Prevalence of Radiographic Findings Consistent With Femoroacetabular Impingement in Military Personnel With Femoral Neck Stress Fractures

Timothy Carey, DO[1]; Christian Key, MD[2]; David Oliver, MD[3]; Timothy Biega, MD[4]; and John Bojescul, MD[3]

A femoral neck stress fracture is a serious condition that affects military personnel and endurance athletes. There is increasing evidence that femoroacetabular impingement contributes to significant hip pathology. This study investigates the prevalence of radiographic abnormalities associated with impingement in military personnel treated for femoral neck stress fractures. The radiographs of 69 consecutive soldiers being treated for a femoral neck stress fracture identified on magnetic resonance imaging were reviewed for radiographic signs of femoroacetabular impingement. In the cohort, the average incidence of a crossover sign was 51% (27/53). The incidence of a center edge angle greater than 40° was 47% (25/53). The alpha angle was greater than 50° in 55% (29/53). In conclusion, it appears that young patients with femoral neck stress fractures have a high prevalence of radiographic abnormalities suggestive of hip impingement. Hip impingement may lead to abnormal stress across the femoral neck, predisposing individuals to stress fractures. (Journal of Surgical Orthopaedic Advances 22(1):54–58, 2013)

Key words: FAI, femoral acetabular impingement, femoral neck stress, hip, stress fractures

A physiologic response of remodeling and repair is initiated when a bone is subjected to subthreshold loading forces. In the bone of certain susceptible individuals these repetitive forces can occur at a rate that does not allow for sufficient remodeling, resulting in a stress fracture. A stress fracture occurring in the femoral neck is a potentially serious condition that is relatively unique to military personnel and endurance athletes. Femoral neck stress fractures (FNSF) make up only 10% of all stress fractures, but the consequences and long-term disability of these particular injuries can be devastating (1). If the fracture progresses and results in displacement, it can lead to prolonged disability secondary to pain, nonunion, or osteonecrosis of the femoral head (2). New military recruits are at increased risk for developing FNSF secondary to their rapid increase in physical activity on enlistment and because of the prolonged running and marching required in military training (1, 2). Multiple systemic medical conditions have been correlated with FNSF, but there is limited research on radiographic anatomic abnormalities that may predispose patients to FNSF.

Femoroacetabular impingement (FAI) is a diagnosis that is being increasingly linked to hip pathology in young, active adults. FAI is the presence of an anatomic variation in the acetabulum and/or the proximal femur that results in abnormal contact stress during terminal motion (3, 4). FAI causes mechanical abnormalities during range of motion that can lead to increased stress across the hip joint. This increased stress results in hip pain and eventually osteoarthritis (3, 5–10). FAI is separated into pincer, cam, and combined lesions. Pincer lesions are abnormalities of the acetabulum that result in overcoverage and impingement of the acetabular rim on the femoral neck. Two common causes of this are acetabular retroversion (AR) (11) and coxa profunda (12).

The center edge angle (CEA) measured on anteroposterior (AP) radiographs is used to quantify coxa profunda

From [1]Department of Orthopaedic Surgery, Irwin Army Community Hospital, Fort Riley, Kansas; [2]Department of Orthopaedic Surgery, Ireland Army Community Hospital, Fort Knox, Kentucky; [3]Department of Orthopaedic Surgery, Dwight David Eisenhower Army Medical Center, Fort Gordon, Georgia; [4]Department of Radiology, Tripler Army Medical Center, Hawaii. Address correspondence to: David Oliver, MD, Orthopaedic Clinic, Building 300, Dwight David Eisenhower Army Medical Center, Fort Gordon, GA 30905; e-mail: david.oliver9@us.army.mil.

All work was completed at Dwight David Eisenhower Army Medical Center. Clinical encounters were performed in the orthopaedic clinic as well as the outpatient physical therapy clinic.

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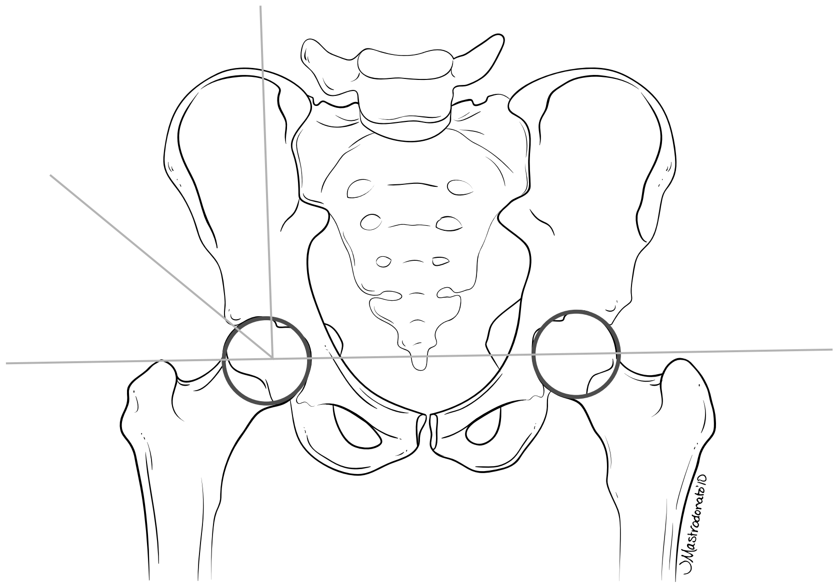

FIGURE 1 This illustration depicts the center edge angle, which is measured by a vertical line bisecting the center of the femoral head and another line connecting the center of the femoral head and the lateral edge of the acetabulum.

(13) and retroversion can be determined by the presence of a positive crossover sign (+COS) on an AP radiograph (14). Cam lesions occur secondary to a nonspherical femoral head. This results in a prominence on the femoral neck, which is forced into the acetabulum during motion. Cam lesions can be determined by measuring the α angle on the frog-leg lateral radiograph (4, 15, 16). Many clinical cases of FAI are a combination of cam and pincer lesions.

The goal of this study is to investigate the prevalence of radiographic abnormalities associated with FAI in active duty military personnel treated for FNSF. These findings were then compared to historical data from both a military and civilian population to determine if FAI may be a risk factor for developing FNSF.

Methods

A retrospective review of the medical records and imaging studies was performed on soldiers diagnosed with FNSF at one military medical center between January 2005 and June 2009. Institutional review board approval was obtained before data collection. Patients included were at least 18 years of age, were active duty soldiers, had AP and frog-leg lateral radiographs, and had magnetic resonance imaging (MRI) findings consistent with femoral neck stress changes to include edema and/or a discreet fracture line. All patients had passed a pre-enlistment physical examination and none of the patients had been identified with pre-existing hip pathology.

The radiographs of the soldiers being treated for FNSF were reviewed by a staff radiologist to determine their adequacy. Radiographs with excessive pelvic tilt or rotation were excluded from the study. Pelvic tilt was evaluated by digitally measuring the distance from the pubic symphysis to the distal end of the coccyx. Distances greater than 20 mm were determined to be inadequate (17). Rotation of the radiographs was determined by drawing a plumb line from the spinous processes to the pelvis. The distance from the plumb line to the center of the pubic symphysis was then measured. A distance of greater then 16 mm was deemed inadequate and those films were excluded (8).

The adequate films and associated MRIs were reviewed independently by three physicians (one attending orthopaedic surgeon, one attending radiologist, one orthopaedic resident). MRIs were evaluated for the amount of the femoral neck displaying stress changes (25%, 50%, 75%, 100%). It was also noted whether the stress change was compression or tension sided. AP pelvis radiographs were used to determine the CEA, neck shaft angle, and presence of +COS. CEA was measured using a digital goniometer to make perfect circles to fit bilateral femoral heads. A plumb line was drawn between the centers of the two femoral heads. A vertical perpendicular line from the plumb line was drawn from the center of the affected hip. The digital angular tool was used to measure the angle between the vertical line and a line drawn to the edge of the acetabular overhang (Fig. 1). The neck shaft angle was determined using the digital angular measurement between a line drawn down the center of the femoral neck and a line drawn down the center of the femoral shaft. The COS was positive if there was crossing of the anterior and posterior wall (18). The frog-leg lateral

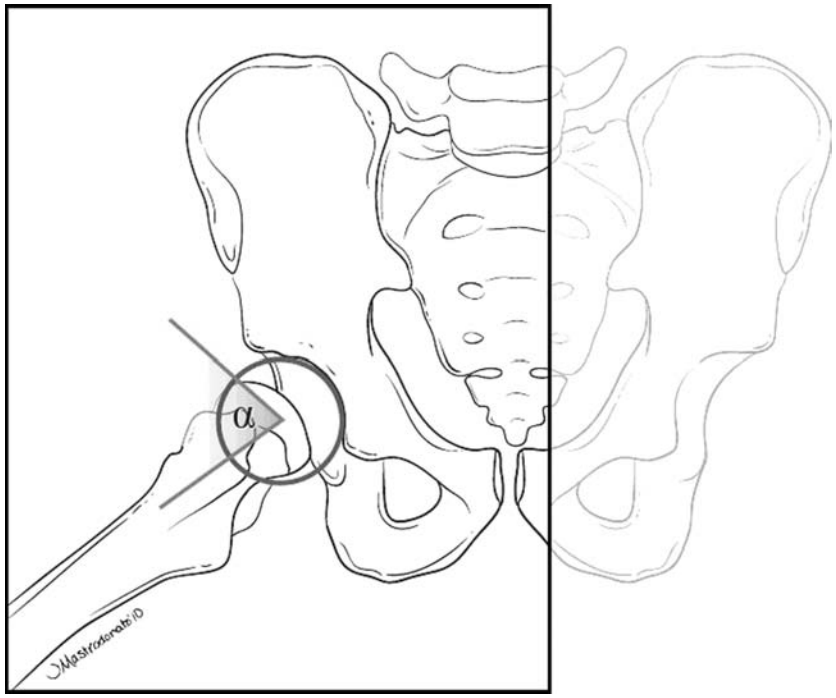

FIGURE 2 This illustration depicts the alpha angle, which is an angle formed by a line through the femoral axis intersecting a line connecting the center of the femoral head with the point where asphericity begins.

radiographs were evaluated for the α angle as described initially by Nötzli et al. (16) and then by Clohisy et al. (Fig. 2) (15). The measurements determined by the three independent physicians were averaged and compared to historical controls. Interrater reliability was calculated for all measurements.

Results

Sixty-nine consecutive patients (33 males and 36 females) treated for a FNSF were identified. Sixteen of these patients (9 males and 7 females) were excluded because of inadequate radiographs. Two patients did not have initial radiographs that could be reviewed and 14 were excluded secondary to excessive pelvic tilt or rotation. Among the cohort (53 patients: 24 males and 29 females) the incidence of a crossover sign was 51% (27/53). The incidence of a center edge angle greater than 40° was 47% (25/53). The α angle was greater than 50° in 55% (29/53). These findings were significantly higher than the same measurements in historical controls.

There was no correlation between severity of the stress fracture on MRI and positive radiographic findings. There was no correlation between sex and radiographic findings either in the severity of the femoral neck stress fracture or in the incidence of FAI. There was no significant variation between neck shaft angle in the present study group compared to historical norms (5). The intraclass correlations between the three independent raters were as follows: crossover = .78, neck shaft angle = .64, center edge angle = .77, α angle = .38; all p values were less than .001.

Discussion

Anatomic variations of the hip measured in this study are more prevalent in patients who develop FNSF while in military training compared to the asymptomatic military and civilian population. Previous studies have demonstrated that the rate of a +COS in the general population ranges from 5% to 31% (19–23). The most recent of these studies was done using computed tomography (CT) scanning and demonstrated that 14% of the general population had AR (9). In that study, the authors also validated the use of the COS because it was confirmed to be 71% sensitive and 88% specific for AR when compared to actual findings on CT (21). In the current study, 51% of patients with FNSF had a +COS, which is significantly greater than demonstrated in the general population in all of the previous control studies. Kuhn et al. performed a similar study in U.S. Marines looking at AR and radiographic findings consistent with FAI in patients with a FNSF. They found 57% of patients with a FNSF had a +COS (22). Our study reinforces their conclusion that AR may predispose military recruits to developing a FNSF. One difference is that their study did not include female patients. The current study included females (55%) and demonstrated similar radiographic findings in males and females.

CEA angles are important for determining acetabular coverage and are also one of the measurements used to gauge pincer-type FAI. Previous studies have defined a CEA angle of less the 20° as being a dysplastic hip, 21° to 38° being within normal limits, 39° to 44° as coxa profunda, and greater than 44° as being protusio acetabuli (14). CEA over 40° has been associated with pincer-type FAI (18). In the present study, 47% of patients with FNSF had a CEA greater than 40°. This is significantly greater than the control study that demonstrated that 16% of asymptomatic patients had a CEA angle greater than 40° (5).

Cam impingement is most commonly determined on the frog-leg lateral. Clohisy et al. compared patients with symptoms of impingement to an age-matched control group using the α angle on the frog-leg lateral (15). The authors found an average α angle in the control group of 43.7° 12.1°. From this finding, the authors determined that a value of greater than 50° was abnormal and consistent with FAI when compared to the general population (15). In the present study, 55% of patients had an α angle greater than 50°. Hack et al. looked at asymptomatic patients using MRI to determine the prevalence of cam lesions and found 14% of 200 patients had an α angle of greater than 50.5° (4). In another study, 55° was used as the cutoff for a positive α angle when looking at an asymptomatic population . The results of that study showed that 10% of patients had an α angle greater than 55°. For comparison, using the current study data, changing the cutoff for a positive α angle from 50° to 55° still resulted in 30% of patients having abnormal findings. In all situations, the current study group had a significant increase in the rate of pathologic α angles.

Kuhn et al. also looked at the association of FAI and FNSF in a military population, measuring femoral head neck offset and synovial herniation pits (22). Using different radiographic criteria, that study reported only 13% of patients had findings other than +COS consistent with FAI (22). The present study yielded different results with 47% of patients having a CEA greater than 40° and 55% of patients having an α angle greater than 50°. Sixty-four percent of patients had at least one finding (CEA or α angle) consistent with FAI. These results suggest that patients with FNSF have an increased rate of radiographic findings consistent with FAI as compared to the general population.

Ochoa et al. studied patients presenting with general hip pain and looked for radiographic criteria corresponding to FAI. The authors found that 87% of these patients had one abnormal finding consistent with FAI. The authors used five radiographic criteria (herniation pits, pistol grip deformity, CEA, α angle, and COS) to determine the presence of FAI (18). Kang et al. used CT images and four criteria (CEA, COS, α angle, and head neck offset) in asymptomatic patients and found 39% to have one finding consistent with FAI (5). Using only three criteria (CEA, α angle, and COS), 75% of the FNSF patients in the current study were found to have at least one positive finding associated with FAI.

There are several limitations to the present study. First, the diagnosis of FAI is usually based on the combination of physical exam and radiographic criteria. Because of the retrospective nature of the present study, we were not able to include physical exam findings and were unable to correlate other risk factors for FNSF that these patients may have had. References to FAI are purely based on radiographic criteria in the present study. These radiographic criteria have been debated in the literature. In particular, when performing retrospective measurements of the α angle, it is difficult to control the exact rotation of the leg on the frog-leg lateral radiographs used. The interclass correlation was relatively poor for this measurement as well. Second, we used historical control data from both the military and civilian population and we did not perform the measurements ourselves.

In conclusion, young service members with femoral neck stress fractures have a high prevalence of radiographic abnormalities suggestive of femoroacetabular impingement when compared to asymptomatic patients. One can conclude that the conditions corresponding to the assessed radiographic findings led to abnormal stress across the hip joint, specifically the femoral neck. This adds evidence to the growing body of work demonstrating the deleterious effect of FAI on hip function. Identifying radiographic risk factors in military recruits may potentially be used in the future as a screening tool for identifying patients at risk for developing femoral neck stress fractures.

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References

1. Shin, A.Y., Gillingham, B. L. Fatigue fractures of the femoral neck in athletes. J. Am. Acad. Orthop. Surg. 5(6): 293–302, 1997.
2. Fullerton, L. R. Femoral neck stress fractures. Sports Med. 9(3):192–197, 1990.
3. Ganz, R., Parvizi, J., Beck, M., et al. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin. Orthop. Relat. Res. 417:112–120, 2003.
4. Hack, K., Di Primio, G., Rakhra, K., et al. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. J. Bone Joint Surg. Am. 92(14): 2436–2444, 2010.

5. Kang, A. C., Gooding, A. J., Coates, M. H., et al. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. Am. J. Sports Med. 38(6) 1160–1165, 2010.
6. Murray, R. O. The aetiology of primary osteoarthritis of the hip. Br. J. Radiol. 38(455):810–824, 1965.
7. Rab, G. T. The geometry of slipped capital femoral epiphysis: implications for movement, impingement, and corrective osteotomy. J. Pediatr. Orthop. 19(4):419–424, 1999.
8. Siebenrock, K. A., Kalbermatten, D. F., Ganz, R. Effect of pelvic tilt on acetabular retroversion: a study of pelves from cadavers. Clin. Orthop. Relat. Res. 407:241–248, 2003.
9. Solomon, L. Patterns of osteoarthritis of the hip. J. Bone Joint Surg. Br. 58(2):176–183, 1976.
10. Tannast, M., Zheng, G., Anderegg, C., et al. Tilt and rotation correction of acetabular version on pelvic radiographs. Clin. Orthop. Relat. Res. 438:182–190, 2005.
11. Reynolds, D., Lucas, J., Klaue, K. Retroversion of the acetabulum. A cause of hip pain. J. Bone Joint Surg. Br. 81(2):281–288, 1999.
12. Gekeler, J. [Coxarthrosis with a deep acetabulum (proceedings)]. Z. Orthop. Ihre. Grenzgeb. 116(4):454, 1978.
13. Manaster, B. J., Zakel, S. Imaging of femoral acetabular impingement syndrome. Clin. Sports Med. 25(4):635–657, 2006.
14. Tönnis, D., Heinecke, A. Acetabular and femoral anteversion: relationship with osteoarthritis of the hip. J. Bone Joint Surg Am. 81(12):1747–1770, 1999.
15. Clohisy, J. C., Nunley, R. M., Otto R. J., et al. The frog-leg lateral radiograph accurately visualized hip cam impingement abnormalities. Clin. Orthop. Relat. Res. 462:115–121, 2007.
16. Nötzli, H. P., Wyss, T. F., Stoecklin, C. H., et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J. Bone Joint Surg. Br. 84(4):556–560, 2002.
17. Mast, J. W., Brunner, R. L., Zebrack, J. Recognizing acetabular version in the radiographic presentation of hip dysplasia. Clin. Orthop. Relat. Res. 418:48–53, 2004.
18. Ochoa, L. M., Dawson, L., Patzkowski, J. C., et al. Radiographic prevalence of femoroacetabular impingement in a young population with hip complaints is high. Clin. Orthop. Relat. Res. 468(10):2710–2714, 2010.
19. Ezoe, M., Naito, M., Inoue, T. The prevalence of acetabular retroversion among various disorders of the hip. J. Bone Joint Surg. Am. 88(2):372–379, 2006.
20. Giori, N. J., Trousdale, R. T. Acetabular retroversion is associated with osteoarthritis of the hip. Clin. Orthop. Relat. Res. 417:263–269, 2003.
21. Kim, W. Y., Hutchinson, C. E., Andrew, J. G., et al. The relationship between acetabular retroversion and osteoarthritis of the hip. J. Bone Joint Surg. Br. 88(6):727–729, 2006.
22. Kuhn, K. M., Riccio, A. I., Saldua, N. S., et al. Acetabular retroversion in military recruits with femoral neck stress fractures. Clin. Orthop. Relat. Res. 468(3):846–851, 2010.
23. Lohan, D. G., Seeger, L. L., Motamedi, K., et al. Cam-type femoral-acetabular impingement: is the alpha angle the best MR arthrography has to offer? Skeletal Radiol. 38(9):855–862, 2009.

