[Primary Care]

CEU

Stress Fractures of the Pelvis and Legs in Athletes: A Review

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Context: Stress fractures are common injuries in athletes, often difficult to diagnose. A stress fracture is a fatigue-induced fracture of bone caused by repeated applications of stress over time.

Evidence Acquisition: PubMed articles published from 1974 to January 2012.

Results: 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. Magnetic resonance is the imaging test of choice for diagnosis.

Conclusions: These injuries can lead to substantial lost time from participation. Treatment will vary by fracture location, but most stress fractures will heal with rest and modified weightbearing. Some may require more aggressive intervention, such as prolonged nonweightbearing movement or surgery. Contributing factors should also be addressed prior to return to sports.

Keywords: stress fractures; athletes; lower extremity; treatment

Stress fractures were first reported in the metatarsals of Prussian soldiers in 1855,[26] and Stechow found radiographic evidence of metatarsal stress fractures of military recruits in 1897.[126] The earliest known diagnosis of a stress fracture on the femoral shaft in an athlete occurred in 1934.[105] Devas published the first comprehensive study of incidence in a series of athletes with fibular stress fractures in 1956.[43]

Growing participation in athletic activity coupled with improving medical technology has resulted in a greater awareness of stress fractures. A comprehensive study of 320 cases in athletes describes the distribution of stress fractures based on bone location, associated activity, sex, and age.[87] Stress fractures most commonly occur in the metatarsals, tibia, fibula, and tarsal navicular of track and field athletes, runners, and dancers.[30] In one study, over a 2-year period, 34 of 914 varsity collegiate 1-AA athletes were diagnosed with a stress fracture.[67] These fractures account for over 10% of all injuries in sports medicine clinics,[125] and in running sports, they may account for up to 31% of all injuries.[73]

A stress fracture is a fatigue fracture of bone caused by repeated submaximal stress.[20,52] The force required to generate a stress fracture is less than the maximum tolerated by bone, but its repetitive application causes a disruption in the bone homogeneity.[101,135] During athletic activity, fatigued muscles subject the bone to increasing force, which may contribute to the overloading process.[47,125] Over time, microfractures accumulate and a stress fracture may develop.[68]

"Stress fracture" is often used synonymously with stress *reaction*. A stress reaction is bone inflammation seen on a magnetic resonance imaging (MRI) or radionucleotide bone scan; it is possibly a microfracture of bone.[68] A stress fracture is a true fracture with cortical disruption.[11,55,87,122]

In the competitive athlete, a stress fracture can be difficult to treat, with return to activity ranging from weeks[43,92] to months[132] depending on the location. A premature return to full activity may increase the risk of complications. If complete union is not obtained prior to a return to full activity, an athlete risks delayed union or nonunion.[20] Therefore, early recognition and

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prompt treatment are important to the management of these injuries.[36]

PREDISPOSING FACTORS

Training

Training habits, combined with biologic and biomechanical factors, contribute to stress fractures. A sudden increase in exercise intensity increases the risk of a stress fracture.[58] When training is progressed rapidly, bones may sustain extra force due to muscle fatigue.[14] This theory is supported by evidence that military recruits are most likely to endure a stress fracture during their first weeks of service.[63] Additionally, in one study, elite male European soccer players with a shorter preseason were at a higher risk for developing stress fractures.[48] The protective effect of physical training in preventing lower extremity stress injury has been demonstrated in recruits entering into the naval conditioning program.[3,111]

Several studies have correlated running mileage and risk of stress fractures.[112,134] In a randomized study of 350 male army recruits in a standard running regimen or a weighted marching program, a reduction in running distance resulted in fewer injuries and lower injury severity.[112] A surveyed cohort of 1680 runners correlated running mileage as well as year-round running with increased risk for injury, including stress fractures.[134]

Bone Health

From development to degradation, bone health is influenced by diet,[9,16] hormone levels,[9,16,133] and biomechanics.[32,53,75,88] Bone of high mineral density may be less likely to endure a stress fracture because it can better withstand repetitive applications of force,[15,119] although studies are contradictory.[13,16,40,106] A prospective cohort of track and field athletes found statistically significant lower values for total body mineral content and lumbar spine and foot bone mineral density in female athletes sustaining stress fractures.[16] A trend was noted for decreased bone density in men sustaining stress fractures, though this was not statistically significant.[16]

Diet may influence bone health and risk of stress fractures.[65,86,106,123] A prospective cohort of competitive female distance runners showed that increased calcium, vitamin D, and protein intake correlated with increased bone mineral density and protection from stress fractures, while potassium was associated with increased bone mineral density alone.[100] Protein likely improves calcium absorption or increases insulinlike growth factor 1 with subsequent skeletal benefit.[71] Potassium is associated with higher fruit and vegetable intake,[84] reduced bone turnover,[99] and increased alkali load.[108] An additional cup of skim milk consumed per day may reduce the incidence of stress fractures by 62%.[100] A double-blind, placebo-controlled trial of female navy recruits showed a 20% lower incidence of stress fractures in those consuming 2000 mg of calcium and 800 international units of vitamin D daily.[76] A small study of male recruits found no statistical difference in stress fractures with a supplemental 500 mg of calcium daily.[118]

The female athlete triad of disordered eating, amenorrhea, and osteoporosis significantly increases the risk of stress fracture because of the negative effect on bone health.[9,16] Amenorrhea in athletes is multifactorial, resulting from energy deficit, decreased leptin levels,[81] decreased gonadotropins,[8] and/or stress from competition. The end result is a hypoestrogenemic state.[49] Lower estrogen levels result in increased calcium resorption and decreased bone storage of calcium.[49] A small case-control study of 19 female athletes showed direct correlations between the incidence of stress fractures and both current menstrual abnormalities and decreased bone mineral density.[98] The relative risk of stress fracture in athletes with menstrual disturbances is 2 to 4 times that of eumenorrheic athletes.[12]

Biomechanics

Leg length discrepancy may predispose an athlete to a stress fracture.[32,53,75] In army recruits, 73% with leg length inequalities sustained stress fractures in the longer leg, and a discrepancy greater than 5 mm increased the likelihood of fracture.[53] In another study, stress fractures occurred more often in the shorter leg, with a mean leg length difference of 1.3 mm between controls and patients.[75] Other studies demonstrate that stress fractures occur in both short and long legs.[16,75]

Athletes with tibial stress fractures have more knee joint stiffness during initial loading.[93] Peak hip adduction and rearfoot eversion angles during the stance phase of running were increased in runners with previous tibial stress fractures.[94] Biomechanical studies suggest that gait retraining to reduce tibial acceleration and loading may reduce stress fractures.[41] A prospective clinical study of military recruits found that those with pes planus (flatfoot) have an increased risk of metatarsal stress fractures, and those with pes cavus (high arch) are prone to femoral and tibial stress fractures.[123] Additionally, foot pronation may be a factor in the development of stress fractures, as biomechanical data in runners suggest that rotation helps distribute the impact throughout the tibia and lower extremity.[88]

Training Surface and Footwear

Hard surfaces usually pose a higher risk for stress fractures.[66,90] Tibial strain and strain rates in runners were 48% to 285% higher when running over ground compared with treadmills.[90] In a prospective cohort study of 582 habitual runners, females had a greater risk of injury when running on concrete surfaces.[82] Worn running shoes may increase the risk for stress fracture because of decreased shock absorption,[56] similar to combat boots.[5] A meta-analysis of randomized controlled trials on insoles suggests a reduction in stress fractures in the military population.[111]

DIAGNOSIS

Patient History

Stress fractures may be preceded by an increase in activity[83] and present initially with discomfort only during activity.[36] The

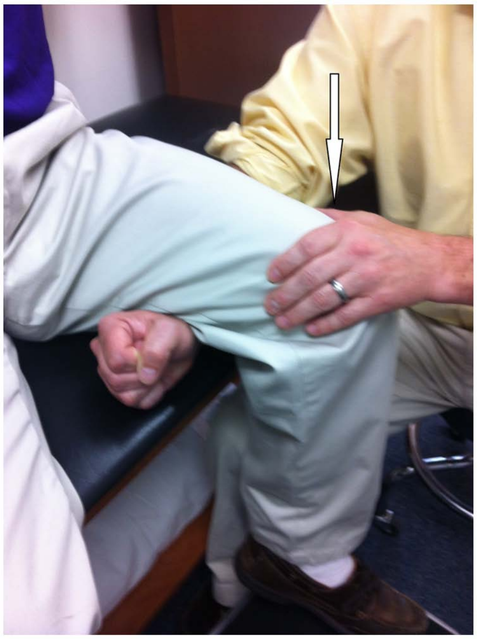

Figure 1. Fulcrum test: Examiner applies downward pressure on the knee with the opposite arm under the patient's thigh. A positive test result elicits thigh pain.

Figure 2. FABER test: Examiner applies downward pressure on the knee. A positive test result elicits pelvic or groin pain.

pain usually progresses after activity, eventually leading to pain at rest.[17] Female athletes are 1.5 to 3.5 times more likely to sustain a stress fracture than male athletes,[32,138] and fewer risk factors are known for men.[16,133] Low testosterone levels may increase risk for male athletes.[15,33] African Americans are less prone to stress fractures, possibly due to increased bone mass, size, and geometry.[77,114]

Physical Examination

Clinical assessment begins with lower limb alignment (varus or valgus) and symmetry in the legs, ankles, and feet, as these may effect biomechanical forces.[27,83] Pes planus or cavus may increase the risk of certain stress fractures.[123] Local tenderness,[29] swelling, and warmth may be present.[87] Chronic cases may present with a palpable callus.[137] If the suspected fracture is not readily palpable, such as the femoral neck, range of motion should be evaluated for pain.[20] The fulcrum test (Figure 1) may help diagnose stress fractures.[67]

Sacral stress fractures may produce a positive FABER (Figure 2); and/or Flamingo test(s), pain with hip flexion, abduction, and external rotation, or pain when standing on the affected limb, respectively.[24,39]

Imaging

Standard radiography. Standard radiographs are commonly used as the initial assessment of suspected stress fractures and can confirm the diagnosis.[124] However, in the early stages, radiographs have a low sensitivity (10%) and are of limited utility.[52]

Figure 3. Sagittal fast STIR image of a 19-year-old female volleyball player with right tibial pain for 9 days. Arrows show edema in the distal diaphysis due to stress lesion. Image reprinted from Gaeta et al[55] with permission from the Radiological Society of North America.

Magnetic resonance imaging. MRI is the most comprehensive method to evaluate a potential stress fracture[4,50,52,74,124] because of a high level of both sensitivity (86%-100%) and specificity (100%). Recovery time may be predictable based on a 4-level grading system originally described in the tibia (Figure 3).[4,17,20,55,74,121] This system can be applied to other bones (Table 1).[4,78]

Table 1. Radiologic grading of stress fractures.

Grade	Radiograph	Bone Scan	Magnetic Resonance Image
0	Normal	Normal	Normal
1	Normal	Mild uptake in one cortex	Positive STIR image
		Poorly defined	
2	Normal	Moderate activity	Positive STIR and T2 images
		Larger lesion confined to one cortex	
		Poorly defined	
3	Discrete line (?)	Sharply marginated increased focal or fusiform activity	Positive T1 and T2 images
	Discrete periosteal reaction (?)	No definite cortical fracture (< 50% width)	Without definite cortical fracture
4	Fracture	More intense fracture line	Positive T1 and T2 fracture line
	Periosteal reaction	Bicortical uptake	

Note: This table was adapted from Arendt et al[4] with permission from Clin Sports Med.

Computed tomography. Computed tomography is useful in detecting stress fractures in the pelvis and sacrum, which are not well visualized by MRI (sensitivity of 42% and specificity of 100%).[17,55] Additionally, computed tomography can differentiate a stress fracture from a stress reaction and can be used for preoperative planning.[60] Radiation exposure with computed tomography can be significant, but the effective dose of radiation decreases substantially with distance of the imaged extremity from the torso.[18]

91mTechnetium-methylene diphosphonate bone scintigraphy. Bone scanning is highly sensitive (74%-84%)[11,55] but nonspecific (33%)[11,55] for stress fractures. False positives can occur from increased bone metabolism in tumors or infections.[86] Differentiating acute stress reactions and stress fractures can be difficult.[95]

Ultrasonography. Ultrasonography may be useful because it is noninvasive and simple to perform (operator dependent).[7,50] In a pilot case-control study of 37 patients with metatarsal pain and normal radiographs, ultrasonography had a sensitivity of 83% and specificity of 76% compared with MRI in detecting metatarsal stress fractures.[7] Also, sonograms may demonstrate fluid collections, soft tissue edema, periosteal thickening, and increased vasculature.[22]

Table 2. Stress fracture risk for delayed union.

High-Risk[20,44,52]	Low-Risk[21,44,52]
Anterior tibial diaphysis	Posteromedial tibial
Lateral femoral neck	Metatarsals
Patella	Calcaneus
Medial malleolus	Cuboid
Navicular	Cuneiform
Fifth metatarsal base	Fibula
Proximal second metatarsal	Medial femoral neck
Sesamoids (great toe tibial)	Femoral shaft
Talus	Pelvis
Femoral head	

HIGH-RISK VERSUS LOW-RISK STRESS FRACTURES

Because of their tendency for nonunion or delayed union, certain stress fractures can be high-risk, requiring prompt treatment and careful monitoring to prevent complications (Table 2).[17,20] For displaced fractures or those on the tension side of the femoral neck (Figure 4), one should consider surgery.[21,95]

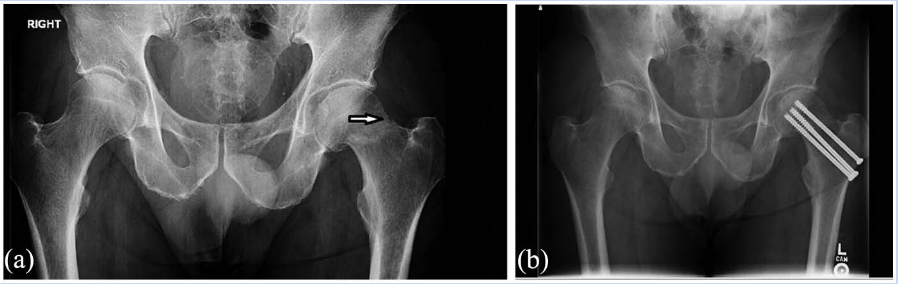

Figure 4. (a) Radiograph of a 51-year-old avid hiker with hip pain. Tension-side stress fracture can be seen (arrow). (b) Surgical fixation of the fracture.

SPECIFIC STRESS FRACTURES

Tibia

The tibia accounts for 25.9% to 49.1% of all stress fractures, particularly in long-distance runners.[31,62,65,87,116] These fractures may occur along the diaphysis and are typically transverse, although longitudinal fractures do occur and are at a higher risk for delayed union or nonunion.[38,117] All running and high-impact activities should cease until the patient is asymptomatic with walking.[52] In some low-risk fractures, when a period of relative rest does not allow the patient to return to a level of full functionality, immobilization may be required to promote healing before a gradual return to activity.[44]

A randomized controlled trial of pneumatic leg bracing versus traditional relative rest in athletes showed that bracing reduced the time to light activity from 21 to 7 days and to unrestricted activity from 77 to 21 days.[129] In military recruits, however, pneumatic bracing had no significant benefit in time to pain-free hop test or 1-mile run.[1]

In the high-risk anterior tibia, radiography can reveal the "dreaded black line" (Figure 5).[102] These stress fractures often take longer to heal and can result in nonunion. In one study, pneumatic bracing for 21 weeks avoided surgical intervention in delayed unions of the anterior tibia, with all patients returning to full activity at 12 months, radiographic evidence of healing in 75% of fractures.[10] Tibial intramedullary nailing with a reamed intramedullary nail and locking screws (Figure 6) is an effective treatment.[31,35,69] Radiographic union of the fracture can be expected at 3 months postoperatively, with return to competition at 4 months.[132]

Medial malleolus stress fractures are rare in young athletes but are seen in the elderly.[17,61] These fractures are well managed with nonsurgical treatment: modified rest and cessation of running and jumping for 3 to 8 weeks.[52] Delayed union or nonunion following conservative treatment may require operative initiative.[110] Oblique drilling of the medial malleolus may promote fracture healing, with a recovery time of 5 months.[103]

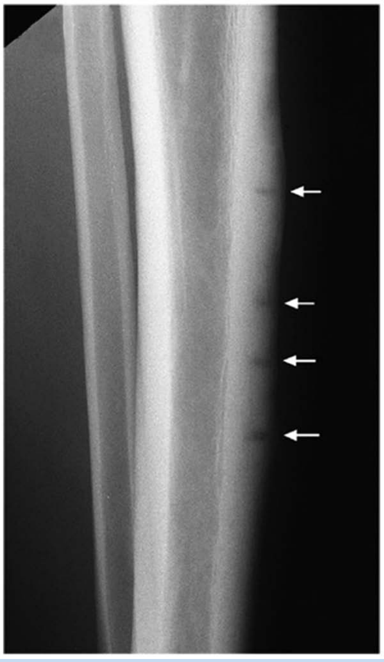

Figure 5. Lateral radiograph of a 21-year-old male football player with intermittent worsening bilateral anterior shin pain. Black lines indicate stress fractures of the anterior tibial cortex. Image reprinted from Fredericson et al[52] with permission from Lippincott, Williams, and Wilkins, Inc.

Fibula

Fibular stress fractures account for 5.1% to 9.3% of all stress fractures.[65,87,116] Most commonly occurring in the distal third,[19,130] they are frequently seen in runners training on hard surfaces.[43] They may be caused by muscle traction and torsional forces, as opposed to weightbearing compression.[36] These fractures are low-risk, and can be managed with cessation of activity until point tenderness resolves.[52]

Femur

Stress fractures of the femur occur most often in the femoral neck and represent 1.0% to 7.2% of all stress fracture injuries.[65,87,116] They are relatively rare, associated with coxa vara (decrease in femoral neck-shaft angle),[34] and range from

Figure 6. Lateral radiograph of a tibial intramedullary nail in a 20-year-old patient with a chronic anterior tibial stress fracture. Image reprinted from Varner et al[132] with permission from SAGE Publications.

Figure 7. Coronal T1 image demonstrating a right tension-sided femoral neck stress fracture in a 27-year-old military recruit. Image reprinted from Provencher et al[107] with permission from SAGE Publications.

low- to high-risk.[120] High-risk fractures result from tension on the lateral aspect of the femoral neck. They are inherently unstable and prone to displacement (Figure 7).[54] Nondisplaced fractures can be treated with strict adherence to nonweightbearing movements until callus is seen radiographically.[6,28] However, percutaneous screw fixation with 6.5- to 7.3-mm cannulated screws is often used in these high-risk fractures.[21,95]

Figure 8. Medial femoral neck fracture on coronal T1 image of a 20-year-old female basketball player. White arrows indicate marrow edema and black arrow points to the fracture line. Image reprinted from Fredericson et al[52] with permission from Lippincott, Williams, and Wilkins, Inc.

Medial femoral neck fractures result from compressive forces and are low-risk (Figure 8).[54] If a fracture line is not visible on radiography, it may be safely treated with a nonweightbearing regimen.[42] Swimming or cycling can be permitted.[69] Insufficiency or fatigue stress fractures in the femoral head are high-risk in otherwise healthy patients.[72] If not recognized early, delayed union, nonunion, displacement, or avascular necrosis may ensue.[17] Suspicion should arise with exercise-induced pain in the groin, hip, or proximal thigh that is relieved by rest.

Nondisplaced stress fractures of the femoral shaft can sometimes be managed with limited weightbearing[28,51] (Figure 9). Surgical intervention should be considered with displaced, delayed union, and nonunited fractures.[51]

Patella

Patellar stress fractures (Figure 10) are rare, representing 0.9% of all stress fractures,[65,87] and are high-risk if left untreated.[18] For transverse patella fractures, immobilization may be successful.[85] Open reduction and internal fixation with tension band wiring and adjunctive iliotibial band release may be a better option for quicker return to activity, with reported recovery of 6 to 12 weeks.[70,85] Nondisplaced longitudinal fractures can be treated conservatively with bracing.[64]

Pelvis

Pelvic stress fractures are rare (1.6% to 7.1% of all stress fractures)[65,87,116] (Figure 11). They may be difficult to detect.[52] Pubic rami fractures are more common in women, with pain in the inguinal, perineal, or adductor region.[91]

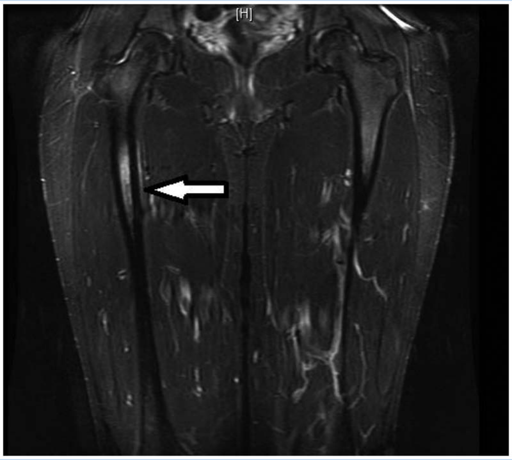

Figure 9. Sagittal STIR image of a femoral shaft stress fracture (arrow) in a 21-year-old college basketball player.

Figure 10. Lateral radiograph of a 20-year-old basketball player with a transverse stress fracture of the inferior third if the patella. Image reprinted from Keeley et al[70] with permission from BioMed Central.

Figure 11. Pelvic stress fracture (arrow) in a 40-year-old distance runner.

Adjunctive Treatment

An athlete recovering from any stress fracture must comply with a gradual return to activity to allow for bone healing and remodeling.[42,69] An athlete who rushes return to play risks further injury, possibly more serious than the initial insult.[58] Animal studies of nonsteroidal anti-inflammatory treatment show delayed stress fracture healing, likely due to prostaglandin synthesis disruption.[2,80] However, a meta-analysis did not find a significant risk of nonunion with nonsteroidal anti-inflammatory exposure.[46]

The use of bisphosphonates is not supported by randomized clinical trials.[89,127] However, a case study of 5 collegiate female runners with stress fractures on bone scan showed recovery within 1 week of treatment with intravenous pamidronate.[127] Bisphosphonates have not been shown to be effective prophylaxis in young military recruits at risk.[89] Concerns exist regarding bisphosphonate use in women of childbearing age. Animal studies show that these drugs may cross the placenta and disrupt fetal osseous development.[59,104] However, a review of 51 cases[45] and a prospective cohort study[79] of pregnancy or prepregnancy exposure to bisphosphonates did not demonstrate a relationship with congenital abnormalities. A recent review highlighted the emergence of atypical subtrochanteric stress fractures of the femur[57] from oversuppression of bone turnover, a finding only observed to date in elderly patients.[97] Side effects of bisphosphonates depend on the route of administration, and may include nephrotoxicity and osteonecrosis of the jaw.[23,136]

Bone stimulation. Both low-intensity pulsed ultrasound and electrical stimulation may increase the rate of bone healing in acute fractures.[37,115] However, the efficacy of stimulation for stress fractures is unknown.[109] In a prospective, randomized, double-blinded study, 26 patients were treated daily with either pulsed ultrasound or placebo until asymptomatic, and ultrasound did not significantly reduce the healing time of tibial stress fractures.[113]

Low-intensity ultrasound promoted an early return to athletic competition in an uncontrolled study of 8 patients with tibial stress fractures (7 posteromedial and 1 anterior).[25] Patients continued competitive sports during treatment.

Electric field stimulation may hasten recovery in acute tibial stress fractures.[12] A randomized control trial of 44 patients with posteromedial stress fractures did not demonstrate an overall benefit from the treatment.[12] However, fractures graded more severe based on radiologic criteria[4] healed quicker when treated with electric field stimulation, suggesting that the device may be helpful in these severe injuries.[12]

In 5 chronic stress fractures, extracorporeal shock wave therapy showed bony union at a mean of 3 months, and return to athletics between 3 and 6 months.[131] A recent retrospective study of male soccer players with fifth metatarsal and tibial fractures treated with 3 sessions of extracorporeal shock wave therapy every 47 hours reported fracture healing in 6 to 14 weeks, and return to competition between 3 and 10 months posttreatment.[96]

CONCLUSIONS

To prevent stress fractures, athletes should progress activity levels gradually (no more than a 10% increase in load per week) to strengthen leg muscles, avoiding sudden increases in activity and running mileage.[6,7,9,13,15,16,30,56,128] Training surface,[66,82,90] footwear, and the female athlete triad may predispose some to stress fractures.[3,14,47,48,58,108,111,112,125,134] MRI provides the highest sensitivity and specificity, making it the test of choice for diagnosing these injuries.[52,74,124] High-risk stress fractures include the femoral neck, patella, anterior tibial diaphysis, and the medial malleolus.[17] The role of bisphosphonates[89,127] and bone stimulation[12,96,131] remain unclear.

Clinical Recommendations

SORT: Strength of Recommendation Taxonomy
A: consistent, good-quality patient-oriented evidence
B: inconsistent or limited-quality patient-oriented evidence
C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

Clinical Recommendation	SORT Evidence Rating
The female athlete triad of disordered eating, amenorrhea, and osteoporosis is a risk factor for development of stress fractures.[3,48,58,111,112,134]	B
Radiographs should be the initial imaging study.[124]	B
Magnetic resonance is the imaging technique of choice for the diagnosis of most stress fractures.[52,74,124]	A

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