The role of ultrasound in sports muscular injuries

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Aims and objectives

The objective of this study was to evaluate the role of ultrasonography (US), compared with magnetic resonance imaging (MRI), in the diagnosis and follow up of traumatic muscle injuries.

Muscle injury is one of the most common events occurring in sport traumatology and require careful clinical and instrumental evaluation and timely treatment in order to restore a good functional outcome.

Particularly in elite athletes, where decisions regarding return to play and player availability have significant financial or strategic consequences for the player and the team, there is an enormous interest in optimizing the diagnostic procedures.

Ultrasound (US) and magnetic resonance imaging (MRI) are the most useful imaging techniques to assess the presence and degree of muscle injuries. The recent advances in US technology producing detailed images allow diagnosis with similar accuracy as MR imaging.

An early post-injury US, performed between 6 and 72 hours after trauma, provides helpful informations about any existing disturbance of the muscle structure, particularly if there is a hematoma.

US also allows real-time functional and dynamic assessment of muscles and tendons, combines this information with physiological assessment of blood flow in Doppler imaging, is well tolerated, noninvasive and cost-effective.

Muscle injuries are classified according to the mechanism of injury into direct or indirect trauma.

- Direct injuries, such as lacerations or contusions, are caused by external forces that cause a blunt trauma of the muscular tissue with associated hematoma at the injured site. The most frequently involved muscles in athletes are the exposed rectus femoris and the intermediate vastus, lying next to the bone with limited space for movement.
- Indirect injuries, such as Delayed Onset Muscle Soreness (DOMS), lengthenings and strains, are caused by a sudden forced lengthening over the viscoelastic limits of muscles and occurring during a powerful contraction (internal force). The typical site of injury is the muscle-tendon junction, a biomechanical weak point. The quadriceps muscle and the hamstrings are
frequently affected since they have large intramuscular or central tendons and can be injured along this interface.

Certain muscle groups are predisposed to injury depending on the type of sport: in soccer and basketball players lower limb are often involved (hamstrings, adductors, quadriceps and calf muscles) and injuries typically occur in non-contact situations.

**Methods and materials**

During a period of three years 114 athletes, mainly soccer and basketball players with a history of traumatic muscle injuries mainly to lower limbs, were examined with US.

The US examination was performed from 6 to 72 hours after the trauma and compared with MRI, performed from 2 to 7 days after the trauma.

US was performed using linear high frequencies probes (7.5-13 MHz) for superficial lesions and hematomas, whereas convex-array traducers (3.5-7 MHz) were used in case of deep lesions to have a superior spatial resolution.

MRI was performed using axial spin echo T1-weighted, axial spin echo T2-w and coronal short time inversion recovery (STIR) sequences. Additional scans were performed in all planes depending on the anatomical site of the lesion.

US and MRI assessed the presence of hematomas, the characteristics and extension of muscle injury and if there was a structural lesion with its approximate size.

Doppler evaluation was performed to assess the blood flow signal.

Traumas were distinguished into minor and major traumas according to the intensity of the injured force and the degree of muscle damage.

Minor traumas included Delayed-onset muscle soreness (DOMS), lengthening and mild contusions.

Major traumas were defined as strains and moderate-severe contusions.

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**Indirect traumas**
Direct traumas

Direct injuries as contusions were graded according to the Jackson-Feagin classification [1] that defined a three-stage clinical grading system:

- mild contusion: range of motion (ROM) less than one-third normal;
- moderate contusion: ROM one-third to two-thirds of normal;
- severe contusion: greater than two-thirds loss of ROM.

Indirect injuries were classified according to the following grades:

- first-degree lesion (only few myofibers involved);
- second-degree lesion (less than ¾ of muscle axial area is damaged);
- third-degree lesion incomplete (more than ¾ of muscle axial area is damaged);
- third-degree lesion complete (total interruption).

Results

US revealed 48 minor and 66 major traumas.

The concordance with MRI was in 99 patients (but the extent of the lesions was generally higher with MRI).

Minor traumas

US demonstrated low sensitivity in detection of minor traumas because US findings were vague and indistinct with poor oedema and without evident fiber disruption (89% mild contusions, 76% lengthenings, 59% DOMS).

In mild contusions, a blunt external force caused a direct trauma. The athlete experienced a dull, diffuse pain but it was able to continue sport activity. MRI showed focal hyperintensity both in T1-w, T2-w and STIR sequences due to the presence of small hematoma and oedema. Mild contusions were not accompanied by a gross structural damage of muscle tissue and US might show only the presence of small hematoma as a focal hypoechogenic area at the injury site, with surrounding inhomogeneous hyperechogenicity due to haemorrhagic infarction.

Lengthenings were characterized by acute localized muscle pain during exercise, exacerbated by contraction or stretching. All patients recalled the precise time of pain onset.
Delayed onset muscle soreness (DOMS) describes a clinical entity characterized by muscular pain, soreness, and swelling that occurs several hours after unaccustomed physical exercise. Delayed soreness typically begins to develop 12-24 hours after the exercise and can increase until 24-72 hours after the exercise has been performed. It resolves spontaneously usually within a week, but if unrecognised and untreated, it may cause structural injuries such as partial tears. Typically, in DOMS several muscles across compartments are affected with a typical geographical distribution. [2]

In lengthenings and DOMS, MRI showed signal hyperintensity on fluid-sensitive sequences (T2-w and STIR) due exclusively to the presence of muscular oedema, without signal alterations in T1-w sequences in absence of evident muscular damage. In comparison US examination was often normal and referred false negative results because there were only slight muscle alterations without significant fiber disruption.

In all these cases the discordant findings between US and MRI scans typically consisted in subtle hyperintensity on T2-w images without muscle fiber tearing in T1-w sequences.

**Major traumas**

US demonstrated high sensitivity for major traumas (95% strains, 100% severe contusions).

Strains were caused by indirect injury and the lesion was typically sited along the musculotendinous junction with the presence of hematoma and oedema. Muscles frequently involved crossed two joints and were stretched in eccentric contractions during strenuous activity.

In moderate-severe contusions, the athletes referred a sudden onset of pain localized in the site of injury; extensive subcutaneous ecchymosis was present distal to the lesion due to intermuscular hematomas.

In these cases both US and MRI correctly detected muscular lesions with grossly interrupted muscle fibers (including muscular retractions), extensive intermuscular hematoma secondary to fascial injury and extensive edema in the surrounding soft tissues.

In severe contusions, there was complete agreement (100%) between MRI and US as regard the lesion site and type, whereas the extent of the lesions was generally higher with MRI.

**Images for this section:**
Fig. 1: Us sensitivity in major and minor traumas.
Fig. 2: Classification of muscle injuries caused by indirect trauma. a) First-degree lesion (only few myofibers); b) second-degree lesion (less than ¾ of muscle axial area); c) third-degree lesion incomplete (more than ¾ of muscle axial area); d) third-degree lesion complete (total interruption).
Fig. 3: Case 1: 1st degree left biceps femoris tear. Male 34 yr., professional soccer player. First US 48 hours after the injury: focal hypoechogenic area due to hematoma with surrounding inhomogeneous hyperechogenicity due to haemorrhagic infarction.
Fig. 4: Case 1: 1st degree left biceps femoris tear. Male 34 yr., professional soccer player. MRI performed 50 hours after the injury: a) Axial T2-w images b,c,d) Axial, coronal and sagittal T2-w with fat suppression images (fat sat): focal area of increased signal of the left biceps femoris consistent with muscle contusion, localized myofibers disruption without gross tear (small hematoma and oedema).
**Fig. 5:** Case 1: 1st degree left biceps femoris tear. Male 34 yr., professional soccer player. US performed 12, 20 and 26 days from the injury: US shows progressive reduction of the focal hypoechogenic area and final resolution.
Fig. 6: Case 2: Iliopsoas musculotendinous junction tear (II degree). Male 17 yr., basketball player. US performed one week after the trauma: a) long-axis: wide hematoma of iliopsoas musculotendinous junction b) panoramic view of the wide hematoma.

Fig. 7: Case 2: Iliopsoas musculotendinous junction tear (II degree). Male 17 yr., basketball player. MRI (low field) performed after 10 days: a,b,c) T2-w images: d)STIR sequence: MRI demonstrates increased signal area in the iliopsoas musculotendinous junction, with the presence of intramuscular hematoma. The distal iliopsoas tendon is intact.
Fig. 8: Case 3: Severe haematoma after indirect trauma in soccer player with suspected acute compartment syndrome. US shows a severe inhomogeneous hypo/hyperechogenic haematoma.
Fig. 9: Case 3: Severe haematoma after indirect trauma in soccer player with suspected acute compartment syndrome. Severe hematoma of rectus femoris muscle (III degree): Axial and coronal T2 FSE with and without fat suppression MR images through the middle of the thigh show an area of high signal cleft in the mid-substance of the rectus femoris muscle. The cleft is filled with high signal material on T2-weighted images, consistent with hematoma and edema. The margins of the cleft are sharply defined and there is extensive edema in the surrounding soft tissues. The complete tear of the muscle belly is associated with proximal and distal retraction of the stumps. The tendon is not significantly involved.
Fig. 10: Case 3: Severe haematoma after indirect trauma in soccer player with suspected acute compartment syndrome. Severe hematoma of rectus femoris muscle (III degree). a) STIR sagittal images show a severe hematoma of rectus femoris muscle, extensive edema in the surrounding soft tissues and “fan” edema of vastus medialis and vastus intermedius. b) Angiography shows no arterial blush from the descending branches of the lateral femoral circumflex artery.
**Fig. 11:** Case 4: Delayed Onset Muscle Soreness (DOMS) Male 36 yr., amateur soccer player. US examination shows an inhomogeneous hypo-hyperechogenicity due to oedema of the soleus muscle.
Fig. 12: Case 4: Delayed Onset Muscle Soreness (DOMS) Male 36 yr., amateur soccer player. MRI performed immediately after US examination shows signal hyperintensity in axial T2-w and STIR sequences due exclusively to oedema of the soleus muscle.
**Fig. 13:** Case 5: Lengthening of right pectineus muscle. Male 18 yr., volleyball player. US shows an inhomogeneous hypo-hyperechogenicity due to oedema of the right pectineus muscle.
Fig. 14: Case 5: Lengthening of right pectineus muscle. Male 18 yr., volleyball player. MRI shows signal hyperintensity in axial SE T2-w and coronal STIR sequences due exclusively to oedema of the right pectineus muscle, without signal alterations in the axial and coronal SE T1-w sequences.
Conclusion

MRI is considered the gold standard examination in the detection of muscle traumas, but the advantages of US over MRI in the acute and hyperacute phase consist in decreased cost, wide availability and superior portability.

US also has an increased spatial resolution over MRI because it allows additional scans in all planes depending on the anatomical site of the lesions and a dynamic evaluation of the injury. [2, 3]

US examination is limited by operator dependency and limited field of view (FOV) acquisition. Linear high-frequencies arrays have low tissue penetration capability and US can miss deep lesions. In these cases, MRI should be regarded as the imaging modality of choice because a panoramic and extended FOV allows a more accurate assessment of subtle and deep muscle injuries. [1]

Another important limit of US examination is that US demonstrated low sensitivity in detection of minor traumas (75% vs 97% in case of major traumas), because US findings are vague and indistinct with poor oedema and without significant fiber disruption. This was due to the ultrasonographic lack of contrast between the relatively low echotexture of normal muscle and the low echogenicity of muscle edema in mild injuries.

Megliola et al [4] confirmed this discrepancy between minor and major traumas (US sensibility 76.9% vs 92.7%) and demonstrated that the ability of US to evaluate muscle traumas is related to the presence of severe muscle oedema. Studying 26 patients with minor traumas, Megliola et al observed that US sensibility was low in detecting DOMS (57%), lengthening (80%) and mild contusions (87.5%) because of the presence of small oedema and no significant muscle damage. Therefore, in the same study, Megliola et al also observed that in 29 patients with major traumas (severe contusions), US was in total agreement with MRI in detecting the presence and the extent of large hematomas.

Connell et al [5] studied 60 professional football players with suspected acute hamstring strain and confirmed that MRI and US are equally useful to identify muscle injuries at baseline. The extent of the injuries was consistently larger on MRI than on ultrasonography and this discrepancy was due to the increased sensitivity of MRI in showing subtle edema.

Studying 17 patients suffering of acute injury of the rectus femoris, Bianchi et al [6] confirmed that US demonstrated high sensibility in detection of superficial muscular lesions and hematomas and that ultrasonographic data were straightly correlated with
MR findings. Bianchi et al concluded that US should be considered the first-line technique in the evaluation of injuries of superficial muscles.

Muscle injuries are extremely common either in professional or in amateur athletes and are a major cause of loss of competitive playing time. Imaging now plays an increasing role in lesion detection, grading and prognosis of muscle injury.

US is the first-line technique for examination of muscle injuries, because it is readily accessible, cheap and dynamic. US also have the benefits of real-time evaluation and Doppler imaging and the ability to perform interventional procedures.

Direct and indirect muscle injuries and their complications are readily assessed using either US or MRI (the gold standard imaging technique), but US is preferred in follow up.

The main limit of US examination is evident in muscular injuries with only slight muscle alterations and without significant fiber disruption and may produce false negative results such as in mild contusions, lengthenings and DOMS.

Personal information

References


