Research article

The use of ultrasound in athletes

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ABSTRACT
Ultrasound is being used by sports physicians in their daily practice to problem solve, but there is still a reluctance for some radiologists to embrace this technique. It has become the “stethoscope” of the sports physician as it is freely available to have in the office setting (Tok, et al. [1]). This has been made possible by advances in technology making it cheaper and more affordable. In the United Kingdom, ultrasound has been performed by sports physicians, rheumatologists, surgeons, physiotherapists, podiatrists, anaesthetists, neurologists and emergency care physicians. It has become a core area of the curriculum in some of these specialties. In athletes it not only provides confirmation of the diagnosis but leads to a better treatment algorithm and can be used to direct intervention.

Radiologists need to be aware of its strengths and weaknesses even if they are not able to perform such examinations.

1. Introduction
This article will highlight the application of diagnostic ultrasound in the musculoskeletal system, showing when its use is complementary, useful or essential in diagnosis. It touches on the reasons why it is not universally accepted in musculoskeletal imaging.

2. Why is ultrasound an important part of imaging?
1 Ultrasound has a better resolution than MRI for soft tissue and therefore the examination can be refined to look at small nerves, ligaments, etc.
2 It can determine whether a mass is cystic or solid and refine the diagnosis in many cases.
3 It can examine structures dynamically with motion of the limb and stress to a site such as a joint can be applied to assess stability.
4 Without the use of injections, vascularity can be measured using colour or power Doppler. Very low flow can be seen with new microvascular applications on some machines permitting analysis of normal blood flow in tendons.
5 The examination can be directed to exactly where the patient has symptoms and both sides of the patient can be examined at the same appointment so that the 2 limbs can be compared, for example both shoulders.
6 The examiner has the opportunity to talk to the patient and find out more information concerning their problem and concerns.
7 It can be used to guide injections into joints and soft tissues, usually immediately after the diagnostic examination.

3. Why is ultrasound not universally accepted?
1 It takes a long time to learn how to perform diagnostic musculoskeletal ultrasound.
2 High quality technique is mandatory, not pushing too hard on the patient’s skin because you will hurt the patient, make small pockets of fluid disappear in tendon sheaths, etc.
3 Detailed anatomical knowledge is vital and the operator must be able to translate this into the ultrasound picture. This knowledge must be detailed and sound, and probably at a higher level than required to interpret MRI: diagnosis depends on what is seen at the time of scanning as you will not get a second look, or be able to ask advice from colleagues.
4 You have to touch the patient and this is not necessarily a skill that all practitioners feel comfortable with.
5 The examiner will have a close connection with the patient throughout the examination and will be asked lots of questions which some operators may find awkward.
6 There may be financial penalties in using ultrasound compared to MRI and if in the private sector this may become a consideration.

4. When is ultrasound complementary in imaging?
When an MRI has been performed for a superficial structure, ultrasound can help refine the diagnosis. It can determine whether something is cystic or solid in the case of a ganglion versus for example a focal pigmented villonodular synovitis (PVNS) of the finger. It can demonstrate tethering of a lesion with its dynamic capability.
5. When is ultrasound useless in imaging?

Muscle injury less than 6 hours old. When a muscle is initially injured the blood surrounding the muscle fibres is highly echogenic and therefore it merges with the fibrofatty interfaces of the muscle making it invisible to ultrasound discrimination. This means that pitch side ultrasound for acute muscle injury is a useless and a misleading examination. MRI should be used to assess an acute injury in the first few hours. MRI becomes less reliable due to widespread adjacent oedema which is apparent more than 6–12 hours after an injury whilst ultrasound become more sensitive and precise in this same interval.

Shoulder instability and labral tears. It may demonstrate the movement of the humeral head with respect to the glenoid but cannot show the glenoid labrum or glenohumeral ligaments in their entirety.

Hip labral tears You may see a paralabral cyst with ultrasound but you may not directly be able to visualise the labral tear in association with this cyst. You will also not be able to assess the articular cartilage and fully assess the presence of a cam or pincer impingement.

Knee internal derangement. It is useful in visualising the extensor mechanism, peripheral ligaments and tendons but cannot assess the ACL and PCL and menisci adequately.

Microfracturing cannot be seen by ultrasound. This may be the cause of the patient’s pain. Fractures are also difficult to fully appreciate especially if they are intra-articular. However, a fracture can often be identified by ultrasound as being present due to cortical disruption and the history. There may also be a haemarthrosis present that will be seen with US in the presence of an acute intra-articular fracture.

6. When is ultrasound useful in diagnosis?

6.1. Muscles

Muscle injury 6 hours post injury can easily be seen due to the early liquefaction of haematoma. Disruption of the muscle fibres will be seen directly by ultrasound and dynamic stress can be used with contraction of the muscle to open up a tear [2]. Liquefaction of the haematoma will show areas of low echogenicity and on dynamic stress of the area, movement can be seen within the liquid which can be accentuated by using colour Doppler.

Follow-up of muscle injury can successfully be done with ultrasound. The liquefying haematoma will decrease in size over time (Fig. 1). If this does not happen then history of a repeat injury should be sought. Occasionally even in the context of injury there may be an underlying abnormality of the muscle such as a tumour. If the liquefying haematoma does not regress then this should be a consideration and MRI performed to assess further.

Scarring of the muscle is easily seen with ultrasound. As you can directly visualise the muscle fibres there will be a loss of the normal fibrillary pattern and an area of high echogenicity in an established scar. There may also be tethering. This can be very difficult to see with MRI.

Myositis ossificans can be detected in its early phases which is often overlooked with MRI. Early calcification is easily seen as an area of high echogenicity with acoustic shadowing behind it. The patient often notices that the region of the muscle tear has increased in size and become more tense or firmer to feel. If there is any doubt, then an x-ray or CT can also be performed to examine for myositis ossificans.

6.2. Tendon

Tendinosis can be identified by the presence of a swollen tendon which has lost its normal fibrillary pattern and is lower in echogenicity. There may be areas of focal low echogenicity which is due to mucoid degeneration or delamination. A split of the tendon can easily be seen. Vascularity within the tendon can also be assessed by using colour or power Doppler (Fig. 2). Specific areas of delamination are difficult to see with MRI and it cannot be used to assess neovascularisation without the use of intravenous contrast. Ultrasound can be used to follow up treatment and rehabilitation. Although there may be a lag in the imaging improvement as compared to the clinical improvement it can be helpful to reassure the athlete [3]. Elastography may be used to detect subtle changes in a tendon that may not be visible by grey scale examination and may be used for follow up of the patient following treatment [4].

Rupture

When a tendon has ruptured then ultrasound can easily see the gap between the tendon ends where the rupture has occurred. It will also demonstrate whether the tendon has avulsed a small bony fragment. Small bony fragments are difficult to see with MRI but easy to see using ultrasound. Movement can be used to enhance the conspicuity of a rupture by the lack of coordinated movement in a similar direction of all tendon fibres. The fibres will be distracted away from one another rather than moving together and there may be a specific artefact with acoustic shadowing behind the tendon due to the puckering effect of the discontinuous tendon that has been distracted (Fig. 3).

It can be used to mark the skin where the tendon rupture has occurred. This is commonly used in the context of Achilles tendon rupture and finger tendon ruptures when showing the surgeon where the tendon ends lie can result in a much smaller incision and better post-operative course (Fig. 4).

Shoulder impingement

Direct visualisation of the rotator cuff is straightforward with ultrasound. Small tears can be appreciated in much more detail, as when using MRI oedema within the tendon can be either tendinosis or partial tearing. With the use of dynamic ultrasound and colour Doppler the neovascularisation of the tendinosis will be seen and small tears will open up on dynamic stress of the tendon/muscle unit [5].

Impingement of tendon will be seen on dynamic motion. Ultrasound allows direct visualisation of impingement at the coracoacromial ligament and the subscapularis bursa. Calcification in a tendon may be seen to cause impingement.

The long head of biceps may be unstable in the bicipital groove. This can be seen on dynamic motion of the shoulder whereas it may be sitting in the groove on MRI due to the static nature of the imaging. Ultrasound is much more sensitive and specific for tendon subluxation.

Elbow

In tendinosis the patient can direct the examination to the exact location of pain and this is more refined when there is a small area of tendinosis with neovascularisation.

6.3. Ligaments and retinacula

Rupture of a ligament is easily identified with ultrasound. Dynamic stress of the joint involved can be used at the time of examination to make the diagnosis easier. Often the plane of a ligament in the body is difficult to appreciate on MRI due to the rigid scan plane protocols that are used and variation in anatomy. The ultrasound probe can move in any direction along the line of a superficial ligament to assess it in its entirety, for example in the ankle the anterior tibio-fibular, anterior...
The talo-fibular and calcaneo-fibular ligaments have very different orientations and are not well seen on MRI if only a fixed scan plane is used (Fig. 5). Ultrasound can easily assess these ligaments and look for small avulsion fractures which are often present when there is injury.

In assessing the stability of the elbow, stress can be placed on the side of the joint and the joint can be seen to open up when there is ligament rupture, for example in lateral ligament disruption.

The annular pulleys of the fingers are readily identified; dynamic examination detects rupture or thickening with finger “triggering”.

The presence of neovascularity around a ligament using ultrasound with colour or power Doppler can assess the age of a ligament injury. This is very useful in the context of an ankle sprain when a patient may have repeat injuries.

Thickening and bowing of the retinaculae is easily seen and although this is also seen with MRI it may be more easily apparent with ultrasound on dynamic imaging.

6.4. Bone

Sometimes pain may be due to a stress fracture. If located in a superficial area such as a metatarsal or anterior tibia, the periosteal reaction with adjacent neovascularisation will be detected by US. Enthesopathy where a tendon attaches to bone will also be identified by US as irregularity of the cortical bone at the tendon bone interface [1].

7. When is ultrasound essential in diagnosis?

7.1. Clicks and clunks

Clicks and clunks cannot be assessed by any other imaging technique. It is a combination of an audible clunk or click, feeling of movement under the probe head and visualisation of structure that is moving abnormally that cannot be appreciated with MRI, radiographs or CT.

The following are commonly seen with clunks or clicks around joints.

- Hip - Iliopsoas tendon, iliotibial band, and sartorius.
- Knee - Iliotibial band and gastrocnemius.
- Ankle - peroneal subluxation and pseudo-subluxation.
- Foot – the Mulder’s click manoeuvre in the assessment of Morton’s neuroma
- Shoulder – Long head of biceps dislocation
- Elbow – Ulnar nerve dislocation
- Wrist – snapping syndromes due to tendons that are tendinopathic moving abnormally against one another for example in De Quervain’s tenosynovitis.
- The presence of soft tissue masses next to tendons and ligaments ie PVNS, ganglions.

7.2. Direct visualisation of nerves

Small nerves can be directly visualised by ultrasound. This is a growing area of use as any accessible nerve can be identified from the brachial plexus to the digital nerves of the hands and within the lower limb. An abnormal nerve will appear swollen and of low echogenicity than normal and will lose its normal fibrillary pattern. It may also show neovascularisation. Nerves are being assessed in the context of trauma where they may be cut, tumours, and abnormality due to compression for example in the cubital and carpal tunnels [6–8].

7.3. Muscle

Small muscle hernia identification is not possible on MRI with the patient in a relaxed mode. The patient can clearly show where the abnormality occurs. In MRI the use of skin markers where the patient reports the abnormality can sometimes obscure the problem. In most cases of small muscle hernias the protrusion is not present in a relaxed phase and therefore the use of muscle contraction or a certain movement is needed to make it appear. Ultrasound can scan dynamically while the muscle is being moved to identify these hernias and make a positive diagnosis (Fig. 6).
7.4. Avulsion fractures

These will often be missed by using MRI due to the poor line pair resolution and inconspicuity.

Ultrasound can easily detect these fractures in superficial tissues as reflectivity of bone fragments increases their conspicuity. Fractures of small bones and sesamoids are also seen easily if superficial as in the hands and feet (Fig. 7a and b).

7.5. Soft tissue abnormalities of the hands and feet

Ultrasound due to its excellent line pair resolution should be the first choice for looking at joints, tendons and ligaments in the hands and feet. When there is a soft tissue mass present it is also very useful in looking for the presence of ganglia versus solid tumours such as PVNS of the tendon sheath, or glomus tumours. Note that ultrasound is transmitted through the nails of the fingers or toes and mass lesions in the nail bed are easily studied [9].
7.6. Visualisation of soft tissue problems next to metalwork

When an athlete has a fracture and internal fixation using plates and screws is necessary the use of MRI is impossible in the context of tendon and nerve impingement. Ultrasound can directly assess the presence of impingement of a tendon or nerve next to metalwork and therefore make the diagnosis. Dynamic examination is particularly helpful in these circumstances [7].

7.7. Identification of small foreign bodies

Identification of small foreign bodies in the superficial soft tissue. MRI will not identify tiny foreign bodies. Ultrasound can see a foreign body in soft tissue as small as 0.1 mm. The examination can be directed at the site of the patient’s concern and the exact location of the foreign body can be determined. The site can also be marked for foreign body extraction and if necessary a localisation wire can be placed under ultrasound guidance to improve the success rate and shorten surgical exploration [10].

7.8. Patients with intracranial clips or other devices preventing MRI

When a patient cannot undergo an MRI because of claustrophobia or implanted devices then the use of ultrasound for soft tissue diagnosis is essential [11].

7.9. Severe claustrophobia

Up to 20 percent of the population shows some claustrophobia. These patients will not be able to enter an MRI scanner without movement, which makes the assessment of small soft tissue problems impossible. Sedation and open MRI scanners can be considered but often ultrasound is as good a way of examination if not better than MRI for a soft tissue problem.

8. Additional benefits of ultrasound

It is now the imaging technique of choice in guiding injections into soft tissue. With the increased accuracy of a guided injection in comparison to a non-guided injection, patients are appreciating that guided injections are not only safer but can be more beneficial. Although there is evidence that steroid injections placed near a structure can add benefit, new treatments such as sodium hyaluronic acid will only treat the affected area if accurately placed in the joint or tendon sheath. Ultrasound guidance also allows the use of smaller volumes of local anaesthetic and steroid.

Patients prefer the experience of an ultrasound guided injection in comparison to a fluoroscopic guided injection due to the easy access to the patient and lack of the confines of machinery. The patient can also adopt a more comfortable position during the procedure.

Ultrasound guided injections are also faster than fluoroscopic guided injections as the needle is seen in real-time and the injection can be observed. They are less painful as bony landmarks are not needed to access joints and soft tissue (Fig. 8). Touching the periosteum with the needle tip is often very tender which accounts for this observation.

9. Conclusion

It is always difficult when talking about musculoskeletal ultrasound not to make an article sound as though you are talking about non-athletes, but athletes get the same problems as the general population. The only difference is they are more likely to want advice quickly if it is stopping them performing their sport or if they are at an elite level they will need an immediate confirmation of diagnosis so that a correct treatment strategy can be instigated.

Ultrasound can offer this diagnostic input very rapidly due to the easy access to ultrasound machines. It does however need to be performed by somebody with the appropriate skills in using it for musculoskeletal diagnosis. Discussion can be made between the sports physian, radiologist, physiotherapist and other individuals looking after the athlete with an informed knowledge of where ultrasound guided intervention may be useful. The radiologist is also best placed to know when other imaging techniques would be a useful adjunct in refining an athlete’s diagnosis.

Conflict of interest

The author declares that there is no conflict of interest.

References


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Fig. 7. a) US showing a fractured medial sesamoid compared to the asymptomatic bifid medial sesamoid in the other foot b) the CT of the same sesamoid fracture.

Fig. 8. US guided injection into the per anserinus bursa.


