

Review Article

Common stress fractures in runners: An analysis

ABSTRACT

Stress fractures are common injuries in both professional and recreational runners. This type of injury occurs more frequently in the lower extremities and can be caused by a number of both extrinsic and intrinsic factors. A wide variety of stress fracture locations have been reported in the literature, but the tibia is most frequently involved followed by the metatarsals, the fibula, the tarsal navicular, and the femur bone. Marathon training and average weekly running distances over 64 km have been consistently demonstrated as factors in the development of a stress fracture. Recent changes in the training regimen, prior injury, and running or training on hard terrain, such as trail running, are among additional considerations when evaluating runners with stress fractures.

Key words: Athletes, lower extremity, running, stress fracture

تحليل لكسور الإجهاد الشائعة للعدائين
تعد كسور الإجهاد من الإصابات الشائعة بين العدائين المحترفين والهواة. وهذا النوع من الإصابة يظهر غالباً في الأطراف السفلى وقد يحدث نتيجة للعديد من العوامل الداخلية والخارجية. وقد تم تسجيل اختلافات عريضة لمواقع كسر الإجهاد في الكتب لكن كسر عظم الساق الأعظم هو الأكثر تكراراً يليه عظام مشط القدم، عظم الساق الأصغر، الرسغ والفخذ. ولوحظ أيضاً أن تمارين الماراثون ومعدل الجري لمسافة أكثر من 64km من العوامل التي ينتج عنها كسر الإجهاد. إن التغيير الذي يجري حالياً في نظام التمرين، قبل الإصابة والجري أو التمرين في الحقل الصلب مثل آلة الجري هي ضمن الاعتبارات الإضافية التي يجب أن توضع في الاعتبار عند تقييم العدائين المصابين بكسر الإجهاد.

Introduction

Stress fractures are a major musculoskeletal problem occurring frequently in professional runners which may lead to significant disability and loss of time from sports training and competition and therefore require particular attention. Nowadays, with the ongoing development of public participation in sports, stress fractures can also affect recreational runners.^[1,2] It is believed that numerous factors contribute to the development of the pathogenesis of stress fractures in runners. These factors are typically grouped into two major categories; extrinsic and intrinsic risk factors [Table 1].^[3-5] In addition, stress fractures can be divided into high- and low-risk stress fracture sites based on the likelihood of uncomplicated healing with conservative therapy [Table 2].^[3,6-9] The incidence of such fractures in

runners accounts for up to 21.1% of all injuries sustained.^[10-12] The most commonly involved bone is the tibia, but the metatarsals, tarsal navicular, femur, and pelvic skeleton are also susceptible to these fractures [Table 3]. Most of the stress fractures develop gradually and usually occur as a result of repetitive overload and/or overuse of the bone, when mechanical stresses exceed bone remodeling and adaptive capacity.^[21]

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Stress fractures can affect any physically active person at any age if he/she participate in repetitive sports activities such as running. This article reviews the common stress fractures in runners with an aim to present the location of stress fractures according to kilometers run per week.

General Review

Tibia

The tibia is the most common site of a stress fracture in the lower body in runners, accounting for between 25% and 59% of all stress fractures reported.^[13-17,19,22-24] Fractures may occur at different locations within the tibia. Tibia stress fractures typically occur in the proximal and distal parts of the bone and over the medial posterior surface of the tibia, with the midpart of the bone and the anterior diaphysis being far less susceptible.^[25,26] Recreational and professional runners are prone to developing a stress fracture on the posterior medial side of the tibia,^[27] while an anterior tibia stress fracture may result from sports demanding frequent jumps,^[28] or which include a multitude of other movements, such as trail running. The scientific evidence shows that a significant number of runners suffer a tibia

stress fracture even when running modest distances of 30–40 km/week.^[29] It is important to note that an anterior tibia stress fracture is a serious injury potentially and adversely affecting an athlete’s career or even leading to its premature termination.^[25]

Metatarsals

The first report of a stress fracture was described by Breithaupt in 1855 and involved the metatarsals of Prussian soldiers after marching long distances.^[30] Overall metatarsal stress fractures constitute between 10% and 25% of all lower extremity stress fractures. Typically, metatarsal stress fractures occur in the distal second and third metatarsal shafts, which are thinner and often longer than the adjacent first metatarsal, while the fifth metatarsal rarely presents stress fractures.^[13-16,19,23,31] There are two distinct areas in the metatarsals where stress fractures can develop: (i) Nonproximal (distal) and (ii) proximal (at the base), the latter may often require surgical intervention and a prolonged recovery period.^[32] Metatarsal stress fractures are not limited to high-level athletes or military recruits; this type of injury presents in runners of all levels, as well as in ballet dancers, rheumatoid arthritis patients, and in people involved in jumping sports.^[33-35] Runners who run 90–110 km/week are more likely to present a metatarsal stress fracture.^[36]

Table 1: Extrinsic and intrinsic risk factors contributing to the pathogenesis of stress fractures

Extrinsic factors	Intrinsic factors
Training load or overuse	Demographic factors
Poor footwear	Gender
Training surface	Age
Type of sports	Ethnicity
Improper technique	Biomechanic factors
Sleep deprivation	BMD
	Bone geometry
	Anatomic factors
	Foot morphology
	Leg length discrepancy
	Knee alignment
	Hormonal factors
	Delayed menarche
	Menstrual disturbance
	Contraception
	Nutritional factors
	Low calcium and Vitamin D intake
	Disordered eating

BMD=Bone mineral density

Table 2: High- and low-risk fracture sites according to their propensity to heal without complication with conservative therapy

High-risk fracture sites	Low-risk fracture sites
Femoral neck	Femoral diaphysis
Patella	Medial tibia
Anterior diaphysis of tibia	First to fourth metatarsals
Medial malleolus	Fibula
Talus	Calcaneus
Tarsal navicular	Pelvic skeleton
Fifth metatarsal	
Sesamoids of the great toe	

Fibula

Problems with the fibula account for 7%–23% of all stress fractures.^[14-19,23] These are not as common as tibia stress fractures because the fibula is not used in load bearing in the same way. The most common sites of stress fracture occur in the distal third of the bone,^[37,38] proximal to the lateral malleolus. Runners (marathon) and especially trail runners (running on hard surfaces) have the highest incidence of developing fibula stress fractures, but many other types of athletic activity may contribute to this, such as jumping sports, ballet, and/or aerobics.^[24,35,39-41] Weekly running over 25 km/week was associated with a significantly increased risk of a stress fracture in the fibula.^[41]

Tarsal navicular

Tarsal navicular fractures are the most common stress fractures of tarsal bones and are classified as high-risk stress fractures.^[21] Tarsal navicular stress fractures account for 1%–3% of all stress fractures,^[16,22,23,42] but a study conducted in Germany presented a disproportionately larger percentage of 20%.^[15] The most common site for stress fractures occurs at the proximal dorsal central one-third of the navicular bone.^[43-47] This fracture is often associated with sprinting, jumping, and hurdling sports, such as athletics generally, basketball, soccer, and/or lacrosse.^[44,45,48-51] However, this type of stress fracture can occur in long-distance runners

Table 3: Percentage distribution of stress fractures in runners by bone: A panorama of the literature

Study ^a	n ^b	Tibia	Metatarsals ^c	Tarsal navicular	Femur ^d	Pelvic skeleton ^e	Fibula	Calcaneus	Patella
Iwamoto, 2003 ^[13]	20	25	10	N/A	N/A	35**	N/A	N/A	N/A
Korpelainen, 2001 ^[14]	114	48.2	24.6	N/A	4.4	3.5	10.5	1.8	N/A
Csizy, 2000 ^[15]	N/A	33	20	20	11	7	7	N/A	N/A
Bruckner, 1996 ^[16]	35	42.9	14.3	2.9	5.7*	5.7	22.9	5.7	2.9
Orava, 1996 ^[20]	98	53.5	18.3	0.7	6.3	1.3	14.1	N/A	N/A
Dowey, 1984 ^[17]	31	58.1	19.4	N/A	N/A	3.2	19.4	N/A	N/A
Sullivan, 1984 ^[18]	57	43.9	14	N/A	N/A	N/A	21.1	N/A	N/A
Smith, 1982 ^[19]	300	59	20.3	2	1.7	N/A	13.7	1.3	N/A

All the numbers represent percentages (%) apart from the second column (n), which represents absolute numbers. ^aCitations have been listed by the first author's last name to conserve space, ^bNumber of fractures in the study, ^cFirst to fifth metatarsal, ^dDiaphysis and neck, ^eSacrum, ilium, ischium, and pubis, *Femur diaphysis, **Pubic bone, ^{||}Pubic arch. N/A=Not available

when their training programs have regimens of 80–160 km/week.^[46,47,52]

Femur

Stress fractures may occur at various sites in the femur including the head, neck, and diaphysis region, but the most common location is the femoral neck.^[53,54] Femur stress fractures are rare and represent 2%–11% of all stress fractures in runners.^[14-16,19,23] These fractures may occur among people who do high-impact athletic activities such as marathon running, cross-country running, skiing, football, and lacrosse,^[1,55-58] although the literature includes an uncommon femoral neck stress fracture in a 15-year-old girl that incurred while swimming.^[59] A training regimen of between 30 km and 70 km/week appears to be a crucial factor for the development of a femur stress fracture.^[55,58,60-63]

Pelvic skeleton

Stress fractures of the pelvic skeleton normally account for 1.3%–7% of stress fractures seen in runners.^[14-17,23] However, a report exists of a study conducted in Japan, which describes an unusual high rate of 35% for stress fractures in the pubic bones.^[13] The most common sites for stress fractures in the pelvic skeleton are the sacrum and pubic ramus. Stress fractures of the sacrum predominantly appear in long-distance runners, particularly females with a combination of female athlete triad (disordered eating, amenorrhea, and reduced bone mineral mass).^[64-68] Sacrum stress fractures have also been reported in a soccer player, a basketball player,^[68] an amateur tennis player,^[69] a volleyball player,^[70] and a weightlifter.^[71] It is notable that a running training program up to approximately 100 km/week appears to contribute to the development of a sacrum stress fracture.^[65-67]

Patella

Stress fractures of the patella are uncommon, only representing approximately 3% of all stress fractures in runners.^[16] Patella stress fractures can take a variety of forms,

with studies identifying transverse stress fractures as more common than longitudinal.^[20,72,73] Running is reported to be the predominant cause of stress fractures,^[73] but other sports also contribute to their development such as tennis,^[74] skiing,^[75] volleyball, and soccer.^[20] Running up to 145 km/week may be a crucial factor for developing patella stress factor.^[73]

Great toe sesamoids

Sesamoid bones are bones present within a tendon. The great toe sesamoids are small and seemingly inconsequential; however, they are susceptible to stress fractures.^[28] Great toe sesamoid stress fractures are relatively rare and constitute approximately 0.4% of all running injuries.^[76] Regarding great toe sesamoid stress fractures, the medial (tibial) sesamoid bears most of the weight-bearing force during running and thus it is more prone to be affected than the lateral (fibular) sesamoid.^[77] Great toe sesamoids stress fractures are often associated with sports requiring increased pressure on the forefoot such as running, jumping sports, and ballet dancing.^[77-80]

Calcaneus

Calcaneus stress fractures are the third most common stress fracture in the foot, following metatarsal and tarsal navicular stress fractures. Calcaneus stress fractures typically occur at the posterosuperior aspect of the calcaneus,^[81] overall accounting for 1.3%–5.7% of all stress fractures.^[14,16,19] Calcaneus stress fractures are common among certain populations including active young people, runners,^[81,82] military recruits,^[83] and in persons with osteopenia.^[82] Runners with an average training distance of 90 km/week are at a risk of developing a calcaneal stress fracture.^[84]

Discussion

Running is generally held to have many positive effects, including cardiovascular and skeletal health. However, running can potentially cause injuries, such as stress fractures, specifically relating to the lower extremities. A stress fracture

is defined as a solution for partial or complete continuity of a bone caused by reported mechanical stress which over time exceeds the intrinsic ability of the bone to repair itself.^[6] Runners can get a wide variety of stress fractures, but the most common locations in the lower extremities include the tibia (25%–59%), metatarsals (10%–24.6%), fibula (7%–22.9%), and tarsal navicular (0.7%–20%), while less common locations include the femur, pelvic skeleton, patella, great toe sesamoid, and calcaneus.^[3,6,12,13,21,24,85] A summary of the distribution of stress fracture sites from previously reported studies is shown in Table 3. Nowadays, stress fracture is one of the most feared running injuries, and more than one in five runners will sustain a stress fracture in their athletic career.

It is well documented that the risk of developing a stress fracture is influenced by many factors, categorized as intrinsic and extrinsic factors.^[3,86] In this multifactorial etiology of stress fracture, some alteration in training regimen seems to play a central and crucial role.^[11,86] It seems that the more kilometers per week a person runs, the greater the incidence of stress fracture. Studies show that marathon training^[1,22,60-63,87] and running more than 64 km/week involve a much greater risk of developing stress fractures.^[88] However, there are studies in which a training program of about approximately 25 km/week can also lead to a stress fracture.^[55,56] Running different weekly distance schedules can lead to stress fractures in different topographical locations of the bones in the lower extremities [Figure 1]. In addition, a

sudden increase in the kilometers run per week, a transition to training on hard terrain, running in worn-out or unsuitable footwear, and insufficient recovery period after previous injuries are also contributory factors.^[89] Stress fractures can also occur in both sedentary people who suddenly start running on a weekly basis and in professional runners who exercise regularly and energetically.^[90]

Conclusion

Today, stress fractures have become commonplace in professional and recreational runners and are caused by repetitive application of a greater amount of force than the bones of lower extremities normally bear. Stress fractures may be due to multiple factors including bone quality, nutritional status, hormone imbalance, and anti-inflammatory drugs, but stress fractures often arise in runners who are in training when they suddenly increase distance or start training on a hard surface (trail running). Marathon training and weekly running of more than 64 km are typically considered as highest risk for stress fractures. The location of such fractures can vary with the weekly distance run.

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Conflicts of interest

There are no conflicts of interest.

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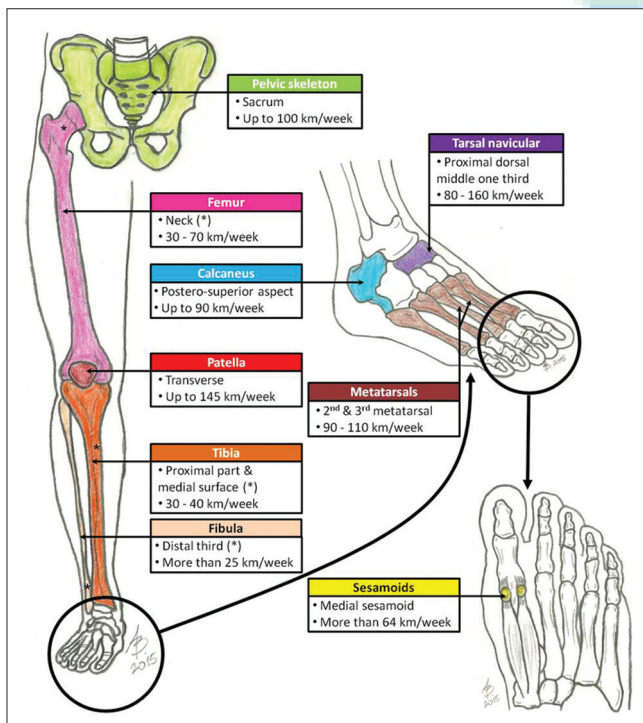


Figure 1: Topographical location of stress fractures in runners according to the weekly running (kilometers load) schedule

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