

# The value of ultrasound in sports medicine

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**Musculoskeletal ultrasound is increasingly being used in the evaluation and treatment of sports-related injuries. This technique is widely available, rapid, and has a high patient acceptance. Its multiplanar capability and dynamic real-time imaging can be correlated with clinical symptoms and compared to contralateral asymptomatic structures.**

Athletes are vulnerable to frequent and sometimes unique injuries, often related to overuse. This applies not only to elite or competitive athletes but increasingly to a large percentage of the general population who are involved in various sporting activities.

Musculoskeletal ultrasound is a rapidly evolving technique that is gaining popularity for the evaluation and treatment of sports-related injuries. A number of recent technical developments have seen marked improvement in musculoskeletal ultrasound with the introduction of higher resolution linear array probes, tissue harmonic imaging, two-dimensional matrix probe technology, extended field of view imaging and power Doppler sonography. These sophisticated technological advances are making it easier than ever to detect and characterize a variety of musculoskeletal pathologies.

Inherent advantages of sonography include accessibility, quick scan time, multiplanar capability and the ability to perform dynamic real-time imaging which can be correlated with clinical symptoms and compared to contralateral asymptomatic structures. In addition the technique has high patient acceptance as it is a non-invasive test, which does not use ionizing radiation and is not associated with any deleterious side effects.

With continuing emphasis on health-care cost containment musculoskeletal ultrasound is an effective but less expensive alternative to magnetic resonance imaging (MRI). However, the major notable drawback of musculoskeletal ultrasound is its operator dependency. The quality and consistency of the modality relies on the expertise of the examiner.

## GENERAL PRINCIPLES AND TECHNICAL FEATURES

In general, the structures examined with musculoskeletal ultrasound will be superficial, therefore high frequency probes (>7–12 MHz) with linear array transducers are usually the most appropriate choice, although for deeper structures lower frequency probes (5–7 MHz) and transducers may be used.

Colour and power Doppler can be used to show the degree of vascularity associated with inflammatory processes. The split-screen function can be used to compare sides and also increase the field of view. However, newer developments, using extended field of view capability, permits display of large continuous sections of anatomy preserving spatial resolution without distorting structural relationships as reported by Barberie et al (1998) and Lin et al (1999).

## ULTRASOUND APPEARANCE OF NORMAL MUSCULOSKELETAL STRUCTURES

Evaluation of tendon abnormality is the most common clinical indication for musculoskeletal ultrasound. The sonographic appearances of tendons are uniform, producing a fibrillar pattern of parallel hyperechoic lines in the longitudinal plane and hyperechoic round-to-ovoid shape in the transverse plane. Ligaments have a similar appearance to tendons but are static stabilizers connecting bone to bone. They tend to have a more compact fibrillar hyperechoic pattern.

Fornage (1987) described an important artefact, anisotropy, produced by a non-perpendicular ultrasound beam, which can make tendons and ligaments appear very hypoechoic. This can be useful in finding structures which have a complex non-linear course but must not be mis-

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taken for pathology. Hyperechogenicity can always be produced in normal structures by making the probe perpendicular to the structure that is being examined, however, pathology always appears hypoechoic.

Normal skeletal muscle demonstrates low- to mid-level echogenicity. In the longitudinal plane brightly echogenic intermuscular septae and perimysium give a 'herring-bone' pattern. In the transverse plane these structures produce echogenic short lines or dots with a reticular echogenic pattern of intra- and intermuscular septa.

Bone cortex appears as an echogenic surface with posterior shadowing, which at articular surfaces has a thin hypoechoic rim paralleling the surface, which represents hyaline cartilage.

### MUSCULOSKELETAL ULTRASOUND IN THE UPPER EXTREMITY

Musculoskeletal ultrasound is particularly useful in the assessment of tendinous injuries of the shoulder, elbow and wrist in athletes participating in throwing, racket and weightlifting sports.

#### Shoulder

Assessment of the integrity of the rotator cuff is the primary indication for shoulder sonography. The supraspinatus tendon is most commonly injured at its insertion onto the greater tuberosity, in isolation or in combination with other rotator cuff tendons.

A full-thickness tear (*Figure 1a*) is diagnosed when disruption of the tendon extends from the articular to the bursal surface of the tendon. Secondary signs of a full-thickness tear reported by Wiener and Seitz (1993), Hollister et al (1995) and Wohlwend et al (1998) include volume loss with associated flattening or concavity of the echogenic subdeltoid bursal fat (often accentuated on compression), substantial bursal fluid,

which may highlight the hyaline cartilage as a white line, the so-called 'cartilage interface sign', and cortical irregularity of the humeral tuberosity adjacent to the tear. Middleton et al (1986) and Hollister et al (1995) have shown that when fluid is seen in the subacromial bursa and within the joint the probability of a rotator cuff tear is 95%.

Sonographic findings of partial tears (*Figure 1b*) reported by van Holsbeeck et al (1995) reveal hypoechoic defects reaching either the bursal or articular surface, typically with no volume loss or subdeltoid contour abnormality.

In experienced hands the accuracy for correctly diagnosing rotator cuff tears is high, reported by Wiener and Seitz (1993) to be 92%, with sensitivities of 93–100% and specificities of 85–94% as reported by Teefey et al (1999) and van Holsbeeck et al (1995).

Tendinopathy or tendonitis, which can be associated with pain and impingement during arm abduction, may reveal thickening and heterogeneity within the tendon. There may also be crepitus during active and passive arm abduction in association with fluid forced out of a subacromial bursa during arm abduction. Calcific deposits may also be identified within the tendon or adjacent bursa as described by Farin and Jaroma (1995).

Biceps tenosynovitis demonstrates fluid surrounding the long head of biceps tendon in the bicipital groove. If there is synovitis there may be increased colour Doppler flow with the inflamed synovium. This tendon can be displaced medially from without the groove in association with a tear in the subscapularis tendon as described by Farin et al (1995).

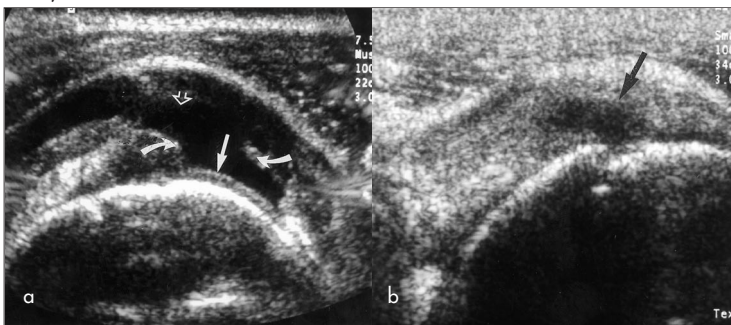
#### Elbow

Sonography is sensitive for the identification of a joint effusion in the elbow as the joint capsule is distended by anechoic fluid. This is best seen in the posterior recess with the elbow flexed. Olecranon bursitis is identified as an anechoic or hypoechoic bursa, which may demonstrate increased flow on power Doppler sonography.

The insertion of both the triceps and biceps can be easily identified on ultrasound, allowing diagnosis of tendinopathy or avulsions as described by Lozano and Alonso (1995). Medial or lateral epicondylitis is identified as thickening of the common flexor or extensor tendons, which may contain calcifications. Correlation with clinical symptoms can also be performed during transducer pressure.

The ulnar nerve is normally positioned in the cubital tunnel along the posteromedial aspect of the distal humerus, in a groove adjacent to the medial epicondyle. Cubital tunnel syndrome is a

**Figure 1.** a. Large full-thickness supraspinatus tear demonstrating a large anechoic bursal fluid collection (open arrow), the tendon ends (curved arrows), and the cartilage interface sign (straight arrow). b. Partial thickness supraspinatus tear reaching the articular surface (black arrow).



result of inflammation of the ulnar nerve manifested by an enlarged, hypoechoic appearance on ultrasound. Dynamic imaging may display intermittent subluxation of the ulnar nerve, a cause of ulnar neuritis.

### Hand and wrist

Ganglion cysts represent the most common soft tissue mass in the hand and wrist, which are usually attached to tendon sheaths, muscles or cartilage. They rarely have a connection to the joint unlike synovial cysts (*Figure 2*). They appear as anechoic well-defined structures with posterior acoustic enhancement.

Tenosynovitis of flexor or extensor tendons is a common sports injury which demonstrate distended, fluid-filled tendon sheaths (*Figure 3*) with occasionally increased colour Doppler flow as a result of inflamed synovium.

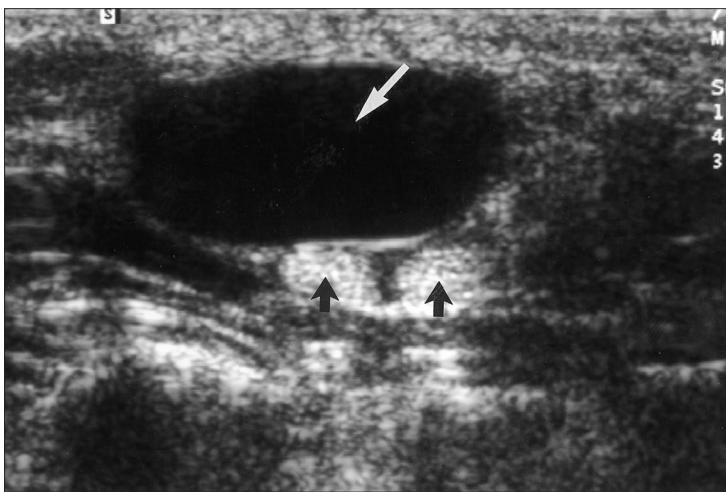
### MUSCULOSKELETAL ULTRASOUND IN THE LOWER EXTREMITY

Musculoskeletal ultrasound can be used to assess tendinous injuries, particularly of the knee, foot and ankle. However, superficial ligaments in the knee and ankle are easily visualized as are bursae around the hip joint. It is also very useful in identifying lower extremity joint effusion.

### Knee

Joint effusions are easily confirmed within the suprapatellar pouch in the extended knee as anechoic fluid deep to the quadriceps insertion. Lipohaemarthrosis indicating derangement of the knee has a characteristic appearance on ultrasound demonstrating a fluid–fluid level with anechoic fluid lying superior to dependant haemorrhage (*Figure 4*). Popliteal cysts (*Figure 5*) are easily diagnosed, usually lying posteromedial to the knee joint with a narrow slit-like connection insinuating between the semimembranosus and medial head of gastrocnemius muscles. Complications such as loose bodies and synovitis can be diagnosed on ultrasound.

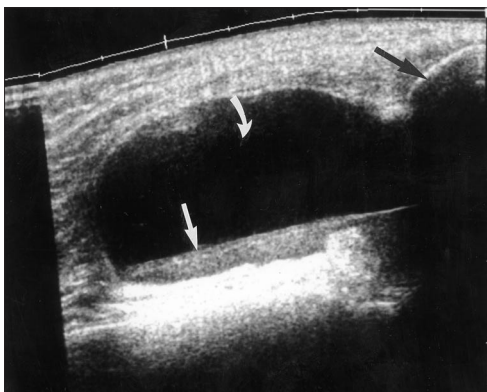
Quadriceps and patellar injuries are the most frequent sports injuries of the knee that are evaluated with ultrasound. Bianchi et al (1994) have shown that ultrasound is sensitive and specific in diagnosing quadriceps tendon rupture (*Figure 6*) as disruption of the tendon fibres separated from the superior pole of the patella by a hypoechoic fluid collection. Gentle traction on the patella and/or contraction of the rectus femoris may help differentiate a complete from a partial tear. Kahn et al (1996) have correlated the ultrasound appearances with histology in patellar tendonitis. Ultrasound demonstrates focal hypoechoogenicity



*Figure 2. Ganglion cyst. Large anechoic fluid collection (white arrow) lying superficial to flexor tendons at the wrist (black arrows).*

of the deep surface of the proximal patellar tendon (*Figure 7*), with variable increased flow on power Doppler sonography features also shown by Weinberg et al (1998). Medial and lateral collateral ligaments can be evaluated on ultrasound but MRI is a better test for significant injury to

*Figure 3. Tenosynovitis of the peroneal tendons of the ankle (curved white arrows) with anechoic surrounding fluid (open arrow).*



*Figure 4. Haemarthrosis. Large anechoic suprapatellar joint effusion (curved arrow) lying superior to the patella (black straight arrow). Echogenic haemorrhage (white straight arrow) lies dependently in the effusion.*

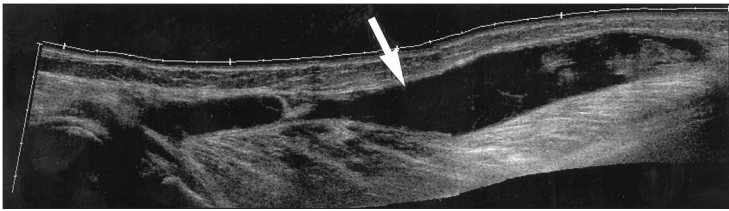


Figure 5. Large posteromedial popliteal cyst demonstrated in its full extent with an extended field of view. The cyst contains some echogenic debris.

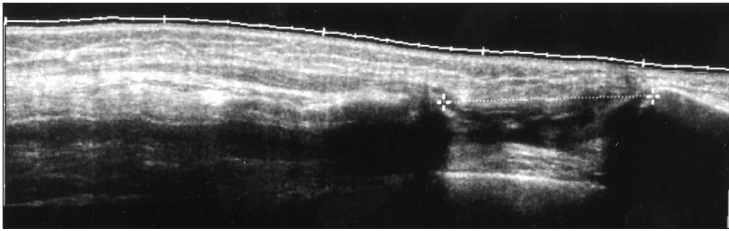


Figure 6. Rupture of the quadriceps tendon at the distal musculotendinous junction. The gap between the tendon ends is marked by callipers.

the knee as ultrasound cannot accurately identify associated internal derangement of the cruciate ligaments or menisci.

Ultrasound is useful, however, in identifying overuse sports injuries that are frequent in the knee, e.g. iliotibial band friction syndrome and pes anserine bursitis, by demonstrating inflamed thick-walled bursae and can also be used to guide local steroid injections to treat these conditions.

### Foot and ankle

Joint effusions are easily identified at the anterior tibiotalar articulation, with the plantar surface of the foot placed on the couch. Effusions can also be seen in the metatarsophalangeal and interphalangeal joints.

The Achilles tendon is frequently examined with ultrasound in the athlete. However, ultrasound is the best method of evaluating all the other tendons crossing the ankle joint as they have a complex course which is best suited to the inherent multiplanar capability of ultrasound. The excellent spatial resolution is ideal for the evalua-

tion of sports injuries in foot and ankle tendons, which include tendinopathy, tenosynovitis or paratendinitis, partial- and full-thickness tears.

Tendinopathy or tendinitis manifests as heterogeneity and swelling of the tendon. Tears demonstrate discontinuity within the tendon. Fessell and van Holsbeeck (1999) recommend dynamic ultrasound in defining the gap between tendon ends, which will also show if the ends can be brought into apposition during plantar flexion. This may help in deciding between conservative cast management and primary surgical repair.

Paratendinitis of the Achilles tendon demonstrates a hypoechoic band around the tendon, which may show increased power Doppler flow.

Ultrasound is very good at identifying anterior talofibular ligament injuries, the most commonly injured ankle ligament following an inversion injury. There is disruption of the normal fibrillar pattern and occasionally an associated bony avulsion injury is identified which is frequently missed on plain films.

Cardinal et al (1996) have described the sonographic appearances of plantar fasciitis on ultrasound. This is a frequent cause of heel pain in the athletic population and can be confidently diagnosed as marked thickening >4 mm as described by Gibbon and Long (1997) with occasionally increased power Doppler flow. This is particularly helpful if the clinical picture is unclear and can be useful in directing a local steroid injection to lie superficial to the inflamed plantar fascia.

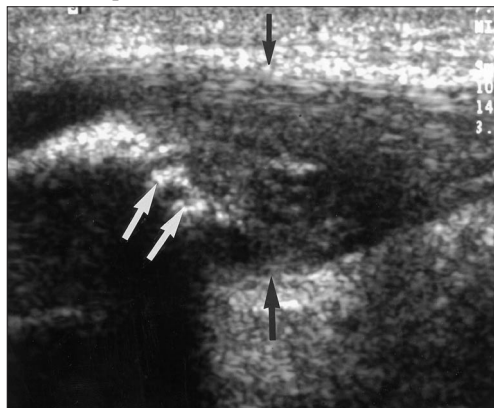
### Hip

Bursitis is the most common sports injury identified on ultrasound in either the greater trochanteric or the iliopsoas bursa. Localized tenderness is often present during the examination when the probe compresses a distended, inflamed, hypoechoic or anechoic bursa. Hip joint effusions can also be identified lying anterior to the femoral neck and aspiration can be directed under ultrasound guidance.

### Muscle injury

Injury to the hamstring, rectus femoris or gastrocnemius musculotendinous junction is the most common injury in athletes. Ultrasound allows identification of partial- or full-thickness tears within the musculotendinous junction, which muscle is injured, and where the injury is located in the muscle. As ultrasound has superior spatial resolution to MRI it can easily differentiate between grade 1 and grade 2 (partial tears) strains, which can appear very similar on MRI. This is important as management and prognosis for rehabilitation may be different.

Figure 7. Patellar tendonitis. Marked hypoechoic thickening in the proximal patellar tendon as it inserts into the lower pole of the patellar (black arrows). The proximal tendon contains calcification (white arrows) indicating chronicity.



Grade 1 strains may produce hyperechogenicity within the muscle in association with swelling (Figure 8a), however, ultrasound may often appear normal. Grade 2 (partial tears) strains on ultrasound demonstrate discontinuity of the echogenic perimysial striae because of disruption of muscle fibres (Figure 8b). These may be associated with an intramuscular fluid collection or a surrounding echogenic halo. Dynamic scans during active and passive contraction may increase the size of the defect making it more conspicuous, as described by Fornage (2000).

Ultrasound can also differentiate between muscle contusion caused by direct trauma and muscle strains. Contusions usually occur deeper in the muscle belly and crosses muscle boundaries. Initially they may be hyperechoic but can become fluid collections containing debris, which if tense and symptomatic can be drained under ultrasound guidance as described by Aspelin et al (1992).

Ultrasound can also be used to objectively follow up muscle injury and assess healing. It also identifies complications such as scar formation, which may cause tethering of the muscle during contraction.

## CONCLUSION

Musculoskeletal ultrasound represents an extension of the clinical examination in superficial sports injuries that affect tendons, ligaments and muscles. Its enhanced spatial resolution, patient acceptance, accessibility and relative inexpense recommends it for use in sports medicine. There are now portable dedicated musculoskeletal machines that are being used by health professionals involved in sport which aid management and rehabilitation decisions. Unlike other imaging modalities, ultrasound is inherently safe, with no associated deleterious effects. However, it must be stressed that musculoskeletal ultrasound does require dedicated training and correct scanning technique is just as important as a sound knowledge of anatomy and pathology. Without appropriate training image interpretation errors can lead to errors in diagnosis. **HM**

Conflict of interest: none.

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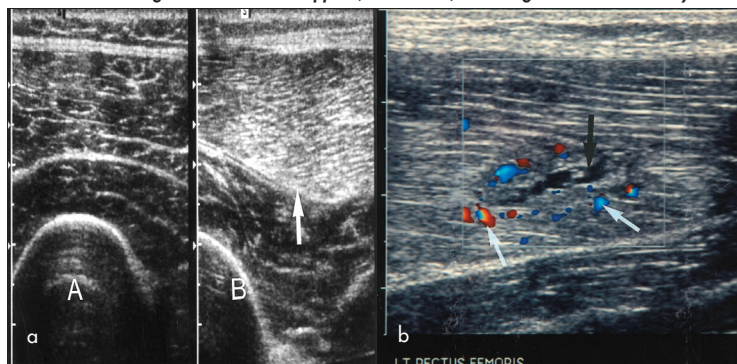
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Figure 8. Muscle injury. a. Grade 1 strain (arrow) in the left rectus femoris muscle (B) which is echogenic and swollen when compared to the right rectus femoris muscle (A). b. Grade 2 sprain (partial tear) of the biceps femoris muscle showing discontinuity in the muscle fibres (black arrow) note the surrounding increased colour Doppler (white arrow) indicating increased vascularity.



## KEY POINTS

- Musculoskeletal ultrasound represents an extension of the clinical examination in superficial sports injuries.
- Musculoskeletal ultrasound is easily accessible, inexpensive and patient acceptable as it is non-invasive and does not use ionizing radiation.
- It aids management and rehabilitation decisions in athletes.
- Musculoskeletal ultrasound requires dedicated training and technique to avoid interpretation errors which can lead to errors in diagnosis.