Diagnosis and management of bone stress injuries of the lower limb in athletes

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James Pegrum
Queen Mary, University of London

Nat Padhiar
Queen Mary, University of London

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CLINICAL REVIEW

Diagnosis and management of bone stress injuries of the lower limb in athletes

James Pegrum *orthopaedic and trauma registrar, honorary research associate* [1 3], Tom Crisp *consultant sports physician* [2], Nat Padhiar *consultant podiatric surgeon and honorary reader* [3]

[1]Centre for Sport and Exercise Medicine, Queen Mary's University, London E1 4NS; [2]BUPA Health and Wellbeing, London, UK; [3]Milton Keynes Hospital, Milton Keynes MK6 5LD, UK

The annual incidence of overuse injuries in track and field athletes is estimated to be 3.9 per 1000 training hours, with a prevalence of 76%,[w1] and 10-20% of consultations in sports medicine practice are for stress fractures.[1] Stress fractures are also common among army recruits.

With the advent of magnetic resonance imaging, stress fractures are diagnosed earlier and more readily than they were in the past, and early surgical treatment is increasingly considered as a management option for patients who are at high risk of fracture non-union. Rapid and accurate diagnosis of stress fractures is important to prevent propagation of the fracture, and early effective treatment may reduce time away from training and participation in sport. Experts think that overtreatment of low risk stress injuries and undertreatment of high risk injuries both occur and lead to unnecessary time away from training.[2] In addition, increasing participation of non-athletes in endurance sports such as marathon running has led to an increase in stress injuries among non-professional sportspeople.

We review the diagnosis and management of stress injuries of the lower limb, drawing on evidence from randomised trials, non-randomised intervention studies, observational studies, and consensus guidelines. Figure 1⇓ presents an algorithm to help readers diagnose stress injuries and refer affected patients appropriately.

Why do stress fractures occur?

Stress fractures occur as a result of overuse injuries to bone, either secondary to bone fatigue or bone insufficiency. Fatigue stress fractures occur when normal bone is unable to keep up with repair when repeatedly damaged or stressed (figs 2⇓ and 3⇓). Insufficiency stress fractures, however, occur in bone that is under normal strain but structurally abnormal because of metabolic bone disease or osteoporosis.

Bone constantly remodels through a balance between the processes of osteoclastic resorption and osteoblastic bone synthesis, both of which are under hormonal control. As part of this remodelling process, the greatest amount of bone is laid down in areas of greatest applied stresses, according to Wolff's law.

What are the most common sites of stress fracture?

Tibial shaft stress fractures constitute about half of lower limb stress fractures.[w2] Metatarsal stress fractures are the next most common, occurring in about 10-20% of athletes, particularly runners.[w3 w4]

Femoral shaft and neck fractures constitute 8% of stress fractures in military personnel and 11% in athletes,[3 4] although these injuries may be underdiagnosed.[5] In the femur, stress fractures typically occur in the neck, medial proximal shaft, and distal shaft.[6] In one series, femoral neck fracture resulted in 50% of patients eventually being discharged from military service on medical grounds.[3]

Who is at risk of stress fractures?

Risk factors can be broadly divided into extrinsic (environmental) and intrinsic (to the athlete) (box 1), and these may be modifiable or non-modifiable. Non-modifiable risk factors for stress fracture are female sex, white race, and high bone turnover.[7] All intrinsic factors are more important in women and girls than in men and boys.[8]

A large number of retrospective studies have examined risk factors for stress fracture with conflicting results. The usefulness of prospective studies is also limited by variations in definition of stress fracture and the inability to control all variables.

The role of sex and the female athlete triad

Retrospective and prospective observational studies have not found female sex to be a risk factor for running injuries other than for stress fractures,[17 w6] and there are several contributing

Correspondence to: J Pegrum jpegrum@doctors.net.uk

Extra references supplied by the author (see http://www.bmj.com/content/344/bmj.e2511?tab=related#webextra)

Summary points

- Stress fractures occur mostly in track and distance runners, athletes who take part in field sports, gymnasts, dancers, and military recruits
- Consider the diagnosis in sports people with risk factors for bone injury and progressively worsening localised bone pain
- Women with the "female athlete triad" are especially at risk of bony stress injury
- Magnetic resonance imaging is the most sensitive and specific imaging modality for diagnosing stress fractures
- Stress fractures with low risk of non-union can be managed in primary care by modifying sports activity and reducing risk factors
- Involvement of a specialist is necessary for fractures at high risk of non-union and operative fixation may be considered

Sources and selection criteria

To write this review we searched Medline, Embase, and the Cochrane Library from inception to October 2011 inclusive using the truncated keywords "stress fracture", "stress injury", "stress reaction". The review also draws on our clinical experience.

Box 1 Risk factors for stress fractures

Extrinsic

Training regimen:
Mileage[w5]

Number of training cycles[w6 w7]

Inadequate recovery/rest periods and training with fatigued muscles[9]

Running pace[w8]

Hill (particularly downhill) running[w9]

Type of exercise: increased risk for running, track and field sports, basketball, gymnastics, and dance[16]

Harder training surface[18]

Footwear (there is only weak evidence that shoes play any role)[20 w13]

Intrinsic

Position: external rotation of the lower limb[10]

Bone anatomy:
- Femoral anteversion[11]
- Leg length discrepancy[12]
- Genu varum and genu valgum[8 w10 w11]
- Narrow tibia[10 13-15]

Muscle: small calf girth[w12]

Female sex[17 w6]

Poor nutrition, particularly low calcium intake and low overall energy intake[19]

Older age (those over 20 years found twice the risk of stress injury as those aged 17-19 years)

Aerobic fitness and sporting experience[w14]

Previous bone stress injury[w7 w14-w16]

Smoking[w17]

Family history of stress injury[w18]

factors. Studies that showed lower bone mineral density, menstrual irregularity, and smaller lower limb mass as risk factors for injury led to the evolution of the term "the female athlete triad," and presence of this triad (low bone mineral density or disordered eating, low body mass index (BMI), and menstrual irregularity or prolonged absence of menses) or any of its components increases the athlete's risk of stress fracture.[8 12 17 21-23] Two prospective studies also associated menstrual dysfunction and poor aerobic fitness with increased risk of stress injury to the lower limb in female military recruits.[17 21] A retrospective study of 240 college athletes found that stress fractures occurred in 49% of female athletes who had fewer than five menses a year compared with 29% for those who had 10-13 menses a year.[24] In addition, female runners who were taking oral contraceptives were half as likely to get stress fractures over the course of a year than those who were not taking oral contraceptives.[24] A Finnish prospective study of female athletes found that those with a BMI of 20-25 had a lower risk of stress fracture than those with a BMI less than 20, although the difference was no longer significant after adjustment for confounding factors.[25] This trend may be explained by a lower bone mass leading to more strain on the remaining bone, which further increases risk of fatigue. A systematic review of observational studies concluded that female athletes and military recruits who consumed more than 1500 mg of calcium daily were at lowest risk of stress fracture injuries.[19]

How are stress fractures diagnosed and graded?

History

Patients with stress fracture usually have pain within the bone of the lower limb, which gradually gets worse and starts to present earlier in a training session. Progressive injury is likely when pain starts to be felt during day to day activities. It is important to locate the pain to help the radiologist interpret any investigations. Ask about the nature of the athlete's training regimen, specifically about recent excessive or sudden increases in training and lack of rest days. Ask about risk factors for bony stress injury as outlined above. Remember that military recruits are also susceptible. Ask female athletes in particular about dietary intake. Information on menstrual function, history of bony injury, or family history of stress fracture can help the clinician assess the likelihood of stress fracture.

Although stress fractures mostly occur in bones of the lower limb, in athletes who throw or row, any upper limb pain or rib pain should increase suspicion of stress fractures in other bones.

Examination

Clinical examination of the affected limb will usually show localised bone tenderness. Later manifestations of the injury, usually caused by delayed presentation, include swelling, bruising, and warmth.

Imaging

Stress fractures are progressive, and their appearance depends on the timing of imaging. Early diagnosis through correct imaging will help to avoid unnecessary time out from training or participation in sport. If stress fracture is suspected on the basis of clinical findings, encourage the patient to avoid weight bearing—for example, by using crutches while waiting for imaging—to reduce the risk of propagation of the fracture. Plain radiography, radioisotope bone scanning, magnetic resonance imaging (MRI), and computed tomography are used most commonly in the diagnosis of stress fractures.

Plain radiographs

A visible fracture on a plain radiograph of the affected limb is diagnostic. Further imaging is usually needed only for operative planning in fractures at high risk of non-union (fig 1). However, plain radiographs often appear normal despite clinical symptoms and signs suggestive of stress fracture for three months or more after symptom onset.[26]

Radioisotope bone scanning

Some authors still refer to stress fractures as "a positive radioisotope bone abnormality."[27] Bone scans are sensitive for stress fractures but not specific because increased uptake of radioisotopes is also found in bony infection, inflammatory joint conditions, and cancer. Bear in mind that the radiation dose for a bone scan is 75 times the dose of a normal chest radiograph.

Magnetic resonance imaging

MRI is sensitive and specific for stress fractures (fig 4⇓) and patients are not exposed to radiation. The advantage of MRI over plain radiography is that it can detect bone changes—a "stress response"—earlier, often weeks before changes are apparent on radiographs, although experience is needed in interpreting the scan to reduce false positives. It is more sensitive than bone scintigraphy. MRI also provides information about surrounding soft tissues, which helps to exclude other potential causes of localised pain.[28] Serial MRI scans are also used to monitor fracture resolution. The table⇓ shows a system for grading the severity of stress fractures on the basis of the results of imaging techniques.

A recent imaging study suggested that MRI may also show features consistent with an impending stress fracture of the hip before a cortical break has occurred.[w20] If true, this could lead to earlier diagnosis and possible intervention through modification of an athlete's training programme.

Computed tomography

Computed tomography has limited usefulness in the diagnosis of stress fracture because it has a lower sensitivity than bone scintigraphy.[26] Computed tomography may be used for patients with contraindications to MRI or those with claustrophobia. In patients with Arendt grade 4 fractures, it may be used to establish the extent of the fracture distance and to plan surgery for displaced fractures or navicular stress fractures.[w21] The difference between findings on MRI and computed tomography can help distinguish stress reactions from fracture damage to the fabric of the bone. A positive MRI scan but negative computed tomogram suggests a stress response and not a complete fracture, which has a better prognosis.

Ultrasonography

Early investigation into the usefulness of ultrasound in the diagnosis of metatarsal stress fractures suggests that it may have a place as an alternative to MRI,[w22] but further research is needed.

How can stress fractures be prevented?

The use of periodisation as a training method optimises gains in performance while minimising the risk of developing a stress fracture. Training is increased over a three week period and this is followed by a relative rest week, which allows subsequent metabolic adaptation to occur. Periodisation was first used in the training of military recruits, and incorporation of rest days reduced stress fractures from 7% to 3.8%, after controlling for other variables, in royal marines.[9]

Stress fractures can also be reduced by dealing with modifiable risk factors. The importance of optimal nutrition for athletes, particularly female athletes, cannot be overstated. Inadequate intake of calcium and vitamin D, which are both needed in bone metabolism, and insufficient energy intake are associated with reduced bone mass.[19] A minimum of 1500 mg of calcium is needed each day.

How are common stress fractures managed?

Most stress fractures can be managed non-operatively by modifying or stopping the stressing activity; the more serious the injury the longer the athlete must rest the limb.[27] Stress fractures can be stratified into those with a low risk or high risk of non-union on the basis of location (box 2), the direction of loading through the fracture during ambulation, and the natural course of fracture healing.[2] Stress fractures classified as being at high risk of non-union occur in zones of tension or have poor blood supply

Undisplaced fractures with a favourable natural course that are in regions of good blood supply and along lines of compression are at low risk of non-union. For these fractures the underlying risk factors need to be dealt with and the training regimen modified to allow osseous healing, while maintaining cardiovascular fitness.

The general principle of managing low risk stress fractures is to slowly increase impact loading once ambulation and day to day activity are pain free. The rate of resumption of activity depends on the individual and should be modified to suit the symptoms.[30]

A review that compared outcomes for stress fractures of the navicular with those with stress reactions found that long term outcomes were worse for patients with stress fractures and

Box 2 Fractures with a low risk and high risk of non-union

Low risk of non-union

- Femoral neck fractures of the medial cortex
- Tibial shaft fractures of the posteromedial cortex
- Fractures of the distal second to fifth metatarsals
- Calcaneal fractures
- Fractures of the fibula
- Fractures of the pubic ramus
- Cuboid fractures
- Cuneiform fractures

High risk of non-union

- Femoral neck fractures of the superior cortex
- Tibial shaft fractures of the anterior cortex
- Fifth metatarsal, at the diaphyseal-metaphyseal junction
- Navicular fractures
- Proximal fractures of the second metatarsal
- Fractures of the talus
- Fractures of the medial malleolus
- Sesamoids

suggested that delay in presentation or diagnosis is detrimental to healing and returning to pre-injury level of participation.[w23]

Fractures in areas of tension—along the anterior portion of the tibia and lateral femoral neck—or in bones with retrograde blood supply, such as the talus and navicular, are at risk of delayed union or non-union and often require operative management. Surgery aims to create an environment with improved stability that is conducive to bony union and a timely return to sport.

Tibial stress fractures

Conservative treatments include rest, ultrasound therapy, extracorporeal shock wave therapy, and, recently, the use of a pneumatic lower leg brace. The more common posterior stress fractures respond well to non-surgical treatment, probably because of improved vascularity posteriorly and reduced compressive loads.[31 w24]

A small prospective randomised controlled trial of low intensity ultrasound therapy for posterior tibial stress fractures found a significant decrease in healing time in the treatment group,[w25] but it is not clear whether this treatment would be efficacious for chronic anterior tibial stress fractures. Observational studies of extracorporeal shock wave therapy report that it is beneficial, although again no good data support the use of this treatment for more difficult to treat anterior stress fractures.[w26]

Anterior tibial stress fractures are more likely than posterior ones to be complicated by delayed union or non-union, and non-operative management normally takes longer than six months.[w27] For athletes and military recruits such a long time away from training and usual physical activity may be psychologically unacceptable, detrimental to fitness, and a financial burden. It may represent the end of a career. Surgical intervention, specifically minimally invasive tibial nailing, has been described in several case series with promising results (radiological union at three months and return to play at four months).[w28] However, 60% of patients may experience anterior knee pain, especially when kneeling, or extensor mechanism disruption. These side effects may be considered unacceptable outcomes in elite athletes and need to be discussed carefully with the patient.[w29]

Anterior tension band plating has been proposed as a more biomechanically sound intervention. In a case series of four patients who underwent this operation, fractures went on to unite at a mean of 10 weeks, after an average delay in operative intervention of 13 months. One patient had symptomatic irritation from the plate, which was subsequently removed. All returned to previous levels of sporting participation, which was Olympic level for two.[w29]

Metatarsal stress fractures

Most of these fractures occur in the distal second to fifth metatarsal and if undisplaced can be managed conservatively with rest and the wearing of a hard soled shoe or walking boot. The rate of non-union of proximal second and fifth metatarsal fractures is high, with proximal fifth metatarsal fractures failing to unite in 20-67% of cases.[w30 w31] Expert advice varies. One group recommended that non-sclerotic fractures of the fifth metatarsal can be treated conservatively with a non-weight bearing cast for six to eight weeks, but that any sign of sclerosis on imaging indicates the need for operative intervention, with medullary curettage and bone grafting followed by non-weight bearing for six weeks.[w3] Another group that reported on the use of intramedullary screw fixation in a series of 22 patients achieved 100% union at six to eight weeks. Athletes returned earlier to sport, albeit with a complication rate of 9%.[32]

Femoral shaft and neck fractures

Femoral shaft fractures are considered low risk compared with femoral neck fractures and are usually treated conservatively. Return to play is guided by pain during activity. A conservative management algorithm for femoral shaft stress fractures is shown in fig 5⇓.[4] However, the algorithm is based on findings from a small case series of high level athletes with an age range of 17-21 years. It is not clear whether this algorithm should be used for people in different age groups and with different sporting abilities, and more research is needed into the optimal management of femoral shaft stress fractures.

The diagnosis of femoral neck fractures is often delayed and serious complications can occur. The biomechanics underpinning stress injuries to the femoral neck are complex.

If late diagnosis and undertreatment occur, patients with resulting displacement of the femoral head are at high risk of avascular necrosis, arthritis, non-union, or mal-union.[w32-w35]

Displaced fractures must be managed surgically. For undisplaced stress fractures of the femoral neck, avascular necrosis and osteoarthritis are unlikely after conservative treatment according to the findings of a Finnish prospective study that followed up 66 military recruits with undisplaced fracture for an average of 18 years.[33] Femoral neck fractures that are treated conservatively should be regularly monitored radiographically to assess progression, displacement, and complications. A graded return to sports may be considered when there is radiographic evidence of a healed fracture and no pain on walking.

In summary, management depends on the risk of non-union. High risk fractures are managed by surgery or non-weight bearing pending imaging results, whereas low risk fractures are managed clinically, depending on symptoms during activities or training.

Adjuncts in the treatment of stress fractures: are they helpful?

Supplementary oxygen therapy and hyperbaric oxygen have been used to promote healing and recovery. However, a 2005 Cochrane review found no evidence to support or refute the use of hyperbaric oxygen.[34]

Bisphosphonates have been used in an attempt to hasten return to play in athletes.[35] In theory, they work to reduce bone resorption during the remodelling phase, which may accelerate bone healing. Prophylactic bisphosphonates in military recruits did not reduce the incidence of stress fractures.[36]

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1 Bennell KL, Malcolm SA, Thomas SA, Wark JD, Brukner PD. The incidence and distribution of stress fractures in competitive track and field athletes. A twelve-month prospective study. *Am J Sports Med* 1996;24:211-7.
2 Kaeding CC, Yu JR, Wright R, Amendola A, Spindler KP. Management and return to play of stress fractures. *Clin J Sport Med* 2005;15:442-7.
3 Milgrom C, Giladi M, Chisin R, Dizian R. The long-term followup of soldiers with stress fractures. *Am J Sports Med* 1985;13:398-400.
4 Ivkovic A, Bojanic I, Pecina M. Stress fractures of the femoral shaft in athletes: a new treatment algorithm. *Br J Sports Med* 2006;40:518-20; discussion 520.
5 Harrast MA, Colonno D. Stress fractures in runners. *Clin Sports Med* 2010;29:399-416.
6 Edwards WB, Gillette JC, Thomas JM, Derrick TR. Internal femoral forces and moments during running: implications for stress fracture development. *Clin Biomech* 2008;23:1269-78.
7 Lappe JM, Stegman MR, Recker RR. The impact of lifestyle factors on stress fractures in female army recruits. *Osteoporos Int* 2001;12:35-42.
8 Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med* 2002;36:95-101.
9 Ross RA, Allsopp A. Stress fractures in royal marines recruits. *Mil Med* 2002;167:560-5.
10 Giladi M, Milgrom C, Simkin A, Stein M, Kashtan H, Margulies J, et al. Stress fractures and tibial bone width. A risk factor. *J Bone Joint Surg Br* 1987;69:326-9.
11 Krivickas LS. Anatomical factors associated with overuse sports injuries. *Sports Med* 1997;24:132-46.
12 Korpelainen R, Orava S, Karpakka J, Siira P, Hulkko A. Risk factors for recurrent stress fractures in athletes. *Am J Sports Med* 2001;29:304-10.
13 Schnackenburg KE, Macdonald HM, Ferber R, Wiley JP, Boyd SK. Bone quality and muscle strength in female athletes with lower limb stress fractures. *Med Sci Sports Exerc* 2011;43:2110-9.
14 Bennell K, Crossley K, Jayarajan J, Walton E, Warden S, Kiss ZS, et al. Ground reaction forces and bone parameters in females with tibial stress fracture. *Med Sci Sports Exerc* 2004;36:397-404.
15 Crossley K, Bennell KL, Wrigley T, Oakes BW. Ground reaction forces, bone characteristics, and tibial stress fracture in male runners. *Med Sci Sports Exerc* 1999;31:1088-93.
16 Field AE, Gordon CM, Pierce LM, Ramappa A, Kocher MS. Prospective study of physical activity and risk of developing a stress fracture among preadolescent and adolescent girls. *Arch Pediatr Adolesc Med* 2011;165:723-8.
17 Shaffer RA, Rauh MJ, Brodine SK, Trone DW, Macera CA. Predictors of stress fracture susceptibility in young female recruits. *Am J Sports Med* 2006;34:108-15.
18 Milgrom C, Finestone A, Segev S, Olin C, Arndt T, Ekenman I. Are overground or treadmill runners more likely to sustain tibial stress fracture? *Br J Sports Med* 2003;37:160-3.
19 Tenforde AS, Sayres LC, Sainani KL, Fredericson M. Evaluating the relationship of calcium and vitamin D in the prevention of stress fracture injuries in the young athlete: a review of the literature. *PM R* 2010;2:945-9.
20 Wegener C, Burns J, Penkala S. Effect of neutral-cushioned running shoes on plantar pressure loading and comfort in athletes with cavus feet: a crossover randomized controlled trial. *Am J Sports Med* 2008;36:2139-46.
21 Rauh MJ, Macera CA, Trone DW, Shaffer RA, Brodine SK. Epidemiology of stress fracture and lower-extremity overuse injury in female recruits. *Med Sci Sports Exerc* 2006;38:1571-7.
22 Bennell KL, Malcolm SA, Thomas SA, Reid SJ, Brukner PD, Ebeling PR, et al. Risk factors for stress fractures in track and field athletes. A twelve-month prospective study. *Am J Sports Med* 1996;24:810-8.
23 De Souza MJ, Williams NI. Physiological aspects and clinical sequelae of energy deficiency and hypoestrogenism in exercising women. *Hum Reprod Update* 2004;10:433-48.
24 Barrow GW, Saha S. Menstrual irregularity and stress fractures in collegiate female distance runners. *Am J Sports Med* 1988;16:209-16.
25 Mattila VM, Niva M, Kiuru M, Pihlajamäki H. Risk factors for bone stress injuries: a follow-up study of 102 515 person-years. *Med Sci Sports Exerc* 2007;39:1061-6.
26 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. *Clin Radiol* 2005;60:1100-5.
27 Tuan K, Wu S, Sennett B. Stress fractures in athletes: risk factors, diagnosis, and management. *Orthopedics* 2004;27:583-91; quiz 592-3.
28 Datir AP. Stress-related bone injuries with emphasis on MRI. *Clin Radiol* 2007;62:828-36.
29 Arendt EA, Griffiths HJ. The use of MR imaging in the assessment and clinical management of stress reactions of bone in high-performance athletes. *Clin Sports Med* 1997;16:291-306.
30 Brukner P, Bradshaw C, Bennell K. Managing common stress fractures: let risk level guide treatment. *Phys Sportsmed* 1998;26:39-47.
31 Boden BP, Osbahr DC. High-risk stress fractures: evaluation and treatment. *J Am Acad Orthop Surg* 2000;8:344-53.
32 Portland G, Kelikian A, Kodros S. Acute surgical management of Jones' fractures. *Foot Ankle Int* 2003;24:829-33.
33 Pihlajamaki HK, Ruohola JP, Weckström M, Kiuru MJ, Visuri TI. Long-term outcome of undisplaced fatigue fractures of the femoral neck in young male adults. *J Bone Joint Surg Br* 2006;88:1574-9.
34 Bennett MH, Stanford R, Turner R. Hyperbaric oxygen therapy for promoting fracture healing and treating fracture non-union. *Cochrane Database Syst Rev* 2005;1:CD004712.
35 Stewart GW, Brunet ME, Manning MR, Davis FA. Treatment of stress fractures in athletes with intravenous pamidronate. *Clin J Sport Med* 2005;15:92-4.
36 Milgrom C, Finestone A, Novack V, Pereg D, Goldich Y, Kreiss Y, et al. The effect of prophylactic treatment with risedronate on stress fracture incidence among infantry recruits. *Bone* 2004;35:418-24.

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Additional educational resources for healthcare professionals and patients

American Orthopaedic Society for Sports Medicine (http://orthoinfo.aaos.org/topic.cfm?topic=a00379)—A useful resource for explaining stress fractures to patients using simplified language; the site also discusses the prevention and management of such injuries

Patient.co.uk (www.patient.co.uk/health/Metatarsal-Fractures.htm)—Patient information sheets that can be printed out and given to specific patients

Questions for future research

Do osteoinductive agents such as bone morphogenetic proteins accelerate stress fracture healing?

Can ultrasound be used to diagnose stress fractures reliably?

Do bisphosphonates have a role in the prevention of stress fractures in athletes?

Table

Table 1| **Grade of stress fracture based on results of plain radiology, bone scintigraphy, and magnetic resonance imaging29**

Grade	Radiography	Bone scanning	Magnetic resonance imaging
1	Normal	Mild unicortical uptake	Positive STIR (short T1 inversion recovery) image
2	Normal	Moderate unicortical uptake	Positive STIR and T2 images
3	Discrete line	Activity in 50% of bone width	Positive T1 and T2 images
4	Fracture or periosteal reaction	Bicortical uptake	Fracture line

Figures

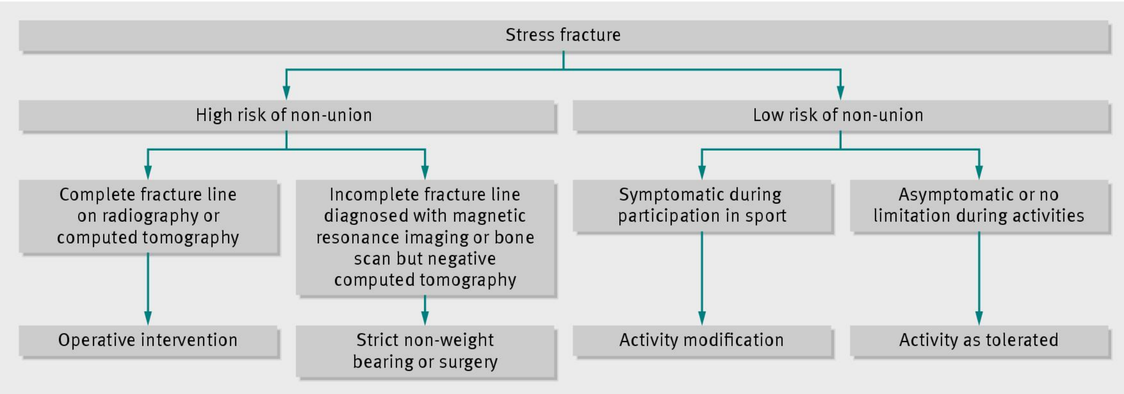

Fig 1 Simplified management algorithm to help doctors decide between activity modification, non-weight bearing, and surgery

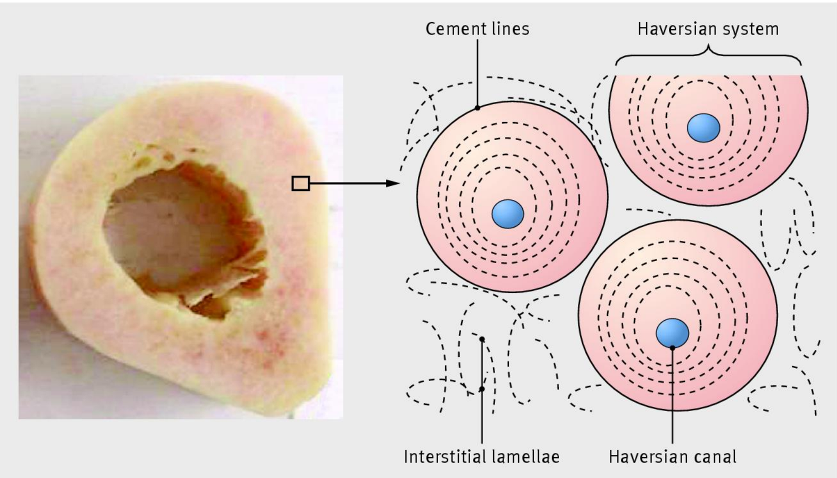

Fig 2 Mature bone is composed of oriented collagen fibres arranged in sheets known as lamellae. In cortical bone the collagen fibres are arranged in concentric rings known as Haversian systems. The Haversian systems are surrounded by cement lines, which are areas of relative weakness, where stress fractures can propagate

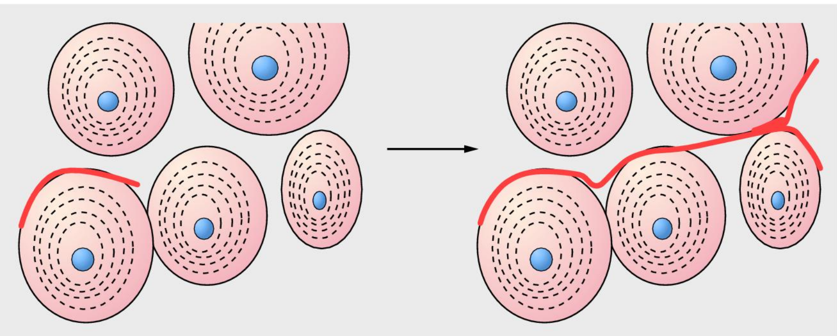

Fig 3 The red line illustrates how cracks in bone arise and propagate with repetitive cyclical loading. Clinically important cracks and stress fractures occur when propagation outstrips repair. Athletes and military recruits experience stress fractures more often than the general population because they endure more repetitive cyclical loading[w3]

Fig 4 T2 weighted magnetic resonance imaging scan with typical high signal appearance seen with a stress fracture of the tibia

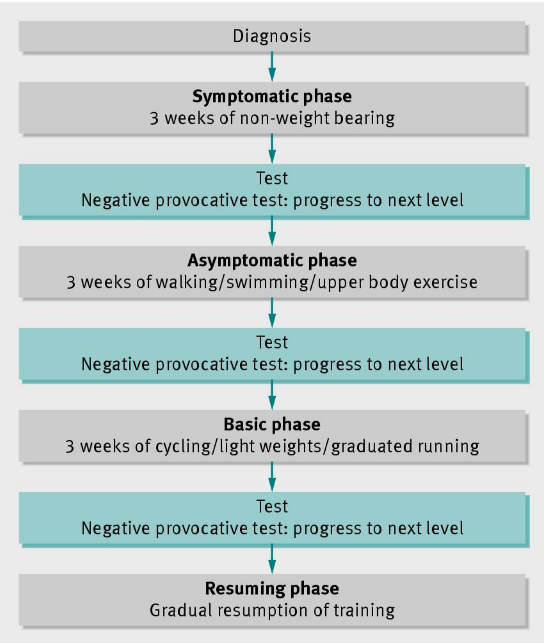

Fig 5 Algorithm for management of femoral shaft fractures[4]