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PRESENCE OF MARKERS OF FEMOROACETABULAR IMPINGEMENT IN THE ASYMPTOMATIC POPULATION

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PRESENCE OF MARKERS OF FEMOROACETABULAR IMPINGEMENT IN THE ASYMPTOMATIC POPULATION

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Abstract

Purpose: To determine the prevalence of Femoroacetabular Impingement (FAI) in asymptomatic individuals, using different criteria values from the literature to classify the presence or absence of cam (alpha angle of 45, 50 and 55 degrees) and pincer (centre-edge (CE) angle of 35 and 40 degrees) impingement, and to determine whether there is an association between the presence of FAI and age and degenerative disease. **Methods:** 88 volunteers were verified as asymptomatic through physical examination and then underwent an MRI of the hip. **Results:** The prevalence of FAI ranged from 23.9 to 67.0% depending on the classification criteria applied. There was no significant association between FAI and age. **Conclusion:** FAI is prevalent in the asymptomatic population. Further research is necessary to verify the validity and reliability of criterion values used to diagnose impingement.

Key words: Femoroacetabular Impingement, FAI, hip, asymptomatic, alpha angle, centre-edge angle, MRI, osteoarthritis.

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Chapter 1: Introduction

1.1 Statement of the Problem

Over the last decade the understanding of degenerative hip pathology has evolved. One such change has come from the discovery of variations in hip morphology that are thought to be responsible for abnormal contact between the proximal femur and the acetabular rim. This condition, that has been coined femoroacetabular impingement (FAI), is thought to cause intermittent groin pain in young active adults and may be a precursor to osteoarthritis (OA). (1-8) There are two different types of FAI: cam impingement and pincer impingement. Cam impingement is a condition where an abnormally prominent portion of the anterolateral femoral head-neck junction abuts against the acetabular rim during flexion and is suggested to cause impingement of the labrum. (5, 6, 8) Pincer impingement is characterized by an anatomical over-coverage of the femoral head by the bony acetabulum. It is thought that this type of impingement can also impinge the labrum and the abnormal bony contact can cause a proliferation, increasing the prominence of the acetabular rim, which in turn will exacerbate the problem. (1-3, 6, 9, 10) It is believed that the labral lesions caused by FAI will also damage the adjacent cartilage, which will lead to degenerative disease of the joint. (1, 3, 4, 7, 9, 10)

Many authors suggest that early detection and treatment of FAI is essential to prevent the progression of degeneration, especially in younger populations. (1-4, 7, 9, 11) Suggested treatment for FAI is arthroscopic osteoplasty of the bony prominence(s) and resection of soft tissue involved in the impingement. (1, 2, 12, 13) Reported short-term results of this

treatment are encouraging. (5, 13-16) Beck et al.(15) treated 19 patients (14 male) for FAI and found that 4.7 years post surgery 13 patients had good to excellent results using the Merle d'Aubigne hip score. Peters et al. (17) followed 30 patients (16 male) who underwent open hip treatment of FAI for 32 months and found a post-operative improvement of 10 points on the Harris hip score. Similarly, Larson et al. (18) followed 96 patients (100 hips) (54 male) post arthroscopic treatment of FAI. Good to excellent results were observed on the impingement test, Harris hip score, SF-12 score and VAS pain score in 75% of the hips at a minimum of one year. However, long-term studies determining the efficacy of surgical treatment of FAI preventing early onset of degenerative disease are lacking.

Ganz et al. (19) has raised the question of whether surgery for FAI should be performed prophylactically in asymptomatic individuals who have abnormal morphology. Knowledge of the natural history of FAI however, is undefined. Most importantly, the prevalence of variations in hip morphology in the asymptomatic population is unknown. Understanding the normal variations of the hip joint in asymptomatic subjects is vital to help researchers and clinicians understand the etiology of FAI and to help guide FAI treatment.

1.2 Related Research

Existing research has focused on identifying pathological features of FAI in symptomatic individuals (i.e. a large alpha angle representing cam-type FAI and/or a large centre-edge (CE) angle representing pincer-type FAI). (4, 7, 8, 10, 20-23) These studies are useful in

identifying pathological features present in those with symptoms; however, these studies do not provide any insight regarding prevalence of FAI in the asymptomatic population. Two studies conducted by Gosvig et al. (22, 24) evaluated plain radiographs from large populations, of an unselected cohort, for prevalence of cam impingement. The 2007 study determined that 6% of males and 2% of women presented with the cam morphology, whereas the 2008 study determined that 17% of men and 4% of women presented with the cam deformity of impingement. However, these patients were unscreened for symptoms of hip pathology and therefore this study does not give any insight into the prevalence of FAI in the asymptomatic population. Of the few studies that have looked at prevalence of FAI, none have attempted to determine the correlation between MRI findings of FAI and age. It is critical to understand the effect of aging on normal variations of hip morphology to help guide prevention and early treatment.

Although a correlation appears to exist between the presence of FAI indicators and the early onset of OA (1, 10, 13, 15), a cause and effect relationship has not been established. Previous studies have only observed radiographic markers for FAI in symptomatic individuals with idiopathic hip arthritis. (3, 4, 8, 10, 20, 21) Further estimates of the prevalence of FAI indicators and markers of degenerative disease in asymptomatic individuals of all ages may allow for a more accurate evaluation of the role of FAI in the etiology of OA.

The measurement of the alpha angle is considered to be the simplest method of determining cam impingement. (7, 9) However, the actual angle, which defines FAI, is

still debated in the literature. Notzli et al. (7) created the alpha angle measurement by comparing 39 subjects (16 male) with suggested impingement with 35 asymptomatic controls (17 male). The symptomatic group yielded a mean alpha angle of 74 degrees (55 - 95), whereas the control group yielded a mean alpha angle of 42 degrees (33 - 48). Several authors have referenced the Notzli study; however, pathological alpha angles used vary from 50 degrees to 83 degrees. (20-22, 24-26) Similarly, the CE angle, which can be used to indirectly diagnose pincer impingement by measuring the over-coverage of the femoral head by the anteriolateral acetabulum, (23) lacks a clear pathological value to define pincer impingement. Two studies have established mean CE angles within symptomatic populations. Reynolds et al. (27) found a mean of 35 ± 2 degrees in the symptomatic population and a mean of 30 ± 2 degrees in the controls and Peters et al. (17) found a mean CE angle of 28 degrees (8 - 50) in a population of symptomatic patients. Furthermore, a few studies have established the mean CE angle of normal populations and the angles have ranged from 18 - 61 degrees. (28-30) Thus, criterion values defining cam and pincer impingement have not been established.

1.3 Purpose

The purpose of this study is to examine the prevalence of FAI markers (anterosuperior acetabular overcoverage and prominence of the anterior femoral head-neck junction) in asymptomatic individuals; the prevalence of cam impingement will be analyzed using three different criteria (alpha angles of 45, 50 and 55 degrees) and the prevalence of pincer impingement will be analyzed using two different criteria (CE angles of 35 and 40 degrees). Secondly, we will determine the magnitude of the association between the presence of FAI markers and age and the association between the presence of FAI

markers and the presence of markers of degenerative disease. It is hypothesized that variations in hip anatomy will be found in asymptomatic individuals and that cam impingement will be more prominent in males than females. Markers of FAI will increase with age and with markers of degenerative disease.

Chapter 2: Literature Review

2.1 Introduction

Femoroacetabular Impingement (FAI) is a variation in hip morphology that may lead to abnormal contact between the femoral neck of the femur and the acetabular rim of the os coxae. These morphologic variations are suggested to lead to a reduction in joint clearance leading to repetitive contact between the femoral neck and the acetabular rim. (1, 15) Since the hip is under such tight constraints the abnormal contact is likely to cause damage to the underlying labrum and cartilage of the joint and thus may be the cause of early osteoarthritis (OA). (1, 10, 13, 15) There are two morphologic variations that are suggested to lead to FAI: cam impingement, which affects the femoral neck, and pincer impingement, which affects the acetabular rim. (1) Existing studies have looked at the prevalence of the type of FAI among the symptomatic population (10, 17, 20) and Gosvig et al. (22, 24) conducted two studies on the prevalence of cam impingement in unselected populations. The 2007 study found a prevalence of 6% in males and 2% in females in an unselected population of 2,803 individuals (1,055 males) and the 2008 study established that 17% of males and 4% of females presented with cam impingement in an unselected cohort of 4,151 subjects (1,184 male). However, to date the prevalence of FAI in the asymptomatic population is unknown.

2.2 Mechanisms of Impingement

Cam impingement appears to be more common in young athletic males and is characterized by a decreased head-neck offset of the anterosuperior or anterolateral portion of the femoral head-neck junction (Figure 2.1B). (1, 10, 13, 22) It is suggested that, during flexion the aspherical femoral head rotates into the acetabulum and the protuberance on the head-neck junction applies compressive and shear forces to the anterosuperior acetabulum limiting range of motion (ROM) (Figure 2.2C). (3, 6, 9, 10) Repetitive osseous microtrauma of the abnormal femoral neck against the acetabulum can cause the formation of osteophytes on the anterior femoral neck, which in turn can exacerbate the problem. (9) These forces can also cause the labrum to be stretched and pushed outwards while the cartilage is being compressed and pushed centrally which will then cause the labrum and the cartilage to separate, (1, 9, 10, 13) often resulting in deep chondral lesions and/or extensive labral tears of the anterosuperior region of the acetabulum. (1, 6, 9) This proposed etiology is supported by a study conducted by Beck et al. (10) that evaluated plain radiographs of 26 patients (24 male) with isolated cam impingements. All hips demonstrated damage to the anterosuperior cartilage and separation of the labrum from the cartilage.

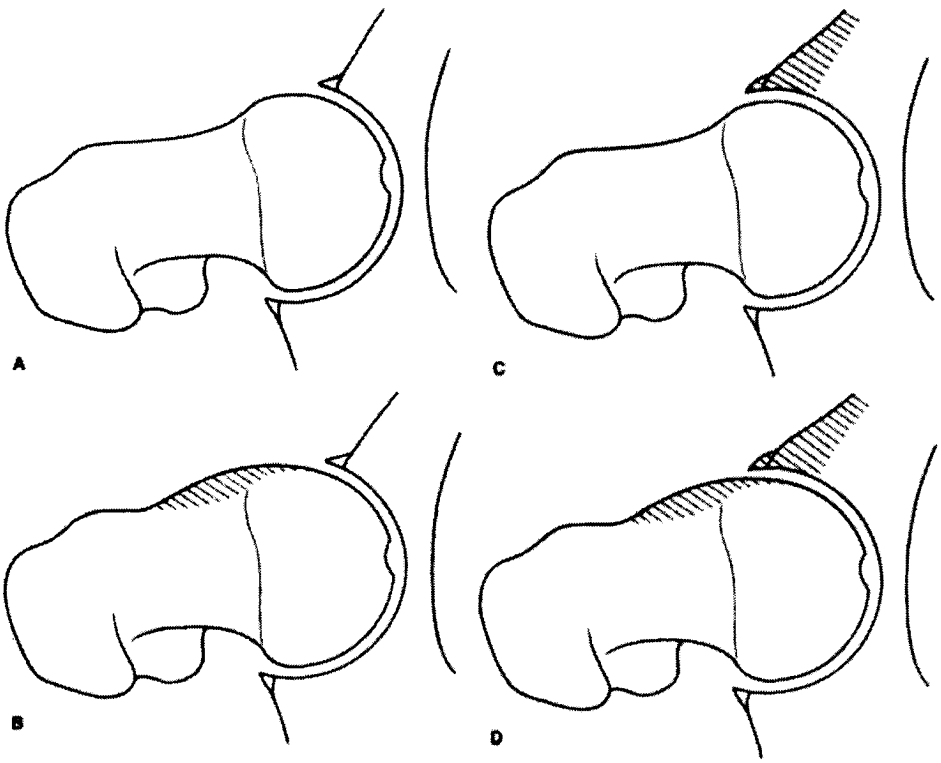

Figure 2.1: Types of FAI: (A) Normal hip joint; (B) Cam-impingement: decreased head-neck offset; (C) Pincer Impingement: acetabulum over-covering the normal femoral head; (D) Mixed cam-pincer impingement: abnormal morphology of both the acetabular rim and the femoral head-neck junction. Reprinted with permission from Lippincott Williams and Wilkins. (3)

Pincer impingement is defined as an abnormally deep acetabulum, which causes excessive acetabular coverage over the anatomically normal femoral head and appears to be more common in active middle-aged women (Figure 2.1C). (1, 5, 10, 13) The overcovering is suggested to limit ROM as the acetabular rim abuts against the femoral neck and causes the labrum to become compressed (Figure 2.2B). Repeated impact may result in damage to the labrum and the forces may be transmitted to the acetabular cartilage resulting in chondral damage. Continued abutment of the acetabular rim against the femoral head may result in the ossification of the underlying bone of the acetabular rim and/or anterior femoral neck leading to exaggeration of the overcoverage and

exacerbation of the impact. (1, 2, 9, 10, 13, 21) Cartilaginous damage associated with pincer impingement is usually small and located along the acetabular rim as a narrow strip; however, chondral damage can also be found in the posterior and posteroinferior aspect of the acetabulum due to a contre-coup injury. (1, 2, 6, 9, 10, 13, 20)

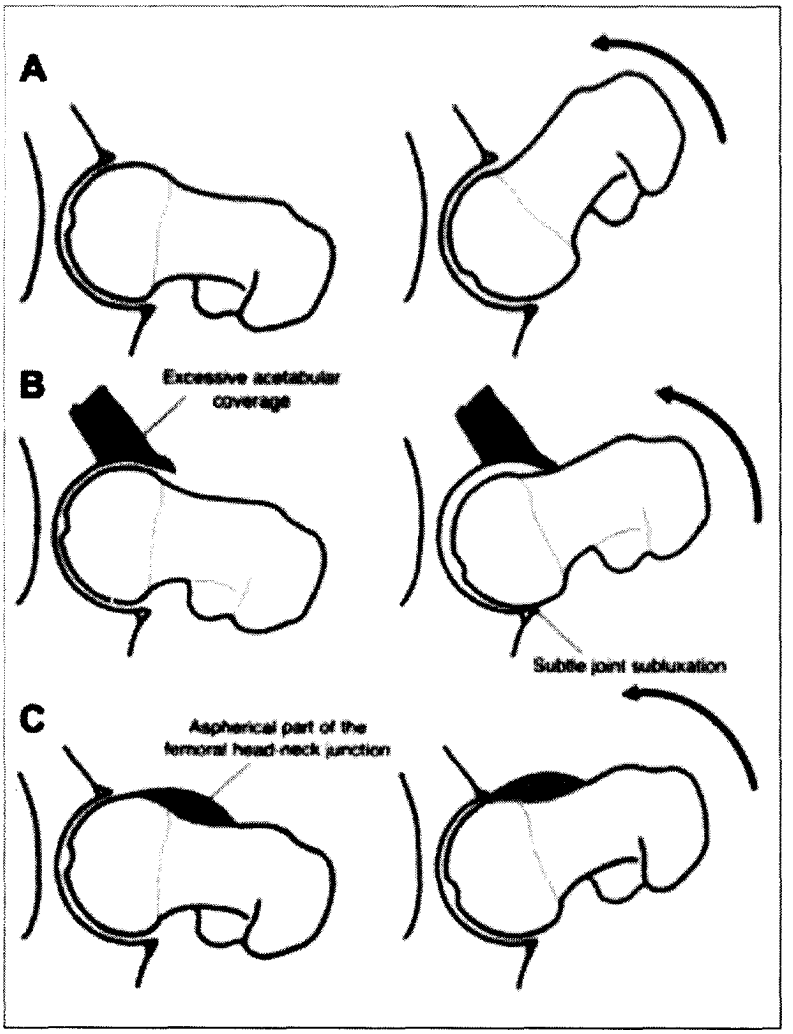

Figure 2.2: FAI pathology during flexion. (A) Normal hip joint clearance and movement during flexion. (B) Pincer impingement limits ROM and results in the acetabular rim impacting against the femur and causes subtle joint subluxation, which can cause a posteroinferior contre-coup injury. (C) The head-neck protuberance of cam impingement rotates into the acetabulum causing compression and shear forces of the anterosuperior acetabulum and limits ROM Reprinted with permission from the American Journal of Roentgenology. (31)

Mixed cam-pincer impingement is a combination of the two mechanisms of impingement and is more common than cam or pincer impingement occurring independently; although, one type usually predominates (Figure 2.1D). (9, 10) Beck et al. (10) radiographically evaluated 149 patients with FAI; 26 were observed to have isolated cam impingement (24 male) and only 16 presented with isolated pincer impingement (2 male). Additionally, Phillippon et al. (8) studied 301 patients (153 males) who were undergoing surgery for FAI and only 50 patients were treated for pincer impingement, whereas 100 patients were treated for cam impingement and the majority, 151 patients, were treated for both cam and pincer impingement. Both patterns of labral and chondral damage are evident in individuals with mixed cam-pincer impingement. (1)

2.3 Possible Causes of FAI

Patients who present with FAI usually lack a clear history of hip disease. It has been suggested that the morphological variations may be caused by subtle developmental abnormalities such as Legg-Calvé Perthes disease and slipped capital femoral epiphysis for cam impingement and coxa profunda, retroversion, protrusio acetabuli, coxa vara and os acetabuli for pincer impingement. (1, 6, 9) However, most cases are idiopathic. (6)

2.4 Association with OA

Abnormal morphology of the hip has been documented as a cause of early OA for some time; however, FAI has only recently been recognized as a clinical problem. (11) It is suggested that FAI primarily limits ROM due to the abnormal contact of the femoral neck and the acetabular rim. Secondly, the repeated abnormal contact and shearing forces

caused by FAI are suggested to lead to labral lesions. (2, 4, 6, 10, 13) Studies show that labral lesions are the most common finding in individuals with FAI and occur in almost all cases. (1, 6, 7, 15) A study conducted by Phillippon et al. (8) found that 99% of 301 patients (153 male) undergoing surgical treatment for FAI had associated labral pathology and 82% had associated chondral pathology. Similarly, Pfirrmann et al. (20) analyzed MRA findings in 50 patients (30 male) with FAI and found that 94% presented with anterosuperior labral lesions and that 84% had anterosuperior cartilage lesions. In agreement, Kassarjian et al. (21) evaluated MRA findings of 40 patients (22 male) with FAI and found that 100% of the patients had an anterosuperior labral tear and 95% displayed anterosuperior cartilage abnormalities. It is suggested that the labral lesions predispose the adjacent cartilage to degeneration. Cartilage degeneration then leads to bone exposure, which will ultimately lead to the development of OA. (1, 4, 7) Thus, it is suggested that FAI is a potential mechanism for the development of OA. (1, 7, 8)

2.5 Clinical Presentation

Young active individuals with FAI present with intermittent groin pain, often after minor trauma, and pain worsens with continued activity and/or prolonged sitting. (1, 2, 4-6, 8) Symptoms of FAI are usually unilateral. (2) Routine radiographs usually appear normal, (1, 6) which often leads to unnecessary diagnostic workups and inappropriate surgical modalities. (1, 6, 13) FAI is suggested if an internally rotated and passively adducted hip at 90 degrees of flexion reproduces the individual's pain as this position recreates the impingement. (1, 3, 5-7) Many other hip tests such as the bicycle test, anterior apprehension test, Thomas test, posterior impingent test, and the Trendelenberg test are suggestive of impingement; however, they are nonspecific. (6) Byrd et al. (32) found that

clinical examination was successful at determining the existence of hip abnormality; however, the assessment is poor at determining the nature of the abnormality. Thus, more specific diagnostic tools, such as imaging, must be used to make an accurate diagnosis.

2.6 Imaging

Standing anteroposterior (AP) and lateral pelvic radiographs are routinely taken for all patients presenting with symptoms that are suggestive of FAI. (1) These radiographs often appear normal (1, 5, 6); however, bony abnormalities of the hip can become apparent upon detailed review. (1) For cam impingement an anterior prominence on a lateral radiograph, the convex cam lesion of the head-neck junction and early onset of degenerative disease can be identified on plain radiographs. (1, 2, 6) Pincer impingement can be identified on radiographs by evidence of impaction between the femoral head-neck junction and the acetabular rim, early onset of degenerative arthritis, herniation pits at the femoral neck and abnormalities that result in the acetabulum overcovering the femoral head (i.e. acetabular protrusion, coxa magna, coxa vara, retrotorsion of the femoral head, retroversion of the acetabulum, ossification of the acetabular rim, os acetabuli). (1, 2, 6) Radiographs can identify bony abnormalities of the hip; however, identifying the extent of the variation in morphology on plain radiographs is difficult. (31) The alpha angle, a measurement used to calculate the severity of cam impingement, measured on AP radiographs can yield false-negative cam malformations. (22) These technical difficulties in addition to the subjective component of reading radiographs cause a decrease in the interobserver reliability of radiographic findings. (11) Furthermore, radiographs are unable to identify any soft tissue damage associated with FAI.

Non-arthrographic magnetic resonance imaging (MRI) can be used to noninvasively identify bony abnormalities and soft tissue findings of FAI. It is thought that MRI with intraarticular gadolinium, magnetic resonance arthrogram (MRA), allows better visualization of labral lesions and cartilage damage associated with FAI (21); however, recent publications show that MRI has similar accuracy in the detection of labral tears and cartilage defects as MRA. (2, 4, 33) Characteristic findings of cam impingement on MR images include an increased alpha angle, anterosuperior labral tears, articular cartilage defects, flattening of the superior femoral head-neck junction and an aspherical femoral head. (2) Pincer impingement findings on MR images include a normal alpha angle, an increased centre-edge angle, anterosuperior acetabular labral tearing, articular surface defects, a spherical femoral head, and evidence of osseous impaction along the anterosuperior femoral neck. (2) Other findings of degenerative disease that has previously been associated with FAI can also be identified on MR images (i.e. os acetabuli, paralabral cysts, herniation pits, periarticular osteophytes, intraarticular bodies, intraarticular bursa, interosseous cysts, synovial cysts and joint effusion). Noncontrast MRI can noninvasively and effectively evaluate the pathology of the hip for screening, diagnostics and presurgical planning of FAI.

2.7 Diagnosis

The alpha angle, which is used to identify cam impingement, is considered to be the simplest and quickest method for measuring the femoral head-neck offset (Figure 2.3). (7, 9) The alpha angle is measured on centre cut axial oblique view MR images and is defined by a line drawn through the centre of the long axis of the femoral neck and head

and a line drawn from the centre of the femoral head to the first point where the contour of the femoral head exceeds the radius of the head. (7) A consensus of which alpha angle value is diagnostic of a hip with impingement does not exist. Notzli et al. (7) created the alpha angle measurement by analyzing MR scans of 39 patients (26 male) who had groin pain, decreased internal rotation and a positive impingement test compared to 35 asymptomatic controls. The mean alpha angle of the symptomatic group was 74.0 ± 5.4 degrees (55 - 95) and 42 ± 2.2 degrees (33 - 48) for the control group. This method of identifying cam impingement is considered the simplest and has a substantial to high degree of intraobserver reliability and a moderate to high degree of interobserver agreement. Notzli et al. (7) tested the reliability of the measurement and found an intraobserver variation of ± 3% and an interobserver variation of ± 7% between four examiners; 2 orthopaedic surgeons and two radiologists. (7, 9) Similarly, Gosvig et al. (24) found a 90% and 96% agreement in intraobserver agreement for the two observers and an 83% agreement in interobserver reliability. Johnston et al. (34) found a 77.6% agreement in intraobserver agreement and a 52.3% agreement in interobserver agreement. Additionally, Nouh et al. (26) found variations in intraobserver agreement when plotting repeated measures around the line of equality. Several authors have referenced the Notzli study; however, the pathological alpha angle used as criteria to diagnose cam impingement varies. Fraitzl et al. (25) compared alpha angle findings of 16 patients (13 male) with mild slipped capital femoral epiphysis to 42 degrees, which was the mean alpha angle of the controls in the Notzli study. They found the FAI affected side to have a mean alpha angle of 86 degrees (55 - 99) and the unaffected side had a mean alpha angle of 62 degrees (45 - 90). The means of the affected and unaffected hips were statistically

significant; however, the mean of the unaffected hips was still different from the Notzli mean of the control group and thus displays that these hips did not develop normally. Many authors suggest that an alpha angle larger than 50 degrees is considered abnormal and that using a criteria value of 55 degrees is specific to impingement. (9, 20, 21) However, Notzli et al. (7) noted that it remains to be shown whether individuals with large alpha angles (> 50°) and positive impingement tests are limited in ROM by contact between the femoral head-neck junction and the acetabular rim. (7) Kassarjian et al. (21) used a 55 degree criteria value when calculating alpha angles of 42 patients (22 male) with clinical cam-type FAI. 39 hips (93%) had an abnormal alpha angle with a mean angle of 69.7 degrees (40.8 - 91.3); notably, three patients with clinical cam impingement had alpha angles below the criterion of 55 degrees. Similarly, Pfirrmann et al. (20) used a 55 degree criteria value when analyzing MRA findings of 50 patients (30 male) with FAI and found a mean alpha angle of 68 ± 19 degrees. Gosvig et al. (24) used an alpha angle of 65 degrees to establish the prevalence of cam impingement in an unselected cohort of 2,803 radiographs (1,055 males). The authors of this study suggested that a pathological criterion of less than 68 degrees be used to determine a normal femoral head-neck junction, 69 to 82 degrees be representative of borderline pathology and an angle greater than 83 degrees be indicative of cam impingement for males. Whereas, it was suggested that an alpha angle of less than 50 degrees represents normal morphology, 51 to 56 degrees represents borderline pathology and greater than 57 degrees is representative of cam deformation in females. Finally, Gosvig et al. (22) conducted another study and used the criteria values suggested in the 2007 study. Alpha angles of 83 degrees for males and 57 degrees for females were used to establish the prevalence of cam impingement in an

unselected cohort of 3,202 radiographs (1,184 male). Future research is required to establish standard pathological values for the alpha angle measurement to ensure accurate identification of FAI.

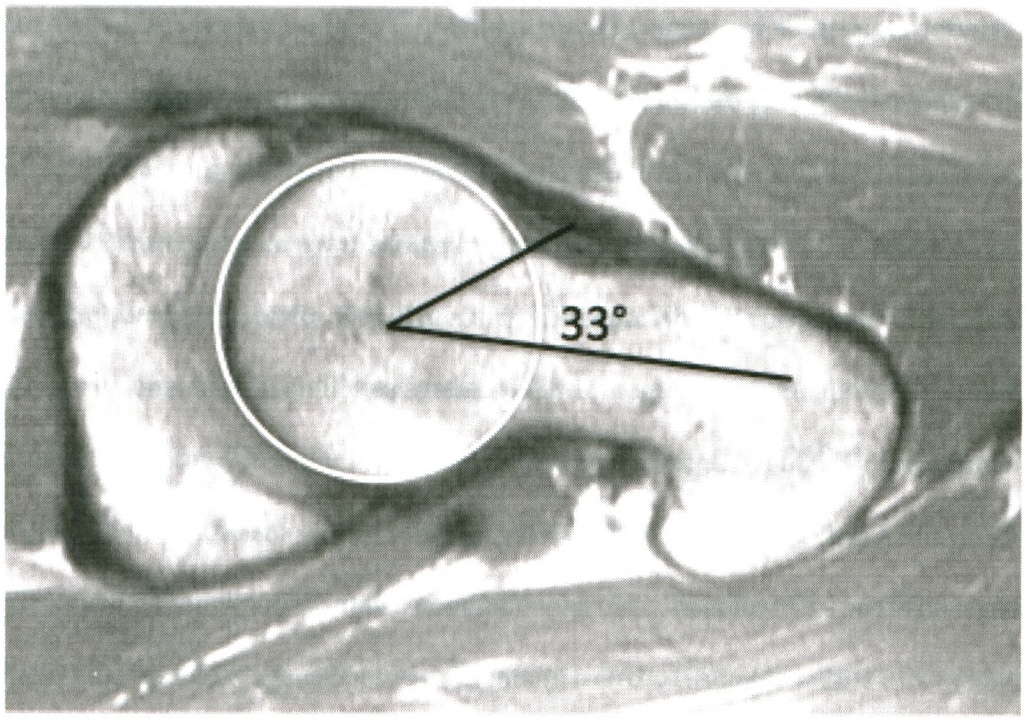

Figure 2.3: A normal alpha angle measurement on an MR image of a 25-year-old male. As established by Notzli et al. (7), normal alpha angles range from 33 to 48 degrees.

The centre-edge (CE) angle indirectly measures the degree of anterolateral overhang of the acetabular rim over the femoral head. (23) The CE angle was created by Wiberg, G. (35) and is measured by two lines drawn from the centre of the femoral head on a centre cut coronal view. One is a vertical line drawn straight up through the acetabulum and the second is drawn through the lateral margin of the acetabulum. The angle formed between these lines is the CE angle. (23) A normal acetabulum is defined by a CE angle of greater than 25 degrees. A small CE angle is used to diagnose acetabular dysplasia (CE < 20°) (7,

22) and conversely a large CE angle can be used to identify pincer impingement. However, there is no consensus in the literature of a value that defines pincer impingement pathology. Two known studies have established mean CE angles within populations of individuals who present with pincer impingement. The first study conducted by Reynolds et al. (27) radiographically compared 43 patients defined as having acetabular retroversion with 174 controls. The study group had a mean CE angle of 35 ± 2 degrees and the control group had a mean CE angle of 30 ± 2. Secondly, Peters et al. (17) radiographically measured the preoperative CE angle of 30 hips (29 patients; 16 male) being treated for FAI. The mean CE angle was 28 degrees (8 - 50) and in 28 of the 30 patients the CE angle was greater than 15 degrees. Additionally, a few studies have established mean CE angles in normal populations. Ozcelik et al. (28) radiographically measured CE angles in 1,316 normal hips of 658 healthy children and adults (296 male). The mean CE angle of the entire population was 32.5 degrees (12 - 56). The analysis was broken down into 8 age groups: 5-10 years (n = 162), CE angle = 25.2 ± 5.1 (12 - 36); 11 - 15 years (n = 152), CE angle = 30.0 ± 5.6 (17 - 48); 16 - 25 years (n = 186), CE angle = 32.1 ± 6.2 (18 - 52); 26 - 35 years (n = 162), CE angle = 33.0 ± 6.2 (18 - 49); 36 - 45 years (n = 224), CE angle = 34.0 ± 6.8 (16 - 56); 46 - 55 years (n = 214), CE angle = 34.8 ± 6.8 (18 - 52); 56 - 65 years (n = 142), CE angle = 35.5 ± 5.8 (21 - 54); >65 years (n = 74), CE angle = 36.8 ± 6.1 (24 - 52). Similarly, Daysal et al. (29) calculated CE angles on radiographs in 118 adult patients (60 males) without clinical evidence of hip pathology when analyzing the relationship between hip joint space width, CE angle and acetabular depth. Patient age ranged from 20 - 79 years and the mean CE angles were 37 ± 7.1 degrees (18 - 58) for right hips and 35.8 ± 7.1 degrees (20 - 61) for left hips. Lastly,

Fredensborg, N. (30) established normal CE angle means in children and adults. The CE angle mean was 30 degrees (15 - 40) for children and 36 degrees (20 - 46) for adults. Additional research is necessary to establish a CE angle criteria value that identifies of pincer impingement pathology.

2.8 Treatment

The intermittent groin pain of FAI is thought to be caused by the secondary labral lesions because of the presence of nociceptive pain fibers located within the labrum. (6, 36) Individuals with evidence of labral lesions often undergo an arthroscopic debridement of the labral tear; however, this solution does not solve the underlying impingement problem (1, 9, 15) and can possibly provide an explanation for the poor results yielded from labral debridements. (37, 38)

Appropriate treatment of FAI should begin with conservative treatment. This may include activity modification/restriction and decreasing unnecessary demand and motion of the hip. Physical therapy consisting of stretches and ROM exercises only exacerbate the problem and should be avoided. Although NSAID treatment may be recommended to decrease acute pain, it may disguise symptoms of the degenerative process. Conservative treatments may temporarily ease the symptoms in some patients; however, compliance is often low because of the athletic lifestyle of this young patient population. (6, 13)

Once nonsurgical treatments have been proven unsuccessful surgical interventions are explored. FAI can be treated via an open procedure, arthroscopy, or both. (11, 15) The

main goal of surgical treatment for FAI is to increase joint clearance to improve ROM and to alleviate the abnormal contact between the femoral head-neck and the acetabular rim. (13) Femoral neck resection osteoplasty is performed to treat cam impingement and resection osteoplasty of the excessive acetabular rim addresses pincer impingement. (1, 2, 13) During FAI surgery any labral or chondral lesions are debrided or repaired. (9, 39) Short-term studies have evaluated the success of FAI surgical treatment and they have yielded good results for individuals who have early degenerative changes (5, 13-16). Beck et al. (15) treated 19 patients (14 male) for FAI, with open treatment, and found that 4.7 years post surgery 13 patients had good to excellent results using the Merle d'Aubigne hip score; however, 5 of these patients had increasing groin pain and had a total hip arthroplasty (THA) at an average of 3.1 years post FAI treatment. Peters et al. (17) followed 30 patients (16 male) who underwent open hip treatment of FAI for 32 months. Pre-operatively 25 patients were diagnosed with primary FAI, 3 had Legg-Calvé Perthes disease and 1 had slipped capital femoral epiphysis. Post-operatively the patients had an average 17-point improvement on the Harris hip score, which is an improvement from a fair classification to a good classification using Harris' original classification scheme. Although an overall improvement was noted, 8 had degenerative progression and 4 underwent THA. Larson et al. (18) followed 96 patients (100 hips) (54 male) post arthroscopic treatment of FAI. Good to excellent results were observed on the impingement test, Harris hip score, SF-12 score and VAS pain score in 75% of the hips at a minimum of one year. These procedures are not found to be successful in patients with advanced degenerative disease and/or extensive cartilage damage. (5, 15) Although short-term results are promising, the lack of long-term outcome data for surgical treatment of

FAI is problematic. The natural history of FAI and the effect surgery has on the natural history of the disease is unknown. (2, 11) The short-term success of correctional surgery for FAI may be due to pain relief from the labral debridement or repair rather than the bony resections. (11) Long-term follow-up studies are necessary in order to understand the true benefit, or lack thereof, from FAI surgery.

Chapter 3: Methods

3.1 Subjects

We conducted a prospective cross sectional case series of 88 adult volunteer subjects, between the ages of 18 and 80 years who have asymptomatic hips. All volunteers that responded to the advertisement (appendix B) were screened for participation in the study. Volunteers deemed eligible had the study explained to them; all participants' questions were answered and written informed consent was obtained (appendix C). Further screening involved a brief patient history of hip pain and demographic data (appendix D) as well as the hip outcome score (HOS) questionnaire (appendix E). Volunteers were excluded from the study if they had ever experienced any hip pain, injured either or both hips, been treated for hip pain, had surgery on either hip, chronic knee problems, been treated with immunosuppressant therapy or chronic steroids, rated their hip function less than 100% on the HOS questionnaire or were unable to undergo an MRI examination.

3.2 Physical Exam

Volunteers who remained eligible after the initial screening underwent a focused physical examination at the Fowler Kennedy Sport Medicine Clinic by an orthopaedic surgeon with subspecialty training in diagnosing and treating hip pathology to ensure that each volunteer's hips were asymptomatic. Physical examination followed a standard protocol of assessment for the determination of hip impingement and OA (appendix F). The examiner also obtained a Harris Hip Score from each potential participant (appendix G). Volunteers were excluded from the study if they had a positive FABER test, log roll test,

Trendelenberg test or impingement test (40-42) as these tests are suggestive of impingement and degenerative hip pathology. (6) Volunteers were also excluded if they scored less than 100 on the Harris Hip Score.

3.3 MRI Technique

One hip of eligible volunteers was randomly selected to undergo imaging using a high resolution MRI technique. All Imaging was performed using a GE 1.5 tesla scanner with a cardiac 4-channel phased array coil. The following pulse sequences were used: oblique axial proton-density (PD) fast spin echo (FSE) TR 2000msec, TE 12msec, [field of view (FOV) 20cm, slice thickness (Sl) 3.5mm skip 0, matrix 320 x 192, 2 acquisitions]; sagittal FSE PD TR 2166 msec, TE 18 msec, [FOV 20cm, Sl 3mm skip 0, matrix 320x192, 2 acquisitions]; sagittal volume gradient recalled steady state TR 55 msec, TE 15 msec flip angle 35 degrees, [FOV 20cm, Sl 1.8mm skip 0, matrix 320x128, 1 acquisition]; coronal FSE PD fat sat (FS) TR 2150 msec, TE 15.2 msec, [FOV 20cm, Sl 3mm skip 0, matrix 256x192, 2 acquisitions]; coronal T1 TR 400 msec, TE 8 msec, [FOV 20cm, Sl 3mm skip 0, matrix 320x224, 1 acquisition]. Total MRI examination time was approximately 40 minutes.

3.4 MR Image Interpretation

One experienced musculoskeletal radiologist, with a subspecialty in musculoskeletal imaging, evaluated the MR images. The radiologist completed a standardized hip

assessment form (appendix H) identifying markers of FAI and degenerative disease, listed in Table 1, for each participant.

Table 3.1: Possible MRI Abnormalities

FAI Markers	Degenerative Disease Markers
Alpha Angle	Labral Defects
Centre-Edge Angle	Cartilage Defects (acetabular and femoral)
	Paralabral Cysts
	Joint Effusion
	Intraarticular Bodies
	Periarticular Osteophytes
	Os Acetabuli
	Synovial Cysts
	Herniation Pitts
	Interosseous Cysts

The marker used to identify cam impingement is an abnormal alpha angle. Variations in reported alpha angles indicative of pathological FAI exist in the current literature and thus data will be analyzed using 45, 50 and 55 degrees. The alpha angle was calculated from a centre cut axial oblique view and was defined by the angle between two lines. The first line was drawn through the centre of the long axis of the femoral neck and head and the second line was drawn from the centre of the femoral head to the point where the neck extends beyond the confines of a best fit circle drawn around the femoral head (Figure 3.1). The alpha angle is considered to be the simplest method to measure femoral head-neck offset and has a substantial to high degree of intraobserver reliability and a moderate to high degree of interobserver agreement. (7, 9, 24, 26, 34)

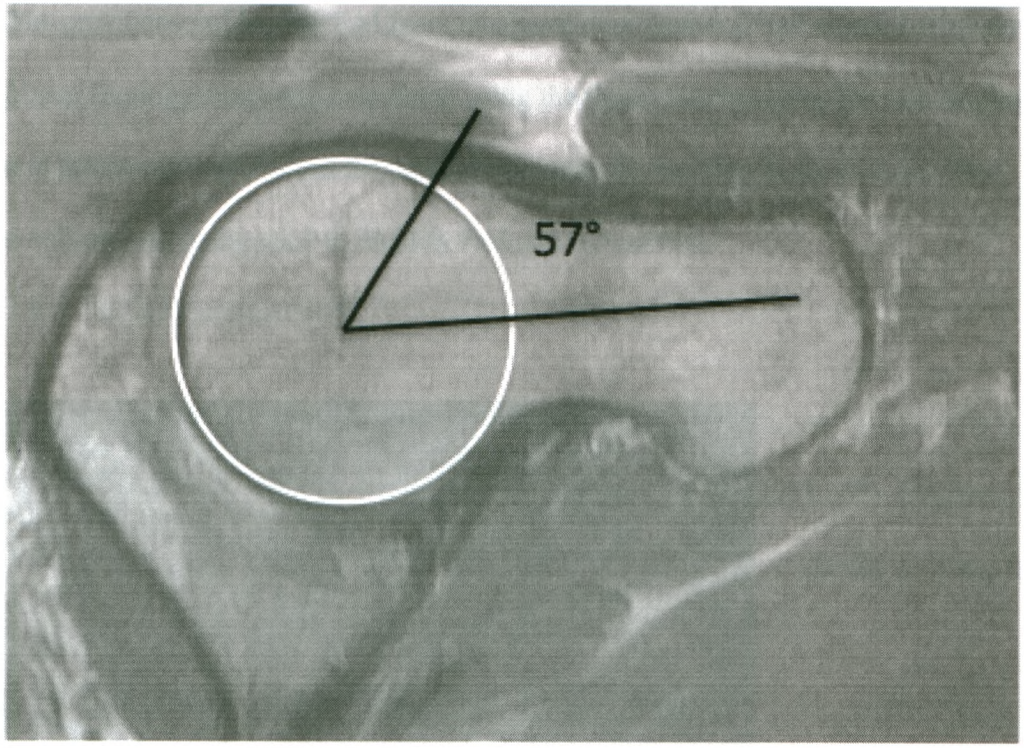

Figure 3.1: MRI of a 24-year-old male displaying an abnormal alpha angle of 57°.

The centre-edge (CE) angle measurement quantifies the anterolateral cover of the acetabulum over the femoral head (23) and a CE angle of greater than 25 degrees is considered to be normal. (7, 43) However, a large CE angle may be indicative of pincer impingement. No pathological criterion exists in the literature to diagnose pincer FAI; therefore, prevalence of pincer impingement will be calculated using a CE angle of 35 and 40 degrees. (17, 27) To measure the CE angle two lines are drawn from the centre of the femoral head on a centre cut coronal view. One is a vertical line drawn straight up through the acetabulum and the second is drawn through the lateral margin of the acetabulum. The angle formed between these two lines is the CE angle (Figure 3.2). (23)

The prevalence of having FAI (cam or pincer impingement) and mixed FAI (cam and pincer impingement) was calculated using the three criteria values for cam impingement and the two criteria values for pincer impingement resulting in six criteria value combinations being used to identify FAI and mixed FAI.

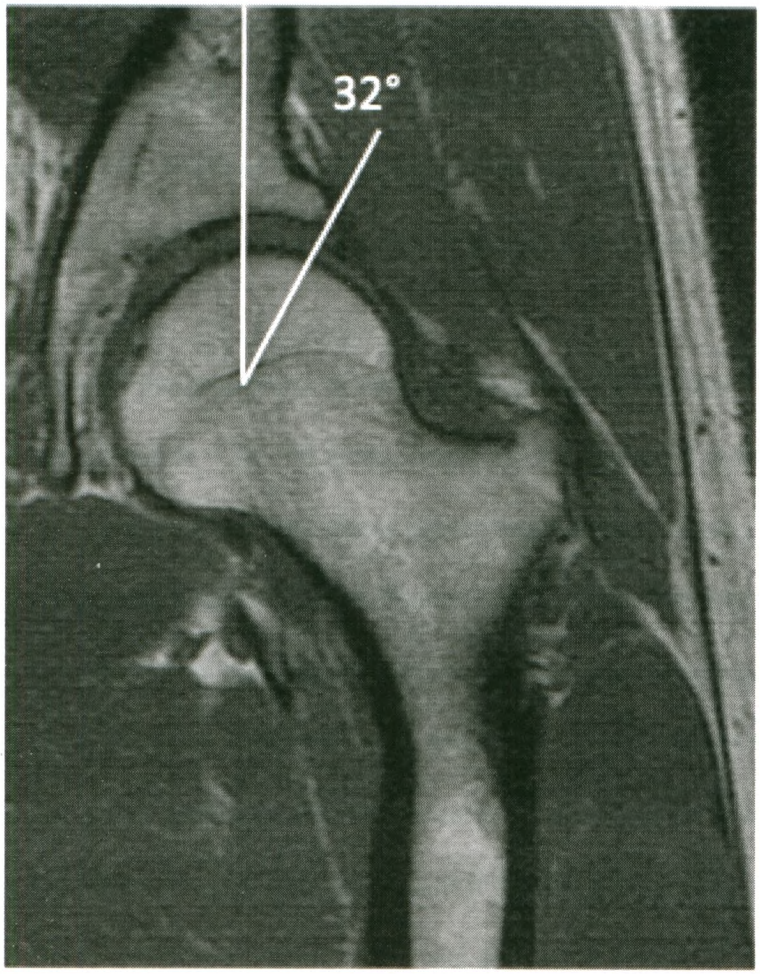

Figure 3.2: MRI of a 25-year-old male displaying a normal CE angle of 32°.

Individuals were identified as having degenerative disease if one or more of the markers of degenerative disease were present. All MRI findings of degenerative disease were classified as present or absent.

3.5 Statistical analysis:

The sample size was based on the hypothesis that the prevalence of the FAI for age groups I, II and II would be 10, 40 and 70% respectively. Using a 95% confidence level and half the width of the confidence interval of .15, the sample size requirement was 15, 41, and 36 individuals for group I, II and III respectively.

We report the proportion of participants in each of the three age groups (Group I = < 30 years, Group II = 30 - 50 years, Group III = > 50 years) with cam or pincer impingement (FAI), cam impingement alone, pincer impingement alone, and both cam and pincer impingement (mixed FAI). A Pearson's Chi square test was used to determine whether the proportion of participants with an FAI marker varied significantly across these age groups. We also report the mean and standard deviation of the alpha and CE angle for those participants who meet the criteria for the presence of the FAI marker. Cam impingement was defined as present if the alpha angle was greater than 45, 50 and 55 degrees and pincer impingement was defined as present if the CE angle was greater than 35 and 40 degrees.

To determine the strength of the association between FAI markers and early OA, we used logistic regression where the presence or absence of an OA marker was the dependent

variable and the presence or absence of FAI (according to the six different criteria for FAI defined above) was the independent variable. We report the odds ratio of having a marker of OA if an FAI marker was present adjusted for age in years. We include a 95% confidence interval around this odds ratio.

Chapter 4: Results

4.1 Demographic Data

Eighty-eight asymptomatic volunteers (42 male) with a mean age of 44.5 ± 13.8 years (21 - 77) were imaged. Images were analyzed within three age groups: group I contained 15 participants (6 male) with a mean age of 24.9 ± 2.0 years (21 - 28); group II contained 40 participants (23 male) with a mean age of 39.8 years (30 - 49); and group III contained 33 participants (13 male) with a mean age of 59.1 years (50 - 77). There were no significant differences between genders among the groups ($P = 2.81$).

4.2 Mean alpha and centre-edge angles

The mean alpha angle of the entire population was 43.40 ± 6.23 degrees and the mean CE angle was 34.53 ± 6.42 degrees. The youngest age group (group I) had a mean alpha angle of 42.89 ± 5.76 degrees and a CE angle of 32.67 ± 5.68 degrees, group II had a mean alpha angle of 42.60 ± 6.35 degrees and a CE angle of 35.07 ± 6.95 degrees, and the oldest age group (group III) had a mean alpha angle of 44.55 ± 6.29 degrees and a CE angle of 34.73 ± 6.09 degrees. Males had a mean alpha angle of 44.83 ± 6.52 degrees and a mean CE angle of 33.69 ± 6.32 degrees, whereas females had a mean alpha angle of 42.09 ± 5.71 degrees and a mean CE angle of 35.28 ± 6.48 degrees.

4.3 Prevalence of FAI

The prevalence of FAI (either cam or pincer impingement) in this asymptomatic population ranged from 23.9 to 67.0% depending on the alpha angle and CE angle used to establish cam and pincer impingement pathology (Table 4.1). There were no significant differences between prevalence of FAI, for each of the criteria values, among the three age groups; *P*-values are listed in table 4.1. The mean alpha angle and CE angle of participants with FAI using the three critical alpha angles to identify cam impingement and the two CE angle criteria values to identify pincer impingement are also displayed in Table 4.1.

Table 4.1: Prevalence of FAI (cam or pincer impingement), in each age category with corresponding *P*-value, alpha angle means and CE angle means of individuals with FAI calculated using six different criteria values.

	Group I (n = 15)	**Group II (n = 40)**	**Group III (n = 33)**	***P*-value**	**Total (n = 88)**	**Mean α-angle**	**Mean CE angle**
45° α-angle 35° CE-angle	8 (9.1%)	28 (31.8%)	23 (26.1%)	.46	59 (67.0%)	44.75 ± 6.62	36.88 ± 6.24
50° α-angle 35° CE-angle	7 (8.0%)	25 (28.4%)	19 (21.6%)	.57	51 (58.0%)	44.33 ± 7.02	38.26 ± 5.45
55° α-angle 35° CE-angle	7 (8.0%)	23 (26.1%)	17 (19.3%)	.74	53.4%)	43.62 ± 6.87	39.20 ± 4.55
45° α-angle 40° CE-angle	5 (5.7%)	19 (21.6%)	18 (20.5%)	.39	42 (47.7%)	46.78 ± 6.41	36.85 ± 7.38
50° α-angle 40° CE-angle	3 (3.4%)	13 (14.8%)	11 (12.5%)	.61	27 (30.7%)	46.63 ± 7.97	39.24 ± 7.33
55° α-angle 40° CE-angle	3 (3.4%)	9 (10.2%)	9 (10.2%)	.83	21 (23.9%)	45.07 ± 8.39	41.67 ± 5.81

4.4 *Prevalence of cam impingement*

Prevalence of cam impingement, within the three age categories, and alpha angle means using three alpha angle criteria values are listed in Table 4.2. There were no significant differences between prevalence of cam impingement, for each of the criteria values, among the three age groups; *P*-values are listed in table 4.2. Males had 18, 10 and 4% prevalence and females had 14, 3 and 0% prevalence of cam impingement when using an alpha angle criterion of 45, 50 and 55 degrees respectively. There were significant differences between sexes when using 50 and 55 degree criteria values ($P < .05$); however, no significant difference in prevalence was found when using 45 degrees ($P = .23$). The radiologist could not determine two alpha angles due to missing axial oblique sequences; these missing values were assumed to be normal.

Table 4.2: Prevalence cam impingement, within the three age groups with corresponding *P*-value, and the mean alpha angle and CE edge angle of individuals with FAI using six different criteria values.

	Group I (n = 15)	**Group II (n = 40)**	**Group III (n = 33)**	***P*-value**	**Total (n = 88)**	**Mean α-angle**
45° α-angle	4 (4.7%)	12 (14.0%)	16 (18.6%)	.22	32 (37.2%)	49.65 ± 3.81
50° α-angle	1 (1.2%)	5 (5.8%)	7 (8.1%)	.39	13 (15.1%)	53.36 ± 2.66
55° α-angle	1 (1.2%)	1 (1.2%)	2 (2.3%)	.73	4 (4.7%)	56.75 ± 1.71

4.5 *Prevalence of pincer impingement*

Prevalence of pincer impingement, within the three age groups, and mean CE angles are presented in Table 4.3 using two different CE angles to identify pincer impingement

pathology. Males had 19 and 7% prevalence and females had 26 and 10% prevalence of pincer impingement when using a CE angle criteria value of 35 and 40 degrees respectively. There were no significant differences between sexes (35°, $P = .24$; 40°, $P = .55$). There were no significant differences between prevalence of pincer impingement, for each of the criteria values, among the three age groups; *P*-values are listed in Table 4.3.

Table 4.3: Prevalence of pincer impingement, in each age category with corresponding *P*-value, and CE angle mean of individuals with pincer impingement calculated using two different criteria values.

	Group I (n = 15)	**Group II (n = 40)**	**Group III (n = 33)**	***P*-value**	**Total (n = 88)**	**Mean CE-angle**
35° CE-angle	6 (6.9%)	22 (25.3%)	17 (19.5%)	.56	45 (51.7%)	39.72 ± 3.88
40° CE-angle	2 (2.3%)	8 (9.3%)	7 (8.1%)	.78	17 (19.8%)	43.88 ± 2.89

4.6 Prevalence of mixed impingement

The number of individuals presenting with normal hips, cam impingement, pincer impingement and mixed impingement (cam and pincer impingement) using each criteria value is listed in table 4.4. Prevalence of mixed impingement within the three age groups and the mean alpha angle and CE edge angle of individuals with mixed impingement, using six different criteria values, is listed in Table 4.5. There were no significant differences between prevalence of mixed FAI, for each of the criteria values, among the three age groups; *P*-values are listed in table 4.5.

Table 4.4: Number of individuals presenting with each type of impingement within the asymptomatic population. (n = 88)

	Normal	Pincer	Cam	Mixed
45° α-angle 35° CE-angle	11	45	32	18
50° α-angle 35° CE-angle	30	45	13	7
55° α-angle 35° CE-angle	39	45	4	2
45° α-angle 40° CE-angle	39	17	32	7
50° α-angle 40° CE-angle	58	17	13	3
55° α-angle 40° CE-angle	67	17	4	0

Table 4.5: Prevalence of mixed impingement (cam and pincer impingement), within the three age groups with corresponding *P*-value, and the mean alpha angle and CE edge angle of individuals with mixed impingement using six different criteria values.

	Group I (n = 15)	Group II (n = 40)	Group III (n = 33)	*P*-value	Total (n = 88)	Mean α-angle	Mean CE angle
45° α-angle 35° CE-angle	2 (2.3%)	6 (6.8%)	10 (11.4%)	.21	18 (20.5%)	48.98 ± 3.57	40.02 ± 3.67
50° α-angle 35° CE-angle	0 (0%)	2 (2.3%)	5 (5.7%)	.13	7 (8.0%)	52.73 ± 2.39	39.63 ± 3.19
55° α-angle 35° CE-angle	0 (0%)	0 (0%)	2 (2.3%)	.18	2 (2.3%)	55.50 ± 0.71	37.00 ± 2.83
45° α-angle 40° CE-angle	1 (1.1%)	1 (1.1%)	5 (5.7%)	.14	7 (8.0%)	48.79 ± 3.16	43.86 ± 2.55
50° α-angle 40° CE-angle	0 (0%)	0 (0%)	3 (3.4%)	.08	3 (3.4%)	51.83 ± 1.76	42.67 ± 0.58
55° α-angle 40° CE-angle	0 (0%)	0 (0%)	0 (0%)	N/A	0 (0%)	N/A	N/A

4.7 Degenerative Disease

Sixty-two (70.5%) of the 88 individuals had at least one marker of degenerative disease. There were no significant differences between prevalence of degenerative disease among the three age groups (group I = 11.4%, group II = 30.7% and group III = 28.4%; $P = .70$). The number of individuals presenting with each type of degenerative disease within age

categories is listed in Table 4.6. No presence of intraarticular bodies or joint effusion was evident in any of the 88 asymptomatic volunteers. Logistic regression was preformed to determine whether prevalence of FAI was a predictor of prevalence of degenerative disease (Table 4.7). Prevalence of FAI measured with the highest criteria value, 55 degree alpha angle and 40 degree CE angle, was a significant predictor of acetabular cartilage lesions (OR = 7.41 (1.56 - 35.33), $P = .01$). Prevalence of FAI measured with a 50 degree alpha angle and a 40 degree CE angle was a significant predictor of periarticular osteophytes (OR = 3.73 (1.30 - 10.69), $P = .02$) and labral lesions (OR = .15 (.03 - .68), $P = .02$).

Table 4.6: Number of individuals presenting with each type of degenerative disease within age groups.

	Group I (n = 15)	**Group II (n = 40)**	**Group III (n = 33)**	**Total (n = 88)**	***P*-value**
Any Marker of Degenerative Disease	10 (11%)	27 (31%)	25 (76%)	62 (70%)	.70
Labral Lesions	4 (5%)	10 (11%)	9 (10%)	23 (26%)	.98
Labral Degeneration	5 (6%)	12 (14%)	16 (18%)	33 (38%)	.25
Acetabular Cartilage Lesions	0	5 (6%)	4 (5%)	9 (10%)	.35
Femoral Cartilage Lesions	2 (2%)	4 (5%)	3 (3%)	9 (10%)	.91
Herniation Pitts	2 (2%)	2 (2%)	3 (3%)	7 (8%)	.57
Paralabral Cysts	1 (1%)	2 (2%)	3 (3%)	6 (7%)	.77
Synovial Cysts	0	3 (3%)	1 (1%)	4 (5%)	.43
Os Acetabuli	2 (2%)	3 (3%)	1 (1%)	6 (7%)	.41
Interosseous Cysts	2 (2%)	7 (8%)	3 (3%)	12 (14%)	.58
Periarticular Osteophytes	2 (2%)	9 (10%)	9 (10%)	20 (23%)	.57
Intraarticular Bodies	0	0	0	0	0
Joint Effusion	0	0	0	0	0

Table 4.7: The odds of having a marker of degenerative disease if you have FAI controlling for age. (OR (95% CI), *P*-value)

	45° α-angle 35° CE-angle	**50° α-angle 35° CE-angle**	**55° α-angle 35° CE-angle**	**45° α-angle 40° CE angle**	**50° α-angle 40° CE angle**	**55° α-angle 40° CE angle**
All Signs of Degenerative Disease	.62 (.22-1.73), *P*=.36	.95 (.37-2.44), *P*=.92	.93 (.37-2.36), *P*=.88	.81 (.32-2.07), *P*=.66	.92 (.33-2.52), *P*=.87	.99 (.33-2.97), *P*=.99
Labral Lesions	.53 (.20-1.42), *P*=.21	.34 (.13-.92), *P*=.03	.45 (.17-1.20), *P*=.11	.47 (.18-1.29), *P*=.14	.15 (.03-.68), *P*=.02	.22 (.05-1.06), *P*=.06
Labral Degeneration	.70 (.28-1.80), *P*=.46	.59 (.24-1.45), *P*=.25	.68 (.28-1.64), *P*=.39	.77 (.32-1.88), *P*=.57	.53 (.19-1.44), *P*=.21	.70 (.24-2.03), *P*=.51
Acetabular Cartilage Lesions	0	0	0	3.43 (.64-18.52), *P*=.15	4.62 (1.00-21.33), *P*=.05	7.41 (1.56-35.33), *P*=.01
Femoral Cartilage Lesions	4.31 (.51-36.45), *P*=.18	6.65 (.79-55.93), *P*=.08	8.25 (.98-69.27), *P*=.05	.83 (.20-3.38), *P*=.79	1.94 (.47-8.00), *P*=.36	2.98 (.71-12.53), *P*=.14
Herniation Pitts	.35 (.07-1.72), *P*=.20	.27 (.05-1.51), *P*=.14	.13 (.02-1.14), *P*=.07	.43 (.08-2.40), *P*=.34	.38 (.04-3.33), *P*=.38	0
Paralabral Cysts	.08 (.01-.73), *P*=.03	.12 (.01-1.06), *P*=.06	.15 (.02-1.33), *P*=.09	.20 (.02-1.77), *P*=.15	0	0
Synovial Cysts	1.33 (.13-13.67), *P*=.81	2.04 (.20-20.78), *P*=.55	2.56 (.25-25.92), *P*=.43	.938 (.12-7.22), *P*=.95	2.07 (.27-15.94), *P*=.48	3.03 (.39-23.59), *P*=.29
Os Acetabuli	3.16 (.34-29.45), *P*=.31	1.78 (.30-10.67), *P*=.53	.96 (.18-5.16) *P*=.96	7.67 (.82-71.43), *P*=.07	3.10 (.55-17.62), *P*=.20	1.96 (.32-12.06), *P*=.47
Interosseous Cysts	.42 (.12-1.45), *P*=.17	.45 (.13-1.56), *P*=.21	.37 (.10-1.36), *P*=.14	.73 (.21-2.53), *P*=.61	1.12 (.30-4.15), *P*=.87	1.04 (.25-4.32), *P*=.95
Periarticular Osteophytes	1.52 (.48-4.75), *P*=.48	1,84 (.62-5.41), *P*=.27	1.35 (.48-3.76), *P*=.57	2.32 (.81-6.63), *P*=.12	3.73 (1.30-10.69), *P*=.02	2.63 (.88-7.86), *P*=.08

Chapter 5: Discussion

This study focused on establishing the prevalence of FAI in the asymptomatic population using three criteria alpha angles to establish cam impingement and two criteria CE angles to identify pincer impingement. Depending on the criteria values used the prevalence of FAI ranged from 23.9 to 67.0%. This study also determined that there was no significant association between age and prevalence of FAI and the highest criteria value, 55 degree alpha angle and 40 CE angle, was a significant predictor of acetabular cartilage lesions.

Cam impingement was identified on the MR images by using the alpha angle measurement to quantify the concavity of the anterior femoral neck. (7) The alpha angle measurement has proven interobserver and intraobserver agreement among radiologists and orthopaedic surgeons. (7, 22, 24) Notzli et al. (7) constructed the alpha angle measurement using oblique axial magnetic resonance imaging scans of 39 subjects (16 male) with suggested impingement and 35 asymptomatic controls (17 male). The average alpha angle was 74 degrees (55 - 95) for the symptomatic group and 42 degrees (33 - 48) for the controls. Many authors use this study to determine imaging criteria for hip pathology; however, this study did not propose a criteria angle for cam impingement and in the literature there is little consensus. The Notzli et al. (7) study found the mean normal alpha angle to be 42 degrees and Fraitzl et al. (25) used this value to compare their radiographic findings of FAI in 19 patients with mild slipped capital femoral epiphysis. Whereas Kassarjian et al. (21) and Pfirrmann et al. (20) used a pathological criteria value of 55 degrees in their studies that established characteristic MRA findings

of patients with FAI. It is suggested that an alpha angle of greater than 50 degrees represents abnormal hip morphology and an alpha angle of 55 degrees is more specific to impingement; (9, 20) however, supporting primary research is lacking. Furthermore, Gosvig et al. (22, 24) conducted two studies attempting to establish the prevalence of cam impingement. In the 2007 study the Gosvig group analyzed 2,803 radiographs (1,055 male) for the prevalence of cam impingement and used a criteria value of 65 degrees and in the 2008 study they analyzed 3,202 radiographs (1,184 male) for prevalence of cam impingement and used a criteria value of 83 degrees for males and 57 degrees for female subjects, due to inherent differences between proximal femoral anatomy. Evidently, there is no reported consensus regarding alpha angle criteria values that define normality and/or cam impingement. Thus, in the current study we established the prevalence of cam impingement using three alpha angle criteria values (45, 50 and 55 degrees).

The mean alpha angle of our sample from the asymptomatic population was 43.40 ± 6.23 degrees. Males had a mean alpha angle of 44.83 ± 6.52 degrees and females had a mean alpha angle of 42.09 ± 5.71 degrees, which is lower than what was reported by Gosvig et al. (24) who found a mean alpha angle of 55 degrees (30 - 100) in males and 45 degrees (34 – 108) in females. Differences between their study and ours could be explained by the difference in the samples. The Gosvig study did not limit their participants to those without symptoms instead they examined AP radiographs from 4,151 participants (1,533 male) from a randomly selected cohort and excluded anyone with radiographic evidence of OA (increased joint space, CE angle $\geq 20^{\circ}$, a Tönnis index of ≥ 0.8 and ≤ 1.2 or childhood developmental abnormalities of the hip). Another study by Gosvig et al. (22)

found the mean alpha angle of males to be 51.9 ± 13.1 degrees for the right hip and 53.2 ± 12.1 degrees for the left hip and 44.5 ± 5.2 degrees and 45.5 ± 5.4 degrees for females respectively. Similar to the first study by this group, the mean alpha angle of males was higher than the mean alpha angle of males that we observed. Our results in female participants were similar to those reported in these two studies. These differences can be explained due to the fact that the Gosvig studies used randomly selected cohorts that were only screened for radiographic hip osteoarthrosis; therefore, these participants could have symptomatic hip pathology, which would explain an increased mean alpha angle.

The prevalence of cam impingement was 37.2, 15.1 and 4.7% (18, 10 and 4% for males and 14, 3 and 0% for females) depending on the alpha angle criterion that was used, 45, 50 and 55 degrees respectively. Gosvig (24) reported a 6% prevalence of cam impingement in males and a 2% prevalence in females using a pathological criteria value of 65 degrees. These results are similar to the prevalence of cam impingement found in our study when using a 55 degree criteria value for males and a 50 degree criteria value for females. Similarly, when using an 83 degree criteria value for males and a 57 degree criteria value for females, Gosvig (22) found a 17% prevalence of cam impingement in males and a 4% prevalence in females, which is similar to the findings in our study when using an alpha angle criteria value of 50 degrees. The inconsistencies in the findings could be due to the fact that the Gosvig studies did not screen for hip symptomology, which may mean that some individuals have symptomatic or asymptomatic impingement, which would increase the prevalence rates. Due to the findings in our study of true asymptomatic individuals the prevalence rates in the Gosvig studies should be higher

than what was observed as their populations may include individuals with symptomatic FAI.

Cam impingement is considered to be more prominent in the male population (1, 13), this is supported by our findings with significantly more males having cam impingement when using the 50 and 55 degree criteria values ($P < .05$). These significant sex-related differences are consistent with the findings of the two Gosvig studies. These findings indicate that higher criteria values are more indicative of clinically significant FAI as the results found resemble results found in symptomatic populations. However, this finding of significance may be a spurious finding due to multiple comparisons applied during statistical analysis. If the Bonferonni correction was applied no significant differences would have been found between male and female prevalence rates.

The mean alpha angle of individuals with cam impingement was 49.65 ± 3.81 degrees when using a 45 degree criteria value, 53.36 ± 2.66 degrees when using a 50 degree criteria value and 56.75 ± 1.71 degrees when using a 55 degree criteria value. These results are consistently lower than the alpha angle means established in symptomatic populations. Fraitzl et al. (25) found a mean alpha angle of 86 degrees (45 - 90) in patients with slipped capital femoral epiphysis being treated for FAI. The increased alpha angles in the Fraitzl study could have been caused by the underlying developmental abnormality of individuals included in this study. Kassarjian et al. (21) used a criteria value of 55 degrees and found a mean alpha angle of 69.7 degrees (40.8 - 91.3) in 39 hips with clinical cam impingement. Similarly, Pfirrmann et al. (20) used a criteria value of 55

degrees and found a mean alpha angle of 68 ± 19 degrees in 50 patients with FAI. The mean alpha angle findings in the previous two studies may be higher, than angles found in the current study, because the patient population is seeking treatment for symptomatic FAI; whereas, our study calculated the mean alpha angle of asymptomatic individuals identified as having cam impingement. Pain is the symptom that causes most individuals with FAI to seek treatment and it is thought that the pain experienced with FAI is due to the underlying soft tissue damage to the labrum as that is where the nociceptive fibers are located (6, 10, 36). It is suggested that the bony abnormalities associated with cam impingement cause damage to the labrum, resulting in joint pain, as well as bony proliferation of the femoral head-neck prominence, which would increase the alpha angle measurement. (9) Therefore, asymptomatic individuals presenting with cam impingement may have been found early in the natural progression of FAI and thus not yet have damage to the labrum and present with a smaller alpha angle.

In the current study, a large CE angle on MR images was used to classify pincer impingement. The CE angle was first described by Wiberg (35) and measures the anterior coverage of the femoral head by the acetabulum and can indirectly be indicative of pincer impingement. A criteria value defining pincer impingement pathology has not been established. Two studies have established CE angle means in symptomatic populations. A study by Reynolds et al. (27) found a mean CE angle of 35 ± 2 degrees in 43 patients with pincer impingement and found a mean CE angle of 30 ±2 degrees in 174 controls. Similarly, Peters et al. (17) reported a mean CE angle of 28 degrees (8 - 50) in 30 hips (29 patients) being treated for FAI. A few other studies have established mean CE angles

in normal populations. Ozcelik et al. (28) established a mean CE angle of 32.5 degrees (12 - 56) in 1,316 normal hips (658 patients; 296 male). Daysal et al. (29) analyzed plain radiographs of 118 adults without clinical evidence of hip pathology and found a mean CE angle of 37.0 ± 7.1 degrees (18 - 58) for right hips and 35.8 ± 7.1 degrees (20 – 61) for left hips. Finally, Fredensborg, N. (30) established a mean CE angle of 36 degrees (20 - 46) for normal adults. The established CE angle means, standard deviations and/or ranges of the symptomatic populations overlap with the means, standard deviations and/or ranges of the normal populations; however, it is possible that individuals with high CE angles in the normal population are living with asymptomatic pincer impingement. In the current study, pathological criteria values of 35 and 40 degrees were used to establish the prevalence of pincer impingement.

The mean CE angle of all 88 asymptomatic volunteers was 34.53 ± 6.42 degrees. The 42 males had a mean CE angle of 33.69 ± 6.32 degrees and the 46 females had a mean CE angle of 35.28 ± 6.48 degrees. This is consistent with the findings in the literature: Ozcelik et al. (28) established a mean CE angle of 32.5 degrees (12 - 56) in 1,316 normal hips; Daysal et al. (29) found a mean CE angle of 37.0 ± 7.1 degrees (18 - 58) for right hips and 35.8 ± 7.1 degrees (20 – 61) for left hips in 118 normal individuals; and Fredensborg, N. (30) established a mean CE angle of 36 degrees (20 - 46) for normal adults.

The prevalence of pincer impingement was 51.7% when using a 35 degree CE angle criteria value and 19.8% when using a 40 degree CE angle criteria value. There are no

known studies that have established the prevalence of pincer impingement within an asymptomatic population. The mean CE angle of the asymptomatic population was found to be 34.53 ± 6.42; thus, using a pathological criteria value of 35 degrees yields a very high prevalence of pincer impingement. However, Reynolds et al. (27) found a mean CE angle of 35 ± 2 degrees in 43 patients symptomatic with pincer impingement and Peters et al. (17) found a mean CE angle of 28 degrees (8 - 50) in 30 hips (29 patients) being treated for FAI. The 40 degree criteria value is greater than the CE angle means of populations without hip pathology and falls outside the majority of the mean standard deviations and thus may be a better criterion for pincer impingement. However, CE angles measured from symptomatic hips range from 8 to 50 degrees; therefore, a high CE angle may not be the best indicator of pincer impingement. In symptomatic populations the prevalence of pincer FAI is higher in females than in males. For example, Pfirrmann et al. (20) analyzed MRA findings of patients with FAI and found significantly more females (14 of 17) had pincer impingement. In the current study females had a higher prevalence of pincer impingement than males using both CE angle criteria values; however, there were no significant differences in prevalence between the sexes (35°, P = .242; 40°, P = .549). No known studies have established the validity and reliability of CE angle measurements of impingement. Future research should test the CE angle measure to assess its validity and reliability in determining pincer impingement.

The prevalence of either cam or pincer FAI was established using each alpha angle criteria value and each CE angle criteria value producing six criteria value combinations. Prevalence of FAI ranged from 23.9 – 67.0% depending on the combination of criteria

values used. There is no known literature that has established prevalence of FAI in the asymptomatic population. Future research needs to establish accurate alpha angle and CE angle criterion to define normal, borderline pathology and definite impingement pathology.

The hypothesized prevalence was 10% in group I, 40% in group II, and 70% in group III. For the majority of the criteria values used for each of the types of FAI measured, these prevalence rates were not found indicating that our sample size may not have had enough power to establish the prevalence among the asymptomatic population. Additionally, multiple comparisons were applied to this population when looking for FAI, mixed FAI, cam impingement and pincer impingement, which decreases the power further.

Previous studies have found that cam and pincer impingement occur together more often than they occur independently. For example, Beck et al. (10) radiographically evaluated 149 patients with FAI; 26 were observed to have isolated cam impingement (24 male) and only 16 presented with isolated pincer impingement (2 male). Additionally, Phillippon et al. (8) studied 301 patients (153 males) with FAI and 50 patients had pincer impingement, 100 patients had cam impingement and the majority, 151 patients, had both cam and pincer impingement. This trend was not observed in our study. Generally, more individuals presented with pincer impingement than cam impingement, and mixed impingement was the least prevalent. This inconsistency is most likely related to using the CE angle measurement to identify pincer impingement, which caused an increased prevalence of pincer impingement. If FAI is involved in the progression of degenerative

disease this finding may be explained by the fact that these individuals are asymptomatic and therefore presenting early in the degenerative process. Developing both anatomic variations may be part of the degenerative process.

No significant differences of prevalence were found between age groups. This finding could indicate that no relationship exists between age and prevalence. If there is a true association between age and FAI, the lack of significant differences between groups may have been due to a lack of power. The sample size for this study was based on determining prevalence of FAI within three age groups not determining whether a difference exists between prevalence among the three age groups.

Early detection and treatment of FAI is suggested because of the role impingement plays in the degenerative process. It is believed that if the bony abnormalities are surgically resected, joint clearance will be improved and there will no longer be abnormal bony contact between the femoral head-neck and the acetabular rim; thus, eliminating the impact that causes damage to the labrum and adjacent cartilage. However, the relationship between FAI and OA is not well defined and long-term studies determining the success of surgical treatment are lacking. Sixty-two of the eighty-eight (70.5%) asymptomatic individuals in this study presented with at least one form of degenerative disease; however, there was no correlation between degenerative disease and age (P = .70). Many studies indicate the close relationship between FAI and labral tears. Pfirrman et al. (20) analyzed MRA findings of 50 patients with FAI and found 94% presented with anterosuperior labral lesions and 84% presented with anterosuperior cartilage lesions.

Additionally, Phillippon et al. (8) found 99% of 301 patients with FAI had associated labral pathology and 82% had associated cartilage damage. Furthermore, Kassarjian et al. (21) found that 100% of 40 patients with FAI had anterosuperior labral tears and 95% had chondral abnormalities. When logistic regression was performed prevalence of FAI using the highest criteria value, 55 degree alpha angle and 40 degree CE angle, was a significant predictor of acetabular cartilage lesions. This suggests that using high criteria value is more indicative of clinically significant FAI. Prevalence of FAI, using a 50 degree alpha angle and a 40 degree CE angle, was a significant predictor of labral lesions and periarticular osteophytes. This is likely to be a spurious finding, as the significant predictability does not increase with an increase in criteria values. This relationship could have resulted from the multiple comparisons applied during statistical analysis. We were underpowered to answer this question as the basis of our sample size was finding the prevalence of FAI within the three age categories. If the Bonferroni correction for multiple comparisons is applied it decreases the p-value and prevalence of FAI would not have been found as a significant predictor of OA suggesting that an association may not exist between FAI and OA.

In our study, prevalence of FAI using the lower criteria values did not predict the prevalence of markers of degenerative disease. The lack of association may be explained by the questionable validity of the CE angle as a measure of pincer impingement and/or because this study is analyzing an asymptomatic population. These individuals could be presenting at an early stage of the degenerative process and thus no physical signs of degeneration, other than the bony abnormalities, are present. The lack of association may

also have been caused by a lack of power. Our sample size was not calculated to establish this association.

Considering FAI as a cause of OA is a recent development and does not have any proven association. When critically thinking about this association one must keep in mind the popularized theory of subacromial impingement. It was suggested in 1972 by Neer, C. S. (44) that variations in the shape of the acromion of the shoulder cause impingement of the rotator cuff against the coracoacromial arch leading to degeneration and tears of the rotator cuff tendons. However, further research proved that primary impingement was unlikely the cause of rotator cuff tendinosis. (45-47) Assuming a cause and effect relationship between FAI and OA before the true association has been established could result in patients having unnecessary and ineffective osteotomies. Future research is required to establish to true relationship between FAI and OA.

Using MRI as the imaging modality as opposed to MRA may have been a limitation to this study, as it is suggested that MRA is more sensitive to identifying labral and chondral defects; however, it is difficult to recruit asymptomatic individuals to undergo a gadolinium injection. Using the CE angle measurement to identify pincer impingement rather than using a more direct method of identification may have also been a limitation.

In conclusion, FAI is prevalent in the asymptomatic population. Asymptomatic alpha angle and CE angle means have been established. Prevalence of FAI, identified using high criteria values (55 degree alpha angle and 40 degree CE angle), predicts the presence

of acetabular cartilage lesions. The lower criteria values were not predictive of degenerative disease suggesting that high criteria values are more indicative of clinically significant FAI. Additional research needs to be done to establish valid and reliable radiological measures of cam and pincer impingement. The natural history of FAI needs to be investigated to understand the true relationship between FAI and age and FAI and OA.

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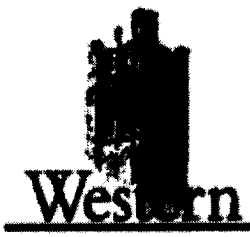
Appendices

Appendix A

Ethics Approval Notice



Office of Research Ethics

The University of Western Ontario
Room 00046 Dental Sciences Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
Website: www.uwo.ca/research/ethics

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. K. Willis

Review Number: 13838E **Review Level:** Expedited

Review Date: October 10, 2007

Protocol Title: The Presence of Markers for Femoroacetabular Impingement in Asymptomatic Individuals

Department and Institution: Surgery, University of Western Ontario

Sponsor:

Ethics Approval Date: November 9, 2007 **Expiry Date:** April 30, 2008

Documents Reviewed and Approved: UWO Protocol, Letter of Information and Consent, Advertisement.

Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Science Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

Chair of HSREB: Dr. John W. McDonald

Ethics Officer to Contact for Further Information			
☐ Janice Sutherland (jsutherland@uwo.ca)	☐ Jennifer McEwen (jmcewen@uwo.ca)	☑ Grace Kelly (grace.kelly@uwo.ca)	☐ Denise Grafton (dgrafton@uwo.ca)

This is an official document. Please retain the original in your files.

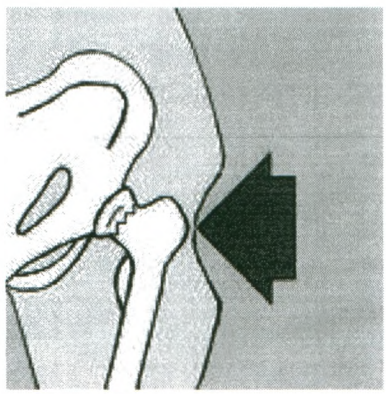
cc: ORE File
LHRI

Appendix B

Study Advertisement

FOWLER KENNEDY
SPORT MEDICINE CLINIC

HIP STUDY



Are your hips normal? If you do not presently have hip pain and have never had significant hip pain in the past you could qualify for a study being conducted at the Fowler Kennedy Sport Medicine Clinic looking at normal variations in hip anatomy. If you are interested in participating, please contact Beth at ext. to arrange an appointment.

Appendix C

Letter of Information and Consent Form

K. Willits
email:

The Presence of Femoro-Acetabular Impingement in Asymptomatic Individuals

You are being invited to participate in this study because you are between the ages of 18 and 80 years old, and you do not experience any pain in your hip, at rest or during physical activity. This research study will be attempting to assess the presence of variations in normal hip anatomy in 92 volunteers.

Hip pain is a common condition. Abnormal bone contact and pinching of the soft tissue in the hip has been identified as a frequent cause of hip pain and this condition has been named Femoro-Acetabular Impingement (FAI). Also, it has been suggested that FAI can also lead to arthritis within the hip joint. Earlier studies on FAI have described abnormal findings in the hips of patients presenting with pain. Newer imaging studies however, have shown normal variations in the hips of subjects experiencing no pain. Thus, it is possible that variations in hip anatomy commonly associated with FAI, may exist in the pain free hip, and the presence of such variations may be correlated with age.

A diagnosis is usually made after the individual has shown signs and symptoms of FAI in both physical examination and imaging (MRI). The study you are being asked to participate in is investigating whether people who do NOT show symptoms of hip pain show signs of FAI when evaluated with MRI. Additionally the study is interested in determining whether these signs, if visible upon MRI, are influenced by age. Lastly, the study would like to see if indicators of FAI are related to indicators of arthritis and other causes of pain in the hip.

Procedure
Participation in this study will require you to complete a Hip Outcome Questionnaire which includes 30 questions that ask you about your current level of function in both daily living and in sport related activity. In addition to this questionnaire, you will be asked general information such as your age, gender, telephone number, health history, and general screening information, including you medical history. It will take approximately 10 minutes to complete this section.

You will be assessed during a physical examination to confirm that you meet the criteria for enrolment into this study and you will be asked to fill out another hip function questionnaire called the Harris Hip Score for hip pain. The assessment will be performed at the Fowler Kennedy Sports Medicine Clinic by Dr. Willits or Dr. Wotherspoon and it should take approximately 20 minutes to complete.

Pt. Initials ____

After your eligibility has been confirmed, you will undergo Magnetic Resonance Image (MRI) of one of your hip joints which will be chosen at random. This will be done under the supervision of an experienced radiologist at University Hospital. The MRI is a non invasive procedure and will take approximately 1 hour to complete.

Risks

The Food & Drug Administration (USA) has indicated that for clinical diagnosis an 'insignificant' risk is associated with human MRI exposure at the intensities used in this project. Current Canadian guidelines follow the USA guidelines. Although very rare, injury and deaths have occurred in MRI units from unsecured metal objects being drawn at high speeds into the magnet or from internal body metal fragments of which the subject was unaware or had not informed MRI staff. To minimize this latter possibility it is essential that you complete a screening questionnaire. Other remote but potential risks involve tissue burns and temporary hearing loss from the loud noise inside the magnet. The latter can be avoided with ear headphone protection that also allows continuous communication between the subject and staff during the study.

If you have any history of head or eye injury involving metal fragments, if you have ever worked in a metal shop or been a soldier, if you have some type of implanted electrical device (such as a cardiac pacemaker), if you have some severe heart disease (including susceptibility to arrhythmias), if you are wearing braces on your teeth, or (for women) if you could be pregnant, you should not have an MRI.

Benefits

A direct benefit to the volunteers participating in the study may be early diagnosis of hip pathology. An indirect benefit is that information from this study may influence the treatment and enhance the outcome for patients presenting with indications of FAI, which could enhance future clinical trials and benefit other individuals in the future.

Compensation

To compensate you for your time and effort, you will be paid a total of $40 for participation in the study. In order to receive the compensation you must meet all criteria and complete the study. The payments will be:

- $10 for parking costs
- $30 for time in MRI procedure

Confidentiality

All information will be kept strictly confidential and you will not be identified in any publication or communication resulting from the study. Your records will be identified by a unique identification number only and will not contain your name in part or in full. These records are kept in locked storage for a minimum of two years following publication of the results of the study. If you are interested in receiving the results of the study or you are interested in participating in future studies please check the boxes accordingly on the consent form.

Pt. Initials ____

Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any question or withdraw from this study at any time with no effect on your future care.

A copy of this letter of information will be given to you to keep.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may contact you or require access to your study related records to monitor the conduct of the research.

If you have any questions about the study, please contact Dr. Willits at If you have any questions about the conduct of this study or your rights as a research subject, you may contact Dr. David Hill, c/o Lawson Health Research Institute a

Sincerely,

Charys Raynor, BSc, MSc Candidate

Dr. Kevin Willits, MD, FRCSC

CONSENT FORM

The Presence of Femoro-Acetabular Impingement in Asymptomatic Individuals

Would you like to receive the results of the study? Yes ☐ No ☐

Are you interested in being contacted about participation in future studies? Yes ☐ No ☐

**If you answered Yes to any of the previous questions please fill out your contact information on the next page.

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All of my questions have been answered to my satisfaction.

_____ _____
Signature of Patient Date

_____
Patient Name (please print)

_____ _____
Signature of Consenting Investigator Date

_____
Consenting Investigator Name (please print)

Appendix D

Demographic Information and Inclusion-Exclusion Form

FAI/Hip
STUDY
DEMOGRAPHIC INFORMATION
& PARTICIPANT ELIGIBILITY FORM

Patient Init.: |__|__|__|
Patient No. : |__|__|__|__|
Date : |__|__|/|__|__|/|__|__|__|__|
D M Y

Name: _____

Date of Birth: ____/____/____ Gender: Male ☐ Female ☐ Phone #: _____

INCLUSION CRITERIA	YES$_1$	NO$_2$
1. Participant is between 18-80 years of age?	☐	
2. Participant can read, write and communicate in English?	☐	
3. Participant believes to have normal hip function?	☐	

****If any of the inclusion criteria are marked NO, the patient is not qualified!**

EXCLUSION CRITERIA	YES$_1$	NO$_2$
1. Does the participant experience any hip pain: ▪ in the groin, or upper thigh area? ☐ ▪ while walking? ☐ ▪ during or after prolonged sitting? ☐ ▪ while going up or down stairs? ☐ ▪ while putting on shoes, socks, or hose? ☐ ▪ at times of high level activity (sports)? ☐		☐
2. Has the patient ever injured either or both hips?		☐
3. Has the participant ever been treated for hip pain with medication or physical therapy?		☐
4. Has the participant ever had surgery on either hip?		☐
5. Has the participant ever had surgery on either knee?		☐
6. Participants has previously or is currently being treated with immunosuppressant therapy or chronic steroids?		☐
7. Participant is pregnant and/or breastfeeding or plans to become pregnant?		☐
8. Does the participant have: ▪ a history of head or eye injury involving metal fragments? ☐ ▪ an occupation in a metal shop or been a soldier? ☐ ▪ an implanted electrical device (pacemaker)? ☐ ▪ severe heart disease? ☐ ▪ metal braces on teeth? ☐		☐

****If any of the exclusion criteria are marked YES, the patient is not qualified !**

Appendix E

Hip Outcome Score (HOS)

Hip Outcome Score (HOS)

Please answer **every question** with one response that most closely describes to your condition within the past week.
If the activity in question is limited by something other than your hip mark not applicable (N/A).

Activities of Daily Living subscale

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Standing for 15 minutes	☐	☐	☐	☐	☐	☐
Getting into and out of an average car	☐	☐	☐	☐	☐	☐
Putting on socks and shoes	☐	☐	☐	☐	☐	☐
Walking up steep hills	☐	☐	☐	☐	☐	☐
Walking down steep hills	☐	☐	☐	☐	☐	☐
Going up 1 flight of stairs	☐	☐	☐	☐	☐	☐
Going down 1 flight of stairs	☐	☐	☐	☐	☐	☐
Stepping up and down curbs	☐	☐	☐	☐	☐	☐
Deep squatting	☐	☐	☐	☐	☐	☐
Getting into and out of a bath tub	☐	☐	☐	☐	☐	☐
Sitting for 15 minutes	☐	☐	☐	☐	☐	☐
Walking initially	☐	☐	☐	☐	☐	☐
Walking approximately 10 minutes	☐	☐	☐	☐	☐	☐
Walking 15 minutes or greater	☐	☐	☐	☐	☐	☐

Because of your hip how much difficulty do you have with:

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Twisting/pivoting on involved leg	☐	☐	☐	☐	☐	☐
Rolling over in bed	☐	☐	☐	☐	☐	☐
Light to moderate work (standing, walking)	☐	☐	☐	☐	☐	☐
Heavy work (push/pulling, climbing, carrying)	☐	☐	☐	☐	☐	☐
Recreational activities	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your usual activities of daily living from 0 to 100 with 100 being your level of function prior to your hip problem and 0 being the inability to perform any of your usual daily activities?

☐☐☐.0 %

Sports subscale

Because of your hip how much difficulty do you have with:

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Running one mile	☐	☐	☐	☐	☐	☐
Jumping	☐	☐	☐	☐	☐	☐
Swinging objects like a golf club	☐	☐	☐	☐	☐	☐
Landing	☐	☐	☐	☐	☐	☐
Starting and stopping quickly	☐	☐	☐	☐	☐	☐
Cutting/lateral movements	☐	☐	☐	☐	☐	☐
Low impact activities like fast walking	☐	☐	☐	☐	☐	☐
Ability to perform activity with your normal technique	☐	☐	☐	☐	☐	☐
Ability to participate in your desired sport as long as you would like	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your hip problem and 0 being the inability to perform any of your usual daily activities?

☐☐☐.0 %

How would you rate your current level of function?

☐ Normal ☐ Nearly normal ☐ Abnormal ☐ Severely abnormal

Appendix F

Pre-imaging Hip Assessment Form

Pre-Imaging Hip Assessment Form Date: ___ ___ / ___ ___ / ___ ___ ___ ___

Patient ID # ___ ___ ___ ___ Patient Initials ___ ___ Randomized Hip: R L

Range of Motion (ROM)

1. Flexion
Description: Patient supine. Opposite hip in full flexion. Examiner positions one hand on iliac crest. Note point at which pelvis begins to rotate. Knee is flexed.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

2. Extension
Description: Patient prone. Small pillow under abdomen. Leg extended with knee flexed or straight.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

3. Internal Rotation in Flexion
Description: Patient supine. Hip and knee flexed to 90° each. Thigh perpendicular to transverse line across anterior superior spines of pelvis. Rotate leg away from midline.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

4. External Rotation
Description: Patient supine. Hip and knee flexed to 90° each. Thigh perpendicular to transverse line across anterior superior spines of pelvis. Rotate leg outward.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

5. Internal Rotation in Extension
Description: Patient prone. Knee flexed 90° and perpendicular to the transverse line across the anterior superior spines of pelvis. Rotate leg outward.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

6. External Rotation in Extension
Description: Patient prone. Knee flexed 90° and perpendicular to the transverse line across the anterior superior spines of pelvis. Rotate leg inward.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

7. Abduction in Extension
Description: Patient supine. Legs extended. Move leg outward.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

8. Adduction in Extension
Description: Patient supine. Legs extended. Move leg toward midline. Examiner raises opposite extremity to allow leg to pass under it.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

9. Abduction in Flexion
Description: Patient supine. Hip flexed 90°.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

10. Adduction in Flexion
Description: Patient supine. Hip flexed 90°.

Active ☐☐☐.☐ degrees
Passive ☐☐☐.☐ degrees

Other Tests

1. Faber Test: Negative ☐ Positive ☐

2. Log Roll Test: Negative ☐ Positive ☐

3. Trendelenberg: Negative ☐ Positive ☐

Physicians Signature: _____

Appendix G

Harris Hip Score

Harris Hip Score

Hip ID:

Study Hip: ☐ Left ☐ Right

Examination Date (MM/DD/YY): / /

Subject Initials: | | | |

Medical Record Number:

Interval: _____

Harris Hip Score

Pain *(check one)*

- ☐ None or ignores it (44)
- ☐ Slight, occasional, no compromise in activities (40)
- ☐ Mild pain, no effect on average activities, rarely moderate pain with unusual activity; may take aspirin (30)
- ☐ Moderate Pain, tolerable but makes concession to pain. Some limitation of ordinary activity or work. May require Occasional pain medication stronger than aspirin (20)
- ☐ Marked pain, serious limitation of activities (10)
- ☐ Totally disabled, crippled, pain in bed, bedridden (0)

Limp

- ☐ None (11)
- ☐ Slight (8)
- ☐ Moderate (5)
- ☐ Severe (0)

Support

- ☐ None (11)
- ☐ Cane for long walks (7)
- ☐ Cane most of time (5)
- ☐ One crutch (3)
- ☐ Two canes (2)
- ☐ Two crutches or not able to walk (0)

Distance Walked

- ☐ Unlimited (11)
- ☐ Six blocks (8)
- ☐ Two or three blocks (5)
- ☐ Indoors only (2)
- ☐ Bed and chair only (0)

Sitting

- ☐ Comfortably in ordinary chair for one hour (5)
- ☐ On a high chair for 30 minutes (3)
- ☐ Unable to sit comfortably in any chair (0)

Enter public transportation

- ☐ Yes (1)
- ☐ No (0)

Stairs

- ☐ Normally without using a railing (4)
- ☐ Normally using a railing (2)
- ☐ In any manner (1)
- ☐ Unable to do stairs (0)

Put on Shoes and Socks

- ☐ With ease (4)
- ☐ With difficulty (2)
- ☐ Unable (0)

Absence of Deformity (All yes = 4; Less than 4 =0)

- Less than 30° fixed flexion contracture ☐ Yes ☐ No
- Less than 10° fixed abduction ☐ Yes ☐ No
- Less than 10° fixed internal rotation in extension ☐ Yes ☐ No
- Limb length discrepancy less than 3.2 cm ☐ Yes ☐ No

Range of Motion (*indicates normal)

- Flexion (*140°) _____
- Abduction (*40°) _____
- Adduction (*40°) _____
- External Rotation (*40°) _____
- Internal Rotation (*40°) _____

Range of Motion Scale

211° - 300° (5)	61° - 100 (2)
161° - 210° (4)	31° - 60° (1)
101° - 160° (3)	0° - 30° (0)

Range of Motion Score _____

Total Harris Hip Score _____

Appendix H

Standard MRI Hip Assessment Form

FOWLER KENNEDY
SPORT MEDICINE CLINIC

Magnetic Resonance Imaging (MRI)
Hip Assessment Form

Subject Information:

Subject Identification (ID) Number: _____ Subject's Initials: _____

Gender: Male _____ Female _____

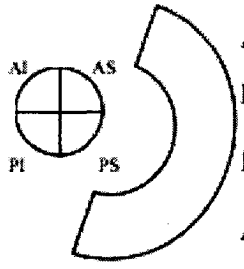
Hip being examined: Right Hip _____ Left Hip _____

MRI Assessment for the Hip:
(Please mark an "X" beside the appropriate box)

1. **Alpha (α) Angle** (in degrees): _____
   Spherical femoral head: Yes _____ No_____
   Additional Notes: _____
   _____

2. **Acetabular Labrum Tears:**

Location: Left Acetabulum (Sagittal View) **Size** **Grade**



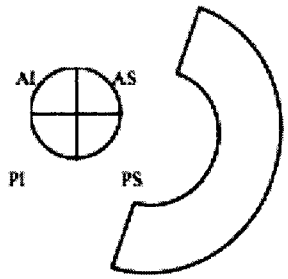
Anterosuperior (AS) ____ _____
Posterosuperior (PS) ____ _____
Posterinferior (PI) ____ _____
Anteroinferior (AI) ____ _____

Additional Note(s): _____
_____
_____

3. **Articular Cartilage Lesions:**

Acetabular:

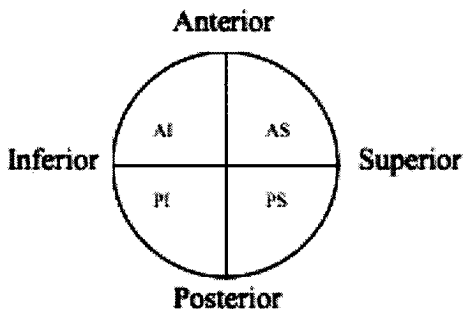
Location: Left Acetabulum (Sagittal View)



	Size	Grade
Anterosuperior (AS)	____	____
Posterosuperior (PS)	____	____
Posteroinferior (PI)	____	____
Anteroinferior (AI)	____	____

Femoral:

Location: Left Femur (SV)



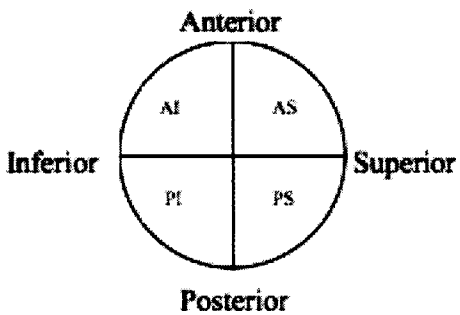
	Size	Grade
Anterosuperior (AS)	____	____
Posterosuperior (PS)	____	____
Posteroinferior (PI)	____	____
Anteroinferior (AI)	____	____

Additional Note(s): _____

_____

4. Evidence of paralabral cyst formation:

Location: Left Femur (SV)



	Size
Anterosuperior (AS)	____
Posterosuperior (PS)	____
Posteroinferior (PI)	____
Anteroinferior (AI)	____

Additional Note(s): _____

_____

7. Other:

Joint Effusion _____ **Intraarticular bodies** _____

Intraarticular bursa _____ **Intraarticular osteophytes** _____

Os Acetabuli _____

Additional Note(s): _____
_____
_____

Appendix I

Permission from Lippincott Williams and Wilkins

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