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# Prevalence, diagnosis and management of musculoskeletal disorders in elite athletes: A mini-review[☆]

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A B S T R A C T

Musculoskeletal injuries in elite sports are ones of the most impact issue because their remarkable impact on performance caused by drastic absence of training and competition and a progressive deterioration in physical health, emotional and social athletes' dimensions. Also, the prevalence of epidemiologic research found an incidence of musculoskeletal disorders vary within sports and in elite athletes which is even higher as a consequence of higher demand physical performance. This way, the loss of physical performance due to an sport injury impacts not only the individual economic sphere of the professional but also that of sports entities, reaching, according to some studies, a loss estimated in the range of 74.7 million pounds. Thus, the purpose of this article is to review and to provide an overview of the most common musculoskeletal injuries in elite sports precipitating factors, clinical presentation, evidence-based diagnostic evaluation, and treatment recommendations with a view to preventing medical conditions or musculoskeletal injuries that may alter performance and general health in the elite athletes.



## Background

Musculoskeletal injuries in elite sports are ones of the most impact issue because their remarkable impact on performance caused by drastic absence of training and competition[1,2] and a progressive deterioration in physical health,[3] emotional and social athletes' dimensions.[4,5] Moreover, the loss of physical performance due to an sport injury impacts not only the individual economic sphere of the professional but also that of sports entities, reaching, according to some studies, a loss estimated in the range of 74.7 million pounds.[6]

☆ This paper has been reviewed by antiplagiarism Turnitin program that guarantees the originality of the manuscript.

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**Table 1**
Risk factors for musculoskeletal injury in elite athletes.

| **Intrinsic** risk factor for musculoskeletal injury in elite athletes | **Extrinsic** risk factor for musculoskeletal injury in elite athletes |
|---|---|
| ○ Age | ○ Protective equipment |
| ○ Gender | ○ Footwear |
| ○ Weight | ○ Coaching training |
| ○ Body segment alignment | ○ Training surface |
| ○ Neuromuscular imbalance | ○ Game rules |
| ○ Sedentary lifestyle | ○ Weather |
| ○ Training overload | |
| ○ Low level of rest | |
| ○ Sleep disturbance | |
| ○ Poor diet | |

In addition, the occurrence of the injury in this area depends on intrinsic factors related to *age*, being more frequent in adults than in young people and *gender*, observing a higher incidence in women than in men.[7] Furthermore, there are factors that depend on the idiosyncrasy of the athlete, such as the presence of an anatomical deformity,[8] biomechanical overload due to tissue stress[9] or even neuromuscular imbalances.[10,11] Besides, predisposition to injury may be mediated by a *sedentary lifestyle*,[12] *overweight*[13] *high levels of physical activity due to periodization errors*,[14] *low levels of rest*,[15] *sleep disturbance*[16] and a *poor diet*.[17]

Other extrinsic factors that can draw elite athlete susceptible to injury are the use of poor material for sports practice such as damaged footwear[18] or protective equipment in poor condition. Also, contextual factors mediated by their coaches due to a modification of the game conditions or teammates due to high-intensity training can trigger a musculoskeletal disorder.[19]) See Table 1. Risk factor for musculoskeletal injury in elite athletes

These conditions have triggered a growing interest among exercise professionals for the identification of injury predictors as well as the rational study of injury mechanisms with the purpose of designing and implementing primary and secondary prevention strategies that promote the personalization of the treatment of the intervention and foreseeably reduce not only the number of interruptions due to injury but also their severity.

### *Epidemiology*

Although there is diversity in the number of athletes and its epidemiology vary within sports, it is estimated that the prevalence of musculoskeletal injuries in elite athletes is between 10% and 42.8%[20] In relation to its incidence, it has been estimated that it would reach to 76% produced by throwing activity (75%), jumping (78%), multi-event (65%), middle- and long-distance running (79%) and sprint (76%).[21]

### *Musculoskeletal disorders to the head and neck*

If we detail by anatomical regions, we identify that in the head and neck, concussion or cervical strains (eg; *whiplash, cervical disc prolapse,* etc…) caused by indirect trauma during exposure to sport are the causes of most important lesion with an incidence of 0.1% to 21.5% per 1.000 h of exposure.[22,23]

### *Musculoskeletal disorders in the upper limb*

In the upper limb, fractures comprise 16.5% affecting distal radius, metacarpus and finger phalanges although the highest prevalence was in the clavicle.[22] Moreover, compressive neurovascular injuries as *outlet thoracic syndrome* with an incidence of 3 to 80 of 1000 inhabitants have a special impact as they are related in most cases to high-velocity traumatic mechanisms or repetitive microtrauma caused by movements that involve the combination of an extreme joint range and the existence of a biomechanical pulley responsible for supporting a moderate to high load.[24] In relation to injuries associated with violent trauma, we can identify *clavicular fractures* with an incidence of 24.4 fractures per 100.000 person-year in throwing sports[25] or *humeral fractures* that arise up to 50% in contact sports as rugby (26) together with acromio-clavicular dislocations which incidence has been stablished on 45 per 100.000 person-years.[26]

On the other hand, the presence of multidirectional repetition mechanisms linked to a technical gesture of the discipline (a*ctivities above shoulder level, throwing, weight lifting*, etc…) are responsible for the existence of repetitive microtrauma injuries that draw mechanical overload of the osteotendinous[9,27] and myofascial tissue.[28,29]

In particular, *rotator cuff syndrome (RCS)* is an example of an injury due to the accumulation of microtraumas provoking pain in 5% of elite athletes in which 16.3% was related to tendinosis and 48.2% were produced by partial-thickness rotator cuff tear[30] RCT can be triggered by morphological changes in the osteotendinous union associated with calcification which prevalence of 2.5 %-7.5%.[31]

Mechanisms of repetitive tissue stress injury could draw *lateral and medial epicondylar pain* associated with tendinopathy are common in throwing sports with a prevalence of 1% in the general population that affects both genders in adults.[32,33]

In the region of the wrist, *de Quervain's tenosynovitis* or the *Intersection syndrome* produced by microtraumatic repetition mechanisms occurs in sports as volley or in sustained gripping sports as ski with an incidence between 1 and 3 % per-100.000 inhabitants.[34]

Lastly, neurovascular injury caused by compression of the different interfaces through which the brachial plexus and arteries run, such as peripheral nerve entrapment as *carpal tunnel syndrome* in adapted Sports athletes with an incidence of 8% or *Cubital nerve entrapment* in *Guyon's Canal* which prevalence and incidence are still unclear but it is often related to intense and repetitive tasks.[11,35]

*Musculoskeletal disorders in the lower limb*

In the lower limb, capsular ligament injuries, tendinopathies and muscle tears are the most relevant musculoskeletal injuries in elite sports, as they are related in some cases to repetitive microtrauma and in others to extreme intrinsic movements associated with a biomechanical disadvantage performed at high speed.[36]

In the first group, the rupture of the *anterior cruciate ligament*, the *sprain of the medial or lateral collateral ligament* of the knee while in the ankle the *anterior peroneal-talar ligament*, or the one corresponding to the syndesmosis tibiofibular seem to be frequent with a prevalence in elite athletes around 75% and an incidence between 28.7% and 59.4% being more frequent in adult males.[37] It should be remembered that these injuries can occur in isolation or in a more serious combination with another injury in the form of triads or pentads.[38,39]

In the second group, tendinopathies are frequent among subjects with poor physical conditioning (sedentary) or those who accumulate risk factors related to the injury *(obesity, high levels of physical activity due to periodization errors, low levels of rest, sleep quality deficit or an impoverished diet*).[40] Among the most relevant diseases in this section we identify *Achilles, patellar, gluteal tendinopathy* or *plantar fasciopathy* and *iliotibial band syndrome* whose incidence 10.52 per 1.000 person-years and a prevalence rate of 11.83 per 1.000 persons-year.[41]

In the third group, and no less important, we identify those diseases of the elite athlete caused by muscle rupture, which is undoubtedly the most common injury in this population group. Beyond the notable differences between injuries, myofascial rupture of the hamstrings as well as of the *triceps surae* muscles are the most frequent with an incidence of 19.4% to 79.3% per-1000 person-years.[42]

## Head and neck

*Introduction*

In sports practice, head and neck injuries are infrequent in relation to other body areas (around 4%), but they should be treated with special attention considering the damage they can cause.[43] In 2020, an epidemiological study[44] was published to quantify head and neck injuries in athletes. It was estimated that over a 5-year period, 11.510 injuries occurred among all National College Athletic Association (NCAA) sports. These were mostly recognized in athletics, soccer, and ice hockey (with rates of 25.5, 18.6, and 14.67 per 100.000 exposed athletes, respectively).

*Head injuries*

Head injuries can occur primarily by two mechanisms.[45] The first one is due to a moving object striking the head in resting position, causing injury at the site of the impact (coup lesion). In the other mechanism, the moving head strikes an object, resulting in an injury in a region away from the impact site (contrecoup lesion). Thus, rotational or translational forces are generated. Rotational forces can cause a concussion, resulting in a loss of consciousness. On the other hand, translational forces generate a compression that can lead to skull fractures, hematomas or cerebral contusion. The severity of the injury is related to the speed and position of the head at the moment of the impact.[45] Coup injuries usually occur in sports where a ball strikes the head of an immobile player. In contrast, in sports such as skiing, head collisions with obstacles are one of the most common causes of accidents, being an example of a contrecoup injury mechanism.

*Cranial lesions*

Cranial injuries are generally classified as focal or diffuse. Focal injuries include cerebral contusions; in which we observe an area of hemorrhage. Symptoms are usually temporary and limited to headaches and loss of balance and coordination. In severe cases they may lead to skull fractures.[46] On the other hand, diffuse injuries are usually concussions, which are associated with changes in neurological function. This is the most common type of head injury, with up to 250.000 cases reported each year just in American footballś players. Only 9% of them involve transient loss of consciousness. The most frequent symptoms include headaches, confusion, vomiting, balance disturbance and visual disturbances.[47]

For early diagnosis and treatment, first of all, the level of consciousness (using tools such as the Glasgow Coma Scale) and possible associated injuries should be assessed. After ruling out spinal injuries and with an adequate level of consciousness, the athlete will be helped to sit up to reduce intracranial pressure. The definitive diagnosis will be obtained through a computed tomography (CT) scan of the head, cervical X-rays and a neurological examination.[45]

Treatment during the first days after a brain injury focuses on rest to allow the brain to recover and coordination exercises in case of neurological lesion. Structural damage will subside naturally, so the treatment will be symptomatic.[45]

### Dental and mandibular injuries

The scientific literature has revealed the existence of a high number of dental and mandibular trauma among athletes. Several authors report that the prevalence of this type of injury ranges from 8% to 45%. Predictive factors include the speed and intensity of the sport, the level of contact and the use of protective equipment.[48] A comparative study[49] assessed the occurrence of dental trauma in different sports and found that the prevalence was higher in martial arts (41%), handball (37%), basketball (36%), soccer (23%) and hockey (11.5%). The most frequently affected teeth are the upper incisors (50.8%) and crown fractures are the most common type of injury.[48,50]

The prevalence and severity of this type of trauma could be limited with the use of mouthguards. However, many athletes report pain, clicking and temporomandibular joint dysfunction when wearing these devices. This is due to the fact that the guard is placed on the teeth and changes the condylar position, producing an anterior displacement of the articular disc that generates alterations in dental occlusion.[51]

The normal occlusal height is 3 mm, being at 6 mm in height when the masticatory muscles are activated. When the mouthguard is tightened, the relationship between the condyle and the disc changes. Athletes should be educated with guidelines and exercises to manage dental tension during sports activity to avoid altering joint mechanics.

### Minor injuries

Minor injuries, such as muscle contractures or cutting wounds, are common in sports practice. Contractures mainly affect the deep muscles of the neck, the trapezius, the sternocleidomastoid and the scalenes. They are quite uncomfortable and can produce hypersensitive nodules that generate pain. Standard treatment is based on manual therapy techniques, stretching and dry needling.[52] Cutting injuries usually occur in contact sports. In these cases, our labor is to stop the bleeding and disinfect the wound to avoid infection.[53]

### Cervical spine injuries

The cervical spine is responsible for providing proprioceptive information to the brain, so musculoskeletal injuries in this segment negatively affect balance and postural control.[54] Among all cervical injuries, those produced during sports represent a 15%.[44] In one study, soccer, along with wrestling and hockey, was shown to have the highest rate of cervical spine injuries of all NCAA sports. This appears to be due to the level of contact, which predisposes these athletes to injury by generating positional changes in the joints and decreasing cervical kinesthetic function.[44,55] The mechanisms of cervical spine injury in athletes appear to be similar regardless of the type of sport. However, some injuries may result from the overlap of several mechanisms. Axial loading is considered the most common pathophysiologic factor of injury in sport. Under normal circumstances, with the neck in an anatomical position and slightly extended due to cervical lordosis, the cervical muscles are responsible for dissipating the forces transmitted to the cervical spine. However, when the neck is slightly flexed, the muscular damping capacity decreases and the result of compression is usually a disc, ligament or bone injury.

It has been established that the compressive load limits of the cervical spine are between 3.340 and 4.450 Newton, which are easily reached when flexing the head at a speed of as little as 2.3 m/s. In addition, the risk of injury can be increased by the existence of muscular imbalances resulting from inadequate conditioning. This mechanism of injury is common in sports such as rugby, American football, wrestling, gymnastics and hockey.[44,56]

Another mechanism is the hyperextension, which is often related to falls. When the neck is hyperextended, the spinal canal can be compromised by up to 30%, which can lead to neurological symptoms and anterior longitudinal ligament injury. This is common in athletics and is frequently associated with a whiplash injury.[57]

Finally, there are less frequent mechanisms of injury such as hyperflexion (due to the rupture of the posterior longitudinal ligament, which can cause a reduction of the spinal canal), rotation (in which a subluxation is generated by misalignment of the vertebrae) and lateral flexion (which produces excessive traction on the nerves and can cause a neurapraxia).[58]

This overloading of the cervical spine in elite athletes is associated with accelerated degeneration and morphological changes that have implications not only for long-term disability, but also for short-term injury risk. Several studies have demonstrated a positive correlation between years of contact sports practice and cervical positioning error, contributing in a 63.1% and a 84.6% to injuries in men and women, respectively.[44,55] According to a study of 2.965 athlete records, the most common diagnose of cervical spine pathology is cervical hypermobility, resulting in spondylosis, stenosis and disc lesions.[59]

### Cervical hypermobility

Cervical hypermobility is defined by White and Panjabi as "the loss of the ability of the spine under physiological loads to maintain its displacement pattern so that there is no neurological deficit, significant deformity and disabling pain." The hypermobility is usually generated by repeated cervical extension mechanisms and is most frequently observed at C3-C4, due to the horizontal orientation of its facets.[59–61]

**Table 2**
Degeneration risk factors according to different sports.

| Classification of sports | Risk level | Symptoms |
|---|---|---|
| Collision sports | High risk: American football, hockey, skiing, wrestling, snowboarding, etc. | - Players with radiculopathy have evidence of severe degenerative disease.<br>- Decreased cervical range of motion.<br>- Chronic neck pain. |
| Contact sports | Medium risk: Basketball, soccer, baseball, handball, etc. | - Early degeneration as a result of mechanisms such as heading the ball.<br>- Reduced cervical range of motion. |

Under normal circumstances, the cervical spine allows little movement between the vertebrae. Instability has been defined as existing when the radiological measurement of the horizontal displacement is greater than 3.5 mm and the angular displacement exceeds 11º between adjacent vertebrae. The Segmental Instability Test, in which a posteroanterior thrust is performed on the vertebral spinous process to assess the amount of motion, confirms the diagnosis of cervical hypermobility.[60]

*Spondylosis and cervical stenosis*

The spondylosis is a joint and disc degeneration. It is usually asymptomatic, but nociceptors located in the degenerated facet joints manage to generate pain in some cases. Osteophytes, together with disc protrusions, can compress the nerve roots generating a stenosis that manifests as a radiculopathy. Furthermore, stenosis has been shown to be a risk factor for developing irreversible spinal cord injury (SCI).[62] The normal radiological diameter of the cervical canal is 18.4 mm at C-3 and 17.8 mm at C4-C7 segments. The diagnosis of stenosis indicates a reduction of this space $<$14 mm.[56]

These degenerative changes generally increase with age, but also result from the high repetitive stresses associated with collision sports. This is exemplified in a study that argued that a 36.6% of retired American football athletes were diagnosed with cervical arthropathy, compared with 16.9% representing the general population.[62]

To compare the risk factors for cervical degeneration between sports, these can be divided into collision sports, contact sports and non-collision and non-contact sports. Table 2 shows the classification of each sport according to the risk level and the most frequent symptoms.

Regarding to the treatment, in minor cases, conservative therapeutic options such as drugs to reduce symptoms and rehabilitation exercises to increase muscle strength, maintain spinal stability and improve balance are recommended. However, in cases of sensory or motor losses due to severe neurological deficit, surgery should be resorted to in order to increase the space and prevent disease progression. Return to play should be considered individually according to each athlete, his or her position and the playing level.[56]

*Cervical discogenic pain*

Cervical disc herniations are common in athletes, especially those involved in contact sports. Interestingly, C3-C4 and C5-C6 are the most commonly affected levels, while C6-C7 is the level where most herniations occur in the general population.[59] Cycling is one of the non-contact sports with the highest incidence of discogenic pain (47.6%). This is because the forces exerted during training increase the strain on the cervical spine, and the surrounding tissue becomes more vulnerable to injury.[63]

Magnetic resonance (MRI) imaging is the tool used to define the diagnosis. The most common symptoms include bilateral pain, tingling and numbness in the upper limbs. These are intensified by the performance of orthopedic tests such as the Spurling, Upper Limb Test or Cervical Compression Test.[60] The results of cervical disc surgery in general population have been reported to be 90% satisfactory. However, surgical implications in athletes can lead to neck stiffness and changes in cervical mechanics, affecting reaction times and muscle strength. These minor modifications can be critical in the performance outcomes of elite athletes, with 28% of athletes finishing their career after suffering an episode of cervical discogenic pain.[64,65] In minor cases, the treatment is based on analgesics, exercises and neural gliding techniques.

*Facet dislocation*

Bilateral facet dislocation is the most catastrophic injury of the posterior ligament complex. These tend to occur most frequently in the lower cervical spine, at the C4-C5 and C5-C6 segments.[58] Several experiments have been performed to simulate the mechanism of bilateral dislocations, suggesting that compression forces are capable of generating a buckling of the cervical spine, leading to vertebral dislocations that occur at very fast speeds (between 2 and 20 ms). The reflex times of the cervical stabilizing musculature range between 50 and 65 ms, minimizing any attempt of protective effect.[58] In these cases, surgical stabilization is recommended for dislocations with radiological displacement greater than 1 cm. Treatment for unilateral dislocation is performed by closed manipulative reduction. However, the reduction of bilateral dislocation is best managed by open methods.[59]

**Table 3**
Vertebral fracture mechanisms according to different sports.

| Sports | Mechanism |
|---|---|
| American Football | Contact and collision with the adversary with the top of the head while the cervical segment is straightened.[66] |
| Rugby | They occur when a player dives to make a tackle and stops abruptly by hitting the ground with his head, transmitting the forces along the straightened cervical spine.[362] |
| Ice Hockey | The triggering event is usually a backstroke that boosts the player against an object. Simulations have shown that collision velocities of 3.1 m/s always cause fractures, while players can reach 6.7 m/s when skating. Considering this biomechanical sequence, the most frequent injuries in this sport are burst fractures of the C5-C7 vertebrae.[43] |

### *Cervical fracture*

The pathophysiology of vertebral fractures in the cervical spine is due to continuous loading, resulting in compressive forces. Initially, a bone deformation occurs, which may lead to dislocations as described above.[43] Finally, if the force continues and reaches around 2000-3000 Newton of force, the spine fails and collapses on itself, producing a fracture.[66] They are generally not associated with neurological injuries; but these may appear in case of burst fractures.[59] Upper cervical vertebrae (C1-C2) fractures in athletes are infrequent. A study realized in American football players revealed that only a 4.6% of injuries occurred in the upper cervical segment. Mountain biking is the sport with the highest incidence of this type of fractures.[59] Regarding lower cervical spine fractures, these usually occur in contact sports such as American football, rugby and ice hockey. The mechanisms of injury are described in Table 3. For diagnosis and prior to reduction, a cervical MRI or CT scan should be performed in order to rule out the presence of disc lesions that could complicate the process.[59] Most isolated fractures in the cervical segment (spinous process or unilateral lamina fractures) can be treated with a hard cervical orthosis, with bone healing being completed after 12 weeks of immobilization. Surgical treatment and reduction is warranted for comminuted vertebral body fractures, odontoid fractures, neurological injuries or posterior ligament tears.[56,59] Patients with radiologically stable fractures and no neurological injury usually have no problems to return to play. However, after immobilization and surgical stabilization treatments, athletes do not have sufficient mobility and strength to withstand the return of participation in contact sports.[56] Strengthening exercises of the cervical musculature can be useful as prevention. However, emphasis should be placed on good education and proper training techniques to prevent these types of injuries from occurring.[66]

## **Thoracic spine related injuries**

From a biomechanical point of view, the thoracic spine with its 12 vertebrae is considered the central point of the spine and a transition zone from the cervical and lumbar region. In addition, it forms part of the posterior wall of the thoracic cage, which in combination with the vertebral morphology forms the least mobile vertebral segment of the spine, especially in the sagittal plane. In addition, the thoracic spine plays a fundamental role in axial rotation movements as well as in the mobility and stability of the upper extremity through various muscular insertions of the scapulothoracic joint, such as the serratus anterior or the trapezius, among others.[67] In this sense, the thoracic spine plays an important role in the transmission of energy in complex sequential movements. This concept, defined as the kinetic chain, makes special sense in the analysis of movement patterns and technical gestures that imply the transmission of energy from the lower extremity to the upper extremity, such as the tennis serve, the golf swing or the clean and jerk in weightlifting.[68–70] Likewise, atraumatic injuries to the trunk due to repetitive stress in sports should be contextualized considering the regional interdependence that exists between the different body segments, defined as the possible relationship or conflict between the main reason for the patient's main complaint and the presence of dysfunctions remote to the target region.[71,72]

Trunk pain in athletes is a common cause of performance limitation in the sporting environment. Chest symptoms are frequently underestimated in the scientific literature as a clinical condition in athletes. Generally, atraumatic injuries to the thoracic spine represent considerable placement as symptom territory in the athletic population. Sports such as rowing (9%) or baseball (10%) presented a considerable percentage of injury incidence of atraumatic injuries to the trunk with a sports prescription period of 3 weeks.[73] Likewise, 60% of the cases of chest pain in the young athletic population are of musculoskeletal origin compared to 30% of the cases in the adult athlete, which highlights the importance of visceral evaluation as a frequent area of derived symptoms.[74]

The highest risk of prevalence of trunk injuries in sports typically involve mechanisms such as repetitive thoracic spine rotations and overhead activities which requires thoracic extension such as rowing or throwing. Structures classified as pain generator a thoracic spine include joint and vertebral structures, chest and rib cage, and abdominal wall and trunk muscles such as serratus anterior.

### *Thoracic spine disorders*

Most of the clinical conditions of the thoracic region of a musculoskeletal nature, related to the appearance of local or referred nociceptive pain, are related to the intervertebral, zygapophyseal, costovertebral and costotransverse joints, or the ribs themselves. The clinical presentation of these conditions in most cases is varied with the appearance of various combinations of pain, restricted mobility in various vertebral segments, increased neural mechanosensitivity and frequently alterations of the paravertebral and extrinsic muscles of the trunk such as stiffness and pain.

Disc herniation in thoracic spine is a rare condition that represents 1% of all levels disc injuries. The T11-T12 level represents between 26 and 50% of all cases of disc herniation of the thoracic spine, the most frequent etiology being disc degeneration followed by direct trauma.[73] The symptoms can be considered both diverse and rare, from unilateral or bilateral located in the mid-axillary region or the anterior region of the chest, as well as a possible radicular pattern radiating to both regions. Throwing sports are more related to the dominant side, as well as activities such as coughing or efforts that involve picking up weight can increase symptoms.[75]

Thoracic joint disorders of the intervertebral, costal or zygapophyseal joints are the main cause of pain in the thoracic region. The onset of symptoms can be sudden or gradual, with examination frequently showing hypomobility of joint segments during manual examination accompanied by local hypersensitivity of vertebral structures such as the spinous or articular processes, as well as the surrounding paravertebral musculature. Symptom relief and restoration of mobility through passive or auto-passive mobility techniques through exercise are one of the main objectives. Soft tissue manipulation techniques and the restoration of the functionality of the periscapular and paravertebral musculature will become more important with the evolution of the intervention.[76,77]

On the other hand, chest pain in most cases of the athlete is related to musculoskeletal causes. Even so, symptoms associated with visceral causes (cardiac, gastrointestinal, pulmonary, or malignancy) should be investigated by the clinician during the examination, especially in those cases that present with symptoms such as palpitation, respiratory pattern alterations, dizziness, reflux, or loss of consciousness.[74] Costovertebral joint disorders usually appear accompanied by local tenderness on palpatory examination as well as symptoms associated with breathing. Some cases of inflammatory spondyloarthropathies such as ankylosing spondylitis can affect the costovertebral joints. In the most severe cases and resistance to conservative management, infiltration of corticosteroids under radiological guidance may be a useful therapeutic alternative.

### *Lumbar spine disorders*

Lumbar pain covers a very broad spectrum of pain from more stimulus-dependent symptoms typically mentioned as nociceptive pain, pain radiating to the lower extremity in different territories with neuropathic characteristics, as well as symptoms frequently related to the perpetuation of the state of pain itself or the role of the central nervous system in their amplification, recently mentioned as nociplastic pain.[78]

Low back pain is a clinical condition that affects 85% of the population at some point in their lives. Most cases improve in a period of 3 months, but around 50% of cases will have at least one period of recurrence or relapse. The prevalence of low back pain is 18% in young adolescents, reaching a peak prevalence between 40 and 69 years of age around 28 - 42% of the population with low back pain.[79] Thus, low back pain is one of the main causes of greater economic and social spending in national health systems, assuming, for example, an expense of 2.8 million pounds in the UK or more than 100 billion dollars in the US. Goetzl et al. estimated the expense derived from absenteeism were greater than those of direct medical expense.[80]

Although it is less common than in the normal population, low back pain in the athlete is reported in at least 30% of the population. The prevalence of low back pain and the type of injury are determined by the type of sport. Sports such as gymnastics present a prevalence of 11% with injuries such as spondylolysis or disc degeneration as the most frequent, as well as herniated disc in soccer is considered the most frequent low back injury with a prevalence of 50% of low back pain. Low back injuries can originate from direct trauma to the spine, as well as muscle imbalance derived from muscle fatigue or repetition of complex movement patterns at high intensity or volume. In this direction, the scientific literature identifies injuries due to direct traumatic events or injuries due to mechanical overuse and repetitive stress.[81,82] Additionally, the association between the appearance of low back pain as a consequence of lower extremity injuries in 24% of collegiate athletes is collected.[83] Despite the importance of exercise in the prevention and treatment of low back pain, high-intensity exercise and handling heavy loads have been associated with increased risk of injury. Elite athletes have a higher risk of suffering low back pain, depending on the intensity, volume, workloads, type of sport, level of competition and experience, and the competitive moment of the season.[84] There is a high correlation in the appearance of low back pain with mechanisms of hyperflexion or repetitive flexion with light loads, for example in sports such as rowing. Likewise, combat and opposition sports have also shown a higher prevalence in the appearance of lumbar symptoms.[84,85]

Numerous conditions can be classified as the etiology of low back pain. Vertebral bone injuries associated with direct trauma or compression fractures from falls and blows usually occur with associated symptoms of the periarticular soft tissue. Root compression of the lumbosacral roots as a consequence of herniated discs, more frequently, or stenosis of the intervertebral foramina in early degenerative conditions in the athlete's spine, are related to the appearance of neuropathic symptoms. Radiating pain to the lower extremity, alterations in reflexes, dysesthetic symptoms such as paresthesias are some symptoms that can frequently appear. Spondylolysis or fracture of the lumbar articular pairs, typically frequent in sports that involve lumbar hyperextension mechanisms, may appear in sports such as gymnastics, weightlifting, or throwing sports, which in less severe degrees may present symptoms of facet pain due to said repetitive mechanisms in extension.

On the other hand, other conditions subclassified within the patterns of low back pain, such as sacroiliac pain, are related to impact sports that involve braking and changes of direction. Likewise, pain in the sacroiliac territory is typically recognized by patients with various conditions that affect the lumbar spine, such as referred pain in degenerations or damage to the lumbar intervertebral disc, somatic pain of muscular origin such as in myofascial or mechanical pain syndrome of the sacroiliac joint.[86] Otherwise, secondary factors such as morphological alterations of the femoral joint such as deformities of the femoral head or the set of symptoms derived from femoroacetabular pain syndrome can debut or accompany symptoms of the lumbar spine. Likewise, lumbar pain or dysfunction as a consequence of groin pain is a condition to be considered by the therapist in the differential diagnosis. The appearance of groin pain is frequent in athletes who participate in multidirectional sports, being subclassified as groin pain related to the adductors, related to the pubic and inguinal region, related to the iliopsoas or related to the hip as mentioned before.[87–89]

The therapeutic management of low back pain has varied greatly in recent years and scientific recommendations currently place much of the focus on patient self-management through physical and psychological therapies, a as well as a reduction in pharmacological and surgical treatment as main therapies.[90] Even so, due to the context of immediacy of the sports performance environment, athletes could benefit from drug therapies in certain circumstances as adjunctive therapies. Regular and gradual physical exercise aims to improve function and reduce the degree of disability.[91] Most clinical guidelines recommend individualized approaches to exercise, and some of them advise against or find less consensus on the use of passive therapies such as lumbar manipulation or massage, or physical therapies such as electrotherapy, short wave or transcutaneous electrostimulation, considering them as alternatives. Complementary and not all of them having shown therapeutic efficacy.[92]

## Shoulder

### *Introduction*

The shoulder is a joint that is stabilized by the surrounding soft tissues. When repetitive loads produced during sporting activity exceed its physiological limits, the stabilizing tissue gets destroyed.[93] The incidence of shoulder injuries in different NCAA sports has been reported at 69% in baseball, 60% in swimming, 50% in tennis, 36% in water polo, 25% in American football and 22% in volleyball.[94,95] Most of these injuries occur during overhead activities, being rotator cuff tendinopathy, acromioclavicular pathology and anterior instability the most frequent diagnoses. Several studies agree that the repetitive load generated leads to structural and functional changes that, in many cases, force athletes to interrupt their activity.[94,96] During the throwing movement, large forces are produced on the glenohumeral joint at excessively high velocities, reaching its physiological load limit. These extreme movements generate an overstretching of the anterior part of the capsule and a shortening of the posterior structures, shifting the rotational range towards greater external rotation and a deficit of internal rotation that increases instability. Unilateral loading also causes a disorder in the coordination of the scapulothoracic musculature, which favors a greater scapular protraction.[93,97]

Biomechanical analysis of overhead activities suggests that the shoulder musculature has two main functions: generating force and stability. In the force phase, the pectoralis and latissimus dorsi musculature contract concentrically to accelerate the ball. In the stabilization phase, deceleration should be facilitated through eccentric contractions of the rotator cuff muscles in order to maintain the humerus in the most favorable position within the glenoid cavity. In addition, the anterior serratus, trapezius and rhomboid act as stabilizers of the scapula throughout the throw.[93] This movement pattern can be observed in many sports such as baseball, volleyball, javelin throwing, and tennis. Baseball pitching has been used to describe the main mechanisms of glenohumeral joint injury. In the first phase of the throw, the shoulder is placed in a position of extension, abduction, and external rotation. This arrangement can result in glenoid impingement, causing pain in the posterior part of the athlete's shoulder. During the latter phases of the throw, the humeral head rotates externally producing a high anterior shear force, which causes an elevation and retraction of the scapula. Table 4 represents the most frequent pathologies and injury mechanisms in different sports.

This position, known as the "peel back" mechanism, generates a twisting of the long head of the biceps tendon that can lead to a superior labrum injury (SLAP). On the other hand, the rotator cuff can be injured by high eccentric forces, leading to tendinopathies and even muscle ruptures. Finally, repetitive stress on the joint in the deceleration phase generates stiffness and thickening of the posterior capsule. This condition is clinically significant as it leads to a decrease in glenohumeral internal rotation (GRID), which increases the chances of injury.[94,98]

Several studies have attempted to evaluate the differences between throwing and non-throwing shoulder in athletes. The results suggest that the external rotation strength of the throwing shoulder is weaker, while the internal rotation and adduction forces are significantly greater. In addition, throwing shoulders have been reported to exhibit supraspinatus weakness relative to the contralateral shoulder. However, the scapulothoracic stabilizers stand out as having greater strength, related to the assistance during throwing.[99]

Shoulder injuries can lead to symptoms such as pain and decreased range of motion, strength or athletic performance (loss of speed or accuracy). Glenohumeral range of motion, scapular coordination, joint stability and periarticular musculature (rotator cuff and biceps tendon) should be recorded for a complete examination. Imaging studies such as radiographs or MRI are helpful in establishing a diagnosis.[97,98]

Most injuries should initially be approached with conservative treatment to restore range of motion, strength, stability and neuromuscular control.[100] However, significant structural injuries such as dislocations, rotator cuff tears, labral injuries, or unstable fractures may require a surgical approach.[98,101]

**Table 4**
Mechanisms and frequent injuries in different sports.

| Sports | Mechanism of injury | Frequent pathologies |
|---|---|---|
| Baseball | Repetitive movements | Rotator cuff tendinopathy<br>SLAP lesion<br>Subacromial impingement<br>Scapular dyskinesia<br>GRID |
| American Football | Contact between players<br>Repetition forces | Rotator cuff tendinopathy<br>Biceps tendinopathy<br>Glenohumeral instability<br>Acromioclavicular injuries |
| Volleyball | Repetitive movements | Rotator cuff tendinopathy<br>Glenohumeral instability |
| Javelin Throw | Repetitive external rotation forces | Rotator Cuff Tendinopathy<br>GRID |
| Handball | Repetitive movements | Scapular dyskinesia<br>Rotator cuff tendinopathy<br>GRID<br>Cystic lesions |

### *Glenohumeral instability*

The glenohumeral joint is structurally unstable as only 25% of the humeral head contacts the glenoid cavity. This deficit of articular surface area underscores the importance of the function of the surrounding soft tissues in providing the stability necessary for motion.[102] Laxity is defined as an asymptomatic passive translation of the humeral head over the glenoid cavity that may be beneficial for athletic performance. However, this can become a clinical problem, resulting in glenohumeral instability that increases susceptibility to subsequent injury and can lead to pain and functional deficits.[102,103] The incidence of glenohumeral dislocations in athletes is higher than in the general population, revealing data of 0.12 instability episodes per 1.000 sports exposures. The scientific literature reports that 75% of these athletes will develop recurrent instability, being increased with the practice of contact and throwing sports.[96,102] The main mechanism of injury in athletes is a traumatic event (96%), commonly unilateral and usually requiring surgical treatment. The remaining 4% are produced by repetitive microtraumas, resulting in multidirectional instability with underlying ligamentous laxity.[96,104] Anterior dislocation is the most frequent one. It occurs when a force is applied to the shoulder placed in abduction and external rotation position. The sports involved include contact and collision sports (American football, rugby, martial arts…). In anterior instability it is common to find structural defects such as Bankart's lesion (which consists of a tear of the glenoid impeller, produced by capsular deformation when dislocation occurs) and bone lesions such as Hill-Sachs fracture (located in the posterolateral part of the humeral head), which increase the chances of reluxation by 90%.[93,105,106]

Posterior dislocation occurs when a force is applied with the shoulder placed in flexion, adduction, and internal rotation. Risk sports that have been documented are American football, lacrosse and rowing.[107] This posterior instability is more common in athletes with increased humeral retroversion, necessary to accommodate range of motion during throwing. Following dislocation, the adductors and internal rotators of the shoulder contract producing a rotation and posterior sliding which further limits humeral head congruency.[105,106] Regarding symptomatology, athletes report joint pain, swelling and a reduction in the speed and accuracy of movements. Anterior instability causes pain in the initial phase of the throw, while posterior instability usually causes pain in the last phase.[102,105] Numerous tests are available when assessing joint stability. The examination should include the Anterior and Posterior Apprehension Tests, the Relocation Test and the Jerk Test, which assess the fear of dislocation occurring. In addition, hyperlaxity should be assessed with the Sulcus Test and the Load and Slide Test. Radiological evaluation is used to rule out bone defects.[99,104,108] However, magnetic resonance imaging can elucidate labral, tendon and ligament injuries.[96] Shoulder dislocations should be reduced as soon as possible to minimize the risk of soft tissue and nerve damage. Rehabilitation should begin with immobilization followed by an exercise program adapted to the return to sporting activity, starting passively and gradually increasing until active development is achieved.[93,104] Closed kinetic chain exercises have been shown to facilitate joint stability provided by the rotator cuff and to increase proprioception.[102]

However, sometimes conservative treatment is not effective enough to restore the stability needed to return to risky sports. According to the literature, it is found a high incidence of reluxation, exceeding 80% of cases. This is why some authors recommend surgical stabilization after the first glenohumeral dislocation in young athletes.[93,106] Return to play is allowed after demonstrating functional, sport-specific range of motion and equal bilateral strength in both shoulders.[96] In addition, associated injuries such as rotator cuff tears, fractures, Bankart lesions or vasculonervous lesion are indications for surgical treatment by arthroscopic reinsertion.[102,106] Fig. 1 describes the treatment of a patient after a first shoulder dislocation.

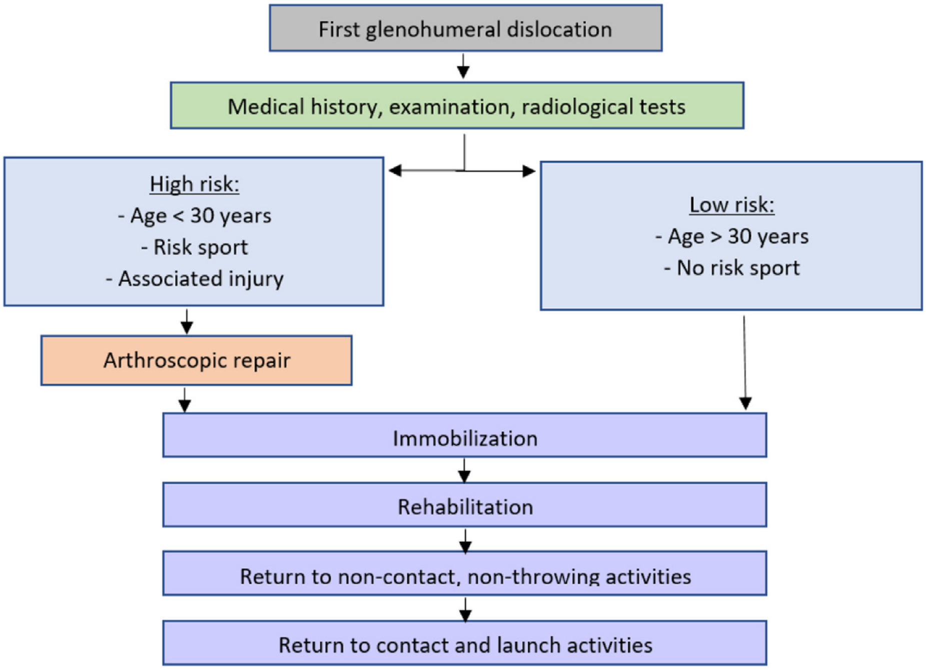


**Fig. 1.** Treatment approach after a first glenohumeral dislocation.

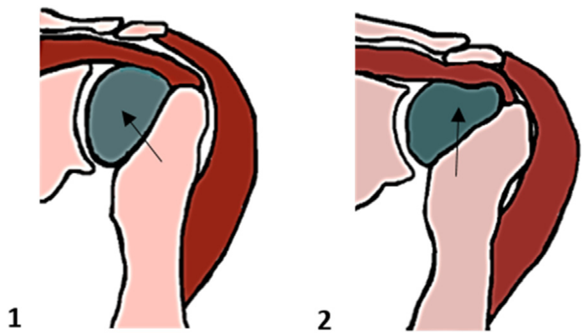


**Fig. 2.** Images of normal subacromial space (1) and subacromial impingement (2).

*Glenohumeral impingement*

The anterior capsule and the glenohumeral ligaments are the main static stabilizers that prevent anterior displacement of the humeral head. However, in the 90° of abduction and external rotation position required for throwing, these structures are placed under a high stress that disrupts the normal mechanics of the joint. Failure of these stabilizing tissues can cause a mechanical compression injury in the rotator cuff musculature.[101,109] This pathology is frequently recognized in sports such as American football, baseball, javelin throwing, tennis, volleyball and swimming, which require overhead movements.[101]

The posterosuperior impingement is an entrapment of the supraspinatus and infraspinatus tendons between the humerus greater tuberosity and the posterosuperior glenoid rim produced by the repetitive contact during abduction and external rotation movements (Fig. 2 represents the tendon thickening due to the upper impaction force of the humerus). The cause is the lack of conditioning and muscle fatigue from excessive throwing, causing the humeral head to pull out of the scapular plane and resulting in a thickening of the posterior capsule and the subsequent tendon entrapment.[101,110,111] Dr. Janda suggests that the impingement is facilitated by a muscular imbalance that includes weakness of the lower and middle trapezius, infraspinatus, deltoid and anterior serratus and tension of the upper trapezius, levator scapulae and pectoralis (pattern known as "superior cruciate syndrome"). This biomechanics alteration causes a deficit of internal rotation and humeral hyperangulation, favoring impingement.[112] Patients usually report pain in the posterior part of the shoulder that is exacerbated during abduction and external rotation, resulting in a loss of throwing speed and motion control. In addition, symptoms of instability, joint clicking and apprehension may occur.[99,101,110]

During physical examination, the Neer, Hawkins and Apprehension tests (which will reproduce the patient's pain) should be performed, along with the Anterior and Posterior Drawer Test and the Load and Slide Test (used to assess humeral head anteroposterior displacement).[99,101] The most common findings are a loss of internal rotation and weakness during scapular retraction and external rotation.[101,113]

Radiological monitoring and MRI will confirm the pathology. In addition, we may find associated lesions such as sclerotic changes in the greater tuberosity, exostosis of the posteroinferior glenoid rim, supraspinatus tendon tears and labral lesions.[101,111] The treatment is initially conservative. This includes sports rest, cryotherapy, oral anti-inflammatory drugs and physiotherapy. The aim of the rehabilitation program will be to strengthen the stabilizing musculature to prevent anterior displacement of the humeral head and restore the flexibility of the posterior capsule.[110,111] Failure of conservative treatment during 4-6 months justifies surgical intervention to increase the space between the humeral head and the coracoid.[111]

### *Rotator cuff injuries*

The rotator cuff is the musculature responsible for stabilizing the humeral head on the glenoid. Injuries to this complex are infrequent in young people; however, it has been noted that there is a high proportion of rotator cuff tears in contact and throwing athletes.[96] These tears may be caused by tensile forces when the cuff acts during the deceleration of the throwing or by compressive forces secondary to musculature fatigue, leading to increased humeral translation and resulting in a subacromial impingement. This motion pattern repeated over time will continue stressing the cuff muscles, which will be more prone to the development of tendinopathies and even ruptures.[105,114]

Athletes with rotator cuff injuries develop scapular compensatory patterns to achieve the movement that will increase the mechanical problem even more. One study reported increased activation of the upper trapezius and decreased and delayed onset of serratus anterior and lower trapezius activity in subjects with tendinopathy, resulting in poor scapular kinematics.[115]

The clinical presentation of rotator cuff tendinopathy includes pain and weakness during overhead activities.[116] Anterior pain is associated with subscapularis, anterolateral pain with supraspinatus, and posterior pain with infraspinatus. In addition, patients may report symptoms of instability or a feeling of subluxation.[117] For diagnosis, an interview with the patient should be performed, including questionnaires such as the Shoulder Pain and Disability Index (SPADI) or the Western Ontario Rotator Cuff Index (WORC), which will allow us to analyze the behavior of the symptoms and functional limitations. In the physical examination we will perform strength tests for each rotator cuff muscle (Jobe test, Patte test, etc). Finally, once the radiological study rules out possible associated bone lesions, MRI will be used to evaluate the integrity of the cuff muscles and tendons.[96]

The treatment will depend on the severity of the injury. The conservative approach is used for contusions and partial cuff tears, and includes pain and inflammation control modalities and physical therapy.[105,117] However, thicker tears in athletes have better functional outcomes with the surgical approach, resulting in full recovery of strength and return to play within 4 to 6 months.[96,114] The main goals of rehabilitation are to regain strength, dynamic stability and proprioception through joint repositioning exercises, axial loading and pain-free reproduction of the injury movement.[116]

### *Glenohumeral internal rotation deficit (GRID)*

GRID is not described as a pathology; however, we may observe it in athletes as a result of capsular tension generated by repetitive movements in throwing sports. It is defined as a loss of more than 20° of internal rotation and more than 5° of full rotational movement compared to the contralateral shoulder, resulting in a strength decrease and an increased risk of injury.[112,118] This loss of joint range appears to be progressive and related with the age and sport intensity, with baseball, tennis, handball, and javelin throwing being the most affected sports.[119]

A recent study examined 122 professional throwers with the goal of determining whether GRID was associated with an increased number of shoulder injuries, revealing that athletes with decreased internal rotation had twice the risk of injury.[100] Several investigations have reported that, in order to achieve greater throwing velocity, there is a 17° increase toward humeral retroversion in the throwing shoulder. This bony adaptation explains the differences observed between the two shoulders, as it results in an increase in external rotation before the anterior capsule and ligaments slow down the movement, and a decrease in internal rotation due to early limitation of the posterior capsule.[108,116,119] To evaluate GRID, the glenohumeral range of motion should be measured. We will find tension on the posterior aspect of the joint and a positive Sulcus Sign. In addition, the Posterior impingement Test is used to detect labral tears and associated supraspinatus lesions.[118] Treatment consists of posterior capsule flexibilization and muscle strengthening to correct scapular mechanics. Surgery is recommended only in case of failure of conservative treatment.[112,118]

### *Scapular dyskinesia*

The scapula plays a key role in optimizing shoulder joint function, providing support and stability during movement, with scapular retraction being the most effective position. Most injuries in athletes arise from a deficit of scapular position control, resulting in a protraction and anterior tilt pattern, which is correlated with a loss of glenohumeral internal rotation.[120,121] This altered pattern is known as "scapular dyskinesia." Scapular dyskinesia has a high prevalence among

**Table 5**
Rockwood's classification of acromioclavicular injuries.

| Degree of injury | AC Ligaments | CC Ligaments | Deltotrapezoidal fascia | CC Distance |
|---|---|---|---|---|
| I | Sprain | Intact | Intact | Normal |
| II | Tear | Sprain | Intact | <25% |
| III | Tear | Tear | Interrupted | <25-50% |
| IV | Tear | Tear | Interrupted | <50-75% |
| V | Tear | Tear | Interrupted | <75-100% |

overhead sports (61%), mainly baseball, due to the lack of scapular rotation shown by pitchers, and swimming, since swimmers show an increase in the anterior tilt of the scapula.[122] It is hypothesized that the decreased subacromial space may be due to a loss of control of the scapular stabilizers. This has been investigated in tennis players with scapular dyskinesia, whose subacromial space (See Fig. 2) has been found to be significantly reduced compared to healthy controls. In populations of swimmers, an anteriorization of the shoulder position has been observed, produced by the great activation of the pectoral muscles and the upper trapezius for the propulsion of the body during the strokes.

This posture generates an increase in thoracic kyphosis and a constant stretching of the posterior muscles involved in scapular stabilization (mainly the lower trapezius and serratus anterior), resulting in a muscular decompensation that increases the risk of mechanical compression and secondary injuries. Regarding this fact, an observational study reported that an 85% of the swimmers presented shoulder pain and a 72% of them take medication to face training.[109,122]

Numerous studies point to a correlation between scapular dyskinesia and shoulder pathology. Scientific evidence has documented a positive association of this position with labral injuries due to the change of alignment in the glenohumeral joint, which increases the traction of the anterior ligaments and the peel back of the labral complex in the glenoid cavity.[120]

The postural changes found in this scapular malposition include the prominence of the medial inferior border, coracoid positional alteration and lack of coordination in scapular motion, clinically represented as an asymmetric scapula and pain.[99] The Scapular Assist Test and the Scapular Retraction Test are used to evaluate this dysfunction.[120] To obtain a correct repositioning, intervention programs are based on static and dynamic scapular strengthening exercises. In addition, some authors have shown the efficacy of taping to modify posture.[95,122]

### *Labral complex and biceps anchorage injuries*

Labrum and biceps anchor injuries are known as SLAP injuries. These can occur primarily by two mechanisms: the most common one is due to a traumatic throw or because of the result of repetitive microtrauma, which often happens in overhead athletes. The second mechanism involves a traumatic event, most commonly seen in contact sports.[105] The primary function of the biceps tendon is to depress the humeral head and, along with the labrum complex, contribute to shoulder stability. During throwing, electromyographic studies show maximal activity of the biceps in the deceleration phase, limiting elbow hyperextension.[110]

With this movement, the forces at the biceps anchor point and the posterosuperior attachment of the labrum increase, so that when the arm gains abduction and glenohumeral external rotation, the biceps tendon changes its angulation, adopting a more vertical and posterior position. This positional change favors a torsion in the anchorage of the tendon and the labrum (mechanism known as "peel back"), which can lead to a tear.[123,124] Regarding diagnosis, the athlete will present anterior joint pain associated with sport activity, reduction of joint range and muscle weakness, leading to a gradual functional loss and decreased throwing speed. In addition, intermittent clicks may appear during the throwing phase.[100,105,116,124] On physical examination we will find pain along the long head of the biceps insertion and positive O'Brien's Test (indicates presence of labral pathology), Yergason's Test (assesses the long head of the biceps function) and Modified Dynamic Labral Shear Test.[116,125] The most useful diagnostic imaging to detect these lesions is MRI, where we will see a cleft between the superior labrum and the glenoid fossa.[124,126] Initial treatment includes a symptomatic approach with pharmacology, rest, ice and immobilization. Once the inflammatory phase has resolved, a strengthening program of the rotator cuff and scapular musculature should be initiated. However, when conservative treatment is not enough to relieve symptoms, surgical intervention by arthroscopic debridement and fixation should be used.[110,127] Surgery has reported data of a 74% of athletes returning to their previous level of competition.[124]

### *Acromioclavicular joint injuries*

The acromioclavicular joint is stabilized by the coracoclavicular ligaments (vertical stabilization) and the acromioclavicular ligaments (horizontal stabilization). Injuries are usually caused by direct blows to the joint or by falls with the arm in extension.[105] These usually occur in contact sports, such as American football, where they represent 40% of shoulder injuries, with an injury rate of 26 per 10.000 sports exposures.[96,128]

Trauma results in a force on the acromion that initially injures the acromioclavicular (AC) ligaments. If this force continues, the coracoclavicular (CC) ligaments will be affected, allowing further clavicular displacement. The injury severity increases if there is also deltotrapezoid fascia disruption.[129] The Rockwood classification (Table 5) is used to standardize the type of acromioclavicular injury. Low grade lesions (types I and II) occur with a frequency of 89% compared to high grade lesions (types III, IV, V), with 11%. In addition, the prevalence of associated pathologies such as SLAP or rotator cuff lesions ranges between 18 and 22%.[128]

Patients with acromioclavicular joint injury usually report pain that increases with the upper limb elevation and joint tenderness. Low grade lesions present pain under pressure and positive glenohumeral adduction and Paxinos (increase joint pressure) tests, without clinically visible asymmetry. However, high-grade tears show a prominent clavicle with a piano key sign.[96,105,129,130]

Radiological examination should be performed with a 10 kg hanging load to assess vertical instability by measuring the coracoclavicular distance. The hallmark sign of injury on MRI is an edema in the distal clavicle.[128,130]

In this type of injury, treatment is based on the severity classification. Types I and II are approached with conservative treatment based on immobilization, anti-inflammatory measures and physiotherapy to restore the range of motion and strength. Type III injury has controversial opinions regarding its treatment; obtaining comparable functional results, but with fewer complications in favor of conservative treatment. Finally, grade IV and V injuries require surgical ligaments reconstruction to restore joint stability.[96,105,128,129]

*Fractures*

*Clavicle fractures*

Clavicle fractures represent the 4% of shoulder injuries in elite atheletes.[131] The most frequent ones are medial diaphysis (70%) and lateral diaphysis (25%) fractures. These usually occur in collision sports, although several studies report that they are the most common type of fracture in cyclists, with the most frequent causes being collision between cyclists, collision with obstacles, and falling off the bicycle.[132] Athletes report pain when moving the shoulder, swelling, bruising and stiffness. Radiographs determine the location, degree of displacement and appearance of possible joint injuries.[132]

In general population, treatment has a conservative approach, offering good functional results. However, pain and residual loss of strength can affect the performance of athletes, with rates of up to 20% of athletes failing to return to sporting activity. This is why recent studies suggest surgical fixation, with the aim of increasing functionality and avoiding risks of refracture.[133,134]

*Humerus fractures*

Humerus diaphysis fractures are generally related to direct trauma. However, in athletes, movements such as throwing or arm wrestling may cause indirect secondary fractures.[132] Symptoms usually include pain, bruising, movement limitation, increased volume and functional loss of the arm. In addition, external deformity may be seen in some cases. Radiographs determine the location, degree of displacement and appearance of possible joint injuries.[132] Conservative treatment includes the use of coaptation splints. However, displaced fractures result in stiffness and movement impairment, leading to an increase in surgical approaches.[135]

## Elbow

*Lateral elbow tendinopathy*

The forearm extensor muscles are involved in many daily tasks. Lateral epicondylitis is often caused by repetitive use of these muscles, especially the extensor carpi radialis brevis.[136] Lateral epicondylitis has a prevalence of 1–3% of the general population.[137] In contrast, according to a study performed in a cohort of 206 beach tennis elite players, lateral epicondylitis was the most prevalent injury.[138] Furthermore, in elite tennis players, the injuries in upper extremities account for 25.0%,[139] being the lateral elbow tendinopathy one of the most prevalent injuries.

Most common causes of lateral elbow tendinopathy include excessive load, inadequate material, or poor technique.[140] Shock transmission also plays an important role in the development of this disorder. In this sense, a greater wrist extensor activity during ball impact, or having a single-handed backhand are risk factors.[141] Compared to recreational players, the string tension does not seem to be related to the onset of lateral elbow tendinopathy in tennis elite players.[142] Lateral elbow tendinopathy is characterized by pain over the lateral elbow, often radiated into the forearm, when loading the wrist extensors. This usually affects the grip strength. Clinical tests include grip strength tests, or the Cozen test.[140] In chronic cases, ultrasound-imaging assessment should be considered. The entrapment of the posterior interosseous nerve is an important differential diagnosis to consider.[143]

Treatment needs to focus on managing the excessive loads, rehabilitating the tendon through isometric and eccentric exercises, and correcting technique defaults.[144] Eccentric exercise improves functionality and decreases pain, since it generates a mechanical stimulus, which leads to remodeling of the tendon and to collagen synthesis, thus increasing the tendinous resistance.[145] In addition, as in many tendinopathies, strength training of the muscles of the area has shown positive results.[146] Sometimes, manual therapy must be included to improve the elbow's range of motion and to reduce pain.[147]

In contrast, to date, there is inconsistence evidence regarding the effectiveness extracorporeal shock wave therapy.[148] Concerning invasive techniques, corticosteroid injections only provide short-term pain relief. On the contrary, platelet-rich plasma injections have shown better long-term results, and lower risks of complications like tendon ruptures.[149,150] Surgery treatment should only be considered when conservative management fails after 6 months.[143] In professional golfers, lateral epicondylitis usually affects the lead arm. According to a study that analyzed the forearm musculature using electromyography in professional golfers, the extensor carpi radialis brevis muscle activity peaked during the forward swing in the lead arm. The extensor carpi radialis brevis helps stabilizing the left wrist (for right-handed golfers) at ball impact. Sometimes lateral epicondylitis in due to over gripping, which may be due to proximal weakness. For this reason, during rehabilitation, glenohumeral and scapular stability must be addressed.[151,152]

*Medial elbow tendinopathy*

In professional golfers, medial elbow tendinopathy usually affects the trailing arm (the right arm for right-handed individuals).[151] According to Farber et al., in the trail arm the pronator teres activity peaked during forward swing, and the flexor carpi ulnaris muscle activity peaked during forward swing.[152] In elite tennis players, medial elbow tendinopathy is a prevalent disorder, since wrist flexors participate in all strokes, especially the pronator teres and flexor carpi radialis muscles.[153] Traditionally, lateral elbow tendinopathy has been more prevalent than the medial elbow tendinopathy, but a recent study reported a ratio of 3:1 towards medial elbow tendinopathy.[139]

The clinical characteristics of medial elbow tendinopathy are decreased grip strength and pain in the median epicondyle, often irradiated to the forearm, mostly during the serve,[154] which is the most demanding stroke, especially for the shoulder and elbow.[139] Physical examination should distinguish medial elbow tendinopathy from ulnar collateral injury or radiculopathies. Medial elbow tendinopathy is characterized by pain during the acceleration phase of the throw or swing, while ulnar collateral injury is more painful during the deceleration phase. The most consistent test for diagnosing this tendinopathy is resisted pronation, which should reproduce pain on the medial elbow.[155]

The flexor-pronator group of the elbow serves as an important dynamic stabilizer to valgus forces, protecting the ulnar collateral ligament of the elbow. This role as a dynamic stabilizer is even more important with the forearm in supination, as observed in overhead throwers or golf players.[156]

The treatment of medial epicondylitis is similar to lateral elbow tendinopathy, paying additional attention to serve biomechanics, and possible coexisting shoulder injuries.[156]

*Elbow medial collateral ligament pain*

The ulnar collateral ligament of the elbow is composed of three bundles, being the anterior oblique ligament the strongest,[157] protecting against forced valgus forces of the elbow from 30° to 120° of flexion.[158] In overhead throwing athletes, large valgus moments on the elbow are generated, challenging the ulnar collateral ligament. This implies that that surrounding musculature like the flexor-pronator muscles must stabilize the elbow, otherwise the anterior bundle of the ulnar collateral ligament will weaken from repetitive micro-trauma, leading to elbow instability or rupture.[159]

Elite tennis players may suffer from ulnar collateral ligament pain due to repetitive excessive valgus stress load during the serve, especially if they have reduced internal shoulder rotation or elbow instability.[160] This also leads to loss of power and accuracy.[161]

Elite soccer players are more likely to suffer from lower limbs injuries, but they are also affected by injuries in the upper limbs. Among them, elbow ulnar collateral ligament injuries are one of the most common, accounting for 6.0% of the injuries of shoulder and elbow. Compared to field players, goalkeepers have a substantially higher risk of shoulder and elbow injuries. Among them, the elbow hyperextension (11.3%), and elbow ulnar collateral ligament (8.8%) are some of the most common. These findings can be explained by the nature of the goalkeeping position, where goalkeepers stop high-velocity shots with their hands, and therefore have five times more risk of suffering an upper limb injury compared to field players.[162] Interestingly, most injuries of goalkeepers occur during training, because they are called into action far more times than during competition. Normally, in many sports the frequency of injuries is significantly higher during competition. Some strategies like the FIFA 11+ Shoulder Injury Prevention Program have been developed to minimize shoulder and elbow injuries in soccer players.[163]

An adequate diagnosis for ulnar collateral ligament pain should include the valgus stress test,[164] while magnetic resonance imaging or ultrasound imaging can assess instability due to ligament ruptures.[165] Depending on the grade of injury, PRP injections combined with a rehabilitation program have showed high success rates (from 88% to 91%) with a return to play in 10 to 15 weeks. In case of complete ligament tears, surgery is required, with a long recovery time (up to 12-16 months).[166]

The severity of ulnar collateral ligament injury can be categorized in grade 1(intact), 2a (partial tear), 2b (chronic injury), and 3 (complete tear), its diagnosis been made using MRI imaging.[164] In complete tears, surgical intervention is advised, while in grade 1 injuries the best option is the nonoperative management. In partial tears, the decision depends on the location of the ulnar collateral ligament injury. Distal injuries are more likely to need surgical treatment, while in proximal tears the conservative treatment may be effective.[167] Another factor to consider is the type of sport, as throwing athletes need an intact ulnar collateral ligament to stabilize valgus forces. Among these athletes, javelin throwers may be the ones that have greater valgus forces on their elbow,[168] and therefore be more likely to need surgical treatment before returning to play.[169]

**Table 6**
More prevalent elbow and wrist injuries in elite athletes according to sport.

| Injury | Sport |
|---|---|
| Medial elbow tendinopathy | Tennis, Golf |
| Lateral elbow tendinopathy | Tennis, Golf |
| Elbow ulnar collateral ligament injury | Throwing athletes<br>Football goalkeepers |
| Flexor carpi ulnaris tendinopathy<br>Extensor carpi ulnaris tendinopathy | Tennis, Golf |
| Triangular fibrocarlage tears | Tennis, Golf, Baseball |
| Ulnar collateral ligament injury | Tennis |
| Wrist fractures | Taekwondo |
| Scaphoid stress fractures gymnastic | Athletes |
| Hand and wrist osteoarthritis | Cricket, Rugby |
| De Quervain's tenosynovitis | Bowling |
| Instability of the carpometacarpal joints | Boxers |
| Finger flexor pulley injuries | Rock climbers |

If choosing a nonoperative treatment, usually programs are divided into three phases. First, during 1 or 2 weeks the goals are to decrease pain, improve range of motion, and strength the elbow, wrist, and shoulder. Second, for 4 weeks the primary goal is to increase proprioception and intensify the strength training, without throwing, and minimizing valgus forces exposures. Finally, the return-to-sport phase should last for 6 weeks. These programs have been successful with 1 and 2a grades proximal ulnar collateral ligament sprains.[170]

In throwing athletes in whom the conservative measures had failed, PRP injections into the location of the tear of the ulnar collateral ligament have shown high return to sport (73-88%) rates.[165] Ulnar collateral ligament prevention programs are based on avoiding overuse throwing, counting the number of throws per match or per training session, and programming the days of rest. Strength programs focusing on specific muscles such as the flexor carpi radialis longus, the flexor digitorum superficialis, and the flexor carpi radialis brevis, can also decrease the incidence of medial elbow injury.[171]

## Wrist and hand

In a recent systematic review including injuries of the upper extremity distal to the elbow in professional athletes describing a total of 4299 injuries, the most common were metacarpal fractures (34.5%), thumb collateral ligament injuries (13.9%), phalangeal fractures (11.0%), scaphoid fractures (7.1%), and wrist fractures (6,8%). These injuries had a high return-to-play rate (98.1%), with an average time of 2.8 months.[172] (See Table 6)

### *Ulnar side tendinopathies of the wrist*

Sports that require repeated radial/ulnar deviation and pronosupination of the wrist are a risk factor to develop to ulnar-sided wrist pathology.[173] To execute an adequate golf swing, an extensive range of motion of both wrists is crucial. According to a recent study, 30% of professional golfers reported having wrist problems, mostly in the leading wrist (67%) (for right-handed golfers, the left wrist) and in the ulnar side of the wrist (35%).[174] The most common wrist injuries in professional golfers are flexor carpi ulnaris and extensor carpi ulnaris tendinopathies, due to excessive radial deviation of the lead wrist during the takeaway phase. Tears of the triangular fibrocartilage cortex are also common due to the repetitive rotation movements of the wrist.[175]

According to observational studies performed in elite tennis players, wrist injuries account for 30-40% of all upper-limb injuries, the most common being the extensor carpi ulnaris tendinopathy, which is often related to overuse.[176,177] In the modern game, wrist biomechanics plays a key role in the racquet head speed.[178] The player's grip type and the wrist injury risk are moderately correlated, so extensor carpi ulnaris tendinopathy occurs more often with western and semi western grips, because of increased loading in extension and ulnar deviation.[179] Other common ulnar wrist injuries include, ulnar collateral ligament enthesopathy and triangle fibrocartilage injuries.[180]

In professional golfers, extensor carpi ulnaris tendinopathy is relatively common in the trail hand. During the golf swing, the trail hand supinates and the ulnar deviates during impact. At the same time, the extensor carpi ulnaris increased its tension as it moves dorsally towards the extensor digiti minimi.[181] The diagnosis of the extensor carpi ulnaris tendinopathy is clinical, with gradual pain over the ulnar side of the wrist, but ultrasound imaging can confirm the tendinopathy.[182] The physical examination usually points out pain and tenderness over the extensor carpi ulnaris tendon, especially with resisted wrist active extension with ulnar deviation. Sometimes, ultrasonography is necessary to accurately diagnose this disorder, which usually has three components: acute tenosynovitis, tendinopathy, and instability/subluxation of the tendon. As this disorder progresses, tendon thickening becomes more evident, and can become dislocated from tearing of its subsheath.[182]

Flexor carpi ulnaris tendinopathy usually occurs in the trail hand of golfers due to the high-intensity wrist flexion that takes place when hitting the ball, and because the flexor carpi ulnaris is the most powerful wrist motor. Treatment consists of first decreasing practice intensity or modifying the golf swing. In elite players, it is occasionally treated with corticosteroid injections. Surgical treatment is only considered after six months of nonoperative unsuccessful treatment.[183]

As with other tendinopathies, treatment of extensor carpi ulnaris tendinopathy should focus on managing the excessive loads, correcting technique deficiencies, and rehabilitating the tendon with isometric and eccentric exercises. After beginning with static strengthening, eccentric exercises should be gradually implemented, and finally plyometrics should be performed when heavy loads are tolerated.[182] The recovery time varies from two weeks to six months.[184] Sometimes, bracing in position of wrist extension for six weeks to four months is necessary if the extensor carpi ulnaris tendon is unstable, to allow proper tissue repair and avoid surgery.[185] If the symptoms persist, corticosteroid injections could be considered. To return to play, the last option to consider would be a surgical treatment consisting of releasing the sixth dorsal compartment.[186]

### *Triangular fibrocartilage complex tears*

The triangular fibrocartilage complex acts as a shock absorber of the wrist. When injured, it can lead to decreased grip strength and distal radioulnar joint instability. This injury is more prevalent in baseball players, tennis players and golf players.[187]

In professional golfers it can occur when playing in long grass, due to the rotational forces that take place in the wrist. To diagnose triangular fibrocartilage complex tears, some provocative tests can be performed, such as the compression test, which consists of forced passive ulnar deviation,[187] or the press test, when a seated patient is asked to push himself up into a standing position, using the sides of a chair.[188]

Nonoperative treatment for the tears of the triangular fibrocartilage includes rest, immobilization, massage, and corticosteroid injections, but there is no solid evidence about the effectiveness of these therapies.[175] The treatment depends on the symptoms of the athlete. Conservative treatment combined with rest and bracing is only moderately successful in athletes who perform repetitive ulnar deviation. Triangular fibrocartilage complex tears in golf are often due to overuse and require a surgical reconstruction with arthroscopic techniques.[186] Following surgical treatment, golf players return to play within eight to twelve weeks once they have sufficient forearm and grip strength and can tolerate playing without protective devices.[189]

### *Hook of hamate fracture in professional golfers*

Due to a high-energy strike to the ground with the club, fractures of the hook of hamate occur in elite golf players, exclusively in the leading hand. Although direct palpation of the hook of hamate causes a characteristic pain, radiographs are necessary to confirm the diagnosis. If this injury is not correctly diagnosed, over time it could affect the finger flexion of the small and ring fingers, or deficits of the ulnar nerve. Regarding treatment, prompt surgery consisting of excising the hook of hamate is recommended, as conservative management have shown failures rates from 80% to 100%, since the hamate has a poor blood irrigation. To prevent this injury, golf players must select golf clubs of adequate length.[190,191]

### *Wrist ulnar collateral ligament injuries in elite tennis players*

In elite tennis players who use a double-handed back hand, ulnar sided wrist pain has been reported in the nondominant wrist, possibly linked to the eccentric contraction of the extensor carpi ulnaris.[192] The ulnar collateral ligament injuries often coexist with ulnar styloid impingement, due to wrist compression forces in the double-handed back hand. There is little research about this injury to guide treatment, but corticosteroid injections may be a solution in the short-term.[193]

### *Wrist fractures in elite taekwondo athletes*

In elite taekwondo athletes, one the most injured body region is the hand and wrist, with a prevalence of 6 to 17 %, especially during competition, due to the higher number of strikes compared to during training. Most of these injuries are fractures.[194,195] In taekwondo, the lower limb is used for attacking kicks, while the upper extremity is used for blocking. Therefore, individual lacking blocking skills is an important protector factor against these injuries.[196]

### *Scaphoid stress fractures in gymnastic athletes*

In gymnastic athletes, the elbow suffers from high valgus and varus forces during many exercises, which often causes ulnar collateral ligament injuries.[197] In addition, the wrist suffers from repetitive high-impact axial compressive forces combined with wrist extension, that can lead to scaphoid stress fractures, mainly in young gymnastics.[198] The diagnosis of this pathology is made via radiography or MRI. Nonsurgical treatment often offers good results, but elite athletes may require percutaneous screw fixation to return to sport early.[199,200]

### *Hand and wrist osteoarthritis in cricket and rugby players*

According to observational studies performed on former male elite cricket and rugby players, these athletes reported a prevalence of severe hand injuries of 31.4%-36.2% in the past. Hand pain in the present was also very prevalent, accounting for 19.7% of the rugby players and 10.0% of the cricket players. Wrist and hand osteoarthritis was uncommon in both groups (1.6% to 3.6%) and was not significantly associated with previous severe hand injuries or hand pain at present. This may suggest that other factors like repetitive micro-trauma when playing these sports may be more relevant in the development of hand and wrist osteoarthritis in these athletes.[201]

*De Quervain's tenosynovitis in elite bowling athletes*

A recent study carried out with 39 elite bowling athletes reported that the commonest injury was de Quervain's tenosynovitis in the playing limb, which was diagnosed in a 53.8% of these athletes.[202] In contrast, another study performed with average population reported an incidence of only 0.49% for de Quervain's tenosinovitis.[203] These findings can be attributed to the kinematics of bowling, where the ball is released mostly via a wrist action, with an unnatural ball-gripping technique that only involves the thumb, the middle and the ring finger. Another factor that should be noted is the time that these athletes spent in training: two and a half hours, five days a week.[204] This musculoskeletal disorder may result in poorer performance and may end careers if untreated. Non-operative training consisting of personalized training with a special load in the tendons involved, improvement in throwing technique, or individualized equipment may be successful. Further studies should focus on developing preventive strategies.[202]

*Hand injuries in boxers*

The metacarpophalangeal joints suffer from constant impact in elite boxers, which puts in a potential risk the extensor hood, particularly the sagittal band, in the middle finger. To prevent these injuries, a proper striking technique is crucial. Sagittal band injuries can lead to extensor digitorum communis instability in severe cases, requiring chirurgical treatment.[205] Instability of the carpometacarpal joints is another common injury in professional boxers. If the condition becomes chronic, surgical treatment is advised, which consist of Kirschner wire fixation or arthrodesis of the carpometacarpal joint, allowing boxers to return to play to elite level.[206]

*Finger flexor pulley injuries in rock climbers*

Isolated closed injury of the finger flexor pulley system is an injury specific to rock climbers. The retinacular component (pulley) of the finger flexor tendon system of the hand serves to promote biomechanical efficiency in finger flexion. Rock climbers submit their pullies to magnitudes of eccentric forces exceeding the normal limits.[207] According to recent statistics, fingers in rock climbers account for 41% of all injuries, being the pulley injuries the most frequent (30%).[208] The ring finger is the most affected, followed by the middle finger.[209] In the physical examination, rock climbers report an acute pain over the affected pulley and present a clinical "bowstringing" in the proximal interphalangeal joint. Imaging evaluation should complete the physical examination.[210]

The finger flexor pulleys mild injuries tend to self-resolve after some weeks of rest, but more extensive injuries may require specific treatment. Conservative treatment has shown to be effective, consisting of physical therapy and pulley protection with taping. The return to climbing is advised to be progressive, wearing some pulley protection with inelastic tape during some 6-8 weeks.[211] If dysfunction persists after the conservative management, surgical repair of the pulleys could be considered.[212] Figs. 3 and 4 summarize the main pathologies in tennis and golf players.

## Lower limb

The lower limb supports the weight of the body, so the bone mass in this area is greater compared to the upper limb. In addition, the joints are, in turn, more stable due to joint congruence and their ligamentous system.[213] However, it is in the lower limb that most musculoskeletal disorders also occur in sports,[214,215] especially in the female gender, according to the study conducted by Aman et al.[215] Similarly, in this same study, the authors observed that most of the injuries resulting in permanent damage occurred in the lower limb, the most frequent being ligament injuries, especially in soccer or handball.[215] However, although perhaps the most serious injuries occur at the ligamentous level, most of the injuries suffered by athletes are muscle-tendon injuries,[216,217] and according to Isern-Kebscull et al., more than 90% of these injuries affect the quadriceps, hamstrings, adductors, or calf muscles in soccer players.[216]

These musculoskeletal disorders involve damage caused by trauma, overload, or overuse, and can be acute or chronic, which means that the athlete must stay away from physical activity for a certain period, at least 24 h, or completely abandon sports practice.[218] The objective of an adequate management of the injury is, therefore, to try to ensure that there is no decrease in the physical competence or functional capacity of the athlete and that his sports performance is not impaired.

The time before returning to sport will depend, in addition to the proper management of the alteration, on several factors such as the severity or type of injury.[219] This means that there are multiple classifications of injuries depending on the different aspects or considerations.

Knowing the frequency of these alterations according to all these characteristics is fundamental to be able to develop better prevention strategies in athletes. In addition, since most of these alterations that occur in the lower limbs are muscular, it is also essential to know the characteristics of the most affected muscle groups, as well as the best diagnostic tools. This,

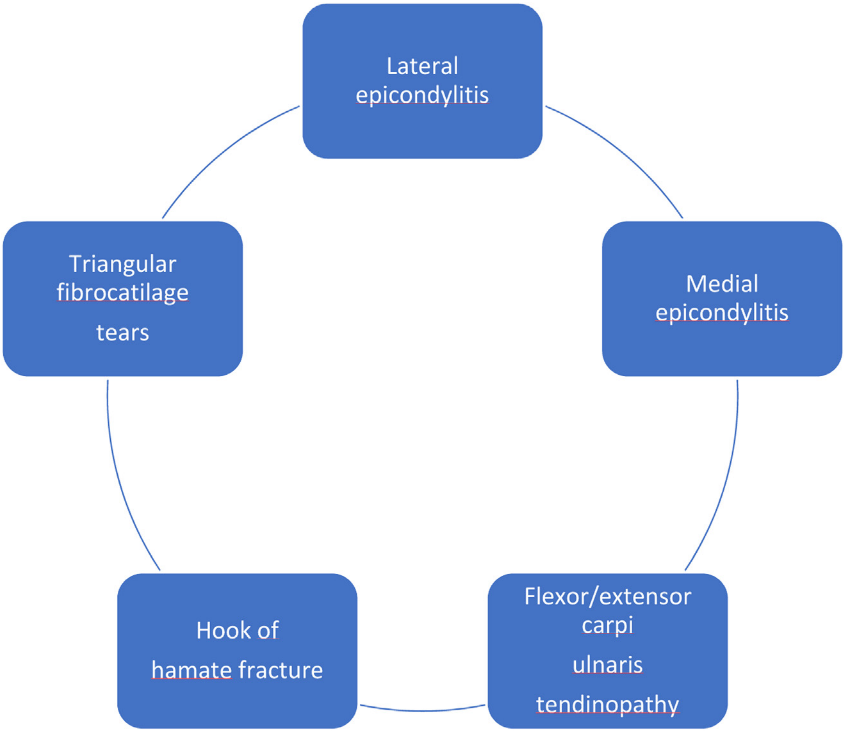


**Fig. 3.** Most prevalent injuries in professional golf players.

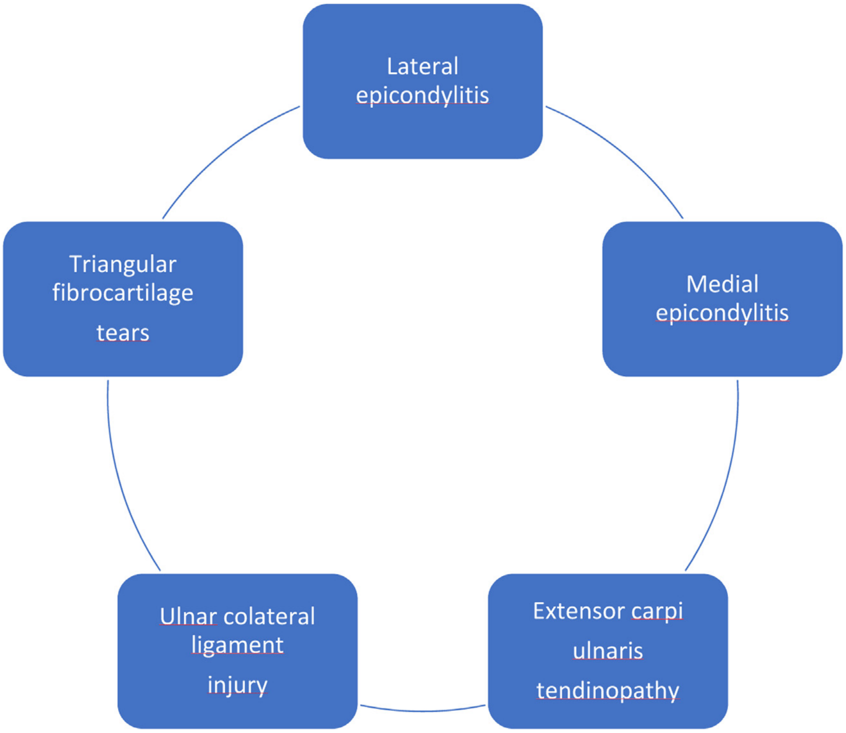


**Fig. 4.** Most prevalent injuries in elite tennis players.

**Table 7**
Classification of injuries according to their location and most frequent injuries of the lower limb in sports.

| Location | Category | Injuries |
|---|---|---|
| **Lower limbs** | - Hip / Groin<br>- Thigh<br>- Knee<br>- Lower leg / Achilles tendon<br>- Ankle<br>- Foot / Toe | - Groin injuries and pubis osteitis<br>- Muscle strain or tear (hamstring or quadriceps)<br>- Sprained or torn ligaments<br>- Meniscal or condral injury<br>- Patella dislocation<br>- Patella / Popliteal / Achilles tendinopathy<br>- Bone Fracture |

in turn, will make it possible to design the best treatment or rehabilitation plan and carry out an adequate management of the musculoskeletal disorder in question.

*Injury classification, prevalence, diagnosis, and management*

There are multiple classifications for the alterations that occur in athletes. The most frequent classifications are: (a) according to location and (b) injury type. However, we can also find in the literature classifications according to mechanisms of injury, gender, severity, the sport practiced, the time at which the injury or alteration occurs, as well as the time of the season.

*According to the location*

The most used classification according to the location of the injury is the one described by Fuller et al. in 2006.[220] This classification differentiates injuries according to whether they have occurred in the lower limbs (Table 7). According to multiple studies, most injuries in most sports, except for a few such as field hockey,[221] occur in the lower limb. In fact, between 47%[222] and 89.6%[223] of injuries occur in the lower limb, being in soccer and, specifically during matches, the most common cause of injury in the lower limb,[223] where the prevalence of injuries in this part of the body is higher, which may be due to the physical exhaustion that players present during the course of the match, as well as the physical contact between players.

In fact, the incidence of injuries in this sport is approximately 17-20% per 1000 h of sports practice, according to the study by Osorio et al.[224] In other sports, such as baseball or basketball, the incidence is around 15% per 1000 h of sports practice, with the prevalence of lower limb injuries being around 30-50%.[214,224]

Regarding the specific location of the lower limb in which the injury occurs, most studies focus on soccer, since it is the most widely practiced team sport and, in this sport, most injuries occur in the thigh, both in elite youth players and in professional adults (22-39%), as observed in the systematic review by Pfirrmann et al.[223] Of the injuries, 11-25% occur in the hip or groin, between 6.8 and 21% occur in the knee and 4.6-15% occur in the lower leg. In contrast, in other sports it is the knee that is most frequently injured -24.1% according to the study by Moreno et al.[225] In basketball most injuries also occur in the knee, affecting in 21.7% of cases the anterior cruciate ligament (ACL), the medial collateral ligament (MCL) and the lateral collateral ligament (LCL).[226]

*According to type*

Regarding the type of musculoskeletal injury or alteration that occurs, as well as the tissue affected, these can be classified into: (a) muscular, (b) articular, (c) ligamentous, (d) tendon and (e) bone, with their possible alterations such as strains, sprains, tendinopathies, dislocations, or fractures.[220,227] Some authors are very specific and make a very detailed classification of all the types of alterations that can occur in athletes.[228] These musculoskeletal alterations are included in Table 8.

*Muscle injuries*

In the systematic review by Pfirrmann et al.[223] it was observed that between 31 and 61% of the injuries occurring in both professional soccer players and elite young players were at the muscular level, with strain being the most frequent alteration, followed by joint injuries (27% approximately), sprains (13-21%), tendon injuries (7-13%), fracture (2-5%), and dislocation (1-4%).

On the other hand, in other sports such as tennis, the most frequent injuries are groin strains, torn knee ligaments, meniscus tears and tendinopathy of the knee extensor musculature.[139] However, it should be taken into consideration that muscle injuries in the lower limbs, especially tears and ruptures, are very prevalent in all sports, as they can be caused by falls, physical contact with another player, blows that may occur, overload or overuse.[215]

Muscle injuries include contusions or lacerations caused by a direct mechanism and elongations (strains and tears), delayed onset muscle soreness and compartment syndrome, among others, produced by an indirect mechanism.[229] The term

**Table 8**
Musculoskeletal alterations according to type of injury.

| Classification | Subclassification | Most frequent injuries |
|---|---|---|
| | Muscular | Strain / muscle rupture / tear |
| | | Muscle spasm or cramp |
| | Joint | Dislocation, subluxation y luxation |
| | | Meniscus or cartilage injury |
| | | Arthritis / synovitis / bursitis |
| | | Impigement |
| **According to type** | Tendon | Tendon rupture |
| | | Tendinosis / tendinopathy |
| | Ligamentous | Sprain |
| | | Ligamentous rupture |
| | Bone | Fractures of traumatic origin |
| | | Overuse fracture |
| | | Other bone injuries |

elongation refers to muscle strains or tears, depending on the degree of muscle involvement.[230] Muscle strain is an elongation of the muscle that generates a rupture of fibers,[231] being one of the most used terms in sports-related injuries.[232] However, a muscle tear refers to a severe strain, which usually affects a bundle of fibers.[231] This muscle tear, in turn, can be partial or complete, involving the muscle.[230] Typically, the muscles most frequently affected by these injuries are biarticular muscles or those that have a more complex muscular structure or architecture and contain fast twitch muscle fibers.[232]

According of Mueller-Wohlfahrt et al. study,[232] in sports, specifically in soccer, 92% of muscle injuries occur in the four major muscles of the lower limbs, most frequently in the hamstrings (37%), followed by the adductors (23%), quadriceps (19%) and calves (13%). In this same study, the authors report that up to 96% of muscle injuries, such as strains, caused in American soccer occur in non-contact situations, while contusions are more prevalent in sports such as rugby, ice hockey or American soccer, sports where contact is greater. On the other hand, it has been observed that, in elite soccer players, 16% of muscle injuries are recurrences and these are associated with a higher absence in competitions compared to absences due to the original injury. Therefore, it is really important to perform a good diagnosis and management of the muscular alteration.

The diagnosis is made based on the clinical manifestations presented by the patient and through diagnostic imaging tools. Clinically, subjects with muscle strains (grade I muscle tears - fibrillar rupture) report a sudden onset of pain during an eccentric contraction. This pain is usually localized in a specific muscle compartment and, depending on its severity, may immediately prevent the athlete from continuing with the sporting activity.[216]

Anatomically, these lesions are microscopic, involving less than 5% of the total thickness of the muscle. Small serohematic liquid cavities are formed that fill the void left by the areas of myofibrillar retraction consecutive to the microrupture, which may be surrounded by muscle edema. They are difficult to evaluate due to their small size, although feasible by ultrasound with the aid of echopalpation, while diagnosis is more difficult by magnetic resonance imaging (MRI).[233] Simple radiographs and tomography computerized (CT) scans are not very useful in muscle injuries, especially in the acute stages.[233] When a partial tear occurs (grade II), the athlete reports a snapping sound accompanied by the sudden onset of focal pain. This lesion is more extensive, involving more than 5% of the thickness. The ultrasound diagnosis is based on the appearance of an area of discontinuity with disruption of the fibroadipose septa, being able to identify an indentation between the fibers, occupied by a hematoma. As for the complete tear, this

Regarding the management of these muscle injuries, several studies suggest a prescription of exercise aimed at the injured muscle to develop its specific functional role. Exercise is a key part of both injury prevention and rehabilitation, as indicated by MacDonald et al. in their study on hamstring injuries. They also highlight the importance of motor control in the risk of hamstring injury and the use of running exercises during warm-up.[234]

According to a systematic review by Rudisill et al. eccentric exercise allowed elite soccer and track and field athletes to return to sporting activity faster compared to conventional training. On the other hand, hamstring stretching exercises were effective in restoring passive range of motion (ROM) and reducing pain in athletes with grade II injuries in this muscle group but did not improve active ROM or strength. However, by increasing the frequency of stretching from 1 to 4 sessions daily, active ROM increased. In addition, stretching after icing produced greater increases in active knee extension and lower extremity functional scale scores compared to icing alone. Another important aspect is early care, after 24 h for athletes with grade I and II injuries and two days after grade II or IV injuries.

Another therapy studied in the treatment of hamstring injuries in elite athletes is pain threshold-based rehabilitation, which is effective in increasing isometric strength. Moreover, the primary reflex release technique was shown to significantly increase active and passive ROM as well as functional scores, while low-level laser therapy revealed no effect. In that systematic review, we also evaluated outcomes of surgical repair of muscle injury with concomitant complete rupture of the central hamstring, noting that players returned to their sporting activity within 4 months and with no new injuries during the first year after surgery. In addition, it was also observed that there was no difference in the time to return to sporting activity between the athletes who received surgical treatment and those who were treated by surgery. However, almost half of the players who received conservative treatment required subsequent surgery because of poor results.[235]

### *Articular injuries*

At the joint level, the injuries that could occur are dislocations or dislocations, bursitis, sprains, arthritis, or impingement such as femoroacetabular impingement. For example, in sports such as karate, it has been observed that the most frequent alteration in the hip joint is arthritis, followed by femoroacetabular impingement and bursitis.[236]

Bursitis is characterized by subacute or chronic pain in the external aspect of the hip, of subacute or chronic course, and increased pain on pressure. The diagnosis can usually be made by clinical examination of the patient and physical examination. In this case, plain radiographs are not very useful either, since the result is non-specific, and certain findings without clinical significance can be observed, however, they are routinely performed to exclude an alternative or concomitant pathology, such as osteoarthritis or femoroacetabular impingement. Ultrasonography, on the other hand, may be useful in acute cases. In this case, the bursa volume would be seen as an anechoic, well-demarcated image surrounded by a thin wall. However, in chronic cases, ultrasound shows a thickened bursa wall, with contents that may be anechoic, hypoechoic or hyperechoic, and is therefore not a very important diagnostic aid. On the other hand, scintigraphy has a low specificity, so the result is not very useful for diagnosis either, while computed tomography shows bone alterations and perilesional calcifications, and nuclear magnetic resonance shows a non-specific signal of high intensity. Trochanteric bursitis is usually accompanied by other alterations, which constitutes the painful syndrome of the greater trochanter, being magnetic resonance imaging the gold test for its diagnosis by image, correlating the results with the clinical findings.

Regarding the management of this alteration, the first choice is conservative treatment including the use of non-steroidal anti-inflammatory drugs, corticosteroid injections, physiotherapy, and extracorporeal shock waves, in addition to the modification of sports activity, while surgical treatment is applied in those cases in which the patients do not respond to conservative treatment.[237,238]

There are different types of femoroacetabular impingement, and it has been observed that the hump type, characterized by alteration of the sphericity of the femoral head with decreased head-femoral neck overhang, has a higher incidence in soccer, basketball, and ice hockey players.[239,240] This deformity is observed in several radiographic projections,[241] although arthroresonance provides more information on the state of the labrum and articular cartilage. This alteration often requires surgical intervention and causes an average of 123 days of medical leave.[214] Conservative treatment can be attempted, which includes both oral and intra-articular analgesics in combination with strengthening exercises of the supporting musculature, but arthroscopic surgery is usually justified to relieve the impingement.

With respect to other alterations such as dislocations or subluxations are more common in the upper limb, specifically the shoulder, however, occasionally it can occur in the patella. A study published in 2019[242] showed that specifically patellar subluxation accounts for approximately 15% of injuries occurring in various sports such as football, basketball, or soccer. Diagnosis is made by patient history, clinical examination, and radiological evaluation, including MRI which is more specific to determine the structures involved. In patellar dislocation, MRI reveals: hemarthrosis, bone edema and osteochondral lesions. Treatment is essential to decrease the risk of recurrence of dislocation, painful subluxation and osteoarthritis. Several authors advocate conservative treatment of inaugural traumatic patellar dislocation. Subjects should be immobilized for approximately 2 weeks in approximately 20-degree flexion and as soon as pain permits, knee braces are used to stabilize the patella and weight bearing is started as a function of pain, beginning mobilization early to maintain articular cartilage trophism. Subsequently, closed kinetic chain exercises are initiated. However, arthroscopy is indispensable in case of intra-articular free body release due to chondral injury or osteochondral fracture. Regarding stabilization surgery, it is performed depending on whether the dislocation is inaugural or recurrent and whether the subject presents predisposing factors. In elite athletes, immediate surgical repair of the stabilizing structures of the patella (medial patellofemoral ligament and medial vastus obliquus muscle) is recommended.[243]

On the other hand, participation in certain sports has been found to increase the risk of knee osteoarthritis, with ACL reconstruction and partial meniscectomy as possible risk factors.[244] Specifically, the prevalence of knee osteoarthritis is higher in elite soccer players and long-distance runners, which makes it necessary to seek risk reduction strategies.[245] Diagnosis is based on physical examination findings and radiographic indicators, with marginal osteophytes and joint space narrowing. Management of osteoarthritis is based primarily on exercise, topical and oral non-steroidal anti-inflammatory drugs and intra-articular steroid injections.

### *Tendon injuries*

One of the characteristics of the tendon is its scarce vascularization, being the area of the body of the tendon the most affected. This is reflected in the injuries caused in this structure. Tendon injuries or tendinosis are very frequent in the practice of high-performance athletes, being the patellar and the Achilles tendons the most affected tendons of the organism in sports such as soccer, rugby, or basketball.[246,247] Patellar tendinopathy or “jumper’s knee” occurs mainly due to tears in this tendon in people who play sports that require very tiring or explosive jumps, where the quadriceps is generally subjected to high eccentric loads, such as volleyball, basketball and long and high jumps in athletics. This can cause strain on both the quadriceps and the patellar tendon.[248] Degenerative tendon rupture can occur in advanced and untreated tendinosis or in older athletes and in the sporting context, Achilles tendon rupture has been noted to be one of the most common tendon injuries affecting athletes.

Patients with patellar tendinopathy usually present with anterior knee pain and MRI shows focal thickening and increased signal in the proximal third of the tendon. Adjacent edema is also seen in the fat pad and inferior pole of the patella.[249] Although it is true that most knee injuries are better evaluated by MRI, the ultrasound is also a very useful technique if there is an area of pain or punctual inflammation. Ultrasound imaging shows loss of normal fibrillar pattern, presence of tendon thickening, hypoechogenicity, and neovascularity. In the case of Achilles tendinopathy, reduced echogenicity, and neovascularization and often enthesopathy affecting the calcaneal insertion are observed.[250]

The confirmation of the diagnosis of tendinopathies is of utmost importance in the clinical treatment because most of them can be managed mainly conservatively, obtaining good clinical results with a specific physiotherapy program.[251] In more resistant cases, treatment may include invasive techniques such as dry needling, platelet-rich therapy or even surgery.[249]

### *Ligament injuries*

Ligament injuries, including sprains, are a very common injury in sports such as soccer, field hockey or basketball. Injuries can affect the body of the ligament or the insertions, which usually is presented as avulsions or as fractures with bone detachments.[252] In the Šiupšinskas et al. study,[226] it was observed that the most frequent musculoskeletal alterations were those of the anterior cruciate ligament (ACL), medial collateral ligament (MCL) and lateral collateral ligament (LCL) of the knee (21.7%), followed by acute ankle ligament injuries (15.2%). A prospective cohort study shows an incidence of ACL injury of 10% over a 2-year period in elite adolescent female athletes, including female soccer and handball players.[253] In another study, conducted in soccer players, it was observed that 3% of the injuries consisted of injuries to the MCL. The mechanism of injury was direct contact in 75% of the cases,[254] while in the case of ACL injury in soccer players, more than 50% of the cases are caused by non-contact mechanisms. Moreover, it is more common for these injuries to occur during matches rather than during training.[227] In the Gagne et al. study after this injury, the players were away from sports practice for approximately 33 days, although 71% of the players, when they returned, did so at the highest level.[255] The diagnosis of ligament injuries is made by physical examination and complementary tests such as dynamic radiography, magnetic resonance imaging, computerized arthrotomography or ultrasound. The injury of collateral ligaments is easily and accurately assessed by ultrasound, showing an alteration of the normal fibrillar arrangement and hypoechogenic, while magnetic resonance imaging is the best option to diagnose a cruciate ligament injury.

The treatment of most collateral ligament injuries is conservative, although it depends to a great extent on the degree of the injury. Most players are treated with the use of orthoses, stabilizing knee braces, as well as corticosteroid and platelet-rich plasma infiltrations. Some players with a grade III injury are treated by ligament repair surgery, especially when there is also a bone avulsion or an associated injury to another ligament such as the anterior cruciate ligament or cartilage.[254]

### *Bone injuries*

At the bone level, the most frequent sports injury is the fracture, either total or partial, commonly called fissure. Fractures can be differentiated into two groups depending on the mechanism of injury: (a) traumatic and (b) stress. According to the study by Pfirmann et al. fractures account for 2-5.1% of all injuries in professional soccer players. With respect to other sports, it has been observed, for example, that the incidence of acute fractures is higher in cyclists compared to runners; however, stress fractures occur more frequently in runners than in cyclists.[256]

Subjects with stress fracture present with pain on palpation or edema after a recent increase in activity or after performing a certain activity repeatedly with limited rest. Diagnosis can be made by plain radiography, although magnetic resonance imaging is an effective tool for early diagnosis of stress fractures and for determining their severity. Treatment of stress fractures consists of activity modification, analgesics, and the use of pneumatic braces to facilitate healing. Once pain is resolved and examination shows improvement, patients can gradually increase their activity level. Treatment by surgery may be appropriate in cases where fractures have originated in high-risk locations, nonunion or recurrent stress fractures.[256]

## Foot and ankle

The foot and ankle complex play an important role during sports such as running, soccer, gymnastics or American football.[257,258] These are the only structures of the body that contacts the ground during sports-related tasks with at least 26 bones, 33 joints and more than 100 tendons, muscles, ligaments and nerves in each foot.[259,260] Several epidemiologic studies have investigated the incidence and prevalence of lower extremity injuries with a special focus on foot and ankle injuries, reporting that a small proportion of injuries required surgical treatment.[259,261,262] Higher incidence of foot and ankle injuries have been found in female athletes and may be due to multiple factors such as anatomic, hormonal, nutritional or functional differences when compared with their male counterparts.[257,259,263] Sports-related injuries around the foot and ankle system have been classified by location of pain,[260] injury mechanisms (overload, trauma or sprain),[259,264] acute/persistent pain, structure (bone and joints, tendon, muscle and nerves) or age (young and middle-age).[260]

*Overload injuries*

The most frequent overload-related injuries are Achilles tendinopathy, plantar fasciopathy, or stress fractures of the ankle and foot bones.[258–260,265] Achilles tendinopathy is a painful overload injury with a high incidence in specific active populations such as elite track and field athletes (runners or jumpers).[266] Achilles tendinopathy is characterized by alterations in the mechanical properties and structure of the tendon, altered lower extremity biomechanics and poor self-reported quality of life.[267] Achilles tendon injuries can be divided into proximal musculotendinous injuries, mid-portion tendinopathy and insertional tendinopathy according to the location of pain.[268] A gradual onset of symptoms such as pain, soreness, morning stiffness and reduced lower extremity function are the primary symptoms of this type of patholofy.[269] The etiology of tendinopathy can be multifactorial, however, the most frequent cause in sports is excessive training load with poor recovery time between sessions.[270] Several risk factors have been described in the scientific literature for developing Achilles tendinopathy, with intrinsic (decreased plantar-flexor strength, poor neuromuscular control of the hip joint, reduced ankle dorsiflexion ROM, excessive foot pronation, increased body weight, systemic diseases or drugs use) or extrinsic factors (footwear, training-load, surface and environmental conditions).[268] Several diagnostic tests have been proposed to confirm Achilles tendinopathy. Pain location on palpation (insertional, mid-portion or proximal musculotendinous) can be useful to divide this pathology according to location and for the differential diagnosis with other pathologies (Achilles tendon rupture, sural nerve irritation, Kager fat irritation, posterior ankle impingement or inflammatory disease).[271] Other additional diagnostic tests used to confirm Achilles tendinopathy are the Royal London Hospital test and the arc sign. These tests have low-medium sensitivity and high specificity.[267,268,271] The clinical presentation often curses with physical impairments such as decreased ankle dorsiflexion ROM or calf-muscle endurance/strength, accompanied by poor psychological health (kinesiofobia, anxiety or depression) and altered tendon structure morphology assessed with ultrasound imaging or shear-wave elastrography.[272] The highest level of evidence treatment for Achilles tendinopathy is exercise rehabilitation and patient education with the main purpose to decrease their pain, improve tendon morphological properties and self-reported quality of life.[267] The treatment of an athlete with Achilles tendinopathy can be structured into different phases (symptoms management and load reduction, progressive load and return to sport).[268]

Mechanical heel pain is a commonly encountered condition presented to foot and ankle sport specialists.[273] Mechanical heel pain can be divided into plantar heel pain (plantar fasciopathy and heel spur syndrome) and posterior heel pain (insertional Achilles tendinopathy, Haglund's deformity with or without retrocalcaneal bursitis) and medial heel pain (tibialis posterior tendinopathy).[274] In addition, heel pain can include traumatic (calcaneal fractures), inflammatory (gout, seronegative arthritis or psoriatic arthritis) and neurological diseases (S1 radiculopathy, tarsal tunnel syndrome, medial calcaneal neuroma o sural neuropathy).[275]

Plantar fasciopathy is the most common pain condition described into mechanical heel pain, with a medium-high incidence in runners and soccer players, limiting their perfomance.[276] The plantar fascia, a dense connective tissue, sustain the medial longitudinal arch of the foot and it extends from the calcaneus to the distal part of metatarsophalangeal joints of each toe.[276] The pathophysiology of this condition is similar to those of tendinopathies, as mentioned above. The most common clinical presentation of plantar fasciopathy is characterized by symptoms of pain on the calcaneal insertion of the plantar fascia and stiffness, especially with the first steps in the morning or during a long rest period.[277] Several intrinsic (limited ankle dorsiflexion or first ray extension and prolong standing) and extrinsic (footwear or incorrect training load) risk factors have been associated with plantar fasciopathy, although with low-medium level of evidence.[274] An exhaustive clinical examination is essential to differentiate several pain conditions around the heel. Pain location may be useful to discriminate the medial calcaneal tubercle or calcaneal tuberosity.[274] Into plantar fasciopathy assessment, Tinel's sign and sensory disturbance can be performed in order to confirm Baxter's nerve compression, where tenderness is often more posterior and dorsal.[278] Calf muscles flexibility with the Silfverskiold's Test (passive ankle dorsiflexion with 90º knee flexion), passive first toe dorsiflexion (to tight the Windlass mechanism and provoke pain) and resisted first toe flexion (to exacerbate heel pain in case of flexor hallucis longus tendinopathy) are valid and reliable tests into plantar flasciopathy clinical examination.[278] Several treatment modalities have been described: rest, ice, heat, taping, night splints, stretching, electrotherapy or plantar fascia surgery.[279] Heavy-slow resistance training, through concentric, isometric, and eccentric phases against a heavy load, was not included in a systematic review that evaluated the comparative efficacy of commonly used treatments for plantar fasciopathy.[280] Heavy-slow resistance is a common treatment modality in tendinopathies. Several studies have concluded that heavy-slow resistance training and load management can be a useful therapeutic approach to reduce pain and improve other outcomes over 12 weeks.[281–283]

Other clinical entities characterized by persistent anterolateral pain such as sinus tarsi syndrome or anterior-lateral ankle impingement, or bone stress fractures have minor incidence in sports such as running but are more common in volleyball, ballet dancing or high-jumping.[284] Assessment of these type of pathologies into a differential diagnosis process of the foot and ankle may be useful to develop individualized-treatment programs.

*Calf muscle strains*

Calf muscle strain is the most common muscle injury in elite athletes when performing sports such as soccer (season injury incidence 1.3 to 2.3), tennis (0.3 to 0.8), basketball (1.2) or American football (2.1 to 2.3).[285] Calf muscle injuries are most prevalent in athletes, especially male, aged between 22 and 28.[286] There are several types of triceps surae injuries according to specific sports. Isolated gastrocnemius injury is frequent in American football during high-intensity running, acceleration and deceleration tasks, whereas soleus muscle injury is more common in Australian football during steady-state running tasks.[264,286] Biomechanical function and muscle fiber type may contribute to this observation. Medial and lateral gastrocnemius contribute to knee flexion and ankle plantar flexion. The soleus muscle contributes to ankle plantar flexion, limiting anterior tibial translation and lower leg postural control.[264,287]

The pathogenesis and clinical presentation of gastrocnemius strain involves knee extension with sudden ankle movement from dorsiflexion to plantar flexion, with high prevalence medial head of gastrocnemius strain.[288] Soleus muscle injuries can occur with passive ankle dorsiflexion and knee flexion, for example while running uphill.[289] There are some specific criteria in the diagnosis of calf muscle strain: 1) an audible pop at the onset of injury, followed by acute severe pain and swelling in the calf within 24 h; 2) tenderness and a palpable defect on palpation; 3) muscle strength weakness of calf muscle; 4) painful and limited ankle dorsiflexion and 5) confirmation of the location and the grade of the injury.[289,290] In addition, Thompson test can be performed in order to rule out acute Achilles tendon rupture.[289] Calf muscle strain is based on the muscle injury classification mentioned above. Conservative treatment of the calf muscle injury is effective and consists of rest, ice, compression and elevation during the acute phase. In the subacute phase, treatment is based on gradual strength exercise (isometric – isotonic contractions), stretching and dynamic tasks. Finally, during the return to sport phase, sport-specifics tasks can be performed to restore agility and strength.[285]

*Lateral, medial and syndesmotic ankle sprain injuries*

Sports such as handball, soccer, basketball or volleyball have a high prevalence of ankle sprain injuries during season. The ankle joint connects the lower limb through the talocrural joint and subtalar joint with a wide variety of muscles such as peroneus complex, tibialis anterior or posterior muscles.[291] A total of 85% of ankle sprains are due to excessive inversion movements, whereas nother injury mechanism described that cause medial ankle sprains is excessive eversion movement.[292] Syndesmotic ankle injuries contribute 10% of all ankle sprains. Several intrinsic (muscle strength weakness, reduced ROM or poor balance) and extrinsic (type of sports or surface) factors have been described for ankle sprains.[293]

The physical examination of these type of injuries should begin with visual inspection for gross abnormalities, neurovascular alterations, ecchymosis or edema. Pain on palpation or tenderness over the lateral or deltoid ligaments, syndesmotic ligaments and osseous landmarks can be useful to exclude distal ankle fractures. The Ottawa Ankle Rules (strongly recommended) should be utilized to determine if imaging is necessary.[294] After ruling out severe ankle injuries, the clinical examination process should include passive and active ROM assessment or ankle muscle strength measures.[295] Several orthopaedic tests have been described to rule in/out ankle sprains including: Anterior drawer test, talar tilt test, external rotation test, tibia/fibula squeeze test and cotton test.[296,297] Ankle sprains is based on a grade 1 to 3 l classification, from athletes with grade 1 ankle sprain present minimal swelling and point tenderness over the lateral/medial collateral ligaments, to grade III ankle sprain associated with inability to ambulate and excessive edema.[297] Syndesmotic ankle sprain are distinguished from isolated lateral or medial ligamentous injuries based on the history, injury mechanism (ankle dorsiflexion and external rotation of the foot) and several positive orthopaedic tests such as squeeze test and the external rotation stress test.[296] In addition to physical examination, dynamic ultrasound examination may be useful during the early diagnosis and grading of ankle sprains, especially syndesmotic sprains.[298]

According to ligamentous healing process the conservative or non-operative treatment of ankle sprains has been divided into different phases. First, the main objectives are to protect the ligament from further injury with ice, compression, elevation, stabilization, mobilization and strength training.[299] In the advanced stages, the essence of treatment is to restore ankle ROM, muscle strength and balance or sensoriomotor control of the lower limb and trunk. Finally, incorporation of pain-free multidirectional agility drills, sprints, jumping or sport-specific tasks.[293,295,300]

*Other foot pathologies*

Several pain conditions have been described around the foot and can be categorized into pathologies of the mid-foot such as degenerative disease or post-traumatic arthritis on the Lisfrac joint and insertional tendinopathy of the peroneal brevis. Another pain conditions such as metatarsalgia, Morton neuropathy, Freiberg disease, hallux valgus, nail pathology or sesamoiditis of the first toe can be diagnosed in the forefoot.[260]

## Clinical applications

The treatment of elite athlete's injuries can generally cover three areas. In the first place, the surgical treatment of the musculoskeletal injury that aims to clean, repair and/or eliminate anatomical structures involved in the process of tissue deterioration.[301–303] In other cases, the purpose of surgery will promote the activation of the inflammatory response through the induction of controlled lesions that promote the process of cell proliferation and replacement of the target tissue. In this scenario, the injuries with the worst prognosis characterized by the loss of tissue continuity solution such as fractures, muscle tears, neurovascular injuries or capsular ligament injuries are in most cases subsidiary to surgical treatment.[304]

Second, the conservative approach has become the most widely used treatment due to its low cost and the failure of some surgical procedures in the secondary prevention of the injury. In this sense, the use of drugs (*non-steroidal anti-*

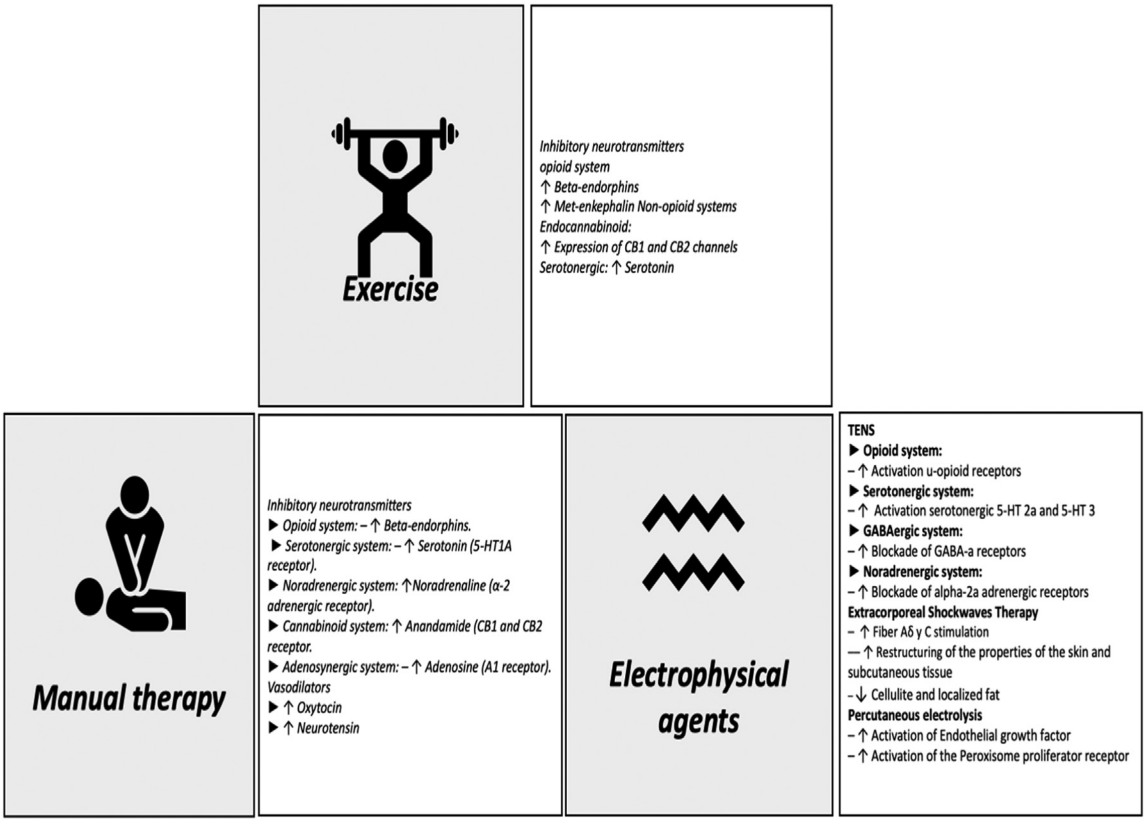


**Fig. 5.** Neurophysiological mechanisms of main treatments for managing musculoskeletal disorders in elite athletes.

*inflammatory* drugs (*NSAIDs*)[305] opioids (eg; *Fentanyl, oxycodone*),[306] alpha-adrenergic receptor agonists (eg; *clonidine*)[307] muscle relaxants (eg; *clobenzaprine*, etc…)[308] as well as non-pharmacological agents, including manual therapy,[309–313] non-ionizing electrophysical agents (TENS,[314] shock waves[315,316] or percutaneous electrolysis[317,318] and therapeutic exercise aimed, on the one hand, at controlling recurrence risk factors (stretching,[319] coordination,[320] strength,[321] aerobics,[322–324] etc…) and on the other, to the control of inflammation and the induction of analgesia through the activation of descending endogenous inhibition systems.[325,326] (See Fig. 5)

*Manual therapy*

Manual therapy directed at the joint in the form of mobilization or manipulation of a joint activates an endogenous inhibition that depends on the one hand, on opioids[327] and on the other hand, on non-opioids such as serotonin, norepinephrine, adenosine and endocannabinoids.[328]

In relation to the first mechanism, the existence of an immediate release of $\beta$-endorphins that is maintained for at least 30 min after joint manipulation has been recorded in asymptomatic subjects.[329] However, the presence of this circulating neurohormone does not seem to be sufficient to generate an inhibitory effect after joint manipulation, as it has been confirmed that in both animals and humans, the reduction in pain caused by joint manipulation is not reversed by the opiate antagonist (naloxone).[330]

The second mechanism that would explain the analgesic action of this joint treatment modality is that dependent on serotonergic and noradrenergic pathways.[328,331] In fact, in animal models, the analgesia produced by grade III oscillatory joint mobilization can be blocked by stimulation of serotonin receptors (5-HT1A), $\alpha$-2 adrenergic and A1 adenosine.[332] Also, the analgesic effect depends on cannabimimetic mechanisms, as it was shown that a rhythmic joint mobilization of the lower limb degrades 2-arachidonoyl glycerol and releases anandamide that binds to the CB1 and CB2 cannabinoid channels.[333,334] Recent research has indicated that spinal joint manipulation also causes the blood release of orexin A and the reduction of proinflammatory and vasodilator peptides such as neurotensin and oxytocin.[335]

Manual therapy directed at soft tissues activates mechanisms that depend on the release of oxytocin[335] both in the plasma and in the periaqueductal gray matter.[328] The opioid system is also involved, as a significant increase in plasma $\beta$-endorphin levels is observed after connective tissue massage.[336] On the other hand, a neurophysiological mechanism has been proposed in which the MT acts as a counter-stimuli when we perform a light or tactile massage that stimulates the low-threshold A$\beta$ fibers and inhibits the nociceptive input of the A$\delta$ and C afferent fibers to the horn spinal cord dorsal.[337,338]

Finally, other studies suggest different hypotheses about the mechanism of action of manual therapy applied to soft tissues. An example of this postulate would explain that these techniques allow restoring normal movement patterns, reducing muscle stress and improving tissue healing through increased blood flow. This would lead to a reduction in the presence of mechanical and chemical irritants that activate the nociceptors, thus reducing the nociceptive input in the CNS and consequently the pain.

Manual therapy directed at soft tissues triggers a hypoalgesic effect dependent on the release of substances involved in tissue inflammation and the activation of the sympathetic autonomic nervous system.[339,340] It has been observed that this treatment modality increases some lymphocyte markers and promotes the release of cytokines in addition to a decrease in cortisol, adrenocorticotropin (ACTH) and nitric oxide (NO) which would imply a reduction in mechanical hyperalgesia.[331] Other effects that are obtained after the massage is the reduction of tissue adhesions, increasing the flexibility of the tissues as well as increased blood flow even in untreated areas, elevation of muscle temperature and the transient decrease in muscle strength.[302]

*Electrophysical agents*

*TENS*

Non-ionizing electrophysical agents such as TENS trigger the closing of the pain control gate by means of a symmetrical biphasic current capable of stimulating large-diameter afferent fibers, inhibiting, on the one hand, nociceptive transmission in the posterior medullary horn and, on the other, blocking the activity of the periaqueductal gray matter, rostral ventromedial medulla, among other centers of the nociceptive pathway.[314]

In low-frequency TENS therapy ($<$ 10 Hz) it seems to have been associated with activation of u-opioid receptors and blockade of GABA-a receptors,[341] serotonergic 5-HT 2a and 5-HT 3[342] as well as the muscarinic receptors M1 and M3 ultimately producing an antihypelagesic effect.[343]

In contrast, pain control of musculoskeletal injury when using high-frequency TENS ($>$ 10 Hz) will be linked to the blockade of alpha-2a adrenergic receptors[344] or even an activation of autonomic mechanisms that affect the transient changes in blood flow in the stimulated region.[345,346]

*Extracorporeal shockwaves therapy*

ESWT is used as therapeutic electrophysical agent characterized by a high-pressure pulse (80 MPa) in a time interval of extremely short duration which produces mechanical pressure waves that promote cavitation in liquid medium (gas bubbles in fluid medium) and increase in local temperature.[347] These shockwaves propagate in the target tissue, generating essential mechanisms of action such as the mechanical impact in the tissues and formation of microbubbles, which favors the achievement of the therapeutic objective.

Despite the effects on bone remodeling of periosteal lesions, the analgesic mechanisms seem to be associated with the activation of the endogenous pain inhibition system. We also consider its local action on biological tissue to be important, since it has been shown in animal models that it leads to the restructuring of the properties of the skin and subcutaneous tissue, clinically improving aspects of cellulite and localized fat.[348] Regardless of the mechanism of action, robust clinical studies indicate decreased pain, increased range of motion, as well as improved functionality and quality of life in elite athletes.[315,316]

*Percutaneous electrolysis*

Percutaneous electrolysis is a treatment technique for soft tissue injuries (eg, tendinopathies, muscle tears, etc…) based on the flow of galvanic current through a sterile needle located in the region of the injury. This technique generates a dissociation of water through an oxidative reaction with the salts in the tissue, producing sodium hydroxide (NaOH).[349] The negative electrode (needle) is capable of liquefying the medium, in addition to increasing the permeability of the membrane and increase vascularization in the environment of the lesion. From a molecular level, an increase in endothelial growth factor has been observed as well as the activation of the peroxisome proliferator receptor and promoters of tissue regeneration in subjects with injury.[350]

*Exercise*

Exercise is the sports injury treatment modality that generates the greatest impact not only in the repair of the affected tissue, such as a muscle tear, but also in the reduction of symptoms by shortening the recovery time.[351,352]

Exercise is capable of promoting tissue repair through the activation of satellite cells and macrophages during muscle regeneration.[353,354] In addition, a descending nociceptive inhibition mechanism has been identified that would explain the decrease in pain perceived by the athlete exercising. This exercise-induced analgesia seems to be dependent on the athlete's baseline physical condition as well as the type of exercise and its intensity. In relation to aerobic exercise, studies carried out in healthy subjects indicate that to obtain an analgesic response it would depend on the opioid pathway ($\beta$-endorphins) when exercise is done at high or vigorous intensities, which would mean 60% to 80% of VO2max.[325] Similar effects on this pathway have also been documented during the execution of a high-resistance exercise performed dynamically with the upper limb, but not for isometric resistance exercises in which high intensity indicated a minor effect on pain reduction.[355–357]

On the other hand, the descending pain inhibition system also depends on other pathways such as endocannabinoids and serotonin.[336,358,359] Although they do not seem to be the only non-opioid inhibition pathways, there are studies that associate increased pain tolerance thanks to a high-threshold motor unit recruitment mechanism that is related to the occurrence of delayed onset muscle soreness (DOMS). Also, an interaction mechanism between the cardiovascular system and pain modulation is hypothesized through the activation of baroreceptors during exercise that triggers an increase in blood pressure during exercise.[360] Finally, we must not forget the repercussion that the inhibition mechanisms dependent on the central nervous system could have when it is identified that moderate intensity aerobic exercise performed on a regular basis causes an increase in the expression of the opioids $\beta$-endorphins and met-enkephalin in regions involved in the inhibitory control of pain such as the thalamus, SGP and MRV, so exercise-induced analgesia could be the result of activation of the primary motor cortex and corticospinal tracts.[361]

## Declaration of Competing Interest

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