenter, 2 parallel arm superiority randomized control trial 348 patients were randomized into one of two groups: hip arthroscopy or 6-10

sessions of individualized physical therapy. At 12 months post intervention, both groups saw improvement; however, the surgical group saw a significantly greater improvement in self-reported pain and function.⁹⁵

Casartelli et. al. published a longitudinal cohort study in 2018 where 31 patients completed 12 weeks of progressive exercise therapy. Half of these patients saw significant improvement in both self-reported pain and function and objective abductor strength and pelvic control. Patients that did not respond to conservative therapy had a higher prevalence of severe cam morphology.⁹⁴

A fifth study was published by Kemp et. al. in 2018. This pilot randomized control trial enrolled 24 patients with symptomatic FAI. They determined that a full scale RCT comparing FAI specific physical therapy to a control group of standard strengthening is feasible based on patient retention, intervention delivery, and within group effect sizes. Both groups attended 8 physical therapy sessions over 12 weeks. The largest differences in effect size were seen in patient reported measures; specifically the International Hip Outcome Tool-33 (iHOT-33) (FAI specific 1.34, control 0.42), Hip Osteoarthritis Outcome Score (HOOS) quality of life scale (FAI specific 1.26, control 0.56), and HOOS pain scale (FAI specific 1.77, control 0.45), as well as hip adduction strength (FAI specific 1.04, control 0.04).⁹⁶

Overall, we can conclude from the available literature that the current standard of care conservative treatment is ineffective for the majority of patients. Though select patients saw decreased pain and improved strength and function those patients generally had lower activity expectations and less severe joint pathology. Further research is necessary to fine-tune the treatment paradigm including duration, dosage, and essential intervention components.

2.4 HIP ARTHROSCOPY

In the absence of effective conservative treatment, and to prevent or delay the progression of osteoarthritis, hip arthroscopy is often performed with the goal of resorting normal joint pathomechanics. Hip arthroscopies have increased dramatically over the past 20 years. From 1999 to 2009, the number of hip arthroscopies performed annually in the United States increased 18-fold.¹³

Hip arthroscopy outcomes

A wide variety of patient reported outcome (PRO) measures are currently being used in patients with FAI. In 2017, Stone et. al identified 21 different PRO instruments reported in the hip arthroscopy literature.⁹⁷ The most common PROs were the Modified Harris Hip Score (mHHS), HOS-ADL, HOS-SS, visual analog scale (VAS), and Nonarthritic Hip Score (NAHS); however, in terms of responsiveness the NAHS and iHOT-12 were superior.⁹⁷ The wide variety of outcome measures being used makes comparisons between studies challenging. The psychometric properties of the five most common hip arthroscopy PROs (Copenhagen Hip and Groin Outcome Score (HAGOS), HOOS, HOS, iHOT-33, and mHHS) were established by Kemp et. al in 2013. The HAGOS has six subscales: pain, symptoms, activities of daily living (ADL), sport and recreation, physical activity, and quality of life. The HOOS has five subscales: pain, symptoms, ADL, sport and recreation, and quality of life. The HOS has two subscales: ADL and sport-specific (SS). The test-retest reliability, SEM, MDC, MIC, and PASS for these five scales can be found in Table 2.3.¹⁷

Outcomes following hip arthroscopy are generally good with the majority of patient's (86%) are satisfied¹⁴ and able to return to their desired level of function; however, there is a subset of patients with suboptimal outcomes. Capongna et. al determined that 10.5% of patients have a poor outcome at a 2-year follow up as defined by a mHHS of <70,¹⁸ and more alarmingly Levy et. al found that in 81 studies (9,317

hips) only 25% of patients met the patient acceptable symptomatic state (PASS) for the HOS-ADL and 30% met the PASS for the HOS-SS at a mean 31 month follow-up.¹⁷

Postoperative pain, measured via a Visual Analog Scale (VAS), is not often reported in hip arthroscopy outcomes studies. The meta-analysis by Minkara et al in 2018 identified three studies that used VAS pain as an outcome variable. Brunner et. al. evaluated 53 hips and found a mean preoperative VAS score of 5.7 and a mean postoperative VAS score of 1.5. ($\Delta 4.2$)⁹⁸ Horisberger et. al. reported similar numbers in a cohort of 20 patients with a preoperative VAS score of 6.0 and a postoperative score of 1.8 ($\Delta 4.2$).⁹⁹ Lastly, Larson et. al. reported a preoperative VAS score of 6.1 and a postoperative score of 1.2 in 94 patients ($\Delta 4.9$).⁸⁷ All of these pre- to postoperative changes exceed the MCID for postoperative VAS scores (1 point), and postoperative VAS scores exceed the Patient Acceptable Symptomatic State (PASS) score of 3.3.¹⁰⁰

Reoperation rates vary in the literature with Minkara et. al. describing a 5.5% risk of reoperation (revision arthroscopy or conversion to a total hip arthroplasty) in a 2018 systematic review and meta-analysis of 1,911 patients⁴, while Kivlan et. al described 24.4% of 1,738 patients in a multicenter epidemiologic study having had prior surgery addressing their current pain.¹² In 2016 Newman et al compared 246 patients undergoing revision hip arthroscopy with a matched cohort of 492 patients undergoing primary hip arthroscopy.¹⁰¹ The reoperation rate in primary hip arthroscopy cases was 8%, and in revision hip arthroscopy cases it was 2%.¹⁰¹

Return to athletic competition following surgical treatment for FAI and acetabular labral tears have been evaluated in a number of systematic reviews. In 2018 one such review examined return to sport in competitive athletes following arthroscopic treatment (repair, reconstruction, or debridement) for a labral tear. The authors identified that 87.4% of competitive athletes returned to their previous level of play in a mean of 7.7

months (range 4 to 9.4).¹⁰² Again limiting surgery to only those done arthroscopically, Minkara et. al. found that of 554 athletes 87.7% were able to return to play.⁴ Expanding surgical procedures to include open and mini-open techniques, Casartelli et. al. found a very similar proportion (87%) of 977 athletes returned to play following hip surgery for FAI, while only 82% returned to the same level of competition.¹⁵ The most recent systematic review by Reiman et al in 2018 evaluated 35 studies with 1,643 athletes (1,828 hips), and found that approximately three in four athletes were able to return to their pre-injury level of competition (74% returned in an average 7.0 ± 2.6 months).¹⁰³ The authors found that professional athletes were able to return, though not to their previous level, at a higher rate than those playing at the collegiate level.¹⁰³ Across reviews, the inability to return to play ranged from 12.3%-26%, with the larger percentage corresponding to studies including open procedures. None of these reviews compared return to play rates between surgical procedures; however, this distinction may be important in counseling patients on recovery expectations. Matsuda et al. performed a systematic review comparing the three major surgical approaches (arthroscopic, open, and mini-open) and found that arthroscopy resulted in superior results clinical outcomes and lower risk of complications.¹⁰⁴ Unfortunately, return to athletic competition was not a variable examined in this review.

One limitation of all four systematic reviews is the underrepresentation of women. Female athletes comprised only 24% to 30.5% of the athletes; however, most literature is consistent that females represent the majority of patients undergoing hip arthroscopy.⁸² This discrepancy may be explained partially by the sports included in these reviews (i.e. football and baseball). Future studies should make a conscious effort to examine return to play rates in female athletes as they may differ from rates seen in male athletes.

Return to full duty rates in military members appear to be slightly worse. In 2016 Byrd et. al. found that 80% of military members were able to return to full duty at an average of 5 months following hip arthroscopy⁹²; however in 2018 Mansell et. al. found that at 2 years post-operation 33% of military members treated for FAI were no longer medically fit for duty.⁴¹ A 2018 systematic review by Reiman et al. reinforced the sentiment of a low return to full duty rate following surgical treatment for FAI. Overall, the authors identified a 57-84% return to duty rate with only 39-59% of military members being able to return without limitations.¹⁰⁵

Based on the evidence described here, and regardless of the outcome variable, there is a subset of at least 10-20% of patients experiencing suboptimal outcomes following hip arthroscopy. As such, researchers have begun exploring plausible risk-factors. The next section in this literature review will be a summary of identified risk-factors influencing poor outcomes following hip arthroscopy.

Factors influencing hip arthroscopy outcomes

Risk-factors leading to a variety of poor outcomes following hip arthroscopy are being identified with increasing frequency. These factors can logically be divided in two categories: modifiable risk-factors and non-modifiable risk-factors. Modifiable factors that have been associated with poorer outcomes following hip arthroscopy include an extended duration of symptoms²¹, smoking²⁰, and a higher BMI²⁰. As previously discussed an extended duration of symptoms is extremely common in treatment seeking patients with symptomatic FAI. There have been two studies that have examined duration of symptoms as a potential factor associated with worse outcomes postoperatively. Dierckman et. al. performed a retrospective review of 680 patients that underwent hip arthroscopy and labral repair.²¹ They found a negative relationship between clinical and patient reported outcomes and duration of symptoms indicating that earlier intervention may be warranted.²¹ Smoking and increased BMI are globally

recognized as risk-factors to poor outcomes across the health care domains.¹⁰⁶⁻¹⁰⁸

Smoking leads to poor tissue healing¹⁰⁹ and BMI increases the risk of multiple postoperative complications.¹¹⁰ Non-modifiable factors associated with the poor outcome measures discussed in detail above include female sex¹⁸, older age²⁰, and revision hip arthroscopy.¹⁰¹ Decreased joint space¹⁹ has also been identified as a factor leading to poor outcomes though is arguably is a symptom of a protracted time to definitive treatment instead of a non-modifiable factor.

Psychosocial variables influencing hip arthroscopy outcomes

There are currently six studies suggesting global emotional health is impacting outcomes for patients with symptomatic FAI. The first two were published by Potter et. al. in 2014.^{24,25} In both of these studies psychological distress was used as the measure of emotional health. Patients were stratified into low, moderate, or high psychological distress based on the Distress Risk Assessment Method (DRAM) questionnaire. Higher psychological distress was negatively related to preoperative patient reported outcomes,²⁵ and patients with higher psychological distress were more likely to request a postoperative nerve block for pain control.²⁴

The third study, by Jacobs et. al. in 2017, determined that preoperative mental component scores (MCS) from the Veterans Rand-12 (VR-12) were more related to preoperative pain than other traditional orthopedic measures such as magnitude of bony deformity, size of the labral tear, and self-reported function.²² These findings were validated when Westermann et. al. published similar results. In lieu of intra-articular findings, similar to Jacobs et.al, Westermann et. al found lower mental health scores were predictive of worse self-reported pain and function preoperatively.²³

The final two studies were published in 2018. Nho et. al. examined outcomes for those with self-reported mental health disorders²⁶ and Ellis et. al. used a self-reported measure of depressive symptoms, The Beck Depression Inventory-II.²⁷ These studies

demonstrate that both self-reported mental health disorders and moderate to severe depressive symptoms lead to worse postoperative self-reported pain and functional outcomes.^{26,27}

2.5 PAIN

Postoperative pain, graded on a 10-point VAS, is the primary outcome measure selected for this dissertation study. As such, an in-depth examination of pain, how it is processed (or misprocessed), and factors that can influence postoperative pain is warranted. Acute pain is a normal response to tissue damage; however, it is important to understand that tissue damage and pain are not synonymous. The traditional biomedical model followed the belief that there was a direct relationship between nociception (tissue damage) and pain or discomfort reported by the patient. Though there can be a relationship between nociception and pain, many studies have demonstrated a stronger, more meaningful, relationship between the patients' mental status and their pain than the integrity of the tissues.¹¹¹⁻¹¹³

The role of the nociceptor is to alert the brain of potential danger (i.e. changes in pressure, temperature, tension). Nociceptors are free nerve endings located in tissue, muscle, and joints. The nociceptor terminal uses glutamate, an excitatory neurotransmitter, to activate N-methyl-D-aspartate (NMDA) receptors. Most nociceptors (~70%) send signals up the spinothalamic tract via c-fibers. C-fibers are small diameter, non-myelinated fibers that send nociceptive signaling to the dorsal root ganglion. A-delta fibers, thicker and faster than c-fibers, are responsible for communicating the remaining nociceptive information to the brain. Between the c- and a-delta fibers, information is delivered to the dorsal root ganglion. From the dorsal root ganglion, the noxious stimulus travels up the spinothalamic tract to the thalamus where the brain then decides based on both the available noxious information and the perceived threat of the environment whether this signal will result in pain.¹¹⁴ Pain is felt when the brain decides, based on a

variety of factors including noxious stimuli, environment, and the individuals neural signature, that the body is in danger.¹¹⁵

When pain is present beyond the tissue healing process (3-6 months) or is present in the absence of tissue injury the pain because a disease state of its' own. Persistent pain, as we will define in these studies, is any pain lasting 6 months or longer. Pain is complex and can never explained by a single variable; however, recent evidence and advances in neuroscience allowed researchers to identify some specific variables and processes associated with persistent or increased pain. The following sections will describe how pain is measured, average pain levels in patients with symptomatic FAI, the impact of chronicity on pain levels and neurologic processing, and lastly, we will explore factors influencing postoperative pain in patients following hip arthroscopy and other orthopedic surgeries.

Measuring pain

In this series of dissertation studies pain will be measured on a visual analog scale (VAS) and treated as either a continuous variable or categorical variable. Increased postoperative pain will be defined as any pain equaling 3 or greater on the VAS scale ranging from 0 (no pain at all) to 10 (the worst pain imaginable). This threshold was chosen as the cut-off as it is consistently used as the cut score for unacceptable pain in both chronic and acute pain studies. In 2009 Tashjian et. al. reported 3 as the patient acceptable symptomatic state (PASS) in patients with chronic rotator cuff disease⁴⁶, and this was validated when in 2017 Myles et. al determined 3.3 as the PASS score for acute postoperative pain.¹⁰⁰

In this dissertation study hip pain will be measured at rest and during activity. These constructs, rest and activity, though both measuring one's level of pain are intrinsically different as pain at rest is a stimulus-independent construct relying heavily on central mediation, while pain during activity is stimulus-dependent relying on

peripheral nociception and tissue damage.¹¹⁶ A 2011 systematic review examining postsurgical quantification of movement-evoked pain and pain at rest found that over 50% of studies did not identify their pain outcome as it related to activity or rest.¹¹⁶ The distinction between pain during activity and pain at rest is important because interventions aimed at reducing pain must target the appropriate pathway to be successful.

2.6 FEAR AVOIDANCE MODEL

The Fear Avoidance Model (FAM) of chronic pain provides a visual description of how psychosocial variables direct rehabilitation outcomes in response to a painful experience. It can be inferred from this model updated to include self-efficacy (Figure 2.1) that one of the first, and most important steps for patients is integrally linked with how they frame and react to painful experiences. The FAM is a widely accepted biopsychosocial model being used with increasing frequency. Its primary purpose is to help clinicians conceptualize the process by which patients transition from a musculoskeletal injury to a chronic pain condition.²⁸ The FAM suggests that the way in which an individual views their pain will dictate the trajectory of their recovery.²⁸ When pain is viewed as a threat, maladaptive psychosocial behaviors increase leading the patient down a path of depression, disability, and worse pain instead of the path to successful recovery.

2.7 PAIN CATASTROPHIZING

Pain Catastrophizing Scale

Catastrophizing is characterized by a patient's inability to stop thinking about their pain, a fear something serious may happen to increase their pain, and a belief there is nothing they can do to resolve their pain.²⁹ These beliefs are measured with the pain catastrophizing scale (PCS). The PCS was developed by Dr. Sullivan in 1995 and is a 13-item patient reported outcome tool that has been demonstrated to be reliable and

have good construct validity in a wide variety of populations.²⁹ To complete the PCS patients rate each statement on a scale from 0 (not at all) to 4 (all the time). The pain catastrophizing scale can be analyzed as a total raw score or it can be broken into its three dimensions: rumination (sum of items 8-11), magnification (sum of items 6, 7, and 13), and helplessness (sum of items 1-5 and 12). The overall PCS results in a score from 0 (best) to 52 (worst). A cut-off score of 19 has been used in the literature because it is the 50th percentile in patients with chronic pain.²⁹ It will be used as the cut-off score to determine the presence of pathologic catastrophizing in this series of dissertation studies. Test-retest reliability and internal consistency (Cronbach's α) can be found in Table 2.4. The PCS has good construct validity when compared to the perception of pain severity ($r=.51$) and the perception of pain interference ($r=.57$).¹¹⁷

Pain catastrophizing beliefs and orthopedic outcomes

As a result of progressing toward a biopsychosocial model, psychosocial variables and their impact on patient outcomes has become of increasing interest in the orthopedic literature. One such variable, pain catastrophizing, has been associated with a more intense pain experience, more severe depression and anxiety, and a greater risk for developing chronic pain.¹¹⁸⁻¹²⁰ Pain catastrophizing is a set of beliefs that are adopted in response to actual or anticipated pain. Pain catastrophizing beliefs can be broken into three individual constructs: ruminating on painful experiences, feeling helpless in overcoming painful situations, and magnifying the circumstances surrounding pain or injury.²⁹ Pain catastrophizing beliefs form in response to an over- or misinterpretation of nociception,¹²¹ and in terms of rehabilitation, catastrophic thinking directly impacts how patients functionally respond to pain.^{34,122} It has also recently been demonstrated that pain catastrophizing indirectly mediates a patient's pain intensity and pain interference meaning that higher levels of catastrophic thinking limit a patient's ability to engage in their activities of daily living and rehabilitation.⁴⁰ Due to the chronicity of FAI it has been

hypothesized as part of this dissertation that catastrophizing behaviors may be exacerbated in this population.

Currently, there is only one study that reports PCS scores in patients with FAI. In a randomized control trial examining the effects of surgical intervention to conservative treatment, military members scored a mean 23.7 ± 11.8 .⁴¹ Of note is that this mean PCS score is above the previously discussed threshold for clinically relevant pain catastrophizing (23.7 vs. 19). Following the FAM, pain catastrophizing beliefs play a pivotal role in a patients' recovery trajectory (Image 1). If clinicians can successfully intervene to minimize exaggerated responses to pain, the impending cascade of events including fear avoidance behaviors and further disability may be prevented.

2.8 SELF-EFFICACY

Pain self-efficacy and orthopedic outcomes

Self-efficacy is a situation and task-specific construct that gauges how confident a person is in achieving tasks despite their current circumstances, in this case pain. Literature suggests that pain self-efficacy mediates the relationship between depressive symptoms and pain¹²³ suggesting that interventions targeted at improving a patient's self-efficacy may improve pain outcomes. Low self-efficacy has been associated with higher pain levels¹²⁴ and increased avoidance behaviors¹²⁵ perpetuating the chronic pain cycle described visually in the FAM (image 2.1). Self-efficacy has never been measured in patients with FAI; however, since global measures of mental health have been shown to drive pre- and postoperative pain in this population,^{22,23,26,27} self-efficacy warrants examination.

Pain Self-Efficacy Questionnaire

There are a variety of scales available to measure self-efficacy.¹²⁶ Though this makes comparison between studies challenging the situation and task-specific nature of self-efficacy warrants a variety of measurement tools. As pain is the primary outcome

measure in this series of studies the Pain Self-Efficacy Questionnaire (PSEQ) will be utilized. Test-retest reliability and internal consistency (Cronbach's α) can be found in Table 2.4. The PSEQ has good construct validity when compared with pain related disability and pain intensity ($r=.51-.6$).¹²⁷

2.9 KINESIOPHOBIA

Kinesiophobia and orthopedic outcomes

Staying consistent with the FAM, patients that have overexaggerated, misinterpreted responses to pain (i.e. catastrophizing) are more likely to become fearful of pain.¹¹⁹ Fear of pain further dictates the recovery trajectory by increasing hypervigilance and avoidance behaviors thus limiting successful engagement in rehabilitation and perpetuating disuse. Literature supports this theoretical relationship. High levels of kinesiophobia have demonstrated a relationship with increased pain and disability in patients with chronic low back pain.¹²⁸⁻¹³⁰ Additionally, kinesiophobia has been identified as a factor influencing decreased functional outcomes one year following total knee arthroplasty (TKA).¹³¹ A 2018 article by Chmielewski et. al. demonstrated the relationship between elevated kinesiophobia and reduced quality of life for patients with musculoskeletal pain at their initial physical therapy visit.¹³² Kinesiophobia has never been examined in patients with symptomatic FAI; however, given the relationships between elevated kinesiophobia and poor outcomes (increased pain, decreased function, and decreased quality of life) this variable warrants consideration. Kinesiophobia may be relevant to hip arthroscopy outcomes.

Tampa Scale for Kinesiophobia

The Tampa Scale for Kinesiophobia (TSK) is a 17-item patient reported outcome that measures patients fear of movement. Patients grade each item on a 4-point scale where 1 corresponds with strongly disagree and 4 corresponds to strongly agree. The total score ranges from 17-68 with higher scores indicating greater fear. Test-retest

reliability and internal consistency (Cronbach's α) can be found in Table 2.4. The TSK has good construct validity when compared to the PCS ($r=.51$), and the two subscales of the Fear Avoidance Beliefs Questionnaire (FABQ) ($r=.35-.53$).¹³³

2.10 ABNORMAL PAIN PROCESSING

In most simplistic terms, sensitization is characterized by a hypersensitive response to a persistent noxious stimulus. As previously mentioned, tissue damage and pain responses are not highly correlated. Sensitization (i.e. over-sensitivity, a decreased inhibition, or increased synaptic activity) can occur at the nociceptive level via increased membrane excitability, at the dorsal root ganglion via increased synaptic efficacy, and/or in the thalamus via decreased inhibition.¹³⁴ Though tissue injury may be responsible for pain at the onset, persistent pain can lead to neuronal plasticity and thereby, abnormal pain hypersensitivity.¹³⁵

Sensitization of pain is multifactorial but is driven at its core by hyperactive afferent nociception from local tissues.¹³⁶ In response, neuroplastic changes such as an increase in the pain receptive field, decreased synaptic thresholds¹³⁷, overlapping of cortical mapping¹³⁸, and increased membrane excitability¹³⁷ occur at the dorsal root ganglion and thalamus perpetuating this hyper-excitability. Pain pressure thresholds (PPTs) are one method of quantitative sensory testing (QST) used to assess local and widespread mechanical pain sensitivity.

Pain pressure thresholds

PPTs can be measured via a handheld pressure algometer. PPTs have never been measured in patients with FAI; however, based on the hip osteoarthritis literature PPTs should be measured at the ipsilateral gluteus medius (3 cm proximal to the greater trochanter) and the contralateral forearm.^{139,140} The gluteus medius has been demonstrated to be the most sensitive location for intraarticular hip pathologies. A small, 1-cm² rubber device is pressed into the identified area at a slow, constant rate

(~40kPa/s). It is important to apply pressure directly to the skin keeping the measuring device perpendicular to the testing site so that the pressure is evenly distributed. The patient is instructed to signal by clicking a button when they feel a transition from a sensation of pressure to a sensation of pain. A maximum pressure of ~1,000 kPa is recommended to avoid capillary damage and subsequent tissue bruising. Two to three trials are conducted in each identified location with a 60 second break between trials. The average of each site is recorded.

Testing on both the ipsilateral side and superiorly on contralateral side is important. The contralateral side is tested to bypass the dorsal root ganglion associated with the location of pain. If both testing sites have decreased PPTs this would indicate centralization at the neurologic levels superior to the dorsal root ganglion. If only the ipsilateral location has a decreased PPT this would indicate only nociceptive level changes to the local tissue. Some normative values are available in the literature for specific conditions such as patients undergoing total hip arthroplasty and chronic low back pain.

Often PPTs are measured at baseline or initial presentation and then again after a given intervention (i.e. surgery, rehabilitation, etc.). Change scores are then calculated to track and analyze PPTs due to the intrinsic variability in these scores. An important consideration when testing PPTs is the Hawthorne Effect. The Hawthorne Effect is a risk to external validity and occurs when patients try to attain a particular score on a test¹⁴¹. During PPT testing patients often attempt to see how much pain they can withstand, when the goal of the test is to measure when the pain sensation first occurs. Communication with patients prior to administering the test is critically important in limiting this effect. Other potential limitations using PPTs are location selection as some injury sites are deep and/or difficult to access, and wide between and within subject variability.

Healthy patients demonstrate significantly greater PPTs when compared to patients with chronic pain injuries indicating the development of a hypersensitivity to mechanical stimuli.¹⁴²⁻¹⁴⁴ Additionally, consequences of pain sensitivity have been studied in patients with end-stage hip osteoarthritis (OA) undergoing total hip arthroplasty (THA), a similar though much more severe disease process than FAI. Such consequences have been found to include increased post-operative opioid use¹⁴⁵ and increased pain intensity¹⁴⁶.

2.11 SUMMARY

When describing and considering the constructs of psychosocial behaviors and pain sensitization it can be helpful to consider sensitization as a hardware issue, and pain catastrophizing, low self-efficacy, and/or kinesiophobia as software issues. Both can occur independently, but they may also present in combination as they are not mutually exclusive. As previously described, these constructs are most prominent in patients with persistent pain conditions. As the average duration of symptoms in patients with symptomatic FAI is upwards of two years^{12,16} it can be reasoned that these variables may be impacting postoperative outcomes following hip arthroscopy. To date no studies have examined the effect of pain sensitization or psychosocial variables on pre- or postoperative pain in patients with symptomatic FAI. Due to feasibility in this series of studies we will largely focus on the software issues of abnormal pain behaviors as they relate to pain in patients with symptomatic FAI; however, studies are necessary to examine the effect and prevalence of pain sensitization in this patient population. Pain catastrophizing, low self-efficacy, and kinesiophobia can be modified with appropriate identification and intervention. Therefore, the overarching purpose of this dissertation is to determine the effect of psychosocial variables on pre- and post-operative pain in patients with symptomatic FAI undergoing hip arthroscopy.

Table 2.1. Normal hip range of motion (ROM) including end feels, minimally clinically important differences (MCID), and standard error of measurements (SEM)

Motion	ROM	End feel	MCID	SEM
Flexion	120 ⁵¹ -130	Firm/Soft	5.5°	3.5 ⁵⁵ - 3.94 ¹⁴⁷
Extension	10 ⁵¹ -30	Firm	1.9°	4.5 ⁵⁵
Abduction	45 ⁵¹	Firm	4.4°	2.36 ¹⁴⁷ - 3.2 ⁵⁵
Adduction	10-25 ⁵¹	Firm	2.5°	2.36 ¹⁴⁷
Internal rotation	15 ⁵¹ -40	Firm	5°	2.24 ¹⁴⁷ - 3.4 ⁵⁵
External rotation	35 ⁵¹ -40	Firm	4.7°	2.53 ¹⁴⁷ - 3.1 ⁵⁵

Table 2.2. Hip muscles grouped by primary and secondary actions⁶⁸

Primary Flexors	Secondary Flexors
Rectus femoris	Adductor brevis
Iliopsoas	Gracilis
Sartorius	Gluteus minimus (anterior fibers)
Tensor fasciae latae	
Adductor longus	
Pectineus	
Primary Extensors	Secondary Extensors
Gluteus maximus	Gluteus medius (middle and posterior fibers)
Biceps femoris (long head)	Adductor magnus (anterior head)
Semitendinosus	
Semimembranosus	
Adductor magnus (posterior head)	
Primary External Rotators	Secondary External Rotators
Gluteus maximus	Gluteus medius (posterior fibers)
Piriformis	Gluteus minimus (posterior fibers)
Obturator internus	Obturator externus
Gemellus superior	Sartorius
Gemellus inferior	Biceps femoris (long head)
Quadratus femoris	
Primary Internal Rotators	Secondary Internal Rotators
	Gluteus minimus (anterior fibers)
	Gluteus medius (anterior fibers)
	Tensor fasciae latae
	Adductor longus
	Adductor brevis
	Pectineus
	Adductor magnus (posterior head)
Primary Abductors	Secondary Abductors
Gluteus medius	Piriformis
Gluteus minimus	Sartorius
Tensor fasciae latae	Rectus femoris
Primary Adductors	Secondary Adductors
Pectineus	Biceps femoris (long head)
Adductor longus	Gluteus maximus (posterior fibers)
Gracilis	Quadratus femoris
Adductor brevis	Obturator externus
Adductor magnus	

Table 2.3. Test-retest reliability, standard error of measurement (SEM), minimal detectable change (MDC), minimal important change (MIC), and Patient Acceptable Symptomatic State (PASS) for five common hip patient reported outcomes (PROs)^{1,2}

Patient Reported Outcome Measure	Test-Retest Reliability ICC (95% CI)	SEM	MCD	MIC	PASS
HAGOS					
Pain	0.94 (0.89-0.97)	4	12	6	-
Symptoms	0.97 (0.94-0.98)	3	8	10	-
ADL	0.93 (0.88-0.96)	5	14	9	-
Sport and recreation	0.95 (0.90-0.97)	5	15	9	-
Physical activity	0.96 (0.93-0.98)	6	18	1	-
Quality of life	0.92 (0.85-0.96)	7	19	9	-
HOOS					
Pain	0.96 (0.93-0.98)	3	10	9	-
Symptoms	0.93 (0.88-0.96)	5	14	9	-
ADL	0.96 (0.92-0.98)	3	9	6	-
Sport and recreation	0.93 (0.91-0.97)	6	17	10	-
Quality of life	0.95 (0.84-0.97)	5	15	11	-
HOS					
ADL	0.95 (0.92-0.97)	3	9	5	87
Sport-specific	0.96 (0.92-0.98)	4	13	6	75
iHOT-33	0.93 (0.87-0.96)	6	16	10	-
mHHS	0.91 (0.84-0.95)	4	12	8	74

Table 2.4. Test-retest reliability and internal consistency (Cronbach's α) for the three psychosocial patient reported outcome measures (PSC, PSEQ, and TSK) used in these dissertation studies.

Patient Reported Outcome Measure	Test-retest reliability	Internal consistency (Cronbach's α)
Pain Catastrophizing Scale (PCS)	0.75 ²⁹	0.78-0.95 ^{29,117}
Pain Self-Efficacy Questionnaire (PSEQ)	0.73 ⁴⁸	0.92-0.94 ^{125,127,148}
Tampa Scale for Kinesiophobia (TSK)	0.80 ¹⁴⁹	0.71-0.83 ^{1,148}

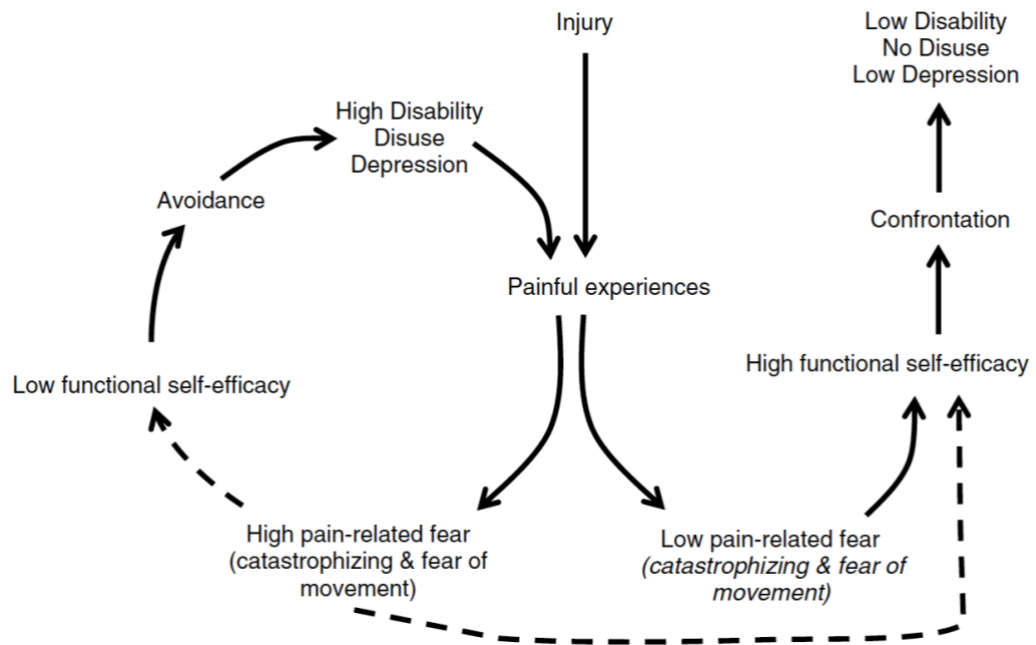


Figure 2.1. Revised fear-avoidance model (FAM) to include all three psychosocial variables included in this dissertation study: pain catastrophizing, self-efficacy, and kinesiophobia/fear of movement.³ Used with permission, John Wiley and Sons – license #4440880674167

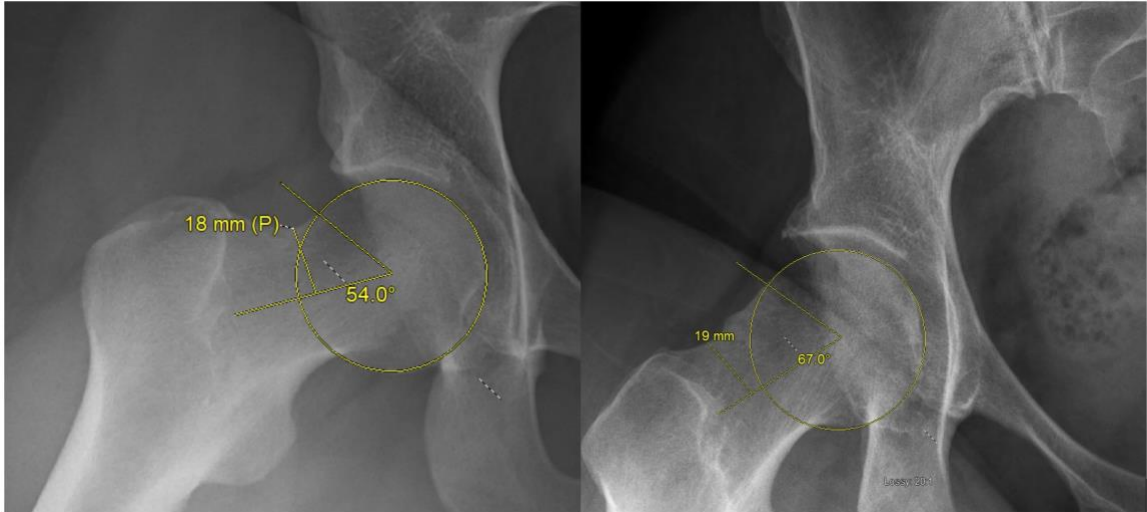


Image 2.1. Healthy (left) and CAM lesion (right) measured with an alpha angle. Alpha angles measure the femoral head-neck offset, or sphericity of the femoral head.

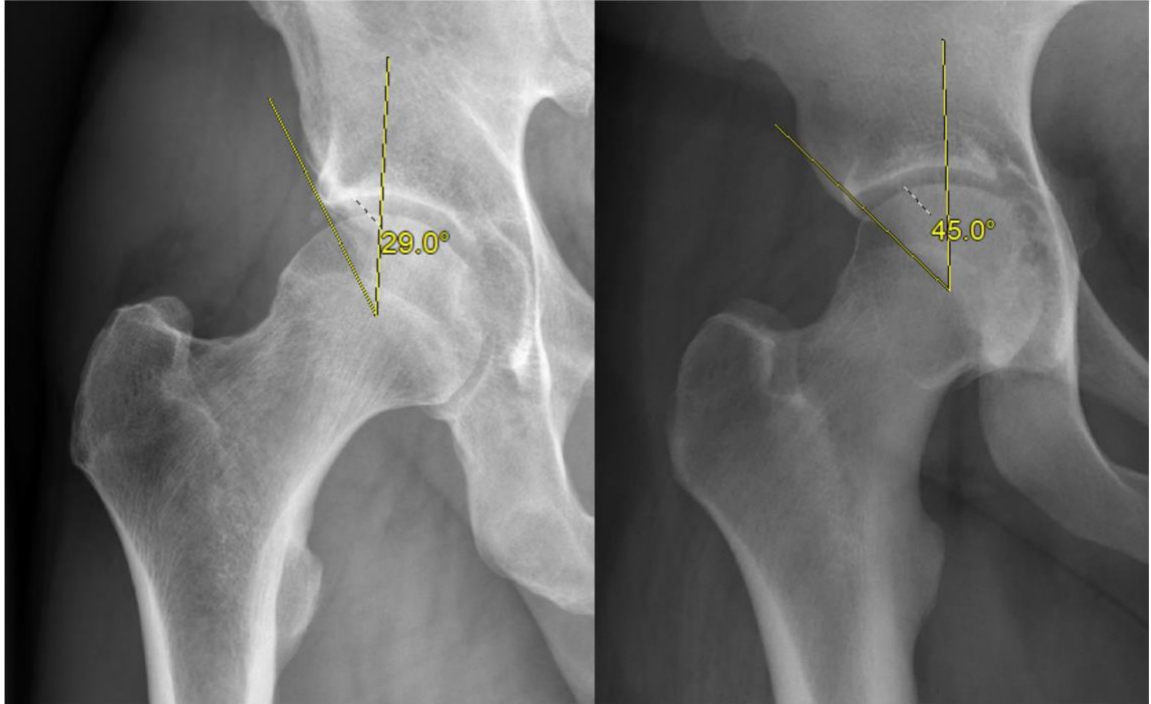


Image 2.2. Healthy (left) and pincer lesion (right) measured with a lateral center edge angle (LCEA). The LCEA is a measure of acetabular coverage on the femoral head.

CHAPTER 3: MENTAL HEALTH DISORDERS IN HIP ARTHROSCOPY: A COMPARISON OF PREOPERATIVE FACTORS

Introduction

Femoral acetabular impingement (FAI) is a non-arthritic hip condition being treated with increasing frequency.^{13,150} Patients for whom conservative treatment was ineffective may elect to undergo hip arthroscopy. Hip arthroscopy procedures have seen an eighteen-fold increase from 1999 to 2009.¹³ Outcomes following hip arthroscopy are generally good with most patients seeing improvements in pain and function; however, a subset of patients fail to meet patient acceptable symptom scores (PASS)¹⁷, return to their previous level of activity¹⁵¹, or are dissatisfied with their surgery.¹⁴

Depressive symptoms and more global mental health have been suggested to impact the outcomes following hip arthroscopy.^{26,27} Preoperatively, Veteran's Rand-12 (VR-12) mental component score (MCS) has repeatedly demonstrated a stronger relationship with preoperative pain than other traditional orthopaedic parameters such as cartilage damage or the size of the labral tear.^{22,23} Patients with depressive symptoms or self-reported mental disorders have not only demonstrated significantly worse preoperative pain and function but also have significantly worse postoperative outcomes after hip arthroscopy.^{26,27}

These findings establish that patients with self-reported mental disorders or depressive symptoms have worse pain and function both prior to and following surgery. The reasoning behind this discrepancy is still largely unknown. The average time between the onset of FAI symptoms and undergoing surgical correction has been reported to range from 15 to 28 months.^{16,41,152,153} Due to the protracted time to definitive treatment, it is unclear if mental health disorders could be adaptations to chronic pain and/or more severe joint deformity. On the contrary, instead of a comorbid mental health disorder being a symptom of chronic FAI pain, mental health disorders may play a

mechanistic role in the more severe FAI pain since mental health disorders have been associated with increased pain sensitivity and lower pain pressure thresholds.¹⁵⁴ To address this question, the purposes of this study were to 1) identify the pre-operative prevalence of mental health disorders, and 2) compare patient factors including duration of symptoms, disease severity, and self-reported pain and function between patients with FAI undergoing hip arthroscopy with and without mental health disorders. We hypothesized that consistent with previous osteoarthritis¹⁵⁵ and total hip arthroplasty¹⁵⁶ literature, mental health disorders would be present in approximately 20% of patients undergoing hip arthroscopy, and that those patients with mental health disorders would present with a longer duration of symptoms (DOS) and worse self-reported pain and function.

Methods

Following IRB approval, we identified 127 consecutive patients (94F, 33M; age = 35.2 ± 12.1 years, BMI = 26.8 ± 5.6 kg/m²) in our prospective outcomes registry that were scheduled for primary hip arthroscopy by a single fellowship trained hip preservation surgeon. To be included in this analysis patients must have had completed pre-operative data and must have been undergoing primary hip arthroscopy for FAI (femoral osteochondroplasty) and/or a labral repair or debridement for a symptomatic labral tear. Surgical indications include symptomatic FAI with a labral tear, cam deformity (alpha angle > 50°), and/or pincer lesion (lateral center edge angle (LCEA) > 40°), and failed conservative treatment consisting of physical therapy, oral non-steroidal anti-inflammatories (NSAIDs), and an intra-articular corticosteroid injection. Patients with preoperative diagnoses of Legg Calve Perthes, slipped capital femoral epiphysis, acetabular dysplasia, or greater trochanteric pain syndrome were excluded. Further, patients undergoing hip arthroscopy for avascular necrosis, trochanteric bursectomy, iliotibial band lengthening, or isolated gluteus medius repair, or patients having an open

procedure were excluded to create a homogenous population of pre-arthritic hip preservation patients.

The magnitude of FAI bony deformity was assessed using a measure of cam deformity (alpha angle) and a measure of pincer deformity (LCEA).¹⁵⁷ Alpha angle and LCEA were measured on standardized preoperative frog leg lateral, Dunn lateral, and anteroposterior (AP) pelvis radiographs.¹⁵⁸ These measures were made using McKesson computer-assisted radiographic measurement software. Patients completed a preoperative survey that included duration of symptoms categorized as ≤ 6 months or > 6 months. A threshold of 6 months was used to categorize duration of symptoms as it has been suggested as a clinically relevant transition from acute to chronic pain.¹⁵⁹ The presence of mental health disorders were recorded based on the following criteria: medical diagnosis of depression, anxiety, or bipolar disorder within the patient's electronic medical record or the presence of a prescription for a selective serotonin reuptake inhibitor (SSRI) or serotonin and norepinephrine reuptake inhibitor (SNRI) in the year of hip arthroscopy. Patients also completed the Hip disability and Osteoarthritis Outcomes Score (HOOS), and the 5 HOOS subscales (Pain, Symptoms, Activities of Daily Living (ADL), Quality of Life (QOL), and Sports)¹⁶⁰ and HOOS_{global} were calculated.¹⁶¹

To compare the pre-operative clinical presentation of patients with and without mental health disorders, Fisher's exact or chi-square tests were used to compare categorical variables, and following Shapiro-Willks tests for normality, continuous variables were compared between the groups using Mann-Whitney U nonparametric tests. All analyses were performed using SPSS Statistics 24 (IBM, Armonk, NY), and the alpha level was set at $p \leq 0.05$ *a priori*. A post hoc power analysis determined that this study was fully powered. A sample size of 116 was necessary to identify a difference between groups with an allocation ratio of .36 (85 patients without mental health

disorders and 31 patients with mental health disorders) with a moderate effect (Cohen's $d = 0.5$).

Results

Overall, 36.2% (46/127) of patients with FAI presented preoperatively with a mental health disorder. Patients with mental health disorders were significantly older than those without a mental health disorder (Table 1); however, age was not significantly correlated with any HOOS scales ($r < 0.3$). Pre-operative measures of FAI deformity did not differ between patient groups (alpha angle frog leg lateral view $p=0.47$; alpha angle Dunn view $p=0.9$, LCEA $p=0.17$; Table 1). The prevalence of patients with symptoms >6 months did not differ between those with or without mental health disorders ($p=.13$). Patients with mental health disorders had significantly lower scores on the HOOS activities of daily living (ADL) scale (49.2 ± 18.6 , 56.1 ± 24.4 , $p=0.05$), HOOS quality of life (QOL) scale (20.9 ± 18.5 , 31.1 ± 19.4 , $p=0.03$), and HOOS sport scale (25.7 ± 17.6 , 34 ± 21.2 , $p=0.03$); however, preoperative HOOS Pain, Symptom, and HOOS_{global} scores did not differ between groups (Table 2).

Discussion

The purposes of this study were to identify the prevalence of mental health disorders in patients undergoing hip arthroscopy and to compare the pre-operative clinical presentation of patients with and without mental health disorders. We hypothesized that approximately 20% of patients undergoing hip arthroscopy would have mental health disorders and that patients with mental health disorders would have a longer duration of symptoms and worse preoperative self-reported pain and function. The prevalence of mental health disorders (36.2%) in this cohort of patients undergoing hip arthroscopy well exceeded our original hypothesis, nearly tripling the previously reported 13% of patients with FAI displaying moderate to severe depressive symptoms

on the BDI-II,²⁷ and nearly doubles the previously reported prevalence in patients undergoing total hip arthroplasty (20%).¹⁵⁶

Contrary to our hypothesis, the duration of symptoms did not differ between patients with or without comorbid mental health disorders. Similarly, the severity of bony deformity did not differ between groups. Though duration of symptoms is a concern for patients with FAI, as the average time to treatment is upwards of 28 months¹⁶, these findings may suggest that the clinical implications of a longer duration of symptoms may be found in patient satisfaction or post-operative outcomes. This concept has been demonstrated by Dierckman et. al who found a negative relationship between a longer duration of symptoms and patient reported pain and function 2 years post-hip arthroscopy.²¹ Findings from the current study are limited in that it is not possible to tease apart which came first, the mental health disorder or symptomatic FAI.

While the duration of symptoms and magnitude of deformity did not differ between groups, patients with medically diagnosed or pharmacologically treated mental health disorders had significantly worse self-reported function and quality of life pre-operatively (HOOS ADL 49.2 ± 18.6 vs. 56.1 ± 24.4 Cohen's $d=0.32$, HOOS QOL scale 20.9 ± 18.5 vs. 31.1 ± 19.4 Cohen's $d=0.54$, and HOOS sport scale 25.7 ± 17.6 vs. 34 ± 21.2 Cohen's $d=0.43$). Though patient acceptable symptom state (PASS) scores for the HOOS subscales in patients undergoing hip arthroscopy are not yet established, minimal important change (MIC) scores are available.¹ The MIC is a quantification of the smallest amount of change in a patient reported outcome score that will be meaningful to the patient.¹⁶² Function and quality of life outcomes for patients without mental health disorders are near or greater than the MIC above that of patients with mental health disorders (ADL group difference = 6.9, MIC = 6; QOL group difference = 10.2, MIC = 11; Sport group difference = 8.3, MIC = 10).¹ As the entire cohort of patients were seeking surgical treatment for their painful hip, a difference in preoperative pain was not

detected. Instead, how patients function in their day-to-day life despite the pain is reflected in the differences in activity and quality of life scores.

Functional outcomes following orthopaedic interventions are heavily influenced by a patient's ability to cope with and move through pain. Previous studies on psychosocial constructs such as pain catastrophizing (a fearful over-exaggeration of painful experiences) and self-efficacy (one's belief in their ability to move through a painful experience) have demonstrated that patients displaying frequent catastrophizing behaviors^{38,40,163} and low self-efficacy^{164,165} do worse in terms of decreased function and increased pain. Both catastrophizing behaviors^{166,167} and low self-efficacy^{168,169} are related to mental health disorders. In fact, some research suggests a compounding effect of these variables as they relate to pain intensity.¹⁷⁰ Therefore, as duration of symptoms and joint damage severity did not differ in the current study it is reasonable to suspect these psychosocial behaviors may be driving worse outcomes in FAI patients with comorbid mental health disorders. Future studies should focus on determining the effect of pain catastrophizing and self-efficacy on outcomes in patients with FAI, specifically those with mental health disorders.

In addition, future research is necessary to better understand the alarmingly high prevalence of comorbid mental health disorders in FAI patients when compared to other orthopaedic populations. Much like what has been demonstrated with increased humeral retroversion in baseball pitchers,^{171,172} participation in contact sports or those that place greater demands on the hip such as football,¹⁷³ soccer,¹⁷⁴ or hockey¹⁷⁵ has been associated with an increased prevalence of FAI. While sports participation appears to increase the prevalence of so-called "acquired FAI", the etiology of FAI may involve genetic factors as well.¹⁷⁶ Furthermore, there may be genetic factors that contribute to the high prevalence of mental health disorders in the FAI patient population. The single nucleotide polymorphism (SNP) iodothyronine deiodinase 2 (*DIO2*) is directly involved

with thyroid hormone synthesis by converting intracellular inactive thyroid hormone (T4) to active thyroid hormone (T3). T3 is important for long bone formation as T3 inhibits chondrocyte proliferation in the growth plate and promotes chondrocyte differentiation, bone matrix synthesis and endochondral ossification.^{177,178} On the contrary, hypothyroidism has been associated with early-onset osteoarthritis with hypertrophic chondrocytes, and *DIO2* has been linked to hip morphology at greater risk of hip osteoarthritis.^{178,179} Similarly, hypothyroidism is relatively common amongst patients with major depressive disorder,¹⁸⁰ and patients with recurrent depressive disorder have demonstrated significantly lower expression of *DIO2*.^{181,182} Future studies are necessary to establish this potential shared genetic mechanism for non-acquired FAI and comorbid depression, as well as to determine if *DIO2* offers a therapeutic target.

This study is not without limitations. Information on orthopaedic in-take paperwork, specifically regarding mental health, is often inconsistent due to the stigma surrounding these diagnoses.¹⁸³ As such is plausible that this study is under-reporting the true prevalence of mental health disorders. SSRIs and SNRIs can be prescribed for indications other than mental health disorders including obsessive compulsive disorder, fibromyalgia, and neuropathic pain. Additionally, we used radiographic measures of impingement deformity (LCEA and alpha angles), which have previously demonstrated limited reliability.⁸⁸ As there was no a priori power analysis conducted as part of this retrospective review of prospectively collected data, we were unable to thoroughly assess specific mechanisms underlying the worse preoperative function reported by patients with mental health disorders. Future studies are necessary to examine this relationship in the context of psychosocial PROs and motion analyses so that appropriate, targeted interventions may be identified for this high-risk group. Lastly, this was a single surgeon study which may predispose to selection bias.

Conclusions

In conclusion, greater than one-in-three patients undergoing hip arthroscopy presented with a mental health disorder—nearly double the rate previously reported for patients with hip osteoarthritis. This high prevalence does not appear to be a direct response to chronic pain as symptom duration was not increased for those with mental health disorders. As previous orthopaedic research has demonstrated a strong relationship between mental health disorders and negative psychosocial constructs such as frequent catastrophizing and low self-efficacy, future studies should focus on the effect of these on pre-and post-operative outcomes in patients with FAI. This subset of patients with comorbid FAI and mental health disorders may require additional services such a mental health specialist referral network.

Table 3.1. Comparison of preoperative clinical factors (mean \pm SD, or number of patients) between patients with and without mental health disorders undergoing hip arthroscopy.

Variable	No mental health disorder	Mental health disorder	p
N	81	46	-
Age (years)	33.7 \pm 12.5	37.9 \pm 11	.03*
Sex (M/F)	24/57 (70.4% F)	9/37 (80.4% F)	.29
BMI (kg/m ²)	26.8 \pm 5.8	26.9 \pm 5.5	.83
Symptom duration >6 months	58 (71.6%)	39 (84.8%)	.13
LCEA	31.1° \pm 6.6°	30.2° \pm 7.6°	.17
Alpha angle (Frog)	62.2° \pm 10.8°	64.4° \pm 10.8°	.47
Alpha angle (Dunn)	66.6° \pm 10.4°	66.7° \pm 8.8°	.90

*statistically significant ($p \leq 0.05$)

Table 3.2. Comparison of preoperative self-reported pain and function (mean \pm SD) between patients with and without mental health disorders undergoing hip arthroscopy.

Variable	No mental health disorder	Mental health disorder	p
N	81	46	-
HOOS Symptoms	45.2 \pm 19.4	41.3 \pm 18.5	.16
HOOS Pain	47.7 \pm 20.9	42.6 \pm 19.8	.08
HOOS ADL	56.1 \pm 24.4	49.2 \pm 18.6	.05*
HOOS QOL	31.1 \pm 19.4	20.9 \pm 18.5	.002*
HOOS Sport	34.0 \pm 21.2	25.7 \pm 17.6	.03*
HOOS _{global}	44.1 \pm 15.9	42.3 \pm 12.8	.16

*statistically significant ($p \leq 0.05$)

CHAPTER 4: LOW SELF-EFFICACY IS PREDICTIVE OF WORSE PREOPERATIVE PAIN IN PATIENTS WITH FEMORAL ACETABULAR IMPINGEMENT

Introduction

Psychosocial constructs pain catastrophizing^{163,184,185}, self-efficacy^{164,186}, and kinesiophobia^{45,132} are important determinants of recovery following orthopedic interventions. Following the Fear Avoidance Model (FAM) of chronic pain, these beliefs directly impact the trajectory of postoperative recovery.³ In accordance with their individual coping abilities and cognitive status patients contextualize pain as threat to fear or a barrier to overcome. This distinction dictates whether the outcome will be disuse and disability or successful recovery.

In fitting with the FAM of chronic pain, the average duration of symptoms in treatment-seeking patients with symptomatic femoral acetabular impingement (FAI) is upwards up two years.¹⁶ Once patients with FAI, a bony incongruence between the femoral head and acetabulum, have failed conservative treatment they progress to hip arthroscopy. Hip arthroscopy definitively treats FAI by eliminating the bony impingement while also addressing injuries to soft tissues. The majority of patients report improved pain and function⁴; however, there are a subset of patients with persistent pain and functional deficits.¹⁷ Given the chronicity of FAI symptoms prior to hip arthroscopy the FAM is an appropriate framework from which to analyze postoperative outcomes.

Pain catastrophizing is a set of behaviors including ruminating on painful experiences, feeling helpless in overcoming painful situations, and magnifying the circumstances surrounding pain or injury.²⁹ Catastrophizing behaviors have been identified as an important mediator between a patient's reported pain intensity and function^{34,187}. Additionally, more frequent catastrophizing is related to worse outcomes such as increased disability, persistent pain, psychological inflexibility³⁴, increased opioid use³⁸. To date the Pain Catastrophizing Scale (PCS) score has only been reported on

once in FAI patients. Higher PCS scores indicate more frequent catastrophizing behaviors, and the mean PCS score in a series of military patients undergoing hip arthroscopy was 23.7 ± 11.8 ⁴¹ which is well above values in both healthy individuals (14.5 ± 9.3),¹⁸⁸ and patients with acute anterior cruciate ligament (ACL) injuries (11.6 ± 10.8)³⁰.

Pain self-efficacy is a task- and situation-specific psychosocial construct that gauges a person's confidence in completing tasks despite their current pain.⁴⁸ Self-efficacy is an important determinant of long-term success following total hip arthroplasty,⁴³ and is a mediator in the relationship between changes in pain and disability in patients with chronic low back pain.⁴² Fear of movement, or kinesiophobia, predicts early functional outcomes and pain levels in patients following total knee arthroplasty,⁴⁵ and greater fear is associated with not returning to pre-injury levels of activity in patients that underwent anterior cruciate ligament reconstruction.¹⁸⁹ To date, neither self-efficacy nor kinesiophobia have been examined in patients with symptomatic FAI.

Recently, self-efficacy, kinesiophobia, and pain catastrophizing measured 4-weeks post-ACL-reconstruction were associated with increased pain and decreased function at the 12-week follow-up.¹⁹⁰ As evidence linking psychosocial constructs and pain severity in orthopedic patients is increasing, understanding the impact of these factors on pain in patients with FAI is warranted. Low self-efficacy, frequent kinesiophobia, and pain catastrophizing are modifiable with appropriate identification and intervention.^{191,192} The first step in developing appropriate interventions is to determine the individual or combined roles of self-efficacy, kinesiophobia, and pain catastrophizing on FAI pain. Therefore, the purposes of this study were to 1) compare these variables between patients with FAI with and without mental health disorders, and 2) determine if these variables were predictive of pre-operative pain. The authors hypothesized that pre-

operative pain would be predicted by low pain self-efficacy and high kinesiophobia and pain catastrophizing. More specifically, we expected pain catastrophizing to be the primary predictor of pre-operative pain. Further we hypothesized that these behaviors would be more severe in patients with mental health disorders.

Methods

Following IRB-approval, 64 consecutive patients consented to participate in this cross-sectional study. Patients were included if they were diagnosed with symptomatic FAI, had closed epiphyseal plates, had failed conservative treatment and were scheduled for hip arthroscopy for symptomatic FAI, and read and spoke fluent English. After consent demographics, duration of symptoms (months), and the presence of a self-reported mental health disorder (anxiety, depression, or bipolar disorder) were recorded. Next, patients completed the pain self-efficacy questionnaire (PSEQ), Tampa scale for kinesiophobia scale (TSK), pain catastrophizing scale (PCS), and a 10-point visual analog scale (VAS) for hip pain both during rest and activity.

The PSEQ asks patients to rate their confidence on a scale from 0 (not at all confident) to 6 (completely confident) in completing tasks despite their current pain.⁴⁸ Scores range from 0-60 with higher scores representing higher self-efficacy. The PSEQ has an internal consistency (Cronbach's α) of 0.92 and a test re-test reliability of 0.73.⁴⁸ Fear of movement, or kinesiophobia, is measured with the TSK which has an internal consistency (Cronbach's α) of 0.76 and a test re-test reliability of 0.82.¹⁹³ The TSK is a 17-item scale. Patients read each of the statements and rate them on a scale from 1 (strongly disagree) to 4 (strongly agree). Higher scores indicate greater fear. Lastly, catastrophizing behaviors are measured via the PCS, which consists of 13 statements. Patients rated each statement on a scale from 0 (not at all) to 4 (all the time). The total PCS score ranges from 0-52, with higher scores demonstrating more frequent or severe

catastrophizing behaviors. The PCS has internal consistency (Cronbach's α) of 0.87²⁹ and a test re-test reliability of 0.93.¹⁹⁴

Descriptive statistics were reported, and PSEQ, TSK, PCS, and pain were compared between patients with and without mental health disorders were compared using independent t-tests. Separate multivariate linear regressions with forward variable entry were used to determine if any individual variables or combinations of variables were predictive of pre-operative pain at rest or pain during activity (SPSS Statistics version 24, IBM, Armonk, NY).

Results

The average duration of symptoms was 29.4 months (1-132 months) for the series of 64 patients, and patient demographics and pre-operative scores are located in Table 4.1. Patients reported an average pain at rest of 4.3 ± 2.3 and an average pain during activity of 7.1 ± 2.2 on a 10-point VAS. Patients with self-reported mental health disorders had significantly higher scores on the PCS (28.8 ± 14.5 , 17.3 ± 11.3 , $p=0.004$, Cohen's $d=0.88$) and TSK (45.5 ± 6.5 , 41.2 ± 6.5 , $p=0.02$, Cohen's $d=0.66$), while presenting with significantly lower scores on the PSEQ (30.4 ± 12.4 , 41.6 ± 13.3 , $p=0.002$, Cohen's $d=0.87$). Pain at rest did not differ between those with or without self-reported mental health disorders (4.8 ± 2.4 vs. 4.0 ± 2.3 , $p=0.22$); however, pain with activity was greater for those with self-reported mental health disorders (7.9 ± 2.2 , 6.7 ± 2.2 , $p=0.05$, Cohen's $d=0.55$) (Table 4.2).

Multivariate linear regression using forward variable entry was used to identify if any of the variables listed in Table 1 were significantly predictive of pre-operative pain at rest or during activity. The PSEQ was found to be predictive of pre-operative pain at rest ($p = <.001$, adjusted $r^2=.21$), and the combination of PSEQ and BMI were found to be predictive of pre-operative pain during activity ($p = <.001$, adjusted $r^2=.29$). In both

prediction models, lower scores on PSEQ were predictive of worse pain, and higher BMI was predictive of worse pain during activity.

Discussion

This is the first study to examine the predictive value of psychosocial outcome scores on pain intensity in patients with FAI. The author's hypothesis that lower self-efficacy and higher kinesiophobia and catastrophizing would be predictive of worse pain was partially supported. Instead of pain catastrophizing as predicted, self-efficacy was the primary predictor being able to explain 21% of pain at rest and self-efficacy combined with BMI were able to explain 29% of pain during activity. Similar to other recent reports²² duration of symptoms, sex, and age were not predictive of pre-operative pain in the current series of patients with FAI.

Pain is complex and can rarely be explained entirely by a single variable; however, the current study demonstrates the importance of self-efficacy when considering pain in patients with symptomatic FAI. Low self-efficacy is related to a variety of poor outcomes in both conservative management and post-operative rehabilitation of musculoskeletal conditions. These consequences range from increased pain and disability⁴² to reduced function.¹⁹⁰ Briet et. al. found that self-efficacy and younger age explained 24% of ankle sprain symptoms and limitations.¹⁹⁵ The median PSEQ score in their study was 46 (IQR 15)¹⁹⁵, which compares well to the current study with a median PSEQ of 42 (IQR 23). In the current study age was not found to be a predictor; however, higher BMI was predictive of worse pain with activity. This relationship is not surprising as increased BMI is associated with impaired function in patients with chronic pain¹⁹⁶, and obesity has been linked to failed hip arthroscopy (conversion to a total hip arthroplasty or modified Harris Hip Score of < 70 at 2 years post-operation).¹⁸

The experience of pain depends heavily on how patients perceive both themselves and the barriers surrounding them. Specifically, in patients with symptomatic FAI how much pain they feel depends on their perception of their ability to complete tasks despite their current pain. A patient's self-efficacy will directly impact the effort they put forth during a challenging task.¹⁹⁷ As such, the findings of the current study are of extreme importance for treating physicians and physical therapists. To date, evidence supporting conservative treatment for patients with symptomatic FAI has been unimpressive.^{41,198,199} Taking the current results into consideration, adjunct treatments aimed at increasing self-efficacy may improve conservative treatment results. With higher self-efficacy, patient's confidence in their ability to complete rehabilitation tasks may increase, facilitating successful treatment.

Treatments such as progressive relaxation have shown success in improving self-efficacy in patients undergoing total knee replacement.¹⁹² Additionally, a 2012 randomized control trial provided support for goal setting as it was found to improve self-efficacy and rehabilitation adherence in patients with non-specific low back pain.²⁰⁰ Unfortunately these studies used different measures of self-efficacy, the Self-Efficacy Expectation Scale and the Sports Injury Rehabilitation Beliefs Survey, respectively, so comparisons between the magnitudes of the problem between populations cannot be made. In spite of this shortcoming, these results are promising. To date no treatment strategies have been implemented for FAI patients' low pain self-efficacy.

A score of 40 on the PSEQ has been suggested to categorize chronic pain patients as high (<40) or low risk (≥ 40).^{48,201} Notably, when patients with symptomatic FAI in this cohort were dichotomized by the presence or absence of a self-reported mental health disorder those with a mental health disorder scored well below this threshold (30.4 ± 12.4), and patients without a mental health disorder scored above (41.6 ± 13.3). The minimal important change (MIC) for the PSEQ is 5.5²⁰². As such the

difference observed between groups ($\Delta 11.2$) is in fact clinically meaningful. Further, 14 of 44 (31.8%) patients without mental health disorders scored below this PSEQ threshold. This suggests that clinicians cannot solely rely on the presence or absence of a mental health disorder as an indication for additional interventions. The interaction between depressive symptoms and pain self-efficacy may in fact be of extreme importance. A 2015 study by Skidmore et. al identified that in patients with chronic low back pain the change in depressive symptoms predicted changes in pain, and this relationship was mediated by pain self-efficacy.¹²³ Those patients that were able to increase their confidence to perform activities despite their current pain displayed fewer depressive symptoms and reported less pain following a four-week rehabilitation program.¹²³

Further, patients with self-reported mental health disorders also scored significantly worse on the PCS (28.8 ± 14.5 , 17.3 ± 11.3 , $p=0.004$) and TSK (45.5 ± 6.5 , 41.2 ± 6.5 , $p=0.02$). This is consistent with previous work demonstrating the relationship between mental health disorders and more frequent catastrophizing^{166,167}, lower self-efficacy^{168,169}, and more severe fear avoidance behaviors¹³¹. Further, and perhaps most importantly, the current findings may shed light on why patients with symptomatic FAI and concomitant mental health disorders do worse in the course of their hip treatments.^{26,27} Following the fear avoidance model, these patients may view pain as a threat and therefore the trajectory of their recovery is unsuccessful. Though pain catastrophizing and kinesiophobia were not predictive of pre-operative pain in patients with symptomatic FAI, future studies are necessary to examine the effect of these variables on post-hip arthroscopy outcomes.

This study was not without limitations. First, as with any cross-sectional study design we cannot assume cause and effect of maladaptive cognitive coping strategies on pain intensity. Future studies should include a control group of healthy age matched

patients. A more thorough comparison could include a group of matched patients with asymptomatic FAI. The authors are currently performing a longitudinal study to assess the effect of pre-operative self-efficacy, kinesiophobia, and catastrophizing on post-operative outcomes following hip arthroscopy.

Conclusion

Low pain self-efficacy was predictive of worse pre-operative pain at rest and during activity in patients with symptomatic FAI. Further, patients with self-reported mental health disorders had lower pain self-efficacy with more severe or more frequent pain catastrophizing and kinesiophobia than FAI patients without mental health disorders. As mental health disorders have already been related to poorer post-operative outcomes following hip arthroscopy, and low self-efficacy has been linked to poorer outcomes in other orthopedic populations, future studies should focus on the development of treatment strategies and interventions aimed at improving the likelihood of a successful clinical outcome for these high-risk groups.

Table 4.1. Patient demographics and descriptive information for variables entered into the linear regression.

Variable	N=64
Age, mean (range)	36.5 (15-59)
Sex, n (%)	
Male	14 (21.9)
Female	50 (78.1)
BMI, mean \pm SD	26.7 \pm 4.8
Symptom Duration (months), mean (range)	29.4 (1-132)
Pre-operative pain at rest, mean \pm SD	4.3 \pm 2.3
Pre-operative pain during activity, mean \pm SD	7.1 \pm 2.2
PCS, mean \pm SD	20.9 \pm 13.4
TSK, mean \pm SD	42.5 \pm 6.8
PSEQ, mean \pm SD	38.1 \pm 14.0
Self-reported mental health disorder, n (%)	20 (31.3)
Revision procedure, n (%)	6 (9.4)

Table 4.2. Patient demographics and variables compared between patients with and without a self-reported mental health disorder.

Variable	Mental health disorder	No mental health disorder	p-value
N	20	44	-
Age, mean \pm SD	37.1 \pm 11.7	36.2 \pm 12.2	.79
Sex, n (%)			
Male	2 (10)	12 (27.3)	.19
Female	18 (90)	32 (72.7)	
BMI, mean \pm SD	26.9 \pm 4.1	26.6 \pm 5.1	.80
Symptom Duration (months), mean \pm SD	28.5 \pm 29	29.8 \pm 31.8	.87
Pre-operative pain at rest, mean \pm SD	4.8 \pm 2.4	4.0 \pm 2.3	.22
Pre-operative pain during activity, mean \pm SD	7.9 \pm 2.2	6.7 \pm 2.2	.05*
PCS, mean \pm SD	28.8 \pm 14.5	17.3 \pm 11.3	.004*
TSK, mean \pm SD	45.5 \pm 6.5	41.2 \pm 6.5	.02*
PSEQ, mean \pm SD	30.4 \pm 12.4	41.6 \pm 13.3	.002*
Revision, n (%)	2 (10)	4 (9.1)	>.99

**Signifies a statistically significant difference between groups at the 0.05 level*

CHAPTER 5: LOW SELF-EFFICACY AND MENTAL HEALTH DISORDERS PREDICT PERSISTENT POSTOPERATIVE PAIN 3 MONTHS FOLLOWING HIP ARTHROSCOPY

Introduction

Femoral acetabular impingement (FAI) is a common, albeit complex, pre-arthritis hip condition resulting in pain⁸² and functional limitations.^{74,203} Recent evidence suggests that emotional health plays a key role in pre- and post-operative outcomes for patients with FAI. The Veteran's Rand-12 (VR-12) mental component score, a generic measure of how emotional health is impacting one's life, was found to be more related to pre-operative pain²² and post-operative pain and function²³ than measures of joint damage. Mental health disorders, including depression, are common in patients with FAI and those patients with depressive symptoms have worse pre- and post-operative outcomes.^{26,27}

In addition to mental health disorders, more specific psychosocial constructs such as pain self-efficacy, kinesiophobia, and pain catastrophizing are of interest as they fall within the fear-avoidance model. The fear-avoidance model is being used with increasing frequency to conceptualize the process by which patients transition from a musculoskeletal injury to a chronic pain condition.²⁸ As a biopsychosocial model the fear-avoidance model suggests that the way in which an individual views their pain will dictate the trajectory of their recovery.²⁸ When pain is viewed as a threat, maladaptive psychosocial behaviors increase leading the patient down a path of depression, disability, and worse pain instead of the path to successful recovery.

Pain catastrophizing is characterized by an exaggerated response to actual or anticipated pain, and can be broken in three distinct constructs: helplessness, magnification, and rumination.²⁹ Pain catastrophizing is associated with more severe³⁴ and persistent^{119,120} pain in a variety of orthopedic conditions. Patients that catastrophize

about their pain may concomitantly develop low confidence in their ability to complete daily tasks, and beliefs that it is unsafe to move their body as a way to avoid or minimize painful situations.

Kinesiophobia, a fear of movement, and low pain related self-efficacy, reduced confidence in a patient's ability to complete tasks despite their current pain,⁴⁸ are barriers to rehabilitation as they lead to hypervigilance and perpetuate disuse. Both kinesiophobia and pain related self-efficacy have been identified as predictors of disability and persistent pain.^{119,164} The relationship between this set of beliefs and functional disuse is bidirectional. The beliefs result in reduced movement, and reduced movement leads to stiffness and disfunction, which in turn reinforces the original set of beliefs. This process is dynamic and maladaptive to successful rehabilitation. Successful interventions have been shown to mediate the effects of these beliefs on postoperative pain.²⁰⁴ To date no studies have examined pain catastrophizing, self-efficacy, or kinesiophobia in relation to postoperative outcomes in patients with FAI undergoing hip arthroscopy.

Therefore, the purposes of this study were to 1) determine the effect of preoperative pain catastrophizing, low self-efficacy, and kinesiophobia on postoperative pain, and 2) determine if these variables were predictive of postoperative pain. We hypothesized that preoperative pain catastrophizing, low pain related self-efficacy, and kinesiophobia would result in worse postoperative pain, and that these variables would be predictive of an increased risk of developing persistent postoperative pain three months following hip arthroscopy.

Methods

A total of 52 consecutive patients diagnosed with symptomatic FAI and scheduled for hip arthroscopy were enrolled in this study. Inclusion criteria included closed growth plates and reading and speaking fluent English. Additionally, patients

must have attempted and failed conservative treatment. Patients scheduled for both primary and first revision surgeries were enrolled. Patients undergoing open hip procedures or 2nd revision hip arthroscopy were excluded. Additionally, patients with comorbid fibromyalgia or complex regional pain syndrome, and worker's compensation cases were excluded. Patients were not excluded on the basis of sex, age, race, or BMI.

Preoperatively patients completed the following: demographics, duration of symptoms (months), self-reported mood disorder such as depression or anxiety, Pain Self-Efficacy Questionnaire (PSEQ), Tampa Scale for Kinesiophobia (TSK), Pain Catastrophizing Scale (PCS), and a 10-point visual analog scale (VAS) for hip pain both during rest and activity. During the 12 weeks following hip arthroscopy, patients were asked to rate their hip pain during rest and activity on a 10-point VAS again.

All three psychosocial patient reported outcome measures (PSEQ, TSK, and PCS) have good test-retest reliability (0.73-0.76)^{48,193,194} and internal consistency (Cronbach's α) (0.82-0.93)^{29,48,193}. The PSEQ is a 10-item scale where patients rate their confidence in completing daily tasks despite their pain on a scale from 0 (not at all confident) to 6 (completely confident).⁴⁸ Higher scores indicate greater self-efficacy,⁴⁸ and a cut-off score of below 40 is used to categorize patients as having low-self efficacy.⁴⁸ The TSK has 17-items, and for each patients rate their agreement with the statement from 1 (strongly disagree) to 4 (strongly agree). Lower scores on the TSK indicate less fear avoidance.¹⁹³ A cut-off score of above 37 can be used to categorize patients as having high levels of movement related fear.⁴⁹ The PCS consists of 13 statements with corresponding scales ranging from 0 (not at all) to 4 (all the time). Lower scores on the PCS indicate less pain catastrophizing beliefs.²⁹ A cut-off score of 19 or above corresponds to the 50th percentile in patients with chronic pain and is used to categorize patients with high levels of catastrophizing.²⁹ The PCS does not have an

established minimal important change (MIC); however the MIC for the PSEQ is 5.5²⁰², and 4¹⁹³ for the TSK.

Descriptive statistics were reported, and Fisher's exact tests were used to examine the prevalence of increased postoperative pain based on preoperative thresholds on the PSEQ, TSK, and PCS. Following tests for normality, Mann-Whitney U tests were used to determine differences between groups. Separate multivariate logistic regressions with forward stepwise variable entry were used to determine if any individual variables or combinations of variables were predictive of persistent postoperative pain at rest or pain during activity. A cut-score of 3 on the 10-point VAS was used to categorize patients as having persistent postoperative pain because it is the established Patient Acceptable Symptom State (PASS) for postoperative pain.⁴⁶

A power analysis was performed using pilot data and a Fisher's exact model. The alpha level was set at 0.05 and power was set at 0.80. To determine if the prevalence of persistent postoperative pain between preoperative psychosocial groups exists, a total sample of 50 was required. All analyses were performed using SPSS Statistics (version 25, IBM, Armonk, NY).

Results

A total of 52 patients (41F/11M; age 36.7 ± 12.2 years; BMI 27.1 ± 4.6 kg/m²) with symptomatic FAI undergoing hip arthroscopy were enrolled in this longitudinal study. The average duration of symptoms was 30.8 ± 31.1 months (range 2.5-120 months). Overall, 51.9% (27/52) of patients had increased preoperative pain catastrophizing, 45.8% (22/48) of patients had low preoperative self-efficacy, and 83% (39/47) had high kinesiophobia. Approximately one-in-four patients (14/52, 26.9%) self-reported a mental health disorder. Of the 52 patients, 5 were undergoing revision hip arthroscopy for labral re-tear or remaining bony impingement. Patients undergoing

revision hip arthroscopy did not differ from the primary hip arthroscopy cohort for any variables included in this analysis (Table 5.1).

At an average 75.3 ± 28.4 days (10.8 weeks) post hip arthroscopy 29.4% (15/51) of patients reported postoperative pain at rest above the PASS and 59.2% (29/49) reported pain during activity above the PASS; however, average pain did significantly improve (pain at rest = 3.9 ± 2.3 preoperatively; 1.5 ± 1.6 postoperatively; $p < .001$ / pain with activity = 7.2 ± 2.2 preoperatively; 3.3 ± 2.6 postoperatively; $p < .001$). Patients categorized as having high preoperative pain catastrophizing beliefs had significantly worse postoperative pain at rest (2.1 ± 1.7 ; $.85 \pm 1.2$; $p = 0.01$) but not during activity (3.8 ± 2.8 ; 2.8 ± 2.3 ; $p = 0.14$) when compared to those with lower PCS scores. Patients categorized as having low preoperative self-efficacy had significantly worse postoperative pain at rest (2.5 ± 1.7 ; 0.8 ± 1 ; $p < .001$) and during activity (4.3 ± 2.5 ; 2.7 ± 2.6 ; $p = 0.02$). Patients categorized as having high preoperative kinesiophobia did not have worse postoperative at rest or during activity ($p = 0.15-0.26$). PCS, PSEQ, and TSK scores all significantly improved pre- to post-operation ($p < .001$; PCS $\Delta 13.3$, PSEQ $\Delta 11.1$, TSK $\Delta 6.6$). The overall cohort met the MICs for the PSEQ and TSK, as did each group (PSEQ MIC $\Delta 9.8-14.1$, TSK $\Delta 5.5-7.8$).

Using odds ratios patients that were categorized as having increased pain catastrophizing preoperatively were 5.6 (95% CI 1.3-23.4, $p = 0.02$) times more likely to develop increased postoperative pain at rest, but not with activity ($p = 0.39$). Patients categorized as having low preoperative self-efficacy were 4.2 (95% CI 1.2-16.1, $p < .001$) times more likely to develop increased postoperative pain at rest, and 4.4 (95% CI 1.2-16.1, $p = 0.03$) times more likely to develop increased postoperative pain during activity). Patients categorized as having high fear avoidance behaviors preoperatively were not more likely to develop postoperative pain ($p = 0.24-0.41$). Patients with both high

preoperative pain catastrophizing and low self-efficacy were 26.6 (95% CI 5.1-138.4, $p < .001$) times more likely to develop postoperative pain at rest, but not with activity ($p = 0.11$).

A model consisting of preoperative PSEQ and self-reported mental health disorders was predictive of postoperative pain at rest ($r^2 = .47$, $p < .001$) and a model consisting of preoperative PSEQ was predictive of increased postoperative pain during activity ($r^2 = .15$, $p = 0.02$). Patients with persistent pain at rest three months following hip arthroscopy had significantly lower scores on the PCS, TSK, and PSEQ preoperatively ($p < .001-.05$). They also had worse preoperative pain at rest and during activity ($p = .013-.015$) (Table 5.2). Patients with persistent pain during activity three months following hip arthroscopy only had lower scores on the PSEQ preoperatively ($p = 0.03$) (Table 5.3).

Discussion

The aims of this study were to determine the effect of preoperative pain catastrophizing, low self-efficacy, and kinesiophobia on postoperative pain at rest or with activity following hip arthroscopy and to identify predictors of persistent postoperative pain. The distinction between postoperative pain at rest and during activity is important and has clinical implications. The logistic regression results from this study suggests that pain at rest following hip arthroscopy is primarily driven by central mediators (i.e. cognitive and neurologic processes) whereas pain during activity can still be largely attributed to peripheral nociception and tissue healing. This is consistent with previous literature demonstrating pain at rest is a more centrally mediated, stimulus-independent construct.¹¹⁶ Clinically this is relevant because traditional physical therapy interventions focus primarily on function and movement and do not target central desensitization or cognitive psychosocial coping skills training.

Both preoperative pain catastrophizing and low self-efficacy were associated with worse postoperative pain at rest ($p < .001-.01$), and low self-efficacy was associated with

worse postoperative pain during activity ($p=0.02$). When examined in terms of odds ratios, patients categorized as displaying high preoperative pain catastrophizing were 5.6 times more likely to develop persistent pain at rest three months following hip arthroscopy, and patients that had low preoperative pain related self-efficacy were 42 times more likely. Kinesiophobia did not increase the odds of developing persistent postoperative pain; however, 83% of patients were categorized as having high preoperative kinesiophobia. This may suggest a more sensitive and specific cut-off score is required for FAI patients that have failed conservative treatment. Interestingly, a higher percentage of patients presented with clinically relevant pain catastrophizing (51.9%) or low self-efficacy (45.8%), but only one-in-four had a self-reported mental health disorder. This finding suggests that pain catastrophizing and self-efficacy are more sensitive to specific negative pain behaviors than the presence of a mental health disorder alone.

Secondarily we aimed to identify predictors of persistent postoperative pain. A model containing preoperative self-efficacy significantly predicted persistent postoperative pain during activity ($r^2=.15$, $p=0.02$). Similarly, a model consisting of preoperative self-efficacy with the addition of a self-reported mood disorder significantly predicted persistent postoperative pain at rest ($r^2=0.47$, $p<.001$).

The findings from both aims in this study are consistent with the available literature. Self-efficacy has repeatedly demonstrated a strong relationship with postoperative pain, and is often more powerful a determinant of disability than kinesiophobia.^{205,206} There is literature to suggest that self-efficacy plays a mediating role between pain-related fear and pain. That is, if a patient has high kinesiophobia and also high self-efficacy the effects on pain will be mediated.³ On the contrary, a patient with high kinesiophobia and low self-efficacy would be more likely to have pain as their lack of confidence in their ability to accomplish tasks such as rehabilitative exercises would

perpetuate hypervigilance, disuse, and avoidance instead of serving as a mechanism to overcome it. Additionally, self-reported mental health disorders and depressive symptoms have been previously associated with worse postoperative pain and function following hip arthroscopy.^{26,27} Based on the previous literature and the results of the current study, pain self-efficacy and comorbid mental health disorders must be screened for prior to hip arthroscopy, and future studies should evaluate adjunct interventions to mitigate their negative effects on postoperative outcomes.

Pain related self-efficacy, pain catastrophizing, and mental health disorders are viable treatment targets as they have proven to be modifiable with evidence-based interventions.^{191,192,207} A 2018 systematic review and meta-analysis identified patient education and relaxation techniques as the most effective interventions for targeting psychosocial variables to decrease postoperative pain following orthopedic surgery.²⁰⁴ Individualizing medicine based on biopsychosocial models such as the FAM is complex in comparison to the traditional medical model. However, this study adds to the literature supporting that treatment options must match the underlying mechanisms of persistent postoperative pain in order to optimize outcomes.

In this study pain catastrophizing proved a more useful screening tool when analyzed as a bivariate rather than a continuous variable. Preoperative pain catastrophizing was not found to be significantly predictive of persistent postoperative pain three months following hip arthroscopy; however, when analyzed in a Fisher's exact model patients with a preoperative score of 19 or higher on the PCS were 5.6 times more likely to develop increased postoperative pain at rest. This threshold provides clinicians with a simple method to identify patients at increased risk of persistent postoperative pain.

Limitations

Though this study was fully powered for the Fisher's exact comparisons, it was underpowered for logistic regressions. Therefore, these findings should be interpreted cautiously, and future research should aim to validate self-efficacy and mood disorders as predictors of persistent postoperative pain following hip arthroscopy. Additionally, mental health disorders in this cohort were self-reported. As such they may have been underreported. This study also included both patients undergoing primary and first revision hip arthroscopy.

Previous research has identified revision arthroscopy as a risk-factor for poor postoperative outcomes citing that patients undergoing revision arthroscopy do not achieve the same level of improvement in terms of self-reported pain and function.^{101,208} However, in the current study those undergoing revision procedures did not present differently from patients undergoing primary arthroscopy (Table 1), and revision was not a predictor of persistent pain three months following arthroscopy. As only 5 patients (9.6%) included in this study were undergoing revision arthroscopy this finding is likely due the small number of revisions, and not truly a reflection of their pre- or post-operative status.

Conclusions

Preoperative pain related self-efficacy, pain catastrophizing, and self-reported mood disorders increase the risk of persistent postoperative pain three months following hip arthroscopy for symptomatic FAI. Self-efficacy, pain catastrophizing, and mood disorders are important determinants of long-term recovery and are viable treatment targets. As such, evidence-based interventions such as patient education and relaxation techniques should be applied in this high-risk population to mitigate the effects of poor preoperative cognitive coping.

Table 5.1. A comparison of variables between patients with symptomatic femoral acetabular impingement (FAI) undergoing revision or primary hip arthroscopy.

Variable	Revision (N=5)	Primary (N=47)	p-value
Age	35.6 ± 11	36.9 ± 12.4	.84
BMI	25.9 ± 3.8	27.2 ± 4.7	.59
Duration of symptoms	17.8 ± 9.7	32.2 ± 32.3	.46
Preoperative PCS	30.4 ± 14.8	18.2 ± 12	.07
Preoperative TSK	48 ± 7	41.9 ± 6.6	.11
Preoperative PSEQ	33.3 ± 19.1	39.2 ± 13.7	.39
Preoperative pain at rest	4.4 ± 3.1	3.8 ± 2.2	.82
Preoperative pain during activity	7.2 ± 2.6	7.2 ± 2.2	.89
Postoperative pain at rest	1.4 ± .55	1.5 ± 1.7	.66
Postoperative pain during activity	3 ± 1.9	3.4 ± 2.7	.97

**indicates statistical significance ≤ 0.05*

Table 5.2. A comparison of preoperative variables between patients with symptomatic femoral acetabular impingement (FAI) that did and did not develop persistent pain at rest 3 months follow hip arthroscopy.

Variable	VAS \geq 3 (N=15)	VAS < 3 (N=36)	p-value
Age	39.9 \pm 10.4	35.4 \pm 12.9	.21
BMI	28.6 \pm 4	26.5 \pm 4.7	.11
Duration of symptoms	37.2 \pm 33.4	28.5 \pm 30.5	.40
Preoperative PCS	25.7 \pm 12.4	17.1 \pm 12	.03*
Preoperative TSK	45.1 \pm 6	41.1 \pm 6.9	.05*
Preoperative PSEQ	28.1 \pm 8.9	43.2 \pm 13.3	.00*
Preoperative pain at rest	5.2 \pm 2.4	3.3 \pm 2.1	.01*
Preoperative pain during activity	8.4 \pm 2	6.8 \pm 2	.02*

**indicates statistical significance \leq 0.05*

Table 5.3. A comparison of preoperative variables between patients with symptomatic femoral acetabular impingement (FAI) that did and did not develop persistent pain during activity 3 months follow hip arthroscopy.

Variable	VAS \geq 3 (N=29)	VAS $<$ 3 (N=20)	p-value
Age	37 \pm 10.4	37.8 \pm 14.7	.85
BMI	27.7 \pm 4.4	26 \pm 5	.23
Duration of symptoms	32.7 \pm 34.2	29.9 \pm 28.4	.76
Preoperative PCS	20.5 \pm 12.4	19.1 \pm 13.5	.70
Preoperative TSK	43.3 \pm 5.9	41.2 \pm 8.4	.37
Preoperative PSEQ	34 \pm 13.3	43.2 \pm 12.9	.03*
Preoperative pain at rest	4.2 \pm 2.4	3.8 \pm 2.3	.57
Preoperative pain during activity	7.4 \pm 2.2	7.3 \pm 2.2	.84

**indicates statistical significance \leq 0.05*

CHAPTER 6: SUMMARY

The primary purpose of this dissertation study was to determine the effect of preoperative pain catastrophizing, pain related self-efficacy, and kinesiophobia on postoperative pain in patients with symptomatic femoral acetabular impingement (FAI) undergoing hip arthroscopy. This was accomplished with three individual aims:

6.1 SPECIFIC AIM 1

- Specific Aim 1: Identify the preoperative prevalence of mental health disorders in patients undergoing hip arthroscopy and examine if the prevalence of mental health disorders differs between patients that have a short duration of symptoms (>6 months) and a long duration of symptoms (<6 months).
 - *Hypothesis 1: We hypothesized that consistent with previous osteoarthritis and total hip arthroplasty literature, mental health disorders would be present in approximately 20% of patients undergoing hip arthroscopy, and that those patients with mental health disorders would present with a longer duration of symptoms (DOS) and worse self-reported pain and function.*
- Findings summary: Greater than one-in-three (36.2%) patients undergoing hip arthroscopy presented with a mental health disorder—nearly double the rate previously reported for patients with hip osteoarthritis. Self-reported pain and function were worse in this subset of patients, but neither symptom chronicity nor the severity of joint deformity differed between those with or without comorbid mental health disorders.

6.2 SPECIFIC AIM 2

- Specific Aim 2: Compare pain catastrophizing, self-efficacy, and kinesiophobia between patients with and without mental health disorders and determine if these variables were predictive of preoperative pain in patients with FAI.

- *Hypothesis 2: We hypothesized that preoperative pain would be predicted by low pain self-efficacy and high kinesiophobia and pain catastrophizing. More specifically, we expected pain catastrophizing to be the primary predictor of preoperative pain. Further we hypothesized that these behaviors would be more severe in patients with mental health disorders.*
- Findings summary: Preoperative pain catastrophizing, pain related self-efficacy, and kinesiophobia were significantly worse for patients with a self-reported mental health disorder. A model consisting of pain related self-efficacy was found to be predictive of preoperative pain at rest, and the same model with the addition of BMI was found to be predictive of preoperative pain during activity.

6.3 SPECIFIC AIM 3

- Specific Aim 3: Determine the effect of preoperative pain catastrophizing, low self-efficacy, and kinesiophobia on postoperative pain, and determine if these variables were predictive of postoperative pain.
 - *Hypothesis 3: We hypothesized that preoperative pain catastrophizing, low pain related self-efficacy, and kinesiophobia would result in worse postoperative pain, and that these variables would be predictive of an increased risk of developing increased postoperative pain.*
- Findings summary: Preoperative self-efficacy and self-reported mental health disorders are predictive of persistent postoperative pain three months following hip arthroscopy for symptomatic FAI. Low preoperative self-efficacy and/or high pain catastrophizing independently increase the odds of abnormal recovery and elevated postoperative pain.

6.4 SYNTHESIS AND CLINICAL APPLICATION OF RESULTS

Based on the findings from this series of dissertation studies we can make the following conclusions:

Concomitant mental health disorders are common in patients with symptomatic FAI undergoing hip arthroscopy. These patients present worse preoperatively in terms of self-reported pain, function, and psychosocial status. Specific Aim 3 also identified that self-reported mental health disorders were part of a model that significantly predicted persistent postoperative pain at rest three months following hip arthroscopy. Combined, these data suggest mental health disorders must be considered during pre- and postoperative counseling for patients with symptomatic FAI undergoing hip arthroscopy.

Findings from Specific Aims 2 and 3 lead to the conclusion that preoperative pain related self-efficacy is an extremely important variable to examine in patients with symptomatic FAI undergoing hip arthroscopy. Low preoperative pain self-efficacy was predictive of worse pre- and postoperative pain. Additionally, preoperative pain catastrophizing increased the odds of persistent postoperative pain three months following hip arthroscopy.

The studies in this dissertation shed light on the important of psychosocial factors on postoperative pain and physical well-being. Pain is multifaceted and will never be explained by a single variable; however, in an attempt to optimize outcomes following orthopedic surgeries researchers and clinicians must embrace the merging of the mind and the body. Transitioning to a biopsychosocial model in lieu of the traditional medical model is imperative to improving postoperative outcomes, specifically following hip arthroscopy. Providing individualized, patient-tailored treatment plans is a complex solution to a complex problem. Many psychosocial interventions target all the risk-factors identified by this series of studies. Preoperative patient education and relaxation techniques have demonstrated success in improving self-efficacy, decreasing catastrophizing, and mitigating preoperative anxieties or depressive symptoms.^{191,192,204,207} Traditional cognitive behavioral therapy should not be overlooked for clinical anxiety and depression; however, adjunct interventions can be applied by

allied health professionals²⁰⁹⁻²¹¹ in the clinic and can assist in providing patients a set of coping skills that can improve their postoperative experience.

6.5 FUTURE RESEARCH

Future research directions were born out of this series of dissertation studies. A primary line of research should examine adjunct interventions aimed at the high-risk group of patients with concomitant mental health disorders, low preoperative pain related self-efficacy, and/or high pain catastrophizing. This research line should focus on the development of treatment strategies and interventions aimed at improving the likelihood of a successful clinical outcome. All three of these risk-factors are important determinants of long-term recovery and are all viable treatment targets. Established interventions such as patient education and relaxation techniques have yet to be applied in patients undergoing hip arthroscopy. It is reasonable to hypothesize that these interventions will assist in mitigating the effects of poor preoperative cognitive coping and mental health disorders in patients with symptomatic FAI. Additionally, a second line of research should evaluate these interventions in high-risk patients with symptomatic FAI during the course of their initial conservative treatment to improve physical therapy outcomes. Results from such studies could determine if psychosocial interventions can improve the response to conservative treatment thereby potentially reducing the need for surgical correction.

There is a well-established relationship between psychosocial variables and decreased physical function^{190,212} and/or aberrant movement patterns^{213,214} in patients with a variety of orthopedic conditions. To date, this relationship has not been examined in patients with symptomatic FAI; however, the data presented in this series of dissertation studies suggests a similar relationship may exist. As such, the third and final line of research should examine the relationship between hypervigilant movement patterns and fear-avoidance, catastrophizing, and self-efficacy in patients with

symptomatic FAI. Following the Fear Avoidance Model of chronic pain, the risk-factors identified in Specific Aims 2 and 3, low self-efficacy and pain catastrophizing, are likely resulting in muscle guarding and hypervigilant movement patterns. By examining these relationships researchers can identify functional treatment targets to specifically address in physical therapy sessions.

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EDUCATION

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Ph.D. in Rehabilitation Sciences

Successful defense date: November 16th, 2018

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Florida International University (FIU); Miami, FL 2012

M.S. in Athletic Training

University of Wisconsin- Green Bay (UWGB); Green Bay, WI 2010

B.S. in Human Biology with an emphasis in Exercise Science

HONORS AND AWARDS

- 2015- 2018 Doctoral Research Assistantship
University of Kentucky Rehabilitation Sciences Department
- 2014 Award for Research in Medical Education
Aurora BayCare Medical Center - Green Bay, WI
- 2011-2012 Graduate Assistantship
FIU Athletic Training Education Department
Responsibilities included research, administration, CAATE reaccreditation
- 2012 Academic Excellence Award
FIU Athletic Training Education Department
Highest grade point average in the graduating class (3.98)
- 2011 Arnold S. Friedman Memorial Scholarship
FIU College of Nursing and Health Sciences

PEER REVIEWED PUBLICATIONS

1. Picha KJ, **Jochimsen KN**, Heebner N. Abt JP. Usher E. Capilouto G. Uhl TL. Measurements of Self-Efficacy in Musculoskeletal Rehabilitation: a Systematic Review. *Musculoskeletal Care*. 2018.
2. **Jochimsen KN**, Malempati CS, Jacobs CA, Duncan ST. A Systematic Review of Return to Sport Following Arthroscopic Treatment of Labral Tears in Competitive Athletes. *Athletic Training & Sports Health Care*. 2018.
3. **Jochimsen KN**, Conley CEW, Malempati CS, Jacobs CA, Mattacola CG, Lattermann C. Meniscus Transplantation: A Systematic Review of Return-to-Play Rates. *Athletic Training and Sports Health Care*. 2018;10(2):76-81.
4. Jacobs CA, Burnham JM, **Jochimsen KN**, Molina IV D, Hamilton DA, Duncan ST. Preoperative Symptoms in Femoroacetabular Impingement Patients Are

More Related to Mental Health Scores Than the Severity of Labral Tear or Magnitude of Bony Deformity. *The Journal of Arthroplasty*. 2017;32(12):3603-3606.

5. Lattermann C, Jacobs CA, Bunnell MP, **Jochimsen KN**, Abt JP, Reinke EK, Gammon LG, Huebner JL, Kraus VB, Spindler KP. Logistical challenges and design considerations for studies using acute anterior cruciate ligament injury as a potential model for early posttraumatic osteoarthritis. *Journal of Orthopaedic Research*. 2017;35(3):641-650.
6. Yde R, **Jochimsen KN**, Goddard J. Conservative Management for a Traumatic Cervical Spine Cycling Injury. *Journal of Science and Cycling*. 2015;4(1):3.

MANUSCRIPTS SUBMITTED FOR PUBLICATION

1. **Jochimsen KN**, Pelton MR, Mattacola CG, Huston LJ, Reinke EK, Spindler KP, Lattermann C, Jacobs CA. Preoperative Pain Catastrophizing Scores Not Predictive of Outcomes After Anterior Cruciate Ligament Reconstruction. *Journal of Sport Rehabilitation*. In review.
2. **Jochimsen KN**, Magnuson JA, Mattacola CG, Noehren B, Duncan ST, Jacobs CA. Mental Health Disorders in Hip Arthroscopy: a Comparison of Preoperative Factors. *The Journal of Hip Preservation Surgery*. In review.
3. **Jochimsen KN**, Mattacola CG, Noehren B, Duncan ST, Picha KJ, Jacobs CA. Low Self-Efficacy is Predictive of Worse Preoperative Pain in Patients with Femoral Acetabular Impingement. *Journal of Arthroplasty*. In review.

MANUSCRIPTS IN PREPARATION

1. **Jochimsen KN**, Mattacola CG, Noehren B, Duncan ST, Jacobs CA. Low self-efficacy and mental health disorders predict persistent postoperative pain 3 months following hip arthroscopy. In preparation.
2. Conley CEW, Howard JS, **Jochimsen KN**, Olson AD, Dressler EV, Lattermann C, Mattacola CG. A Comparison of Neuromuscular Electrical Stimulation (NMES) Parameters for Postsurgical Quadriceps Strength in Patients After Knee Surgery: A Systematic Review. In preparation.
3. **Jochimsen KN**, Conley CE, Jacobs CA. A Model for Improving Patient Reported Outcomes in Patients with Femoral Acetabular Impingement and Varying Attachment Styles. In preparation.
4. **Jochimsen KN**, Duncan ST, Jacobs CA. Improving Access to Underserved Populations: The Validation of a Likert Scale Version of the iHOT 12. In preparation.
5. **Jochimsen KN**, Jacobs CA, Mattacola CG. Kinesiology of the Hip (Book chapter). In preparation.
6. Duncan ST, **Jochimsen KN**, Nzgewu I, Jacobs CA. Assessing the Role of

Synovitis in Femoroacetabular Impingement. In preparation.

7. Mechas C, **Jochimsen KN**, Jacobs CA, Duncan ST. The Relationship Between Preoperative Symptoms and Sexual Activity in Patients with Femoral Acetabular Impingement. In preparation.

GRADUATE STUDENT MENTORSHIP

- 2015-2017 Margaret Pelton
Thesis: *Effects of Pain Catastrophizing on Patient Reported Knee Function After Index Anterior Cruciate Ligament Reconstruction*
- 2016-2018 Kelsea Kocan
Thesis: *Are High Preoperative Pain Catastrophizing Scores Associated with a Longer Duration of Symptoms in Patients Undergoing Hip Arthroscopy?*
- 2016-2018 Autumn Overhiser
Thesis: *Validation of a 2-D Step Down Test in Post Hip Arthroscopy Patients*

ACADEMIC APPOINTMENTS

- 2013-2015 University of Wisconsin, Green Bay, Department of Human Biology
Associate Lecturer

TEACHING

- 2016-2018 University of Kentucky, Department of Athletic Training
AT 695- Lower Extremity
- 2016-2018 University of Kentucky, Department of Athletic Training
AT 740- Cadaver Anatomy
- 2016-2018 University of Kentucky, Department of Physical Therapy
PT 686- Athletic Taping
- 2013-2015 University of Wisconsin, Green Bay, Department of Human Biology
Hum Bio 210- Prevention and Treatment of Athletic Injuries

PERSONAL INFORMATION

Birthplace: Auburn, Washington