Bone injury

Index:

Stress fracture

1. Definition

Stress fractures are fractures which occur to the bone due to an imbalance between the strength of the bone itself and the chronic mechanical stress it is subjected to, in other words, when the bone is not able to absorb repetitive loads.

We can differentiate between stress fractures according to the state of the bone and the applied load:

a) Fatigue fractures: result from an increase in the load applied to normal bone (e.g., high volume of stress exercises).
b) Insufficiency fractures: caused by normal loads on weakened bones (e.g., osteoporosis, osteomalacia).

2. Injury mechanisms (pathophysiology)

Bone is a living, dynamic tissue that is in a constant state of remodeling and repair. This remodeling function is carried out through the concerted action of osteoblasts and osteoclasts. A complete cycle of bone turnover, remodeling and mineralization requires a period of three to four months.

The bone receives repetitive forces of tension, compression and impact, and it responds by deforming itself to absorb these forces and then returns to normal. It is when these forces exceed the range of bone elasticity that microfractures occur. If these cannot be remodeled with sufficient speed, they end up producing stress fractures.

Since stress fractures are the result of repeated loads, it is considered that training factors, such as volume, intensity and surface, are important. Other risk factors include the type of sport, low levels of vitamin D, muscle fatigue, osteopenia, female gender, hormonal factors such as late menarche, oligoamenorrhea or amenorrhea, or a body mass index (BMI) <19 (Table 1: Risk factors for stress fracture).

Table 1: Risk factors for stress fractures

EXTRINSIC	INTRINSIC
1. High training volume and intensity.	1. Low bone density.
2. Hard training surface.	2. Lack of physical activity.
3. Unsuitable or worn-out footwear.	3. Female gender.
4. Type of sport: run>swim.	4. Low bone density.
5. Low levels of vitamin D.	5. Reduction in muscular strength.
6. Alcohol.	6. Menstrual changes.
7. Tobacco.	7. BMI<19.
	8. Changes in diet.
	9. Thyroid dysfunctions.

Source: Prepared by the author

3. Most common fractures

Stress fractures can theoretically occur in any bone, but they are much more frequent in the lower extremities than in the upper extremities.

We classify stress fractures into high risk and low risk injuries according to their probability of healing without complications, with conservative treatment:

a) High risk: fractures in locations where there is a greater risk of lack of union, displacement or progression to a complete fracture. These cases require long-term and specialized treatments (Table 2: Classification for high-risk stress fractures).

They are:

- Posterior tubercle of the calcaneus.
- Talus neck.
- Neck of the 2nd to 4th metatarsals.
- Base of the 5th metatarsal: the area of greatest risk is the lateral plantar area because it is the area where most traction forces are concentrated. It is the most common fracture among soccer players (Image 1).

Source: Prepared by the author:

- Tarsal scaphoid: the majority of fractures occur in the middle third, because this area has less vascularization. They are difficult to diagnose and treat.
- Medial malleolus: infrequent, but may cause significant morbidity.
- Anterior tibial diaphysis: second most common. If a prolonged discharge is not made over time, there is a risk of a delay in consolidation and even failure of this consolidation (Image 2).

Source: Prepared by the author

- Sesamoids: very infrequent.
- Femur: can be located in the femoral neck, intertrochanteric/subtrochanteric, or in the femoral diaphysis.
- Spondylolysis: the affected area is the pars interarticularis, most common at the L5 level, Image 3

Source: Prepared by the author

- Transversal fracture of the patella.

Table 2: Classification of high-risk stress fractures

• Posterior tubercle of the calcaneus. • Talus neck. • Neck of the 2nd to 4th metatarsals. • Base of the 5th metatarsal. • Tarsian scaphoid. • Medial malleolus. • Anterior diaphysis of the tibia. • Sesamoids. • Femur. • Spondylolysis. • Transversal fracture of the patella.

Source: Prepared by the author

b) Low risk: fractures that, due to their location, heal correctly and do not tend to progress to a complete fracture. Treatment is simple and, when intensity and volume loads are adapted, the athlete can continue training and competing. They are:

- Diaphysis of the 2nd to 4th metatarsals: called "gait fractures".
- Sacrum.
- Postero-medial diaphysis of the tibia: frequent.
- Ribs.
- Ischiopubic ramus of the pelvis.
- Fibula.
- Longitudinal fracture of the patella.

Table 3: Classification of low-risk stress fractures

• Diaphysis of the 2nd to 4th metatarsals. • Sacrum. • Postero-medial diaphysis of the tibia. • Ribs. • Ischiopubic ramus of the pelvis. • Fibula. • Longitudinal fracture of the patella.

Source: Prepared by the author

4. Clinical

Stress fractures are usually accompanied by progressive and insidious pain in the area of the fracture without any history of trauma. The pain appears during activity, either training or competition, and disappears with rest. When the athlete resumes the activity, the pain reappears in the same location. Often, there is a history of increased load or a major change in training type or duration.

During exploration, there will be "tip of the finger" sensitivity in a certain location or diffuse pain across an area; both may be accompanied by edema in the area. The pain may be constant, nocturnal or only appear with certain movements or loads. This pain increases over time if the precipitating factors continue. In this case, the injury will progress and will limit athletic motor pattern. Kaeding and Miller (2013) outline a classification of stress fractures based on the presence of pain and imaging findings (Table 4: Classification of stress fractures by Kaeding and Miller).

Table 4: Classification of stress fractures

Grade	Pain	Imaging			
		XRAY	Bone Scan	CT	MRI
I	No	Without fracture line and scelerosis.	↑ Of the uptake.	Sclerosis.	Bone marrow edema.
II	Yes	Without fracture line and scelerosis.	↑ Of the uptake.	Sclerosis.	Bone marrow edema.
III	Yes	Non-displaced fracture.			
IV	Yes	Displaced fracture.			
V	Yes	Fracture with nonunion.			

Source: Kaeding, Miller (2013)

5. Diagnosis

The diagnosis of a stress fracture is essentially a suspected diagnosis based on clinical and sporting history (changes in type of training). Imaging tests are essential for confirming suspicions. These

complementary tests, used in order of diagnostic usefulness, are (Table 5: Radiological grading of stress fractures):

Table 5: Radiological grading of stress fractures

	XRAY	Bone Scan	MRI	TREATMENT
Grade I	Normal.	Hypercaptant areas poorly defined.	STIR positive T1 and T2 negative.	Rest 3 weeks.
Grade II	Normal.	More intense uptake, but undefined.	STIR and T2 positive. T1 negative.	Rest 3 - 6 weeks.
Grade III	Barely perceptible lines. Incipient periosteum reaction.	Well defined uptake areas with well contrasted margins.	T1 and T2 positive without cortical rupture.	Rest 12-16 weeks.
Grade IV	Fracture or periosteal reaction.	Intense transcortical uptake.	T1 and T2 positive with fracture line.	Rest for 16 weeks plus.

Source: **Berger, F., de Jonge, M., Smithuis, R., & Maas, M.** (2007)

a) Simple X-ray: the first exploration since it is accessible and low cost. Stress fractures may not appear in the X-ray during the first 2-4 weeks after the injury, therefore there is a high rate of false negatives. This can delay the diagnosis. The first radiography finding may be a localized periosteal reaction or a cortical thickening, which are signs that the body is attempting to form a bony callus.

b) Nuclear magnetic resonance (MRI): recommended as the second line of diagnostic imaging. Has high sensitivity and specificity. It allows us to differentiate spinal damage from cortical, endosteal and periosteal damage, allowing injuries to be graded with respect to their severity and prognosis. There are two types of sequences known as fat suppression sequences: STIR (Short Time Investment Recovery) and FAT SAT or SPIR (Spectral Presaturation with Investment Recovery), which allow us to suppress the signal of specific elements or tissues in a specific way, especially fat.

c) Bone scan: high sensitivity and low specificity. Shows evidence of a fracture within a few days after the onset of symptoms. The fracture may be reflected in a focus of increased radioisotope

activity ("hot spot") due to increased bone turnover at the site of new bone formation. However, the increased uptake may also be due to osteomyelitis, bone tumors or avascular necrosis.

d) Computed Axial Tomography (CT): very similar to an X-ray. Detects areas of bone remodeling, microfractures in the trabecular bone, periosteal reaction and formation of callosal bone. Useful for differentiating between bone tumors and osteomyelitis. The TC-SPECT (Single Photon Emission Computed Tomography/Computed Tomography by Emission of Simple Photons) is useful in the diagnosis of stress fractures in the dorsal spine, specifically spondylolysis.

6. Treatment

Treatment will depend on where the stress fracture is located and the possibility of undergoing rehabilitation. In general terms, we must reduce overload at the affected site, administer analgesics or anti-inflammatory drugs to control pain, administer bisphosphonates to inhibit bone resorption and implement physiotherapeutic rehabilitation.

Low-risk fractures usually require conservative treatment, along with medication, decreased loads, and modification of pain-producing activities.

If we are dealing with a high risk fracture, we may need to immobilize the affected area. In this case, we will need to take into account the harmful effects of this immobilization on muscles, tendons, ligaments and joints, and develop a parallel adapted rehabilitation program.

In the event of any stress fracture, regular check-ups will be needed along with a program to maintain flexibility, strength and cardiovascular fitness.

A high percentage of high-risk fractures can evolve towards non-consolidation of the bone, and surgical intervention can become necessary to stabilize the fracture.

Recently, treatment with plasma rich in growth factors (PRGF) is being used, particularly in during surgery, since it accelerates and improves recovery.

One complication that may be encountered is a delay in consolidation. These are fractures that continue beyond the usual consolidation period without any sign of consolidation appearing in complementary tests (X-ray). This is the case with a localized periosteal reaction. In such cases, we will increase the initial measures established within a prudent time frame. With low-risk fractures we will be more forgiving than with high-risk fractures, for which a delay in consolidation can most often be interpreted as non-consolidation, in which case the definitive treatment will be surgical intervention.

7. Prevention

To prevent stress fractures adequately, we must identify the risk factors which can lead to them. We will start by evaluating the anatomy and biomechanics of the affected area; we will look for changes in hormones and muscle strength, and we will identify whether there is a low cardiovascular condition. All this will help us to identify the probable cause. Once a cause is established, we will correct the athletic movements, change training sites that may be contributing to bone overload, change eating habits and modify the type of footwear according to each type of sport.

Fracture due to trauma

1. Definition and Classification

A trauma fracture is a non-pathological break in a bone due to the application of an acute load that exceeds the resistance capacity of the periosteum. Depending on the application of force and the focus of the fracture, we can divide fractures into direct trauma, when the fracture occurs directly where the blow occurs; or indirect trauma, when the fracture occurs at a distance from where the blow occurs. In this case, the causes are torsion or bone angulation.

We can classify them depending on the location of the fracture, the type of fracture, the displacement of fragments, and whether the fracture is open.

1. Depending on the location:
   a. which bone has fractured;

   b. which part of the bone has fractured: epiphysis, diaphysis, metaphysis, physis, tubercle, epicondyle, etc.
2. Depending on the type of fracture:
   a. Complete fracture: crosses the total width of the bone.
      - Transversal: fracture line perpendicular to the axis of the bone.
      - Oblique: Oblique fracture trace.
      - Spiral: helical fracture trace
      - Comminuted: when there are more than two fragments.
   b. Incomplete fracture: does not cross the total width of the bone.
      - Due to torsion.
      - Green stick: the bone is broken, and also bent (only in children).
3. Depending on exposure:
   a. Open: when the focus of the fracture has an open exterior wound. There is a possibility of infection.
   b. Closed: when there is no wound, or if there is a wound, it is not connected to the focus of the fracture.
4. According to displacement: translation, angulation, rotation and length of the distraction.

2. Most common fractures

Trauma fractures can occur in any bone, but they are much more frequent in the lower extremities then the upper extremities (Table 6: Most common trauma fractures).

Table 6: Most common trauma fractures

Upper extremities	Lower extremities
• Clavicle. • Greater tubercle of the humerus. • Neck and head of the radius. • Olecranon. • 5th metacarpal. • Phalanges of the fingers.	• 5th metatarsal. • Medial and lateral malleolus. • Head of the radius.

Source: Prepared by the author

1. Lower extremities:
   a. 5th metatarsal: avulsion from ankle sprain, a Jones fracture or a metaphyseal fracture (Image 4).

Source: Prepared by the author

   b. Medial and lateral malleolus: normally a consequence of an ankle sprain (Image 5).

Source: Prepared by the author

   c. Head of the fibula: fractures due to indirect trauma to the ankle.
2. Upper extremities:
   a. Clavicle: direct or indirect trauma. Typically, the middle third fractures.
   b. Greater tubercle of the humerus: falling on extended arms or on the lateral side of the shoulder. Presentation resembles a rotator cuff injury.
   c. Neck and head of the radius, and olecranon: produced by direct trauma, a fall on extended arm or arm sprain (Image 6).

Source: Prepared by the author

d. 5th metatarsal: produced by direct trauma (Image 7).

Source: Prepared by the author

e. Phalanges of the fingers (Image 8).

Source: Prepared by the author

3. Clinical

Fractures are usually accompanied by pain, functional impairment and deformity. They may also occur with crepitus.

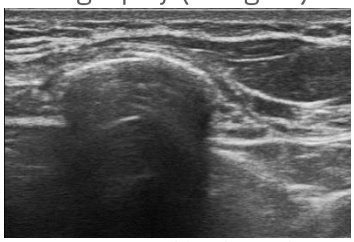
Some fractures, most often incomplete ones, can cause very little pain; enough to be an annoyance, but not so much that it prevents the player from continuing to train. To ensure these fractures do not go unnoticed, when an athlete has recurrent pain after a traumatic incident, it is

obligatory to rule out a fracture. Examples of this are green stick fractures in children, some diaphyseal fractures of the metatarsals, and incomplete fractures in the sacrum.

4. Diagnosis

The diagnosis will typically be made with an X-ray, and two views will always be requested in order to better identify the type of fracture and whether there is displacement (see above). In most fractures we will not need other complementary tests for making the diagnosis.

Musculoskeletal ultrasound is also useful for superficial bones. With this test, we can only observe the involvement or not of the periosteum, but in experienced hands the immediacy and the dynamic exploration offered by ultrasound can be very useful for an initial diagnostic orientation. This can be useful with rib fractures for example, since some incomplete fractures of costal arches are not diagnosed with radiography (Image 9).



Source: Prepared by the author

Other complementary tests are CT and MRI, which we can refer to if a confident diagnosis was not obtained through radiography and we strongly suspect a fracture. These tests are useful, for example, in spondylolysis. MRI also gives us information on the existence of bone edema (trabecular fractures) and provides images of the soft tissues around the bone.

5. Treatment

The treatment of fractures is based mainly on realignment and immobilization.

These steps will depend on the type of fracture and location, although the degree of displacement must also be taken into account. It must also be decided whether surgical treatment is required for the type of fracture. In

cases where the need for surgical treatment is not clear, we must first immobilize and wait for the natural evolution of the fracture. Some fractures, once reduced, are unstable, which will lead to a decision on surgical treatment. If the fracture is in a lower extremity, load must be taken off to avoid displacement.

We must always remember that fractures are painful, so we must administer analgesics or anti-inflammatory drugs.

Fracture by other mechanisms

1. Types of fractures

We can find two types of fractures:

1. Pathological fractures: occur without trauma or with trauma that should not cause a fracture in bones which are weakened for some reason, whether benign or malignant, and where the lesion is focal, such as a metastasis, benign bone cysts, malignant bone tumors, osteolytic tumors, or illnesses that cause bone fragility such as osteogenesis imperfecta, fibrous dysplasia, osteoporosis, osteomalacia, Paget's disease and osteitis (Image 10).

Source: Prepared by the author

2. Fragile fractures: the result of normal activities, such as a jump or fall. The most frequent locations for these fractures are the vertebral bodies, the neck of the femur and the Colles fracture in the wrist.

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