

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Bencardino JT, Kassirjian A, Palmer WE. Magnetic resonance imaging of the hip: sports-related injuries. <i>Top Magn Reson Imaging</i> . 2003;14(2):145-160.	Review/Other-Dx	N/A	To review use of conventional radiography and MRI in recreational and professional athletes with painful hip joints.	In patients with suspected sports related stress fractures of the hip and normal radiographs, MRI of the entire pelvis should be the next imaging modality for evaluation.	4
2. Li ZC, Dai LY, Jiang LS, Qiu S. Difference in subchondral cancellous bone between postmenopausal women with hip osteoarthritis and osteoporotic fracture: implication for fatigue microdamage, bone microarchitecture, and biomechanical properties. <i>Arthritis Rheum</i> . 2012;64(12):3955-3962.	Observational-Dx	60 patients	To determine whether this difference might be attributable to the different quantity and quality of subchondral cancellous bone in the 2 conditions.	Both the ultimate stress and the elastic modulus of cancellous bone from OA patients were significantly higher than those of cancellous bone from OP patients ( $P<0.05$ ). Compared to cancellous bone from OP patients, the bone volume fraction and trabecular thickness were significantly increased, but bone matrix mineralization was significantly decreased, in cancellous bone from OA patients ( $P<0.05$ for each comparison). The microcrack density was significantly higher in OP cancellous bone than in OA cancellous bone ( $P<0.001$ ), irrespective of fatigue loading. In addition, fatigue loading resulted in a significant increase in microcrack density in both OA and OP cancellous bone ( $P<0.001$ ). There was no significant difference in nanoindentation elastic modulus and hardness between cancellous bone from OA and OP patients, as well as between bones with and without fatigue loading.	3

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<p>3. Fredericson M, Jennings F, Beaulieu C, Matheson GO. Stress fractures in athletes. <i>Top Magn Reson Imaging</i>. 2006;17(5):309-325.</p>	<p>Review/Other-Dx</p>	<p>N/A</p>	<p>To review stress fractures in athletes by focusing on MRI, which provides highly sensitive and specific evaluation for bone marrow edema, periosteal reaction as well as detection of subtle fracture lines.</p>	<p>A stress fracture is a partial or complete bone fracture that results from repeated application of stress lower than the stress required to fracture the bone in a single loading. Otherwise healthy athletes, especially runners, sustain stress injuries or fractures. Prevention or early intervention is the preferable treatment. However, it is difficult to predict injury because runners vary with regard to biomechanical predisposition, training methods, and other factors such as diet, muscle strength, and flexibility. Stress fractures account for 0.7% to 20% of all sports medicine clinic injuries. Track-and-field athletes have the highest incidence of stress fractures compared with other athletes. Stress fractures of the tibia, metatarsals, and fibula are the most frequently reported sites. The sites of stress fractures vary from sport to sport (eg, among track athletes, stress fractures of the navicular, tibia, and metatarsal are common; in distance runners, it is the tibia and fibula; in dancers, the metatarsals). In the military, the calcaneus and metatarsals were the most commonly cited injuries, especially in new recruits, owing to the sudden increase in running and marching without adequate preparation. However, newer studies from the military show the incidence and distribution of stress fractures to be similar to those found in sports clinics. Fractures of the upper extremities are relatively rare, although most studies have focused only on lower-extremity injuries. The ulna is the upper-extremity bone injured most frequently. Imaging plays a key role in the diagnosis and management of stress injuries. Plain radiography is useful when positive, but generally has low sensitivity. Radionuclide bone scanning is highly sensitive, but lacks specificity and the ability to directly visualize fracture lines.</p>	<p>4</p>

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4. McCormick F, Nwachukwu BU, Provencher MT. Stress fractures in runners. <i>Clin Sports Med.</i> 2012;31(2):291-306.	Review/Other-Dx	N/A	To review the pathophysiology, risk factors, diagnosis, treatment, and prevention of stress fractures in runners.	Stress fractures are a relatively common entity in athletes, in particular, runners. Physicians and health care providers should maintain a high index of suspicion for stress fractures in runners presenting with insidious onset of focal bone tenderness associated with recent changes in training intensity or regimen. It is particularly important to recognize “high-risk” fractures, as these are associated with an increased risk of complication. A patient with confirmed radiographic evidence of a high-risk stress fracture should be evaluated by an orthopedic surgeon. Runners may benefit from orthotics, cushioned sneakers, interval training, and vitamin/calcium supplementation as a means of stress fracture prevention.	4
5. Williams TR, Puckett ML, Denison G, Shin AY, Gorman JD. Acetabular stress fractures in military endurance athletes and recruits: incidence and MRI and scintigraphic findings. <i>Skeletal Radiol.</i> 2002;31(5):277-281.	Review/Other-Dx	178 patients	To evaluate the incidence and the MRI and scintigraphic appearance of acetabular stress (fatigue) fractures in military endurance athletes and recruits.	Stress fractures are common in endurance athletes and in military populations; however, stress fracture of the acetabulum is uncommon. 12/178 patients (6.7%) in our study had imaging findings consistent with acetabular stress fractures. 7 patterns were identified. 7 of the 12 (58%) patients had acetabular roof stress fractures. In this group, 2 cases of bilateral acetabular roof stress fractures were identified, with a synchronous tensile sided femoral neck stress fracture. The remaining 5/12 (42%) patients had anterior column stress fractures, rarely occurring in isolation, and almost always occurring with inferior pubic ramus stress fracture (4 of 5, or 80%). 1 case of bilateral anterior column stress fractures was identified without additional sites of injury.	4

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6. Bernhard A, Milovanovic P, Zimmermann EA, et al. Micro-morphological properties of osteons reveal changes in cortical bone stability during aging, osteoporosis, and bisphosphonate treatment in women. <i>Osteoporos Int.</i> 2013;24(10):2671-2680.	Review/Other-Dx	35 patients	To analyze morphological characteristics of osteons along with the geometrical indices of individual osteonal mechanical stability in young, healthy aged, untreated OP, and bisphosphonate-treated OP women.	The morphological assessment of osteons and quantification of their osteocyte lacunae revealed significant differences between the young, aged, osteoporosis and bisphosphonate-treated groups. Calculated osteonal geometric indices provided estimates of the individual osteons' resistance to compression, bending and buckling based on their size. In particular, the osteons in the bisphosphonate-treated group presented improved osteonal geometry along with increased numbers of osteocyte lacunae that had been formerly impaired due to aging and osteoporosis.	4
7. Tokumaru S, Toita T, Oguchi M, et al. Insufficiency fractures after pelvic radiation therapy for uterine cervical cancer: an analysis of subjects in a prospective multi-institutional trial, and cooperative study of the Japan Radiation Oncology Group (JAROG) and Japanese Radiation Oncology Study Group (JROSG). <i>Int J Radiat Oncol Biol Phys.</i> 2012;84(2):e195-200.	Review/Other-Dx	59 patients	To investigate pelvic insufficiency fractures after definitive pelvic radiation therapy for early-stage uterine cervical cancer, by analyzing subjects of a prospective, multi-institutional study.	The median follow-up was 24 months. The 2-year pelvic insufficiency fractures cumulative occurrence rate was 36.9% (21 patients). Using Common Terminology Criteria for Adverse Events version 3.0, grade 1, 2, and 3 insufficiency fractures were seen in 12 (21%), 6 (10%), and 3 patients (5%), respectively. 16 patients had multiple fractures, so insufficiency fractures were identified at 44 sites. The pelvic insufficiency fractures were frequently seen at the sacroileal joints (32 sites, 72%). 9 patients complained of pain. All patients' pains were palliated by rest or nonnarcotic analgesic drugs. Higher age (>70 years) and low body weight (<50 kg) were thought to be risk factors for pelvic insufficiency fractures ( $P=.007$ and $P=.013$ , Cox hazard test).	4

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8. Lassus J, Tulikoura I, Kontinen YT, Salo J, Santavirta S. Bone stress injuries of the lower extremity: a review. <i>Acta Orthop Scand.</i> 2002;73(3):359-368.	Review/Other-Dx	N/A	To review bone stress injuries of the lower extremity.	Bone stress injuries can cause long-lasting damage, especially in young athletes and military conscripts, if not diagnosed and treated properly. Diagnosis has been traditionally based on clinical, radiographic and scintigraphic examinations, but MRI has become increasingly important. High resolution MRI is particularly valuable for the grading of bone stress injuries. The clinician should be aware of the wide range of bone stress injuries and available diagnostic methods. Early diagnosis is the prerequisite for avoiding long-lasting complications. Most bone stress injuries heal with closed treatment, but surgery is necessary in some cases. They heal well if the diagnosis is not delayed and the treatment adequate	4
9. Dobrindt O, Hoffmeyer B, Ruf J, et al. Blinded-read of bone scintigraphy: the impact on diagnosis and healing time for stress injuries with emphasis on the foot. <i>Clin Nucl Med.</i> 2011;36(3):186-191.	Observational-Dx	84 patients	To evaluate the use of bone scintigraphy for the diagnosis of stress fractures in athletes and its validity for the prediction of healing time, with a focus on foot injuries.	For the diagnosis of stress injuries (n = 50/93), mean sensitivity, specificity, PPV, NPV, and accuracy were 97.3%, 67.4%, 77.7%, 95.6%, and 83.5%, respectively. Interobserver analysis showed a high agreement between all 3 readers (mean kappa = 0.83). In univariate analysis healing time of grade 3 to 4 stress injuries was significantly higher (median, 87 days; interquartile range, 69–132 days) compared with grade 1 to 2 lesions (median, 63 days; interquartile range, 43–95 days; $P=0.0067$ ). Moreover, healing time of scintigraphic high grade stress injuries was significantly longer in a general linear model with adjustment for cofactors (grade, 3-4 vs. 1-2; $P=0.033$ ).	2
10. Bryant LR, Song WS, Banks KP, Bui-Mansfield LT, Bradley YC. Comparison of planar scintigraphy alone and with SPECT for the initial evaluation of femoral neck stress fracture. <i>AJR Am J Roentgenol.</i> 2008;191(4):1010-1015.	Observational-Dx	38 patients had planar scintigraphy and 33 patients had planar scintigraphy and SPECT before MRI	Retrospective study to compare the accuracy of planar scintigraphy alone vs planar scintigraphy with SPECT for the initial evaluation of femoral neck stress fractures in a young military population.	The sensitivities of planar scintigraphy alone and with SPECT were 50% and 92.3%, respectively ( $P=0.03$ ). Accuracy of each technique for the detection of high-grade fractures was 12.5% and 70%, respectively ( $P=0.025$ ). Results suggest that SPECT should be performed with planar bone scintigraphy for the evaluation of patients with suspected femoral neck stress fractures.	3

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11. Hatem SF, Recht MP, Proffitt B. MRI of Little Leaguer's shoulder. <i>Skeletal Radiol.</i> 2006;35(2):103-106.	Review/Other-Dx	4 patients	To describe MRI findings and review the literature of young baseball players with stress injury of the proximal humerus.	MRI clearly shows the osseous and marrow changes in these patients with shoulder pain.	4
12. Liong SY, Whitehouse RW. Lower extremity and pelvic stress fractures in athletes. <i>Br J Radiol.</i> 2012;85(1016):1148-1156.	Review/Other-Dx	N/A	To review the incidence, presentation, radiological findings and management options for athletes with stress fractures of the lower limb.	Stress fractures are relatively common in athletes, particularly in long-distance runners. Strong clinical suspicion in concert with radiological imaging (in the form of plain radiographs, MRI, CT or bone scan) play important roles in the detection of stress injuries in athletes. Early recognition and treatment of stress fractures reduce athletic morbidity and allow timely return to high-level activity. It is therefore important for radiologists to be aware of mechanisms leading to, and locations of, stress injuries, to facilitate timely diagnosis.	4
13. Oka M, Monu JU. Prevalence and patterns of occult hip fractures and mimics revealed by MRI. <i>AJR Am J Roentgenol.</i> 2004;182(2):283-288.	Review/Other-Dx	73 patients	To evaluate the patterns of injury seen on MRI that are difficult to diagnose on radiography.	46% (35/76) of the studies showed subtle fractures. 17 fractures were in the proximal femur and 18 in the innominate bone. Soft-tissue abnormalities were common, found in 65% of the studies. 20% of the MRI findings were considered normal because there was no apparent finding on the images to explain the patients' symptoms.	4
14. Sankey RA, Turner J, Lee J, Healy J, Gibbons CE. The use of MRI to detect occult fractures of the proximal femur: a study of 102 consecutive cases over a ten-year period. <i>J Bone Joint Surg Br.</i> 2009;91(8):1064-1068.	Review/Other-Dx	102 consecutive patients	To investigate the use of MRI in making an early diagnosis and formulating a management plan in patients with no visible fracture of the proximal femur on plain radiographs.	There were 98 patients who fulfilled our inclusion criteria, of whom 75 were scanned within 48 hours of admission, with an overall mean time between admission and scanning of 2.4 days (0 to 10). A total of 81 patients (83%) had abnormalities detected on MRI; 23 (23%) required operative management. The use of MRI led to the early diagnosis and treatment of occult hip pathology. There is a high incidence of fractures which are not apparent on plain radiographs, and shows that MRI is useful when diagnosing other pathology such as malignancy, which may not be apparent on plain films.	4

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15. Ahovuo JA, Kiuru MJ, Visuri T. Fatigue stress fractures of the sacrum: diagnosis with MR imaging. <i>Eur Radiol.</i> 2004;14(3):500-505.	Observational-Dx	380 conscripts	Retrospective study to describe the MRI findings and clinical observations in fatigue stress fractures of the sacrum in Finnish military recruits.	MRI detected signal abnormalities compatible with sacral stress fractures in 31 patients. The linearity of the fracture lines on MRI is characteristic. MRI should be the procedure of choice for evaluating for sacral stress fractures.	3
16. Anderson MW. Imaging of upper extremity stress fractures in the athlete. <i>Clin Sports Med.</i> 2006;25(3):489-504, vii.	Review/Other-Dx	N/A	To review the most common sites of stress injuries in the upper extremity, their underlying pathophysiology, and their spectrum of imaging findings.	Although a three-phase bone scan is highly sensitive in this regard, MRI has become the study of choice at most centers.	4
17. Berger FH, de Jonge MC, Maas M. Stress fractures in the lower extremity. The importance of increasing awareness amongst radiologists. <i>Eur J Radiol.</i> 2007;62(1):16-26.	Review/Other-Dx	N/A	To review stress fractures of the lower extremity.	Raised awareness of medical staff and increased athletic activity have increased the incidence of stress fractures, now making up about 15% of the general sports medicine practice. These fractures can affect essentially every bone in the body, but are most frequent in the lower extremity. Timely diagnosis is essential to prevent dramatic consequences for the athlete, yet this is not easy. Thorough knowledge of typical sport mechanics and a high index of suspicion is needed to accurately image a professional or recreational sportsman/woman.	4
18. Campbell SE, Fajardo RS. Imaging of stress injuries of the pelvis. <i>Semin Musculoskelet Radiol.</i> 2008;12(1):62-71.	Review/Other-Dx	N/A	Review the pathophysiology and imaging appearances of stress injuries of the pelvis and sacrum.	Relevant literature regarding risk factors, problem-solving issues, and an imaging algorithm are discussed, with the goal of improving accuracy in the diagnosis of these common injuries.	4
19. Gaeta M, Minutoli F, Scribano E, et al. CT and MR imaging findings in athletes with early tibial stress injuries: comparison with bone scintigraphy findings and emphasis on cortical abnormalities. <i>Radiology.</i> 2005;235(2):553-561.	Observational-Dx	42 patients;10 volunteers	To prospectively compare CT, MRI, and bone scintigraphy in athletes with clinically suspected early stress injury of tibia.	Sensitivity of MRI, CT, and bone scintigraphy was 88%, 42%, and 74%, respectively. Specificity, accuracy, and PPVs and NPVs were 100%, 90%, 100%, and 62%, respectively, for MRI and 100%, 52%, 100%, and 26%, respectively, for CT. Significant difference in detection of early tibial stress injuries was found between MRI and both CT and bone scintigraphy (McNemar test; $P<.001$ and $P=.008$ , respectively). MRI is the single best technique in assessment of patients with suspected tibial stress injuries; in some patients with negative MRI findings, CT can depict osteopenia, which is the earliest finding of fatigue cortical bone injury.	3

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20. Kijowski R, Choi J, Mukharjee R, de Smet A. Significance of radiographic abnormalities in patients with tibial stress injuries: correlation with magnetic resonance imaging. <i>Skeletal Radiol.</i> 2007;36(7):633-640.	Observational-Dx	80 patients; 99 tibias evaluated, 2 reviewers	Retrospective review. To correlate radiographic findings with MRI findings in patients with suspected tibial stress injuries in order to determine the significance of radiographic signs of stress injury in these individuals.	Strong association between the presence of periosteal reaction on radiographs at the site of the clinical symptoms and a Fredericson grade 4 stress injury on MRI. The presence of periosteal reaction on radiographs at the site of clinical symptoms is predictive of a high-grade stress injury by MRI criteria.	2
21. Krestan C, Hojreh A. Imaging of insufficiency fractures. <i>Eur J Radiol.</i> 2009;71(3):398-405.	Review/Other-Dx	N/A	Review occurrence, imaging and differential diagnosis of insufficiency fractures.	Radiographs are still the most widely used imaging method for identification of insufficiency fractures, but sensitivity is limited, depending on the location of the fractures. MRI is a very sensitive tool to visualize bone marrow abnormalities associated with insufficiency fractures. Thin section, MDCT depicts subtle fracture lines allowing direct visualization of cortical and trabecular bone. Bone scintigraphy still plays a role in detecting fractures, with good sensitivity but limited specificity. The most important differential diagnosis is underlying malignant disease leading to pathologic fractures. Bone densitometry and clinical history may also be helpful in confirming the diagnosis of insufficiency fractures.	4
22. Lee SH, Baek JR, Han SB, Park SW. Stress fractures of the femoral diaphysis in children: a report of 5 cases and review of literature. <i>J Pediatr Orthop.</i> 2005;25(6):734-738.	Review/Other-Dx	5 patients	Small report on patients with stress fractures without a history of recent increase in activity.	MRI is most useful in diagnosing stress fractures when other causes of leg pain are being considered.	4
23. Muthukumar T, Butt SH, Cassar-Pullicino VN. Stress fractures and related disorders in foot and ankle: plain films, scintigraphy, CT, and MR Imaging. <i>Semin Musculoskelet Radiol.</i> 2005;9(3):210-226.	Review/Other-Dx	N/A	To review the various diagnostic imaging techniques in evaluating patients with suspected stress fractures.	MRI is the new “gold standard” and the modality of choice in evaluating for early stress injury.	4
24. Nguyen JT, Peterson JS, Biswal S, Beaulieu CF, Fredericson M. Stress-related injuries around the lesser trochanter in long-distance runners. <i>AJR Am J Roentgenol.</i> 2008;190(6):1616-1620.	Review/Other-Dx	9 long-distance runners, 2 reviewers	Retrospective study to assess the MRI findings associated with symptomatic stress injuries at the lesser trochanter in long-distance runners to develop guidelines for clinical management.	Long-distance runners with hip or groin pain and abnormal MRI findings involving the insertion of the iliopsoas tendon and marrow edema in the lesser trochanter may be at risk of stress injuries at the femoral neck.	4



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25. Niva MH, Sormaala MJ, Kiuru MJ, Haataja R, Ahovuo JA, Pihlajamaki HK. Bone stress injuries of the ankle and foot: an 86-month magnetic resonance imaging-based study of physically active young adults. <i>Am J Sports Med.</i> 2007;35(4):643-649.	Review/Other-Dx	378 bone stress injuries in 142 ankles and feet imaged	To assess incidence, location, and type of bone stress injuries of the ankle and foot in military conscripts with ankle and/or foot pain using MRI.	Incidence is 126 per 100,000 person-years. This incidence represents the stress injuries not diagnosable with radiographs and requiring MRIs. Of injuries, 57.7% occurred in the tarsal and 35.7% in the metatarsal bones. Multiple bone stress injuries in one foot were found in 63% of the cases. The calcaneus and fifth metatarsal bone were usually affected alone. Injuries to the other bones of the foot were usually associated with at least one other stress injury. The talus and calcaneus were the most commonly affected single bones. High-grade bone stress injury (grade IV-V) with a fracture line on MRIs occurred in 12% (talus, calcaneus), and low-grade injury (grade I-III) presented only as edema in 88% of the cases.	4
26. Sofka CM. Imaging of stress fractures. <i>Clin Sports Med.</i> 2006;25(1):53-62, viii.	Review/Other-Dx	N/A	To review the use of CT, nuclear scintigraphy, US, and MRI in patients with suspected stress fractures.	Imaging should begin with radiography of the area of question. CT is useful for fine bony detail and endosteal scalloping. Nuclear imaging shows area of stress remodeling. MRI provides the most comprehensive evaluation of stress injuries.	4
27. Sormaala MJ, Niva MH, Kiuru MJ, Mattila VM, Pihlajamaki HK. Stress injuries of the calcaneus detected with magnetic resonance imaging in military recruits. <i>J Bone Joint Surg Am.</i> 2006;88(10):2237-2242.	Observational-Dx	30 recruits displayed calcaneal stress injuries	Retrospective study to assess the anatomic distribution, nature, and healing of calcaneal stress injuries in a group of military recruits based on MRI.	MRI yielded an incidence of 2.6 (95% CI, 1.6 to 3.4) per 10,000 person-years. Most stress injuries of the calcaneus occur in the posterior part of the bone, but a considerable proportion can also be found in the middle and anterior parts. To obtain a diagnosis, MRI is warranted if plain radiography does not show abnormalities in a physically active patient with exercise-induced pain in the ankle or heel.	3
28. Sormaala MJ, Niva MH, Kiuru MJ, Mattila VM, Pihlajamaki HK. Bone stress injuries of the talus in military recruits. <i>Bone.</i> 2006;39(1):199-204.	Observational-Dx	51 consecutive recruits displayed bone stress injuries; 56 bone stress injuries 3 reviewers	Retrospective study to assess the incidence, anatomic distribution, and nature of fatigue bone stress injuries of the talus in military recruits based on MRI.	On MRI, the majority of the bone stress injuries of the talus were revealed in the head. A grade IV injury was discovered in 18% of the cases; in the remaining 82%, only grade I-III injuries were ascertained. In all locations, the lower grade bone stress injuries dominated. This study established the incidence of fatigue bone stress injury of the talus and indicated that these injuries are rare but not unseen in military recruits.	3

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29. Nachtrab O, Cassar-Pullicino VN, Lalam R, Tins B, Tyrrell PN, Singh J. Role of MRI in hip fractures, including stress fractures, occult fractures, avulsion fractures. <i>Eur J Radiol.</i> 2012;81(12):3813-3823.	Review/Other-Dx	N/A	To review the current applications of MRI highlighting its benefits and limitations in the use of hip fracture imaging.	MRI has proven to be a sensitive, cost effective and efficient modality in the use of fracture imaging. MRI aids in streamlining patient care, can help guiding towards adequate treatment decision making, as well as detecting different causes of the patient symptoms. Although MRI may not be as readily available in some hospitals and more expensive than bone scan and CT, it does however achieve definitive diagnosis much quicker. Overall cost are reduced, hospitalization stay is less due to a speedier correct diagnosis, correct treatment is started early and the risk of complications reduced.	4
30. Fottner A, Baur-Melnyk A, Birkenmaier C, Jansson V, Durr HR. Stress fractures presenting as tumours: a retrospective analysis of 22 cases. <i>Int Orthop.</i> 2009;33(2):489-492.	Review/Other-Dx	22 cases	To analyze the quality of different examinations in detecting stress fractures mimicking tumor-like lesions in MRI.	A stress fracture was diagnosed in 15 cases after the additional CT scan, in 5 cases with the review of the MRI and in 2 cases with a combination of several examinations. Especially in stress fractures of the tibia and the femur, CT scanning was essential for making a diagnosis by detecting the fracture line. Bone scans and biopsies, in contrast, were not helpful in making a correct diagnosis.	4
31. Nattiv A, Kennedy G, Barrack MT, et al. Correlation of MRI grading of bone stress injuries with clinical risk factors and return to play: a 5-year prospective study in collegiate track and field athletes. <i>Am J Sports Med.</i> 2013;41(8):1930-1941.	Observational-Dx	211 patients	To examine the relationships between MRI grading of bone stress injuries with clinical risk factors and time to return to sport in collegiate track and field athletes.	34 of the athletes (12 men, 22 women) sustained 61 bone stress injuries during the 5-year study period. The mean prospective assessment for participants was 2.7 years. In the multiple regression model, MRI grade and total-body bone mineral density emerged as significant and independent predictors of time to return to sport. Specifically, the higher the MRI grade ( $P=.004$ ) and lower the bone mineral density ( $P=.030$ ), the longer the recovery time. Location of the bone injury at predominantly trabecular sites of the femoral neck, pubic bone, and sacrum was also associated with a prolonged time to return to sport. Female athletes with oligomenorrhea and amenorrhea had bone stress injuries of higher MRI grades compared with eumenorrheic athletes ( $P=.009$ ).	3

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32. Wright AA, Hegedus EJ, Lenchik L, Kuhn KJ, Santiago L, Smoliga JM. Diagnostic Accuracy of Various Imaging Modalities for Suspected Lower Extremity Stress Fractures: A Systematic Review With Evidence-Based Recommendations for Clinical Practice. <i>Am J Sports Med.</i> 2016;44(1):255-263.	Review/Other-Dx	21 studies	To determine the diagnostic accuracy statistics of imaging modalities used to diagnose lower extremity stress fractures and to synthesize evidence-based recommendations for clinical practice.	Reported sensitivity and specificity (95% CI) were as follows: For conventional radiography, sensitivity ranged from 12% (0%–29%) to 56% (39%–72%) and specificity ranged from 88% (55%–100%) to 96% (87%–100%). For nuclear scintigraphy, sensitivity ranged from 50% (23%–77%) to 97% (90%–100%) and specificity from 33% (12%–53%) to 98% (93%–100%). For MRI, sensitivity ranged from 68% (45%–90%) to 99% (95%–100%) and specificity from 4% (0%–11%) to 97% (88%–100%). For CT, sensitivity ranged from 32% (8%–57%) to 38% (16%–59%) and specificity from 88% (55%–100%) to 98% (91%–100%). For US, sensitivity ranged from 43% (26%–61%) to 99% (95%–100%) and specificity from 13% (0%–45%) to 79% (61%–96%).	4
33. Bianchi S, Luong DH. Stress fractures of the ankle malleoli diagnosed by ultrasound: a report of 6 cases. <i>Skeletal Radiol.</i> 2014;43(6):813-818.	Review/Other-Dx	6 patients	To present the US appearance of stress fractures of the ankle malleoli.	At US patients showed thickening of the periosteum in all patients, calcified bone callus was evident in 3 out of 6 patients. Cortical irregularities and subcutaneous oedema were found in all but 1 patient. Color Doppler showed local hypervascular changes in all patients. Local compression with the transducers during real-time scanning increased pain in all cases.	4
34. Banal F, Etchepare F, Rouhier B, et al. Ultrasound ability in early diagnosis of stress fracture of metatarsal bone. <i>Ann Rheum Dis.</i> 2006;65(7):977-978.	Review/Other-Dx	1 patient	To report a case of US diagnosis of metatarsal stress fracture.	No results stated in abstract.	4
35. Banal F, Gandjbakhch F, Foltz V, et al. Sensitivity and specificity of ultrasonography in early diagnosis of metatarsal bone stress fractures: a pilot study of 37 patients. <i>J Rheumatol.</i> 2009;36(8):1715-1719.	Observational-Dx	37 patients	To evaluate sensitivity and specificity of US vs dedicated MRI (0.2 Tesla), taken as the gold standard, in early diagnosis of metatarsal bone stress fractures.	41 feet were analyzed on US and dedicated MRI from 37 patients (28 women, 9 men, mean age 52.7 +/- 14.1 years). MRI detected 13 fractures in 12 patients. Sensitivity of US was 83%, specificity 76%, PPV 59%, and NPV 92%. Positive likelihood ratio was 3.45, negative likelihood ratio 0.22.	2

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36. Gaeta M, Mileto A, Ascenti G, Bernava G, Murabito A, Minutoli F. Bone stress injuries of the leg in athletes. <i>Radiol Med.</i> 2013;118(6):1034-1044.	Review/Other-Dx	N/A	To review the imaging findings of the whole spectrum of stress-induced bone lesions of the leg in athletes.	Bone stress injuries, whose incidence is increasing among competitive and recreational athletes, represent a pathophysiological continuum along which a bone responds to a changing mechanical environment. Frank stress fracture is the endpoint of this process, resulting from the accumulation of microinjuries due to repeated abnormal stresses. The legs are largely the most frequently affected bone district.	4
37. Hulkko A, Orava S, Nikula P. Stress fractures of the olecranon in javelin throwers. <i>Int J Sports Med.</i> 1986;7(4):210-213.	Review/Other-Dx	4 patients	To review stress fractures of the olecranon in javelin throwers.	Between the years 1977 and 1984, 4 javelin throwers with a stress fracture of the olecranon were seen and treated. In 1 patient, acute painful dislocation of the fracture occurred during a competitive throw. 2 patients had stress fracture of the tip. The fracture treated conservatively healed in 18 months. The patient treated by excision of the tip was able to throw after 2 months. 2 patients had slightly oblique, more distally located stress fractures, which were treated with a tension band and 2 Kirschner wires. The fractures healed in 4 months. One of the patients had a refracture 11 months after the primary operation. It was successfully treated with a compression screw and 2 bone pegs. Because of the high risk of delayed union and nonunion, stress fractures of the olecranon should be treated operatively in javelin throwers.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
38. Khan KM, Brukner PD, Kearney C, Fuller PJ, Bradshaw CJ, Kiss ZS. Tarsal navicular stress fracture in athletes. <i>Sports Med.</i> 1994;17(1):65-76.	Review/Other-Dx	N/A	To review tarsal navicular stress fracture in athletes.	Stress fracture of the tarsal navicular bone is now frequently recognized. The majority of navicular stress fractures are partial fractures in the sagittal plane. They occur mainly in track and field athletes. A number of theories regarding the etiology of this fracture have been proposed. Athletes with a history of vague, activity-related midfoot pain, with associated tenderness over the dorsal proximal navicular ('N' spot) should be suspected of having a navicular stress fracture. Plain radiography frequently fails to demonstrate the fracture, thus radionuclide scanning is the investigation of choice to detect navicular stress injury. A CT scan should be performed to confirm the presence of the fracture. Various methods of treatment have been employed. A minimum of 6 weeks of strict non-weightbearing cast immobilization is the treatment of choice. After removal of the cast, a further 6 week program of rehabilitation with a graduated return to activity, joint mobilization and soft tissue massage is required. Surgery for nonunion or delayed union is rarely required if initial treatment is appropriate.	4
39. Behrens SB, Deren ME, Matson A, Fadale PD, Monchik KO. Stress fractures of the pelvis and legs in athletes: a review. <i>Sports Health.</i> 2013;5(2):165-174.	Review/Other-Dx	N/A	To review the literature regarding stress fractures of the pelvis and legs in athletes.	Intrinsic and extrinsic factors may predict the risk of stress fractures in athletes, including bone health, training, nutrition, and biomechanical factors. Based on their location, stress fractures may be categorized as low- or high-risk, depending on the likelihood of the injury developing into a complete fracture. Treatment for these injuries varies substantially and must account for the risk level of the fractured bone, the stage of fracture development, and the needs of the patient. High-risk fractures include the anterior tibia, lateral femoral neck, patella, medial malleolus, and femoral head. Low-risk fractures include the posteromedial tibia, fibula, medial femoral shaft, and pelvis. MRI is the imaging test of choice for diagnosis.	4

\* See Last Page for Key

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
40. Fullerton LR, Jr., Snowdy HA. Femoral neck stress fractures. <i>Am J Sports Med.</i> 1988;16(4):365-377.	Observational-Dx	49 patients	To review our results as to classification, incidence, race of patients, bone scintigraphy, and treatment of femoral neck stress fractures.	No results stated in abstract.	3
41. Monteleone GP, Jr. Stress fractures in the athlete. <i>Orthop Clin North Am.</i> 1995;26(3):423-432.	Review/Other-Dx	N/A	To describe stress fractures in athletes.	Stress fractures are common injuries in the athletic population. High clinical suspicion is required for the diagnosis because of vague historical and physical features. Bone scans are the gold standard of diagnosis, though MRI and CT may be helpful adjuncts. Most stress fractures do very well with the nonsurgical treatment approach. Some fractures of the proximal diaphysis of the fifth metatarsal, femoral neck fractures, and any displaced, completed fracture require surgery. Consideration must also be given for correctable risk factors and preventive measures must be addressed.	4
42. DeFranco MJ, Recht M, Schils J, Parker RD. Stress fractures of the femur in athletes. <i>Clin Sports Med.</i> 2006;25(1):89-103, ix.	Review/Other-Dx	N/A	To describe the pathoanatomy, cause, clinical assessment, and treatment options will facilitate the care of athletes with a femoral stress fracture and the return to a preinjury level of competition.	Femoral stress fractures represent an uncommon but important lower-extremity injury in athletes and soldiers. Careful assessment of the involved and contralateral lower extremity and the spine is required to make the diagnosis. Based on a review of the literature, specific treatment is based on individual patient assessment. In most cases, nonoperative management results in an excellent outcome. Certain fractures will require operative intervention to prevent displacement or to reduce a displaced fracture and return stability to the lower extremity. Complications in athletes with femoral stress fractures are rare. Most athletes can expect to return to their preinjury level of competition, if they are compliant with the treatment plan.	4
43. Boden BP, Osbahr DC. High-risk stress fractures: evaluation and treatment. <i>J Am Acad Orthop Surg.</i> 2000;8(6):344-353.	Review/Other-Dx	N/A	To describe the evaluation and treatment of high-risk stress fractures.	No results stated in abstract.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
44. Goolsby MA, Barrack MT, Nattiv A. A displaced femoral neck stress fracture in an amenorrheic adolescent female runner. <i>Sports Health</i> . 2012;4(4):352-356.	Review/Other-Dx	1 case	A case report to demonstrate the potential serious consequences of the female athlete triad and its effects on bone.	Displaced femoral neck stress fractures cause significant morbidity, and this case highlights the preventable nature of this injury. The treatment was focused on improving low energy availability, and, although challenging, improvements were made. This injury could have been prevented if the signs and symptoms of her injury had been addressed and there had been better knowledge of her risk factors. This case highlights the need for further education in the sports and health communities.	4
45. Jones BH, Thacker SB, Gilchrist J, Kimsey CD, Jr., Sosin DM. Prevention of lower extremity stress fractures in athletes and soldiers: a systematic review. <i>Epidemiol Rev</i> . 2002;24(2):228-247.	Review/Other-Dx	423 scientific publications	To review the reported research on the causes of and risk factors for stress fracture, to determine what is known about the prevention of stress fracture and to make recommendations for a systematic approach to future research and prevention.	This review summarizes an extensive body of literature on stress fractures. It also highlights how little we know about what works to prevent one of the most common and potentially serious sports- and exercise-related overuse injuries. The available research suggests that for many persons, stress fractures and other physical training-related injuries can be prevented by reducing the amounts of weight-bearing exercise performed without sacrificing fitness. The data also suggest that the most sedentary and least physically fit persons are most vulnerable to stress fractures when starting a vigorous exercise program and that they would benefit most from starting exercise gradually and reducing training volume. Until more definitive solutions become available, a common-sense approach to training and overuse injury prevention must be recommended.	4
46. Craig JG, Widman D, van Holsbeeck M. Longitudinal stress fracture: patterns of edema and the importance of the nutrient foramen. <i>Skeletal Radiol</i> . 2003;32(1):22-27.	Review/Other-Dx	N/A	To review the MR appearances of 6 cases of longitudinal stress fracture of the lower extremity.	One fracture was in the femur and 5 were in the tibia. 4 of the tibial fractures showed edema starting in the mid-tibia at the level of the nutrient foramen with the fracture on the anteromedial cortex. The other tibial fracture started at the nutrient foramen. 3 fractures (2 tibial and the femur fracture) showed eccentric marrow edema; all fractures showed either eccentric periosteal reaction or soft tissue edema.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
47. Groves AM, Cheow HK, Balan KK, Housden BA, Bearcroft PW, Dixon AK. 16-Detector multislice CT in the detection of stress fractures: a comparison with skeletal scintigraphy. <i>Clin Radiol.</i> 2005;60(10):1100-1105.	Observational-Dx	26 patients	To test the hypothesis that the improved resolution afforded by MDCT provides better stress fracture detection when compared with skeletal scintigraphy.	Scintigraphy detected more stress fractures. MDCT should not be used as the initial investigative tool for suspected stress fractures.	2
48. Fredericson M, Bergman AG, Hoffman KL, Dillingham MS. Tibial stress reaction in runners. Correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. <i>Am J Sports Med.</i> 1995;23(4):472-481.	Review/Other-Dx	14 runners	To evaluate tibial stress injuries in runners, develop a grading system based on MRI findings, and try to identify clinical parameters correlating with more severe grades of injury.	Medial tibial pain in runners has traditionally been diagnosed as either a shin splint syndrome or as a stress fracture. Our work using MRI suggests that a progression of injury can be identified, starting with periosteal edema, then progressive marrow involvement, and ultimately frank cortical stress fracture. 14 runners, with a total of 18 symptomatic legs, were evaluated and, within 10 days, referred for radiographs, a technetium bone scan, and a MRI scan. In 14 of the 18 symptomatic legs, MRI findings correlated with an established technetium bone scan grading system and more precisely defined the anatomic location and extent of injury. We identified clinical symptoms, such as pain with daily ambulation and physical examination findings, including localized tibial tenderness and pain with direct or indirect percussion that correlated with more severe tibial stress injuries. When clinically warranted, we recommend MRI over bone scan for grading of tibial stress lesions in runners. MRI is more accurate in correlating the degree of bone involvement with clinical symptoms, allowing for more accurate recommendations for rehabilitation and return to impact activity. Additional advantages of MRI include lack of exposure to ionizing radiation and significantly less imaging time than three-phase bone scintigraphy.	4



**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
49. Arendt E, Agel J, Heikes C, Griffiths H. Stress injuries to bone in college athletes: a retrospective review of experience at a single institution. <i>Am J Sports Med.</i> 2003;31(6):959-968.	Review/Other-Dx	74 patients	To review, in a college athlete population, the epidemiologic aspects of stress injuries to bone, and to examine a subset of patients who were treated with a uniform protocol for return to activities, with MRI as the primary tool for diagnosis.	74 athletes had lower extremity symptoms consistent with stress injury to bone. Diagnosis was confirmed in 68 of these athletes, 61 via MRI, 6 via positive radiographs only, and 1 via bone scan only. Distance runners accounted for the most stress injuries to bone for both men and women. The tibia (37%) was the most frequently involved bone; however, as an anatomic region, the foot (44%) was the site of the most stress injuries. There was a significant correlation between grade of injury and time to full return to activity.	4
50. Beck BR, Bergman AG, Miner M, et al. Tibial stress injury: relationship of radiographic, nuclear medicine bone scanning, MR imaging, and CT Severity grades to clinical severity and time to healing. <i>Radiology.</i> 2012;263(3):811-818.	Observational-Dx	40 patients	To examine the relationship between severity grade for radiography, triple-phase Tc-99m nuclear medicine bone scanning, MRI, and CT; clinical severity; and recovery time from a tibial stress injury, as well as to evaluate interassessor grading reliability.	Image assessment reliability was high for all grading systems except radiography, which was moderate ( $\alpha = 0.565-0.895$ ). Clinical severity was negatively associated with MRI severity ( $P \leq .001$ ). There was no significant relationship between time to healing and severity score for any imaging modality, although a positive trend existed for MRI ( $P = .07$ ).	3
51. Yao L, Johnson C, Gentili A, Lee JK, Seeger LL. Stress injuries of bone: analysis of MR imaging staging criteria. <i>Acad Radiol.</i> 1998;5(1):34-40.	Observational-Dx	35 patients	To examine the prognostic value of MRI in stress injuries of bone.	The MRI finding of a "fracture" or "fatigue" line or a cortical signal intensity abnormality was predictive of a longer symptomatic period, whereas muscle edema was predictive of a shorter symptomatic period. A published grading system could be used in only 24 patients; the MRI grade of injury did not show correlation with clinical outcome.	3
52. Kijowski R, Choi J, Shinki K, Del Rio AM, De Smet A. Validation of MRI classification system for tibial stress injuries. <i>AJR Am J Roentgenol.</i> 2012;198(4):878-884.	Observational-Dx	138 patients including 142 tibial stress injuries	To compare an MRI classification system for tibial stress injuries with semiquantitative MR features of injury severity and clinical outcome.	Grade 4b injuries had significantly ( $P < 0.002$ ) more severe and grade 1 injuries less severe periosteal and bone marrow edema than grades 2, 3, and 4a injuries. Grade 4b injuries had significantly ( $P < 0.002$ ) longer time and grade 1 injuries shorter time to return to sports activity than grades 2, 3, and 4a injuries. There was no significant difference ( $P = 0.06-0.79$ ) among grades 2, 3, and 4a injuries in the degree of periosteal and bone marrow edema and the time to return to sports activity.	3

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
53. Matheson GO, Clement DB, McKenzie DC, Taunton JE, Lloyd-Smith DR, MacIntyre JG. Stress fractures in athletes. A study of 320 cases. <i>Am J Sports Med.</i> 1987;15(1):46-58.	Review/Other-Dx	320 patients	To provide descriptive data from 320 cases of bone scan-positive stress fractures in athletes and to document the results of conservative treatment.	The most common bone injured was the tibia (49.1%), followed by the tarsals (25.3%), metatarsals (8.8%), femur (7.2%), fibula (6.6%), pelvis (1.6%), sesamoids (0.9%), and spine (0.6%). Stress fractures were bilateral in 16.6% of cases. A significant age difference among the sites was found, with femoral and tarsal stress fractures occurring in the oldest, and fibular and tibial stress fractures in the youngest. Running was the most common sport at the time of injury but there was no significant difference in weekly running mileage and affected sites. A history of trauma was significantly more common in the tarsal bones. The average time to diagnosis was 13.4 weeks (range, 1 to 78) and the average time to recovery was 12.8 weeks (range, 2 to 96). Tarsal stress fractures took the longest time to diagnose and recover. Varus alignment was found frequently, but there was no significant difference among the fracture sites, and varus alignment did not affect time to diagnosis or recovery. Radiographs were taken in 43.4% of cases at the time of presentation but were abnormal in only 9.8%. A group of bone scan-positive stress fractures of the tibia, fibula, and metatarsals (N = 206) was compared to a group of clinically diagnosed stress fractures of the same bone groups (N = 180), and no significant differences were found.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
54. Tsiridis E, Upadhyay N, Giannoudis PV. Sacral insufficiency fractures: current concepts of management. <i>Osteoporos Int.</i> 2006;17(12):1716-1725.	Review/Other-Dx	N/A	To raise awareness and outline the clinical presentation, methods of diagnosis and treatment of sacral insufficiency fractures.	Insufficiency fractures represent a special category of stress fractures that occur in bones with reduced mineral content and elastic resistance. Sacral insufficiency fractures, a well-defined subgroup of the latter group, are not uncommon, but lack of clinical suspicion results in many being undiagnosed. Sacral insufficiency fractures are set to become an important clinical entity of both social and economic significance as the Western population ages. Subtle clinical presentations and signs coupled with radiographic findings that can mimic other unrelated or overlapping conditions, such as sacroiliac joint infection, spinal stenosis and metastatic bone disease, often make sacral insufficiency fracture diagnosis a challenge.	4
55. Shah MK, Stewart GW. Sacral stress fractures: an unusual cause of low back pain in an athlete. <i>Spine (Phila Pa 1976).</i> 2002;27(4):E104-108.	Review/Other-Dx	1 patient	To document the occurrence of sacral stress fractures in athletes and to recommend it in the differential diagnosis of low back pain, especially in runners and volleyball players.	In a 16-year-old volleyball player with a 4-week history of low back pain, MRI of her pelvis revealed a stress fracture of the left sacral ala. She was treated with nonsteroidal anti-inflammatory agents, rest, and conditioning exercises and had a good functional outcome.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
56. Fujii M, Abe K, Hayashi K, et al. Honda sign and variants in patients suspected of having a sacral insufficiency fracture. <i>Clin Nucl Med.</i> 2005;30(3):165-169.	Review/Other-Dx	34 bone scans of 26 patients	To reassess whether the Honda sign and its variants on bone scans can be used to differentiate an insufficiency fracture of the sacrum from a metastasis and to evaluate extrapelvic tracer accumulation in patients suspected of having a sacral insufficiency fracture.	24 of the patients had a sacral insufficiency fracture and 1 had a sacral metastasis from prostate cancer and another from lung cancer. The bone scans of only 15 (63%) of the 24 patients with a sacral insufficiency fracture exhibited the Honda sign, 8 (33%) scans exhibited variants, and 4 (4%) scans showed whole-sacrum uptake. One of the 2 patients with metastasis exhibited the Honda sign and the other exhibited a variant. The sensitivity and PPV of Honda sign plus its variants as diagnostic criteria for sacral insufficiency fracture were 96% and 92%, respectively. 17 patients (71%) had extrasacral accumulation. The most common site was the pubic bone (50%, 12/24), and the second most common site was the spine (46%, 11/24), where the accumulation was the result of a compression fracture or degenerative joint disease of the spine.	4
57. Beltran LS, Bencardino JT. Lower back pain after recently giving birth: postpartum sacral stress fractures. <i>Skeletal Radiol.</i> 2011;40(4):461-462, 481-462.	Review/Other-Dx	1 case	A case report of a woman presented to the emergency room with severe lower back pain after recently giving birth.	No results stated in abstract.	4
58. Kiuru MJ, Pihlajamaki HK, Ahovuo JA. Fatigue stress injuries of the pelvic bones and proximal femur: evaluation with MR imaging. <i>Eur Radiol.</i> 2003;13(3):605-611.	Observational-Dx	340 consecutive conscripts	To determine the imaging and patient characteristics of stress injuries in patients with hip or pelvic pain and clinically suspected stress injury bases on MRI results.	The sensitivity of radiography was 37%, specificity 79%, accuracy 60%, PPV 59% and NPV 61%. The kappa value for agreement between radiography and MRI was poor (0.17, $P=0.0008$ ). Patients suffering from stress-related hip pain, MRI revealed bone stress injuries in 40%; of these, 60% were located in the proximal femur and 40% in the pelvic bones. MRI of the entire pelvis and proximal femurs should be used to evaluate patients suspected of having stress injuries presenting with hip or pelvic pain.	3

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
59. Theodorou SJ, Theodorou DJ, Resnick D. Imaging findings in symptomatic patients with femoral diaphyseal stress injuries. <i>Acta Radiol.</i> 2006;47(4):377-384.	Review/Other-Dx	7 patients	To assess the imaging findings seen in symptomatic patients with stress injuries of the femoral diaphysis.	Radiographs depicted 3 frank fractures in 2 patients, and revealed findings of stress injury in 6 patients. Available scintigraphic and CT findings were abnormal. On MRIs, a solitary fracture was seen in 2 patients; 2 patients presented with bilateral stress fractures of the femoral diaphysis; and all 7 patients had the imaging features of stress injury. Femoral diaphyseal stress fractures (n = 6) appeared as linear regions of T1- and T2-weighted low signal intensity, surrounded by diffuse bone marrow edema. 3 of the 6 frank fractures, with an evident fracture line, were longitudinal and parallel to the cortical surface.	4
60. Schmid L, Pfirrmann C, Hess T, Schlumpf U. Bilateral fracture of the sacrum associated with pregnancy: a case report. <i>Osteoporos Int.</i> 1999;10(1):91-93.	Review/Other-Dx	1 case	To describe a 33-year-old woman with a bilateral fracture of the sacrum associated with pregnancy.	Dual-energy X-ray absorptiometry of the lumbar spine and femoral neck showed normal bone mineral density, whereas bilateral osteopenic areas in the massae laterales were demonstrated by the initial CT-scan.	4
61. Soubrier M, Dubost JJ, Boisgard S, et al. Insufficiency fracture. A survey of 60 cases and review of the literature. <i>Joint Bone Spine.</i> 2003;70(3):209-218.	Observational-Dx	60 patients	Retrospective review to report findings on risk factors, location, clinical course, and imaging of insufficiency fractures.	Radiography showed a fracture line or osteocondensation in 65% (39/60) of cases. Scintigraphy was positive in 87.5% of cases (21/24), showing a fracture line (15) or a callus (6). Bone CT scan was positive in 98.1% (54/55) of cases. Insufficiency fractures occur in elderly women with osteoporosis and most commonly in the pelvis. Since radiologic signs are inconstant, scintigraphy is the choice procedure.	3

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
62. Fayad LM, Kamel IR, Kawamoto S, Bluemke DA, Frassica FJ, Fishman EK. Distinguishing stress fractures from pathologic fractures: a multimodality approach. <i>Skeletal Radiol.</i> 2005;34(5):245-259.	Review/Other-Dx	N/A	To present select examples of fractures that underscore imaging features that help distinguish stress fractures from pathologic fractures.	Whereas stress fractures occur in normal or metabolically weakened bones, pathologic fractures occur at the site of a bone tumor. Unfortunately, stress fractures may share imaging features with pathologic fractures on plain radiography, and therefore other modalities are commonly utilized to distinguish these entities. Additional cross-sectional imaging with CT or MRI as well as scintigraphy and PET scanning is often performed for further evaluation. For the detailed assessment of a fracture site, CT offers a high-resolution view of the bone cortex and periosteum which aids the diagnosis of a pathologic fracture. The character of underlying bone marrow patterns of destruction can also be ascertained along with evidence of a soft tissue mass. MRI, however, is a more sensitive technique for the detection of underlying bone marrow lesions at a fracture site. In addition, the surrounding soft tissues, including possible involvement of adjacent muscle, can be well evaluated with MRI. While bone scintigraphy and FDG-PET are not specific, they offer a whole-body screen for metastases in the case of a suspected malignant pathologic fracture.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
63. Steib-Furno S, Luc M, Pham T, et al. Pregnancy-related hip diseases: incidence and diagnoses. <i>Joint Bone Spine</i> . 2007;74(4):373-378.	Review/Other-Dx	N/A	To report the incidence of gestational and postpartum hip diseases and evaluate their incidence.	During the 2-year prospective survey, 3 patients (4 hips) of pregnancy-related hip disease were observed over 4900 pregnancies (1 case of transient osteoporosis of the hip and 2 cases of occult fracture of the femoral head). During the 15-year retrospective study, 12 patients (17 hips) with hip diseases during pregnancy or early postpartum were identified. There were 6 patients (9 hips) with transient osteoporosis of the hip, 4 patients (6 hips) with occult fracture of the femoral head, 1 patient with osteonecrosis of the femoral head, and 1 coxitis in a patient with ankylosing spondylitis. Differentiating diagnosis between transient osteoporosis of the hip and occult fractures could only be made by MRI. 5 of the 6 women with transient osteoporosis of the hip had osteopenia at the lumbar spine at dual energy X-ray absorptiometry. The 4 women with occult fractures had either osteopenia or osteoporosis at the lumbar spine.	4
64. Blomlie V, Rofstad EK, Talle K, Sundfor K, Winderen M, Lien HH. Incidence of radiation-induced insufficiency fractures of the female pelvis: evaluation with MR imaging. <i>AJR Am J Roentgenol</i> . 1996;167(5):1205-1210.	Observational-Dx	18 women	To assess the incidence, time of appearance and evolution of radiation-induced insufficiency fractures of the female pelvis with MRI.	16 (89%) of 18 patients (7 premenopausal and 9 postmenopausal) showed findings compatible with insufficiency fractures. 13 patients had more than 1 lesion. The first fracture was detected between 3 and 12 months after the end of radiation therapy. During the study, the fractures associated with edema subsided without treatment in 41 (79%) of 52 lesions in 15 (94%) of 16 patients. Fractures were confirmed with additional imaging in all 16 patients (CT in 14 patients and bone scanning in 9 patients).	3

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
65. Stacy GS, Dixon LB. Pitfalls in MR image interpretation prompting referrals to an orthopedic oncology clinic. <i>Radiographics</i> . 2007;27(3):805-826; discussion 827-808.	Review/Other-Dx	N/A	To review the benign entities that may be mistaken by the radiologist for a malignancy and thus lead to needless referral to an orthopedic oncologist.	The MRI appearance of osteonecrosis, Paget disease, benign bone lesions, and rheumatologic conditions may be confusing; in such circumstances, radiographic findings may help formulate a correct diagnosis. Knowledge of the common locations and appearances of bursae and ganglia is necessary so that radiologists do not misinterpret these benign entities as soft-tissue sarcomas. Soft-tissue trauma and inflammation also may mimic tumors at MRI, but a familiarity with the imaging patterns of nonneoplastic change in muscle allows the avoidance of misinterpretation. The clinical history, as always, is an important component of proper diagnosis. The radiologist can be especially useful to both the clinician and the patient by recognizing entities that are highly unlikely to represent malignancy and by confidently reporting those entities as benign, thereby sparing the patient an unnecessary trip to the orthopedic oncologist.	4
66. Erly WK, Oh ES, Outwater EK. The utility of in-phase/opposed-phase imaging in differentiating malignancy from acute benign compression fractures of the spine. <i>AJNR Am J Neuroradiol</i> . 2006;27(6):1183-1188.	Observational-Dx	21 patients	To assess whether in-phase/opposed-phase imaging of the spine can differentiate these 2 entities.	21 patients had 49 vertebral lesions, consisting of 20 malignant and 29 benign fractures. There was a significant difference ( $P < .001$ , Student t test) in the mean signal intensity ratio for the benign lesions (mean, 0.58; SD, 0.02) compared with the malignant lesions (mean, 0.98; SD, 0.095). If a signal intensity ratio of 0.80 as a cutoff is chosen, with $>0.8$ defined as malignant and $<0.8$ defined as a benign result, in-phase/opposed-phase imaging correctly identified 19/20 malignant lesions and 26/29 benign lesions (sensitivity, 0.95; specificity, 0.89).	3



**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
67. Brenner AI, Koshy J, Morey J, Lin C, DiPoce J. The bone scan. <i>Semin Nucl Med.</i> 2012;42(1):11-26.	Review/Other-Dx	N/A	To review the clinical strength of planar bone imaging, in comparison SPECT, SPECT/CT, FDG-PET imaging and briefly reviews the re-emergence of 18F sodium fluoride bone PET imaging.	The power of bone imaging lies in the physiological uptake and pathophysiologic behavior of Tc-99m diphosphonates. Its clinical utility, sensitivity and specificity was established based on planar imaging data. Planar bone imaging data are often sufficient for diagnosis and may be enhanced by SPECT. New imaging modalities, including FDG-PET, CT and MR are complementary to Tc-99m bone imaging. FDG-PET and Tc-99m bone imaging reflect different biological processes (FDG uptake by tumor cells; methylene diphosphate uptake by osteoblastic activity). We can lower radiation doses by prescribing lower injected doses and minimizing unnecessary additional imaging. We are physicians and should all adopt a "value-added" approach to image interpretation.	4
68. Kannus P, Palvanen M, Niemi S, Parkkari J, Jarvinen M. Epidemiology of osteoporotic pelvic fractures in elderly people in Finland: sharp increase in 1970-1997 and alarming projections for the new millennium. <i>Osteoporos Int.</i> 2000;11(5):443-448.	Review/Other-Dx	N/A	To determine the current trend in the number and incidence of OP pelvic fractures in Finland, a country with a Caucasian population of 5 million.	The total number of OP pelvic fractures increased considerably in Finland during the study period, from 128 in 1970 to 913 in 1997, an average increase of 23% a year. The corresponding fracture incidence (per 100,000 persons 60 years of age or older) was 20 in 1970 and 92 in 1997. The mean age of the patients also increased, from 74 years (1970) to 80 years (1997). Despite this, the age-adjusted incidence of OP pelvic fractures also showed a steady increase from 1970 to 1997: in women, from 31 to 103, and in men, from 13 to 38 (relative increases were 232% and 192%, respectively). If this trend continues, the current number of OP pelvic fractures in this country (about 900 fractures per year) may treble by the year 2030 (about 2,700 fractures per year).	4
69. Breuil V, Brocq O, Euler-Ziegler L, Grimaud A. Insufficiency fracture of the sacrum revealing a pregnancy associated osteoporosis. First case report. <i>Ann Rheum Dis.</i> 1997;56(4):278-279.	Review/Other-Dx	1 case	A case report on the insufficiency fracture of the sacrum revealing a pregnancy associated osteoporosis.	No results stated in abstract.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
70. Karatas M, Basaran C, Ozgul E, Tarhan C, Agildere AM. Postpartum sacral stress fracture: an unusual case of low-back and buttock pain. <i>Am J Phys Med Rehabil.</i> 2008;87(5):418-422.	Review/Other-Dx	1 case	A case of postpartum sacral stress fracture.	To date, only 8 postpartum sacral stress fractures have been reported in the literature. A 32-year-old woman presented with low-back and right buttock pain that started 15 days after uneventful cesarean section delivery. Imaging studies revealed a right sacral stress fracture. Lumbar spine and femoral neck bone mineral density were normal and, except for pregnancy and lactation, no risk factors for osteoporosis were identified. There was no history of trauma, excessive weight gain, strenuous physical activity, or contribution of mechanical factors. The question remains whether this is an insufficiency fracture or a fatigue fracture. Clinicians should consider sacral fracture during pregnancy and the postpartum period as a diagnostic possibility in patients with low-back and/or buttock pain.	4
71. Lin JT, Lutz GE. Postpartum sacral fracture presenting as lumbar radiculopathy: a case report. <i>Arch Phys Med Rehabil.</i> 2004;85(8):1358-1361.	Review/Other-Dx	1 case	To present a case of a young, postpartum, recreational runner who developed low back pain and radicular symptoms suggestive of L5 radiculopathy found to be secondary to sacral stress fracture.	Sacral stress fractures are a rare entity that may occur in exercising postpartal women. The specific explanation for these fractures remains unclear. Symptoms include low back pain and radicular pain, which may initially be attributed to a diskogenic cause. Overall, these patients have a good clinical outcome. Rehabilitation, including light weight-bearing exercise, is essential for bone healing and may be performed with the use of adequate pain control. Underlying causes for fracture, such as osteoporosis or other metabolic bone disease, should ideally be ruled out to correct potentially treatable conditions. Clinicians caring for postpartum exercising women should have a high clinical suspicion for sacral stress fracture in patients with low-back, buttock, or groin pain.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
72. Rousiere M, Kahan A, Job-Deslandre C. Postpartal sacral fracture without osteoporosis. <i>Joint Bone Spine</i> . 2001;68(1):71-73.	Review/Other-Dx	1 case	To report a new case of nontrauma-related postpartal sacral fracture.	Pregnancy-related sacral fractures are uncommon but should be considered by rheumatologists in the differential diagnosis of buttock pain during pregnancy or the early postpartal period. MRI usually provides the diagnosis. Increased awareness of pregnancy-related sacral fractures through the publication of case reports will increase the number of diagnosed cases.	4
73. Thein R, Burstein G, Shabshin N. Labor-related sacral stress fracture presenting as lower limb radicular pain. <i>Orthopedics</i> . 2009;32(6):447.	Review/Other-Dx	N/A	To review sacral stress fractures.	No results stated in abstract.	4
74. Thienpont E, Simon JP, Fabry G. Sacral stress fracture during pregnancy--a case report. <i>Acta Orthop Scand</i> . 1999;70(5):525-526.	Review/Other-Dx	1 case	A case report of sacral stress fracture during pregnancy.	No results stated in abstract.	4
75. Leroux JL, Denat B, Thomas E, Blotman F, Bonnel F. Sacral insufficiency fractures presenting as acute low-back pain. Biomechanical aspects. <i>Spine (Phila Pa 1976)</i> . 1993;18(16):2502-2506.	Review/Other-Dx	10 cases	To describe 10 cases of spontaneous sacral insufficiency fractures, confirmed by CT, characterized by the onset of acute low-back pain.	Sacral insufficiency fractures are an often unsuspected cause of low-back pain in elderly women with osteopenia who have sustained unknown or only minimal trauma. Differential clinical and radiographic diagnosis of these fractures is often difficult. Recognition of the characteristic scintigraphic patterns in sacral fractures, which are frequent in osteopenic patients, could avoid mistaken diagnoses and unnecessary tests or treatment. One of the striking features of these sacral fractures is their invariable location. The fractures extend vertically in the sacral alae, parallel to the sacroiliac joints. They are located just lateral to the margins of the lumbar spine. This distribution suggests that such fractures could be partially caused by weight-bearing transmitted through the spine.	4
76. American College of Radiology. <i>Manual on Contrast Media</i> . Available at: <a href="http://www.acr.org/Quality-Safety/Resources/Contrast-Manual">http://www.acr.org/Quality-Safety/Resources/Contrast-Manual</a> .	Review/Other-Dx	N/A	Guidance document on contrast media to assist radiologists in recognizing and managing risks associated with the use of contrast media.	N/A	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
77. ICRP, 2000. Pregnancy and Medical Radiation. ICRP Publication 84. Ann. ICRP 30 (1). Available at: <a href="http://www.icrp.org/publication.asp?id=ICRP%20Publication%2084">http://www.icrp.org/publication.asp?id=ICRP%20Publication%2084</a> .	Review/Other-Dx	N/A	Thousands of pregnant patients and medical radiation workers are exposed to radiation each year. Lack of knowledge is responsible for great anxiety and probably unnecessary termination of many pregnancies. This report discusses how to deal with these problems.	No results stated in abstract.	4
78. Winer-Muram HT, Boone JM, Brown HL, Jennings SG, Mabie WC, Lombardo GT. Pulmonary embolism in pregnant patients: fetal radiation dose with helical CT. <i>Radiology</i> . 2002;224(2):487-492.	Review/Other-Dx	23 pregnant women	To calculate mean fetal radiation dose from helical chest CT by using maternal-fetal geometries obtained from healthy pregnant women and to compare the calculated CT doses with the fetal doses reported with scintigraphy.	For helical CT, estimated mean fetal doses in mGys at varying gestational ages were as follows: 3.3–20.2 mGy, first trimester; 7.9–76.7 mGy, second trimester; and 51.3–130.8 mGy, third trimester. These values were all less than mean fetal doses reported with scintigraphy, with 37–74 MBq of macroaggregates of human serum albumin labeled with technetium 99m. If 200 mAs (pitch of 1.8) was used, the mean fetal doses were still less than those with scintigraphy.	4
79. Lowe SA. Diagnostic radiography in pregnancy: risks and reality. <i>Aust N Z J Obstet Gynaecol</i> . 2004;44(3):191-196.	Review/Other-Dx	N/A	A literature review of appropriate databases, articles and relevant institutional protocols was performed. Data was sought regarding any adverse effects of diagnostic radiation in pregnancy, fetal absorbed dose of diagnostic radiation and how the timing of exposure and form of administration might influence these effects	The estimated radiation dose for a fetus from background sources as well as medical imaging was identified. Most diagnostic radiation procedures will lead to a fetal absorbed dose of <1 mGy for imaging beyond the abdomen/pelvis and <10 mGy for direct or nuclear medicine imaging. Potential adverse outcomes related to radiation exposure during pregnancy include teratogenicity, genetic damage, intrauterine death and increased risk of malignancy. The only adverse effect statistically proven at the dose levels associated with diagnostic radiation procedures is a very small increase in childhood malignancy, with an estimated increase of one additional cancer death per 1700 10 mGy exposures. The important exception was the risk to the fetal thyroid from radioiodine exposure after 12 weeks' gestation.	4
80. ICRP, 1996. Radiological Protection and Safety in Medicine. ICRP Publication 73. Ann. ICRP 26 (2). Available at: <a href="http://www.icrp.org/publication.asp?id=ICRP%20Publication%2073">http://www.icrp.org/publication.asp?id=ICRP%20Publication%2073</a> .	Review/Other-Dx	N/A	To clarify how the recommended system of radiological protection as described in the 1990 Recommendations of the International Commission on Radiological Protection should be applied in medicine.	No results stated in abstract.	4

**Stress (Fatigue-Insufficiency) Fracture Including Sacrum Excluding Other Vertebrae**  
**EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
81. American College of Radiology. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation. Available at: <a href="http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf">http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf</a> .	Review/Other-Dx	N/A	Guidance document to promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques.	N/A	4
82. American College of Radiology. ACR-ACOG-AIUM-SRU Practice Parameter for the Performance of Obstetrical Ultrasound. Available at: <a href="http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/US_Obstetrical.pdf">http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/US_Obstetrical.pdf</a> .	Review/Other-Dx	N/A	Guidance document to promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques.	N/A	4
83. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. <i>J Magn Reson Imaging</i> . 2013;37(3):501-530.	Review/Other-Dx	N/A	Guidance document on MR safety practices to help guide MR practitioners regarding MR safety issues and provide a basis for them to develop and implement their own MR policies and practices.	N/A	4

## Evidence Table Key

### Study Quality Category Definitions

- *Category 1* The study is well-designed and accounts for common biases.
- *Category 2* The study is moderately well-designed and accounts for most common biases.
- *Category 3* There are important study design limitations.
- *Category 4* The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:
  - a) the study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);
  - b) the study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;
  - c) the study is an expert opinion or consensus document.
- M = Meta-analysis

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Dx = Diagnostic

Tx = Treatment

## Abbreviations Key

CI = Confidence interval

CT = Computed tomography

FDG-PET = Fluorine-18-2-fluoro-2-deoxy-D-glucose-positron emission tomography

MDCT = Multidetector computed tomography

MRI = Magnetic resonance imaging

NPV = Negative predictive value

OA = Osteoarthritis

OP = Osteoporotic

PPV = Positive predictive value

SD = Standard deviation

SPECT = Single-photon emission tomography

STIR = Short tau inversion recovery

US = Ultrasound