Module 1. Diagnostic imaging in sports medicine

1.1 Using ultrasounds and magnetic resonance imaging of muscle injuries for sports physicians

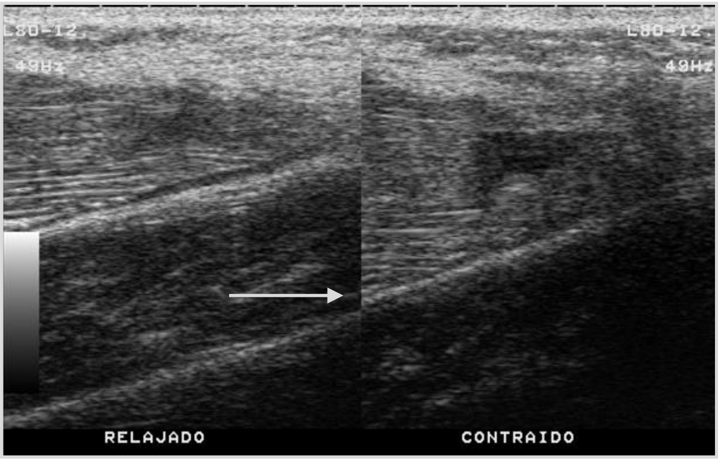
Diagnostic imaging is a tool that sports physicians should utilize to improve the accuracy of the diagnosis, prognosis and treatment of muscle injuries. In this way, sports physicians and radiologists should work together to optimize the imaging of sports injuries and achieve more accurate diagnoses.

In this unit, we want to answer frequently asked questions on this topic in order to have a clear idea of how magnetic resonance imaging, and ultrasounds in particular, can help sports physicians in their diagnoses and prognoses.

1.1.1 Using imaging in sports medicine and its relationship with radiology

Ultrasound imaging is less sensitive than MRI imaging, but ultrasounds are also less expensive and allow the injury to be monitored, observing its progression and detecting complications. Another advantage of using ultrasound for assessing muscle injury recovery is the ability to carry out a dynamic assessment before and after a muscle contraction, which may or may not represent persistence in the fiber alteration following rehabilitation or clinical treatment (Figure 1). This is very important for the assessment of minor and more serious muscle injuries as it will affect how much time an athlete needs to return to play.

Figure 1: Myofascial injury of the rectus femoris at the distal third



Note: Dynamic longitudinal view. In the image on the left, the patient is relaxed, while in the image on the right, the rectus femoris is contracted and the tear (arrow) is more clear.

Source: Prepared by the author.

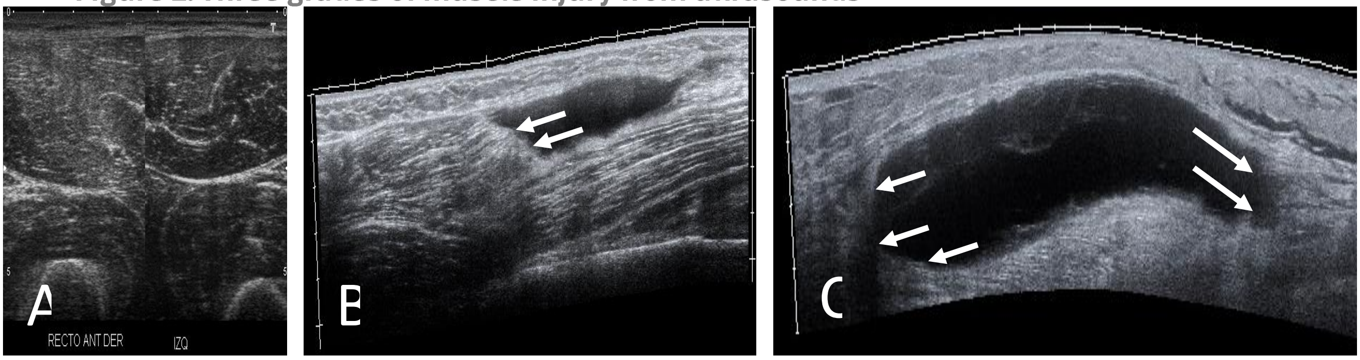
Diagnostic imaging is fundamental in confirming and evaluating the significance of muscle injuries in the field of sports. It helps when making decisions about treatment, which directly affects prognosis and return to play. Currently, ultrasounds and MRIs are the most frequently used techniques in sports medicine. Therefore, the prognosis based on available clinical information along with that obtained from diagnostic imaging is fundamental.

Sports injuries are an important part of a sports physician's daily tasks. A well-done diagnosis requires an accurate anamnesis and physical examination, as well as an imaging procedure performed in order to confirm the clinical diagnosis. This may be a conventional X-ray, soft tissue ultrasound, CAT scan, planar bone scan or Magnetic Resonance Imaging (MRI).

Until now, it was primarily radiologists who were responsible for completing the corresponding ultrasound assessments. However, it is now being suggested that the team sports physician is capable of using this tool for better diagnosis and prognosis of injuries.

Sports physicians should perform ultrasound assessments on athletes within the scope of their knowledge. The next step is to consult with a radiologist specializing in musculoskeletal pathology to review the ultrasound test or perform additional imaging tests. In short, the ultrasound is shared between a sports physician with a strong clinical basis and knowledge of ultrasounds and a radiologist possessing a strong diagnostic basis and clinical knowledge of the patient.
It is important to obtain the best diagnosis after a muscle injury in order to determine the seriousness of the injury, which will then determine recovery time and the risk of repeating the injury (Figure 2).

Figure 2. Three grades of muscle injury from ultrasounds



Note:
A Grade 1. Increased echogenicity is seen only in the rectus femoris (*). The image on the right shows the contralateral image.
B Grade 2. Collection of fluid partially in the biceps femoris muscle (arrows).
C Grade 3. Collection of fluid that completely preserves a full tear of the gastrocnemius on its medial head (arrows).

Source: Prepared by the author.

For this reason, it is essential to count on the collaboration between sports physicians with extensive experience in muscle injuries, ultrasound, and athletes' return to the field of play, along with radiologists specialized in musculoskeletal systems, with training in sports injuries and experience in new diagnostic imaging alternatives, especially MRIs from 1.5 to 3.0 teslas.

1.1.2 Clinical use of ultrasounds

Ultrasound assessments form part of regular clinical examinations within many specialties. In 1998 the radiologist Wayne W. Gibbon (1) foretold that ultrasounds would become popular around the world. The trend has occurred due to various factors – all related to the evolution of ultrasound techniques starting at the turn of the century to the present day.

The first factor is technological. More and more, ultrasound devices have transducers with higher frequencies, capable of visualizing the structures of the locomotor system more effectively. Because of this, it is now possible to assess nerves, tendons, muscles and joints with extreme precision. In addition, these ultrasound devices continue to get smaller, making them more portable and easy to use.

The second factor is economic. Due to decreased costs and better device techniques, it is now easy to access an ultrasound with sufficient quality to make a diagnosis and apply instrumentation to the patient at any medical consultation.
The third factor is professional. Locomotor system professionals now have very high levels of medical knowledge. Their level of responsibility for their patients is also very high. Immediate clinical information obtained with ultrasound tests on the locomotor system and subsequent monitoring make this technique of great interest for doctors and is very

beneficial for patients. Furthermore, including ultrasounds in routine medical practice should be similar to how cardiac auscultation is included in cardiology examinations or ultrasounds for obstetric monitoring.

In this context, it makes sense for companies to offer these high-frequency and reasonably-priced sonographs to health professionals who in turn have an urgent need to use ultrasounds to improve the quality of their medical practice for the benefit of their patients.

In fact, in many countries, especially in Europe, doctors regularly perform ultrasound tests. Cardiologists and gynecologists have always used this technique with their patients. Diverse medical specialties have gradually been incorporating musculoskeletal ultrasonography. For decades, rheumatologists have used ultrasounds to examine the locomotor system and sports physicians, anesthesiologists and rehabilitation specialists have had become increasingly interested in using this technique. Now it is orthopedists' turn.

Ironically, the greatest limitation to using ultrasounds today has more to do with learning the technique rather than its accessibility. In this sense, the ultrasound technique implies an ever steeper learning curve while its financial cost continues to drop. This means that, in spite of their special clinical use, ultrasounds are sometimes misused. And for this reason, responsible and mature health professionals do not want to see this technique used gratuitously and frivolously, but rather in an orderly and serious manner.

1.1.3 Role of the MRI in the classification of muscle injuries

For assessing the anatomical-pathological details of a muscle injury, an MRI is considered superior to an ultrasound. Therefore, an ultrasound study should adapt its findings to the classifications established during an MRI study. MRIs are mainly performed with devices that produce 1.5-3.0 teslas to obtain high quality images of muscle architecture and muscle injuries. This allows the level and amount of micro-connective tissue damage to be assessed. Assessment of the grade and location of the affected extracellular matrix is fundamental to providing a reliable prognosis, since the greater the amount of damaged connective tissue, the greater the functional deterioration and the worse the prognosis will be. These details must be exemplified in the classification of muscle injuries.
The main problem with the diagnosis and prognosis of muscle injuries is the lack of consensus around classification of muscle injuries. This is due to the current difficulty of using imaging to evaluate the true alteration of the muscular architecture and the severity of the injury. In addition, the type of activity performed by the athlete and the production mechanism must be taken into account when considering a classification with a prognostic interest.

Recently, three classifications have been proposed:

1) Munich Consensus Classification (Mueller-Wohlfahrt et al. 2013).
2) British Classification System (Pollock et al. 2014).
3) FCB Barcelona and Aspetar Classification (Valle et al. 2017).

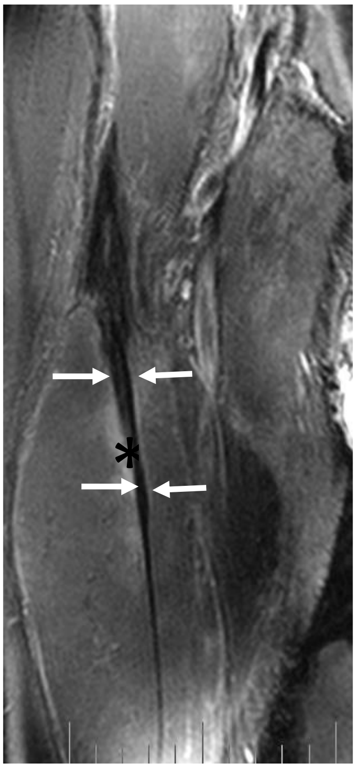
These classifications are directed toward different factors that are fundamental to obtaining a better diagnosis and prognosis. Some of these are based on achieving high quality MRI images. In such imaging, the following items may be assessed:

1) Injury mechanism
2) Injury location
3) Damage to the myoconnective junction: tendinous, myofascial, musculotendinous or intramuscular
4) Presence of fiber retraction
5) Extension of the edema (cross-sectional area)
6) Whether it is the first instance of an injury or a reinjury

1.1.4 The role of imaging in an athlete's return to play and reinjury assessment

There is still currently no conclusive evidence to show that ultrasounds or MRIs are useful for predicting when an athlete will be able to return to sporting activity. Evidence from sports medicine demonstrates that the normalization of increased MRI signal intensity is not necessary for the return to sporting activity to be successful and, in turn, suggests that functional recovery is preceded by a structural recovery based on diagnostic imaging (Figure 3).

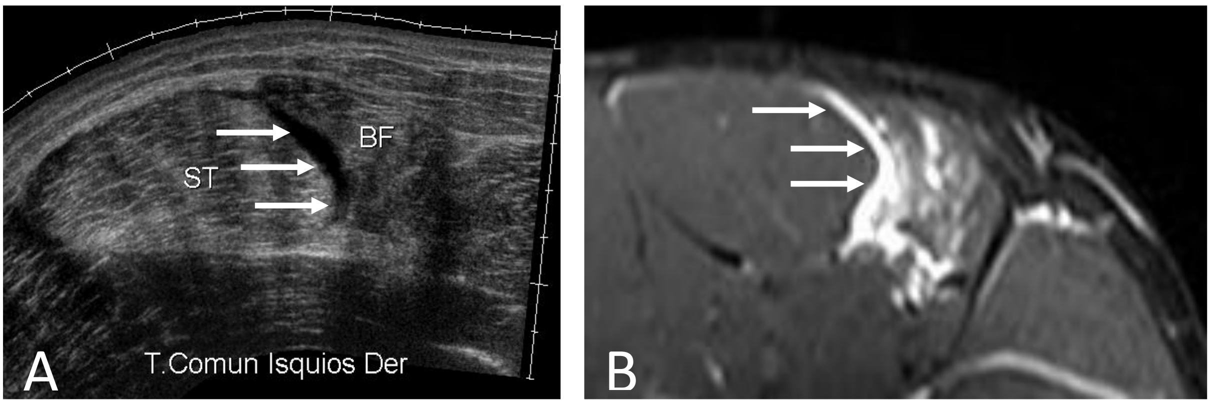
Figure 3. fs T2 axial MRI test of the upper third of the right thigh, at the level of the central tendon of the rectus femoris



Note: Fibrous repair of the central tendon (arrows) is observed, with pericicatricial edema (*). The athlete was asymptomatic and returned to play without reinjury.
Source: Prepared by the author.

There are various criteria for using MRIs or ultrasounds in relation to an athlete's return to play. First, an athlete's return to play must be based on a positive clinical assessment that incorporates the pain examination, flexibility, fatigue and strength. Diagnostic imaging is only a supporting tool in this process. Second, in terms of diagnosing and monitoring injuries, ultrasounds and/or MRIs are more useful for early identification of complications rather than for monitoring positive progression towards repair (Figure 4).

Figure 4. Injury of the hamstring tendon (arrows), confirmed via image-based evidence



Note:

A: Transversal ultrasound test of the upper middle third of the right thigh ST: semitendinosus. BF: Biceps Femoris.
B: fsT2 axial MRI test of the upper third of the right thigh.
Source: Prepared by the author.

In our experience, ultrasounds are helpful for monitoring the recovery process and checking for hematomas, fibrosis, repairing the muscle architecture, etc. They are useful and less expensive, but are clearly not the best indicator for deciding when athletes should return to their sports activity.

Furthermore, there is not sufficient evidence to support the use of MRIs to identify athletes that possess a greater risk of reinjury. The decision to return to play and risk of reinjury is not a question that can be assessed with one tool only, but rather the set of all available tools. Thus, clinical evaluation and other tools such as the values obtained from GPS should play a role in making a final decision on whether an athlete is ready to return to activity.

Currently, at least in Spain, the use of ultrasounds is comparable to that of stethoscopes in cardiology.

1.1.5 Ultrasound-guided procedures for muscle injuries

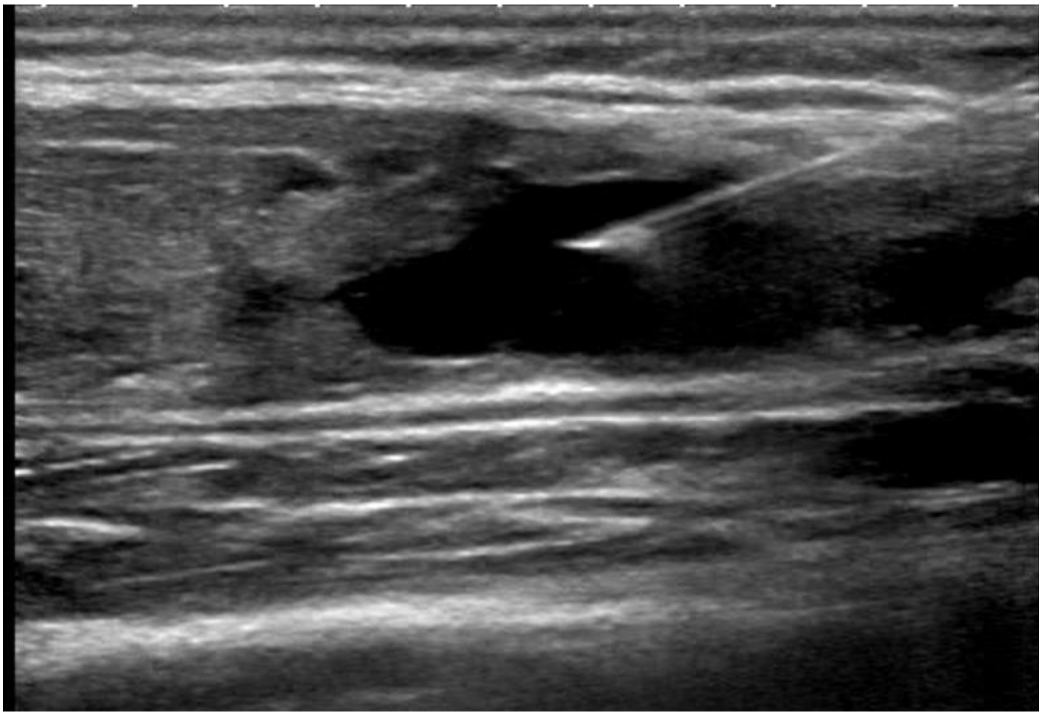
Ultrasounds of muscle injuries also have a therapeutic role. The technique must be precise and orderly. An ultrasound-guided puncture can be conducted in two very different situations: first, with some acute injuries and second, with chronic injuries.

The objective of an ultrasound-guided puncture of an acute injury is to decrease tension in the affected muscle segment. Therefore, we will only recommend punctures when the collected hematic fluid causes distal vascular nerve problems or if there is a clinical risk thereof. Corticosteroids are never infiltrated. Empirically, we have begun to infiltrate platelet-rich plasma in acute injuries, with the goal of reducing biological tissue repair time. The results of these interventions are not yet available.

Fibrous scarring, encrusted hematoma, and Morel-Lavallée lesions are chronic tributary muscle injuries that are treated by ultrasound-guided procedures.

Fibrous scarring should be infiltrated by peppering the fibrous area with the needle. If this is performed during an ultrasound, it can be difficult, as controlling the needle will not be possible while it is constantly moving. Therefore, it is better to locate the area using ultrasound and calculate the depth and area to be infiltrated. The puncture is indirectly guided by ultrasound. Encrusted hematomas are usually seen in myofascial injuries – frequently in tennis leg and injuries of the distal rectus femoris myotendinous junction. The aspect of the drawn aspirated blood indicates the age of the hematoma. Therefore, if we draw blood we will know whether the injury (or its recurrence) is recent. If the extracted sample is plasmatic fluid, the injury is old. The Morel-Lavallée lesion puncture-aspiration obtains a variable, but usually significant, amount of thin, yellow and plasmatic fluid. For most of these procedures, it is essential to place a circular or compression bandage on the puncture afterwards (Figure 5).

Figure 5. Longitudinal view ultrasound of a rectus femoris injury in its posterior fascia with hematoma and fibrous repair (*)



Note: From a reinjury. An ultrasound-guided infiltration with PRP is conducted, with the ultrasound of a residual hematoma aspiration shown here.
Source: Prepared by the author.

Future challenges and techniques

The most advanced MRI techniques available for muscle assessments are not frequently used in clinical practice. Therefore, it is necessary for professionals working in the clinical environment to promote direct contact with radiologists and to consult with them on new techniques to obtain better diagnoses and prognoses. For example, T2-powered mapping can be useful from a sports medicine perspective. T2 values increase in stressed muscles and this can help us know the activation or changes in muscle recruitment after muscle injuries.

Also, Diffusion Tensor Imaging allows us to quantify the diffusion of anisotropic tissues and observe the path of the muscle fiber direction in order to detect minor injuries and differentiate between injured and non-injured muscles.

Furthermore, ultrasounds are beginning to include elastography or shear wave in their usual protocols to study the physiological reaction of damaged or healthy muscles. In fact, it was discovered that muscle stiffness changes after an injury.

In the near future, it is likely that the use of Positron Emission Tomography (PET) will be included, with the objective of learning more about metabolic and functional muscle changes and the relationship that exists before and after muscle injuries along with the recovery process.

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