Stress Fractures of the Pelvic Ring and Hip

INTRODUCTION

Stress fractures of the pelvic ring and hip are not common. However, with increasing reports in the literature, there has been increased awareness of these injuries as an etiology of low back and buttock pain, and groin pain in patients. In general, there are two types of stress fractures: insufficiency-type stress fractures and fatigue-type stress fractures. Insufficiency fractures result from physiologic (normal) stresses within abnormal bone (e.g., osteoporotic bone). Insufficiency fractures are typically seen in older populations, and have been reported to be associated with postmenopausal osteoporosis, patients with history of radiation to the pelvis, corticosteroid-induced osteopenia, secondary osteoporosis (hyperparathyroidism, renal osteodystrophy, lumbosacral fusion, and Paget disease), rheumatoid arthritis, osteomalacia, transient osteoporosis associated with pregnancy and lactation, and osteopenia secondary to the female athletic triad. Fatigue-type stress fractures are the result of mechanical overload (repetitive loading) within a normal bone. In athletes, there may be a combination of insufficiency- and fatigue-type mechanisms. These generally occur in a younger, more active population such as distance runners and military recruits. The incidence of stress fractures ranges from 0.3% to 8% in the military population. In a sports medicine clinic, approximately 10% of all injuries seen are stress fractures. Specifically, runners presenting to a sports medicine clinic with stress fractures can make up 15% of all the injuries seen. This chapter will discuss stress fractures of the femoral neck and pelvic ring.

FEMORAL NECK STRESS FRACTURES

EPIDEMIOLOGY AND CLASSIFICATION

Femoral neck stress fractures account for approximately 5% of all stress fractures. Most of these fractures are seen in skeletally mature individuals, however, more recently children and adolescents have been reported to develop femoral neck stress fractures. In a large Finnish study of male military recruits, body mass index, neck shaft angle, and leg dominance were not shown to correlate with the development of femoral neck stress fractures. The development of femoral neck stress fractures has been reported to be due to a decrease in the absorption effect of the abductor musculature and secondary muscle fatigue with a compensatory alteration in gait pattern.

Based upon the radiographic presentation of 54 femoral neck stress fractures, one study felt that previous classifications were inadequate. They found a combination of a biomechanical model and the degrees of displacement to be more clinically useful. They divided their classification into stages of tension- and compression-sided fractures. Initially, tension-sided fractures have normal radiographs with positive bone scans on the tension side of the neck. Later, the fracture exhibits either endosteal or periosteal callus or a tension-sided fracture line without displacement. In the final stages, complete displacement of the femoral neck fracture is seen. Compression-sided stress fractures initially exhibit sclerosis on the medial side of the neck. In this stage, a negative plain radiograph with a positive bone scan on the compression side is commonly seen. Later, sclerosis is seen on plain radiographs, followed by a compression-sided cortical break. Finally, compression-sided widening of the fracture line is seen. In this series no fracture, either compression- or tension-sided, went on to displacement.

Compression-sided fractures are commonly seen in athletes, while tension-sided stress fractures have historically been reported in the elderly population. Recently, Provencher et al. reported on tension-sided femoral neck stress fractures seen in the adult military population. As with the adult population, most femoral neck stress fractures in children are compression-sided, however, a recent report demonstrated a tensile-sided femoral neck stress fracture in a child.

CLINICAL PRESENTATION AND DIAGNOSIS

Femoral neck stress fractures usually present with an insidious onset of vague anterior thigh and groin pain with weight bearing. Pain noted about the posterior aspect of the hip joint and greater trochanter is a less frequent presentation. Patients usually report a recent change in their activity, equipment, or training intensity level. Pain may be exacerbated by hop-
piercing on the affected leg or running long distances. In more advanced stages, the pain occurs earlier during these activities and often requires longer recovery periods. Patients may report a history of previous stress fractures and acute severe pain should alert the clinician that a displaced fracture may be present.

On physical examination, patients will typically demonstrate a full range of motions of the affected hip with a mildly antalgic gait. Groin or deep lateral hip pain may be elicited at the end ranges of hip internal and external rotations. Hip flexion and axial compression, and a single leg hop test may recreate the patient’s groin pain. Patients less commonly have palpable pain or swelling in the inguinal region.11

**IMAGING**

The vague symptoms associated with femoral neck stress fractures often lead to a delay in the diagnosis.13 Radiographs, initially, are normal and it has been reported that 75% of femoral neck stress fractures are missed because they do not appear on plain radiographs.13 The delay in diagnosis and the resulting inadequate treatment may lead to a progression of the fracture and ultimately fracture displacement.

Radiographs, including anteroposterior (AP) and Frog leg or cross-table lateral views of the affected hip, are taken as a screening tool. Femoral neck stress fractures typically demonstrate a gradual alteration in the trabeculae of the femoral neck on plain radiographs.9 Historically, bone scans were

![Figure 21.1](image-url)

*Figure 21.1.* Thirty-one-year-old female runner training for marathon with 2 weeks of bilateral hip and proximal right thigh pain. Anterior and posterior scintigrams (A) show focal uptake at the medial left femoral neck, consistent with incomplete stress fracture (arrow), and another focal stress reaction/fracture of the contralateral right medial subtrochanteric region (arrowhead). Sequential slices of coronal SPECT images (B) further define the location of the stress fracture to the anteromedial left femoral neck (arrow). SPECT imaging allows postprocessing reconstruction to 3D volume images that can be rotated (C) which even more visually shows uptake consistent with stress fractures at the anteromedial left femoral neck and right femoral anteromedial subtrochanteric region (arrows).
recommended (Fig. 21.1) to make the correct diagnosis, as this imaging modality may be positive several days after the onset of symptoms. More recently, magnetic resonance imaging (MRI) is emerging as the gold standard secondary to a higher degree of specificity (Fig. 21.2).

**TREATMENT AND OUTCOMES**

Treatment strategies are primarily based on the classification of the fracture. Harmon has developed a protocol for the treatment of femoral neck stress fractures. Compression-sided lesions only seen on the MRI as bone edema are treated with protected weight-bearing activity until the patient is asymptomatic, followed by a gradual increase in the activity over the course of 4 to 6 weeks. After this time period, the patient may resume full activity if pain free. If during the increase in activity a relapse of symptoms occurs, the patient is instructed to return to pain-free activity. When a fracture line less than 50% of the width of the femoral neck is present, patients should remain nonweight bearing on crutches until they are asymptomatic (typically 4 to 6 weeks). If the patient is not improving then additional radiographic studies should be obtained to evaluate

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**Figure 21.2.** Forty-five-year-old female with right hip pain 2 weeks prior to running a 5 km race. MR arthrogram was performed. A coronal T1 image (A) shows decreased signal intensity of the marrow of the medial aspect of the right femoral neck (arrow). A coronal STIR image (B) shows increase in signal intensity. This signal intensity pattern is consistent with early stage stress reaction/fracture. A coronal STIR image (C) of 6 month follow-up MRI shows resolution of bone marrow edema.
fracture healing or progression. When a fracture line extends over 50% of the femoral neck width, then orthopaedic consultation should be obtained, as the incidence of displacement increases dramatically. Percutaneous pinning may be considered in this situation.

Surgical treatment is considered for tension-sided fractures or failed nonoperative treatment of compression-sided fractures with percutaneous pinning of the affected hip (Fig. 21.3). Displaced femoral neck stress fractures require emergent closed or open reduction and percutaneous pinning to minimize the risk of avascular necrosis and nonunion. Displaced nonunions may benefit from vascularized bone grafting. A high index of suspicion and appropriate treatment has been shown to minimize complications as a result of femoral neck stress fractures. In 2006, Pihlajamaki et al. reported the long-term outcomes of nondisplaced femoral neck fatigue fractures in a young, adult male military population. With proper conservative management, no patient developed a displaced fracture or avascular necrosis, nor did they find an increased incidence of hip osteoarthritis at mean 18.3 years follow-up. In 2006, Pihlajamaki et al. reported on 19 patients over a 20-year period with displaced femoral neck stress fractures. Among the patients with displaced femoral neck stress fractures, a very high incidence of delayed or nonunion, avascular necrosis, and osteoarthritis was seen. They reported that almost every patient had prodromal symptoms. The Finnish army subsequently implemented a policy regarding hip pain: "Conscripts complaining of pains in the hip, the proximal part of the femur or groin associated with or following physical activity were to be promptly referred for bone scans or MRI at the main military hospital." As a result, the army increased detection of femoral neck stress fractures from 13.2/100,000 service years to 53.2/100,000 service years. In addition, the rate of Garden IV displaced femoral neck stress fractures decreased from 3.8/100,000 service years to 0/100,000 service years. They concluded that by increasing awareness of this injury, early diagnosis and treatment can prevent displacement of these fractures. Few complications have been reported in skeletally immature individuals with femoral neck stress fractures.

PELVIC STRESS INJURIES

EPIDEMIOLOGY AND CLASSIFICATION
Pelvic stress fractures are uncommon injuries. Running athletes and military recruits are typical populations that are at increased risk for this injury. Pelvic ring stress fractures have also been reported during pregnancy or the postpartum period and following total hip arthroplasty.

Most of the initial reports describing fatigue-type fractures of the pelvis were in military recruits. Meurman reported one of the largest series of pubic stress fractures among 630 stress fractures in Finnish soldiers. In this population, stress fractures are believed to result from the onset of repetitive training activity commonly seen in basic training of military recruits. Selakovich and Love hypothesized that the precipitating factor is the repeated pull of the adductor muscle and hamstring complexes in unconditioned individuals.

Athletes, in particular, long-distance runners, are a significantly at risk population. The precise incidence of pelvic stress fractures in running athletes is unknown. In a recent review of the literature, pelvic stress fractures represented about 1.25% of all stress fractures in running athletes. In a report of 11 patients with 12 pubic rami fractures, all athletes were runners, with 9 of the 11 being distance or marathon runners.

Pelvic ring fractures are also reported to occur during pregnancy. Risk factors reported in the literature include vaginal delivery, increased birth weight, increased lumbar lordosis, excessive maternal weight gain, and selected obstetric maneuvers. It has been hypothesized that breech position and constant pressure against the superior rami, and transient osteoporosis of the hip could account for this fracture. Pubic insufficiency fractures have also been reported following total hip arthroplasty.

Pelvis stress fractures occur in both males and females, with an increased prevalence among women. Differences in pelvis...
geometry and gait have been reported to account for this gender disparity.\textsuperscript{20,44} It has been suggested that increased content of cancellous bone within the pelvis and the greater sensitivity of cancellous bone to estrogen deficiencies play a role.\textsuperscript{44} It has also been hypothesized that tensile forces on the medial portion of the pubic rami are produced by strong musculature moments on the lateral part of the pubic rami and ischium with hip extension. Inferior pubic rami fractures are reported to be more common than superior rami fractures.\textsuperscript{19,20,23} Pubic symphysis stress injury (“Osteitis Pubis”) is another overuse injury of the pelvic ring.\textsuperscript{44} This diagnosis must also be considered in the differential diagnosis of pelvic stress fractures, and can be associated with “athletic pubalgia.”

**CLINICAL PRESENTATION AND DIAGNOSIS**

The clinical history is extremely important in making the diagnosis, and a high index of suspicion is necessary. Pain is the most common complaint, and is typically localized to the inguinal region.\textsuperscript{18,19,44} Initially, pain is activity-related and resolves with rest, but with continued insult, symptoms can occur at rest. In the training athlete, the onset of symptoms is typically several weeks to months after starting a new training program or after a significant change in an existing training program. Eliciting the details of their training program is important, including changes in training schedule or technique, increases in mileage, and changes in footwear or running surfaces.\textsuperscript{19}

Physical examination may reveal an antalgic gait. Pain or inability to stand unsupported on the leg of the affected side is a positive “standing test.”\textsuperscript{18} Noakes et al.\textsuperscript{18,45} noted that diagnosis of a pelvic stress fracture can be confidently made, even when the radiograph is normal, when there is: groin pain of sufficient severity to prevent running, a positive “standing test” or “Hop test,” and exquisite tenderness localized to the affected pubic rami.

**IMAGING**

Plain radiographs are initially obtained. An AP view of the pelvis should be obtained and additional views, such as inlet/outlet views or Judet views, may also be beneficial. Findings of a stress fracture include increased sclerosis with or without radiographic lucency. It is important to remember that normal radiographs do not exclude a stress fracture, especially if the clinical suspicion is high. Noakes et al.\textsuperscript{18} reported that only five of 13 clinically diagnosed pelvic stress fractures in their series had abnormal initial radiographs.

If the clinical suspicion is high, treatment should proceed, with follow-up radiographs in approximately 2 weeks. For the in-season athlete, it is reasonable to consider further imaging modalities to confirm the diagnosis. MRI and bone scintigraphy are useful modalities.\textsuperscript{14,46} A bone scan will show increased uptake in the area of the stress fracture (Fig. 21.4). Bone scans, however, are very nonspecific, and MRI is emerging as the imaging modality of choice (Fig. 21.5). Bony edema is observed as a low intensity signal on T1-weighted sequences and high signal on T2-weighted sequences. Fracture lines are observed as linear low-intensity signals on both T1- and T2-weighed sequences.

Figure 21.4. Twenty-three-year-old female training for marathon with left groin pain 1 week before the race. Anterior scintigram of bone scan (A) shows focal uptake at the left inferior pubic ramus (long arrow), and more subtly, increased uptake of the inferior pubic ramus nearer the symphysis pubis (short arrow). A TOD (tail-on-detector) scintigram (B) better delineates the two foci of uptake (arrows) in the left inferior pubic ramus consistent with two stress fractures.

**TREATMENT AND OUTCOMES**

Pubic rami stress fractures are typically treated with relative rest and activity modification.\textsuperscript{16-20,23,31,37,44} Although, there is a low risk of complications, delayed union or nonunion can occur without adequate cessation of inciting activity. For most patients, symptoms resolve over a period 3 to 8 weeks.\textsuperscript{30,44} Most importantly, errors in training, improper equipment, as well as nutritional or hormonal deficiencies must be corrected.
Figure 21.5. Twenty-six-year-old female runner with right hip pain for 5 days. Decreased signal intensity on coronal T1 image (A) and increased signal intensity on coronal STIR image (B) of marrow of the right inferior pubic ramus (arrow) reflects abnormal bone marrow edema, associated with surrounding soft tissue edema seen as increased signal on coronal STIR image (arrowheads). Axial T2 fat-suppressed image (C) shows a nondisplaced stress fracture (arrow), adjacent bone marrow edema, and soft tissue edema (arrowheads).

STRESS INJURIES OF THE SACRUM

EPIDEMIOLOGY AND CLASSIFICATION

Similar to other stress fractures, there are fatigue- and insufficiency-types. The true incidence of sacral stress fractures is unknown, as most of the data in the literature is based on case reports and small series. Sacral insufficiency fractures are a well described in the elderly population. Weber et al. performed a review of the literature and reported that 93% of the sacral insufficiency-type fractures were in females. Nearly 2% of women aged 55 years, who presented to the hospital with low back pain, were found to have sacral insufficiency fractures. Risk factors for sacral insufficiency-type fractures include osteoporosis, steroid-induced osteopenia, history of radiation therapy to the pelvis, and secondary osteoporosis. Fatigue-type fractures are less common. Athletic populations (distance runners) and military personnel are at increased risk due to the strenuous and repetitive activity demands. Volpin et al. reported only three sacral stress fractures in 194 military recruits during basic training. Significant risk factors for this injury include a rapid increase in a training regimen, nutritional and metabolic abnormalities, and leg length discrepancy. Many athletes with fatigue-type sacral fractures have been found to have low bone density on DEXA scan, which indicates a component of insufficiency-type stress injury.

Currently, there is no specific classification system to describe sacral stress fractures. The classification system described by Denis et al. used to describe traumatic sacral...
fractures, however, may be applied. Zone 1 is the area lateral to the sacral foramina, known as the sacral ala, and are usually not associated with any neurologic symptoms. Zone 2 includes the sacral foramina and has a higher prevalence of associated neurologic symptoms. Zone 3 is the sacral body and includes the central canal and also has a higher incidence of neurologic symptoms compared to sacral ala fractures. Typically, sacral stress fractures are most commonly found in the sacral ala (Zone 1).50 Insufficiency-type fractures are typically vertical (parallel to the sacroiliac [SI] joints), with a horizontal component occasionally seen.56,64

**DIAGNOSIS/CLINICAL PRESENTATION**

Diagnosis of sacral stress fractures requires a high index of suspicion, and low back pain or buttock pain is a common complaint.47,49,50,55,58 Symptoms are exacerbated by weight-bearing activities and relieved by rest. Unilateral symptoms are more common with fatigue-type injuries. Radicular symptoms are uncommon but may be present if fractures involve the sacral foramina, central canal, or if callus formation abuts lumbar sacral nerve roots.64 Groin pain and anterior thigh pain are less commonly noted.47

Physical examination may reveal an antalgic gait and pain with deep palpation along the posterior aspect of the sacrum or with lateral pelvis compression. A thorough neurovascular examination is important to identify subtle changes in neurologic function. FABER test (Patrick test) is performed with the patient supine. The foot of the affected side is placed on the contralateral knee. Pain in the groin suggested hip joint pathology rather than lumbar spine pathology. Posterior pain with application of pressure to the flexed knee and the contralateral anterior superior iliac spine (ASIS) suggests sacral or SI pathology. Gaenslen test is performed with the patient supine, with maximal hip flexion on one side and the opposite hip extended. This maneuver stresses both SI joints simultaneously.

**IMAGING**

AP and lateral views of the lumbosacral spine, AP pelvis, as well as inlet and outlet views of the pelvis, are useful views to obtain for radiographic assessment. Although initial plain radiographs are usually normal, they are useful to rule out other disorders.47,49,50,52,53,55 The complex geometry and overlying bowel gas shadows complicate accurate interpretation.51,55 Delayed radiographs may demonstrate radiographic changes, such as fracture lucency or callus, but there still must be a 30% to 50% change in trabecular bone density to be appreciated.49 Kiuru et al.53 have reported that plain radiography has a sensitivity and specificity of 37% and 79%, respectively, for diagnosing a sacral stress fracture. Several reports have noted the majority of patients ultimately diagnosed with sacral stress fractures had normal initial plain radiographs.47,49,50

Technetium-99 m bone scans are reported to have a sensitivity approaching 100% for the diagnosis of sacral stress fractures, with poor specificity (Fig. 21.6).47,49,50,52,54,62,63 Bone scans usually show increased uptake at the fracture site location, and can be positive as early as 72h after the onset of symptoms.14,49,52 Appearance on the bone scan ranges from ill-defined area of radiotracer uptake in the sacral ala to focal linear uptake. The classic “Honda sign” is a H-shaped area of increased tracer uptake in the sacrum and is pathognomonic of bilateral insufficiency fractures.50,51,55,56,62,64

MRI is reported by some to be the gold standard in the radiographic diagnosis of sacral stress fractures (Figs. 21.7 & 21.8).51,52,53,55,58,60 The advantages of MR examination of these patients are the greater soft tissue detail and no radiation exposure. The earliest MRI finding is typically an area of low signal on T1-weighted images and high intensity signal on T2-weighted fat-suppressed sequences.51,52 A low signal intensity (void line), which represents the actual fracture line, may be seen on both the T1- and T2-weighted sequences.51

Interestingly, sacral fatigue-type stress fractures and insufficiency-type fractures are reported to show different patterns. Insufficiency-type fractures of the sacrum show edema and fracture parallel to the SI joint whereas, fatigue-type fractures typically seen in the upper-most part of the sacral ala, occasionally extending to the first and second sacral foramina.51,55,56,64 Recently, there has been some concern about the time frame, and bony changes will become evident on MR examination. Fredericson et al.21 recently reported two cases of sacral fatigue-type fractures, where the initial MRI was negative for stress fracture. If clinical suspicion is high, a bone scan can be obtained and treatment for suspected sacral stress fracture should proceed, with repeat imaging to confirm or deny the diagnosis.

Computed topography (CT) examination is also a potential imaging modality.47,49,50,52,53,58 Weber et al. utilized CT examination for diagnosis of all 20 of their insufficiency-type sacral fractures. However, Johnson et al.49 reported that in only three sixth of the patients did the primary CT reading successfully identify the site of the lesions in their athletic population. The radiation exposure of CT scans is much higher than that of conventional radiographs, however, CT scans are less expensive than MRI.

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**Figure 21.6.** Seventy-six-year-old female with posterior pelvic and left anterior groin pain. Anterior and posterior bone scan scintigrams document marked increased uptake of bilateral sacral ala and the left pubis (arrows). The location of these findings in this age group is consistent with insufficiency fractures.
TREATMENT AND OUTCOMES

Treatment of sacral insufficiency or fatigue fractures is typically nonoperative. Frequently, some time passes before the diagnosis is confirmed either via MRI or bone scan. Initial treatment involves "relative rest" with protected weight bearing with crutches as needed. Low-impact activities are a good transition back to activity/sport (e.g., pool running, stationary bike). Gradual return to sport is based on a pain-free activity level.

Patients typically return to normal activity levels in 4 to 6 weeks with up to 7 months recovery time for fatigue-type fractures. Treatment must also address estrogen deficiency states, deficient dietary intake of calcium, eating disorders, and any underlying metabolic bone disease. It is also recommended by some that any female with a stress fracture be evaluated for the female athlete triad, which consists of amenorrhea, an eating disorder, and osteoporosis. Upon return to sports, training issues such as footwear, training surface, cross training, core strengthening, and modification/evaluation of exercise technique and training method should be addressed.

Insufficiency fractures are treated similarly. As most insufficiency fractures are in the elderly, physical debilitation may complicate mobilization. A short period of bed rest may be necessary with oral analgesics. Early mobilization is emphasized with ambulatory aids as necessary. Weber et al. reported pain resolution in about 4 to 6 weeks, with complete resolutions of

Figure 21.7. Fourteen-year-old male with right upper buttock pain for 2 weeks since running in the track. Coronal T1 image (A) shows decreased signal intensity in marrow of the right sacral alae (arrows). Corresponding coronal STIR image (B) shows a small low signal intensity stress fracture (arrow) associated with surrounding increased signal of adjacent bone marrow edema.

Figure 21.8. Eighty-five-year-old female with 6 weeks of severe pelvic/buttock pain since injury bending down. Coronal T1 image (A) through the sacrum and sacroiliac joints shows decreased signal intensity of marrow of bilateral sacral alae, right greater than left (arrows). Coronal STIR image (B, C) show increased signal intensity of the bone marrow edema with contained foci of serpiginous decreased signal intensity which represent bilateral sacral insufficiency fractures, right greater than left (arrows).
ACETABULAR AND ILIAC STRESS FRACTURES

Acetabular and iliac stress fractures are much less common than the above noted stress fractures, but deserve mention and should be included in the differential diagnosis of hip pain. Acetabular and iliac stress fractures are usually insufficiency-type stress fractures in elderly women. These are often associated with other insufficiency stress fractures such as sacral and rami stress fractures, and may also be confused with metastatic disease. One report, however, noted 12 acetabular stress fractures in 178 military endurance trainees presenting with hip pain. Another report described an iliac stress fracture in a young female runner. Plain radiographs are typically normal or reveal ill-defined medullary sclerosis. Both MRI and bone scan can be diagnostic for acetabular and iliac stress fractures.

Treatment for acetabular and iliac stress fractures focus on relative rest and gradual return to activity after workup for training errors and possible underlying osteoporosis and metabolic abnormalities. Displacement is rare, however, intra-articular acetabular stress fractures may warrant more stringent weight-bearing restrictions as prosuicuo acetabuli has been reported.

CONCLUSIONS

Stress fractures about the hip and pelvis occur in both young athletic and elderly populations. Although pelvic ring stress fractures are typically self-limited, femoral neck stress fractures can have grave consequences if not treated in a timely manner. A high index of suspicion and appropriate imaging studies and treatment can help to minimize disability and morbidity as a result of these injuries.

REFERENCES