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# Musculoskeletal ultrasound imaging in sports

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### Abstract

Diagnosis of ligament and musculotendinous unit injury and overuse represents an increasingly important clinical problem in the athletic population. A review of recent literature on diagnostic ultrasound in sports medicine is presented. There is limited, but increasing, objective proof to support the use of diagnostic ultrasound using in common sports disorders. The improvements in ultrasound allow visualisation of soft tissue injuries in exquisite detail. The ability to perform interventional procedures real-time with ultrasound is an additional benefit compared to MRI. An overview is given of ultrasound applications in sports medicine. **Keywords: u**ltrasonography, ultrasound diagnosis, sports, musculoskeletal diseases, athletic injuries

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### Introduction

Diagnosis and treatment of ligament and musculotendinous unit (MTU) injury and overuse represents an increasingly important clinical problem in the athletic population. In the elite athlete significant financial and professional pressures may also exist that emphasize the need for rapid diagnosis.

While plain radiography and CT imaging have only a limited role in the diagnosis of MTU and ligament abnormalities, the improvements in ultrasound and magnetic resonance imaging (MRI) technology allow visualisation of soft tissue injuries in exquisite detail and readily demonstrate previously undetectable abnormalities[1,2]. The ability to perform interventional procedures real-time with ultrasound and Doppler imaging is an additional benefit compared to MRI that makes ultrasound the most appropriate diagnostic procedure to study superficial soft tissue lesions[3]. In addition, the cost of ultrasound is considerably less than MRI examinations for the patient and the community.

### Method

This review only considered publications from 1998 and later that were higher quality clinical studies or systematic reviews utilizing the quality assessment of diagnostic accuracy studies (Quadas) tool to assess and rank the research (see Table 1)[4]. There is limited, but increasing, objective proof to support the use of diagnostic ultrasound using these strict criteria, even in common sports disorders. It is important to keep in mind that these criteria include basic conditions utilizing state of the art high end equipment and experienced accredited radiologists or clinical physicians. Ultrasound and MRI are the most frequently used to study the shoulder and the knee.

*Table 1: QUADAS tool levels of efficacy for radiological examinations*

| Hierarchy | QUADAS efficacy level | Description |
|---|---|---|
| **1** | Technical | Can I see it? Is an adequate technique and hardware applied?<br>If yes -> level 2 |
| **2** | Diagnostic accuracy | With sensitivity, specificity, NPV and PPV: how well can I see it? Is the examination performed by an experienced radiologist?<br>If yes _> level 3 |
| **3** | Diagnostic thinking | Is there an impact on clinical diagnosis?<br>If yes -> level 4 |
| **4** | Therapeutic | Does the test change therapy?<br>If yes -> level 5 |
| **5** | Outcome | Does the therapy change patient outcome?<br>If yes -> level 6 |
| **6** | Societal | Cost-benefit, cost-effectiveness etc. |

Demonstration of efficacy at each lower level in this hierarchy is logically necessary, but not sufficient, to assure efficacy at higher levels.

## Specific anatomic sites

### Shoulder

Both diagnostic ultrasound and MRI are used to investigate the presence and severity of rotator cuff lesions. Current studies have not reached consensus regarding which is the more accurate and cost-effective technique. The accuracy of ultrasound for the preoperative evaluation of shoulder impingement syndrome, rotator cuff tear, and abnormalities of the long head of the biceps tendon compared to surgical outcome was determined by Read and Cullen. Ultrasound detected all of the full-thickness cuff tears identified at surgery with few false positive examinations [sens 100%, spec 89-97%, positive predictive value (PPV) 100%], but performed less well in detecting partial-thickness cuff tears (sens 46-79%, spec 94-97%, PPV 87%). Shoulder ultrasound, in the hands of an experienced radiologist with the use of modern high-resolution equipment, is highly sensitive in differentiating complete tears and partial-thickness tears (Figure 1). Dynamic scan criteria correctly diagnosed impingement in the majority of cases (sens 79%, PPV 96%). Abnormalities of the long head of the biceps were accurately diagnosed with the exception of low-grade tendinosis and the superior labral tear - anterior to posterior (SLAP) lesion. These results are similar to the best published results for MRI[5]. US is also sensitive to detect extracapsular biceps tendon pathology. (Figure 2) Dynamic ultrasound can help confirm, but not exclude, a clinical diagnosis of impingement[5]. Given that ultrasound is significantly cheaper and more available, US by a well trained and experienced radiologist or musculoskeletal physician should be considered a primary diagnostic tool for imaging the rotator cuff[6]. Hyperlaxity, a cause of secondary impingement, of the lead shoulder in golfers with shoulder pain can be missed by clinical exam, US and dynamic US[7].

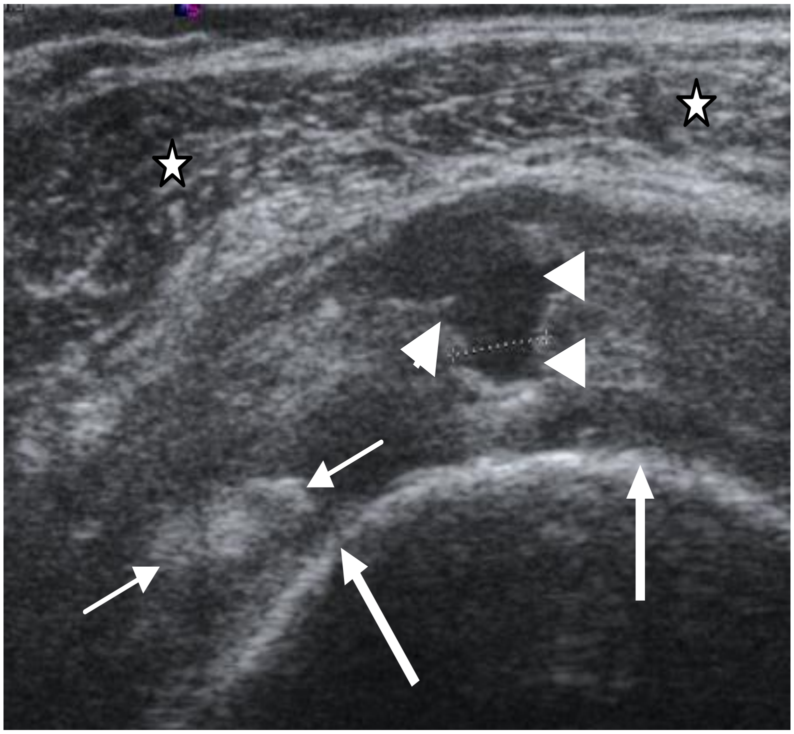

*Figure 1: Partial thickness tear of the supraspinatus tendon*
Axial imaging plane at the supraspinatus tendon, central part. Hyporeflective disruption (arrowheads) of the continuity of the tendon continuous with the bursal surface of the tendon. The axial section of caput longum biceps tendon at the rotator cuff interval is obvious (small arrow). Subchondral bone of the humeral head (large arrows). Superficial located deltoid muscle (asterisk).

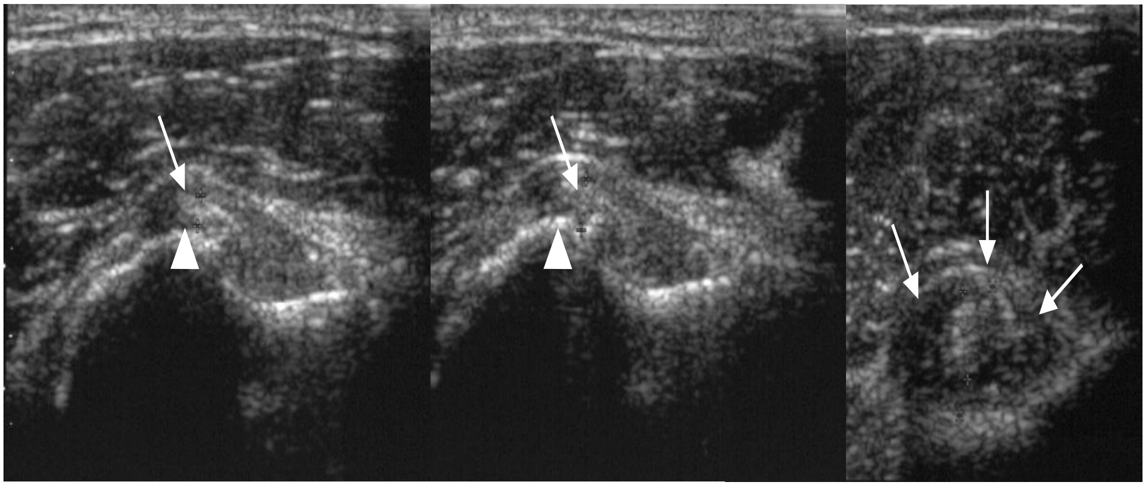

*Figure 2: Biceps caput longum tendon dislocation*
Axial imaging planes, left = medial side. Left and middle pane: at the level of the tuberculum minus, right pane: inferior to the sulcus intertubercularis. Left and middle pane: transverse section through the caput longum biceps tendon that presents as a reflective oval (arrow). The tendon is located on horseback of the reflective curved line that presents the cortical lining of the tuberculum minus (arrowhead). Right pane: caput longum biceps tendon distal to the sulcus intertubercularis is surrounded by hyposonant fluid at its tendon sheath (arrows).

**Knee (patellar tendon excluded)**

Although MRI is the best diagnostic tool to study meniscus lesions, US may add to the detection of a meniscus lesion. US examination is better for detection of medial meniscus lesions compared to clinical exam testing. US of the medial meniscus has a lower accuracy (sens 91.1%, spec 80.0%, PPV 83.6%, and NPV 88.9%) in acute injury compared to chronic meniscus disease (sens 97.2%, spec 90.2%, PPV 86.0%, and NPV 98.2%)[8]. (Figure 3)

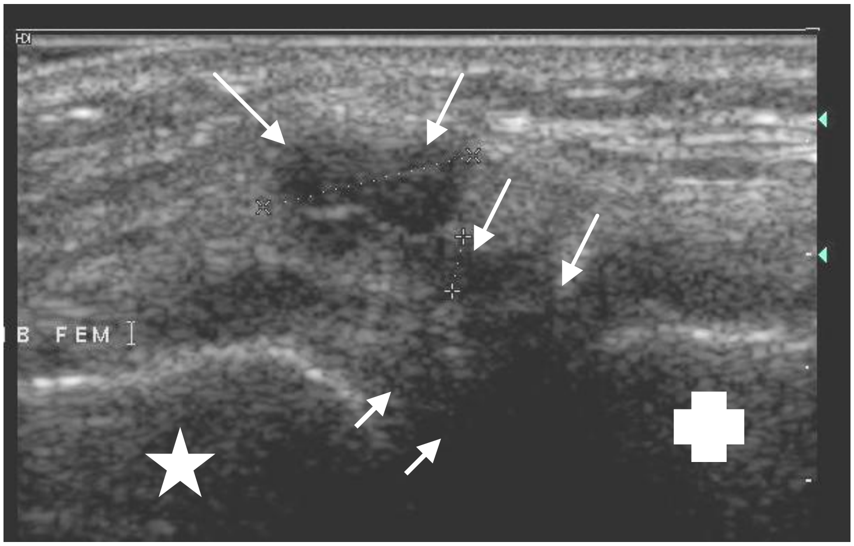


*Figure 3: Chronic medial meniscal lesion: meniscal tear with cyst*
Longitudinal imaging plane at the medial collateral ligament and medial tibiofemoral joint space. The ligament is displaced by the assonant cyst (large arrows) with stalk to the meniscal surface (small arrows). Femur: asterisk. Tibia: plus.

Injuries of the anterior cruciate ligament are common in several sports. US has a sensitivity (87.1%), specificity (97.7%), PPV (98.2%) and NPV (84.3%) in a diagnosis of fresh lesions of the anterior cruciate ligament [9]. In the very acute situation, US, in experienced hands, has a superior sensitivity approaching 100%. Accuracy of MRI depends on the sequences and field strength used. In later studies, the sensitivity is between 70% and 100% the specificity is 100%[10,11].

**Patellar tendon and Achilles tendon**

Palpation is an important clinical physical exam test for jumper's knee. Compared to US in symptomatic tendons, the positive predictive value of palpation was 68%. As a screening examination in asymptomatic subjects, the positive predictive value of tendon palpation was 36%-38%. In junior athletes, palpation is a reliable test, but is not cost-effective as a screening test in detecting patellar tendinopathy in asymptomatic athletes. In symptomatic tendons, palpation is a moderately sensitive, but not specific test. Mild tenderness in the patellar tendons in asymptomatic jumping athletes could be a normal finding[12].

US is a promising screening tool for tendon disease in jumpers. Normal clinical exam and US findings indicate a low risk for volleyball players to sustain jumper's knee during intensive training and playing[13]. Asymptomatic soccer and basketball players with an increased risk of developing both Achilles and patellar tendon changes can be diagnosed with US up to 12 months before they become symptomatic injuries. A prophylactic eccentric training and stretching program reduces the risk of developing ultrasonographic abnormalities in the patellar tendons but has no positive effect on the risk of injury. On the contrary, in asymptomatic players with ultrasonographically abnormal patellar tendons, prophylactic eccentric training and stretching actually increased the injury risk[14]. Recent studies have revealed structural changes with neovascularisation in patients with jumper's knee and Achilles tendinopathy, this was present in about two-thirds of patients with jumper's knee and Achilles tendonosis (Figures 4 and 5).

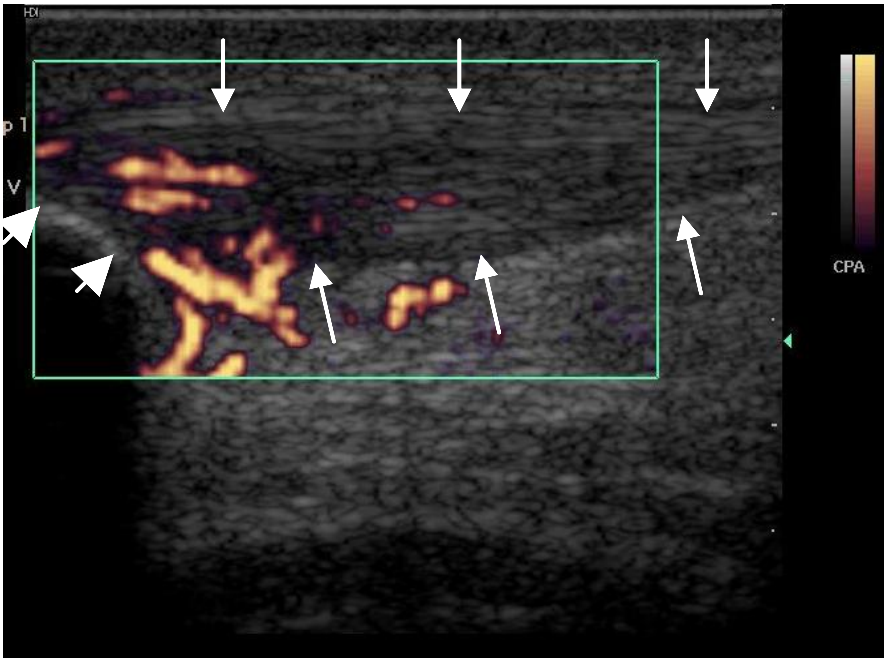


*Figure 4: Patellar tendon tendinosis*
Sagittal imaging plane at the level of the patellar tendon (arrows) origin at the patella apex (arrowheads). The tendon is thickened at its proximal third with marked hypervascularitiy on power Doppler colour duplex (orange colour at the colour box) at the thickened part and at the superficial part to Hoffa's fat pad.

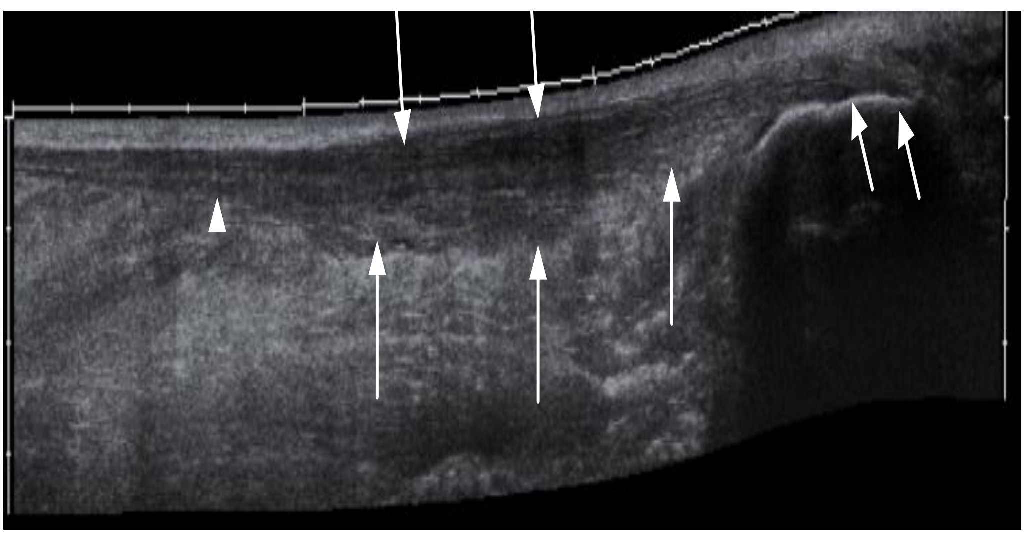

*Figure 5: Achilles tendinosis with partial rupture*
Panoramic view, sagittal imaging plane of the Achilles tendon, left = proximal.
The tendon is thickened with non-homogeneous hyposonant aspect in its mid portion (large arrows), the posterior lining is regular (top), the anterior lining is irregular (bottom) as sign of partial rupture. The tendon has a normal size and structure at its soleus musculotendinous junction (arrowhead) and at the insertion on the calcaneum (small arrows).

There was no significant correlation between neovascularisation score and clinical severity at baseline, however on follow-up examinations there was a significant correlation between the two. Neovascularisation at baseline did not predict clinical outcome after conservative treatment[15]. There is a close relationship between areas with vasculo-neural ingrowth and tendon pain. Targeting the area of new vessel growth outside the tendon using US-guided sclerosing polidocanol injections, good clinical outcomes remained at two-year follow up visits, and sonographic signs of remodelling with a significantly thinner tendon and more normal structure were demonstrated. Sclerosing polidocanol injections resulted in a significant improvement in knee function and reduced pain in patients with patellar tendinopathy[16]. Despite the fact that treatment with sclerosing injections that influence vascularisation has shown promising clinical results, there was no relationship between changes in US neovascularisation and knee function after sclerosing treatment[17]. Whether the effects of polidocanol injections are mediated through destruction of neovessels, activity on nerve conduction, or a combination of both, is being evaluated[18]. An extensive review on tendinopathy published by Cook in 2009 introduces three continuous stages in tendinopathy and defines load as the stimulus that drives a tendon forward and backward along the continuum. In reduced load the tendon returns to a previous level of structure and capacity within the continuum. The first stage or reactive tendinopathy is characterised with thickening of the tendon only, without structural anomalies. The next stage in the continuum is the disrepair stage or failed healing with minor angiogenesis and structural damage of the collagenous tendon matrix. The continuum progresses with ongoing overload to degenerative tendinopathy characterised with increasing areas with structural anomalies, major fibroblast apoptosis and vascular invasion of the tendon. Power Doppler detection of angiogenesis in the tendon marks the progression of reactive to disrepair stage, and thus marks the stage in which conservative load management supplements reduced overload to restore normal tendon. Degenerative tendon disease is regarded as a permanent stage of tendon disease out of which a tendon is not able to fully recover[19]. US demonstrates superior and clinical relevant staging capacities over MRI.

**Elbow**

Tennis elbow is a tendinopathy affecting the origin of the wrist extensor and supinator muscle group. Recent studies have shown high sensitivity for US examination and high specificity for colour Doppler (CD) examination of tennis elbow. Angiogenesis detected by Doppler, but not structural abnormalities in gray scale US, might be related to the clinical changes after intra-tendinous injection treatment of tennis elbow[20]. (Figure 6)

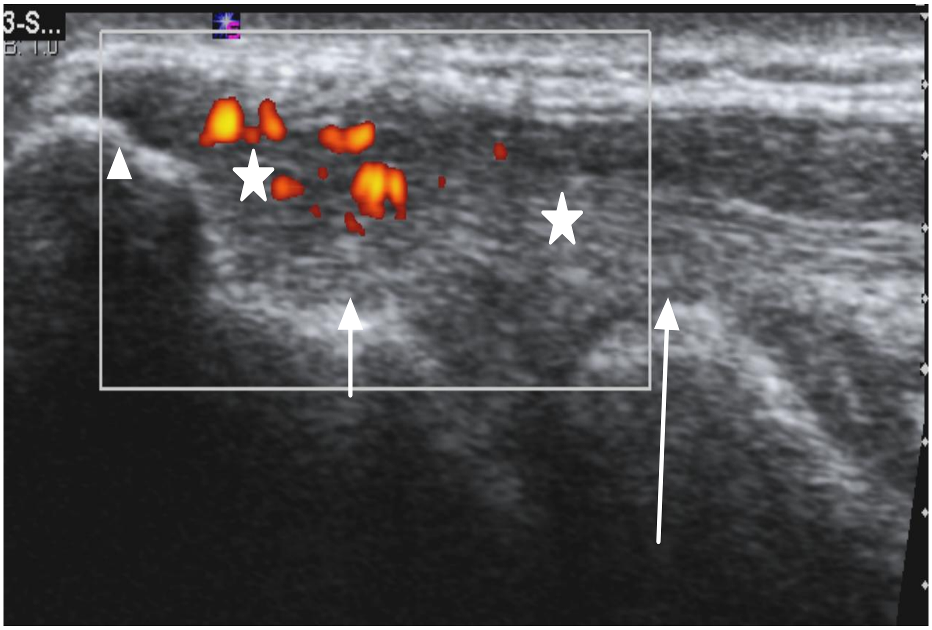


*Figure 6: Tendinosis at the origin of the extensor carpi radialis brevis tendon (tennis elbow)*
Longitudinal plane through the common extensor origin (extensor carpi radialis brevis region) on the epicondylus lateralis of the humerus (arrowhead). The tendon (asterisks) is thickened with non-homogeneous hyposonant aspect and hypervascularity on power Doppler. Caput radii: large arrow. Capitellum humeri: small arrow.

**Wrist**

MacLennan et al. studied the efficacy of dynamic US to diagnose subluxation during supination and pronation of the extensor carpi ulnaris (ECU) and assess the results of a new technique for anatomic ECU tendon sheath reconstruction. (Figure 7) All patients who presented with symptomatic ECU tendon subluxation were confirmed by dynamic US of the wrist. Dynamic US is an effective and non-invasive method of diagnosing ECU tendon subluxation. According to quadas criteria this indication has the highest actually available level of evidence of US of the musculoskeletal system. Type of study/level of evidence: Therapeutic IV[21].

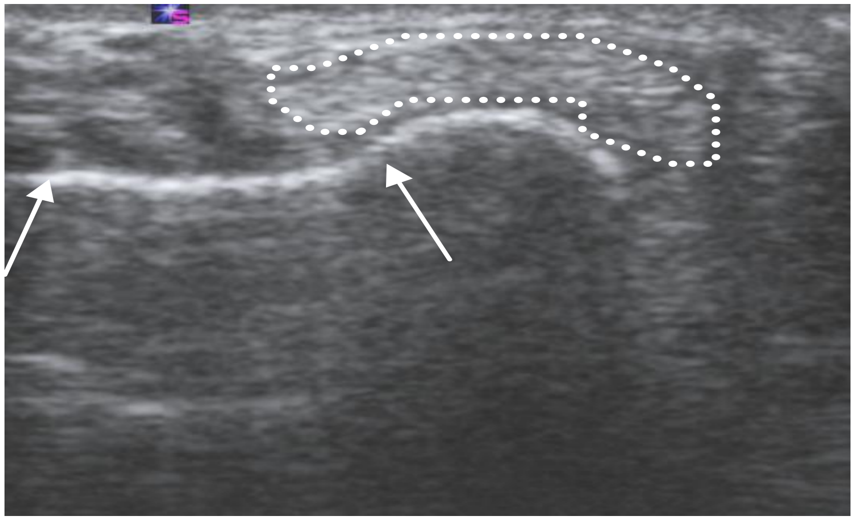

*Figure 7: Extensor carpi ulnaris tendon dislocation*
Axial imaging plane at the level of the extensor carpi ulnaris tendon (ECU) (dotted line) and its groove (arrows: margins of the groove). The tendon is during flexion of the wrist dislocated to the ulnar side out of the ulnar groove.

**Fingers**

Dynamic US illustrates finger pulley injuries with excellent detail, studied in rock climbers. A distance between the flexor tendon and phalanx of greater than 1.0 mm is considered positive for a pulley injury. The sensitivity for detection of finger pulley injuries by US was 98%, and with a specificity of 100%[22].

**Muscle injury**

Traumatic muscle pathology (strain or contusion) is frequent in the athlete, and can be acute or chronic and a direct or indirect injury. Muscle strain injury is one of the most common clinical problems presenting to sports physicians[23]. Usually these lesions heal spontaneously leaving no sequelae. The ability to estimate the healing process duration will help avoid an inappropriately long period of inactivity and protect the athlete from an improper early return to sport and increased risk of a recurrent tear. Medical imaging can define the precise location and severity of muscle trauma and detect critical elements that will delay complete repair. US provides a good visualisation of muscle fibres, tendons, and aponeurosis, but has limited resolution of the deep structures, such as the hamstring tendons, and detects muscle scar poorly. Clinical symptoms show good correlation to the US results[24], and US is the least expensive imaging technique for analysing muscle trauma (Figure 8). MRI is the most sensitive imaging technique for analysing muscle trauma, but it is also far more expensive and the muscle fibres are not visualised. Thus MRI remains a secondary technique adapted to the insufficiencies of US[25].

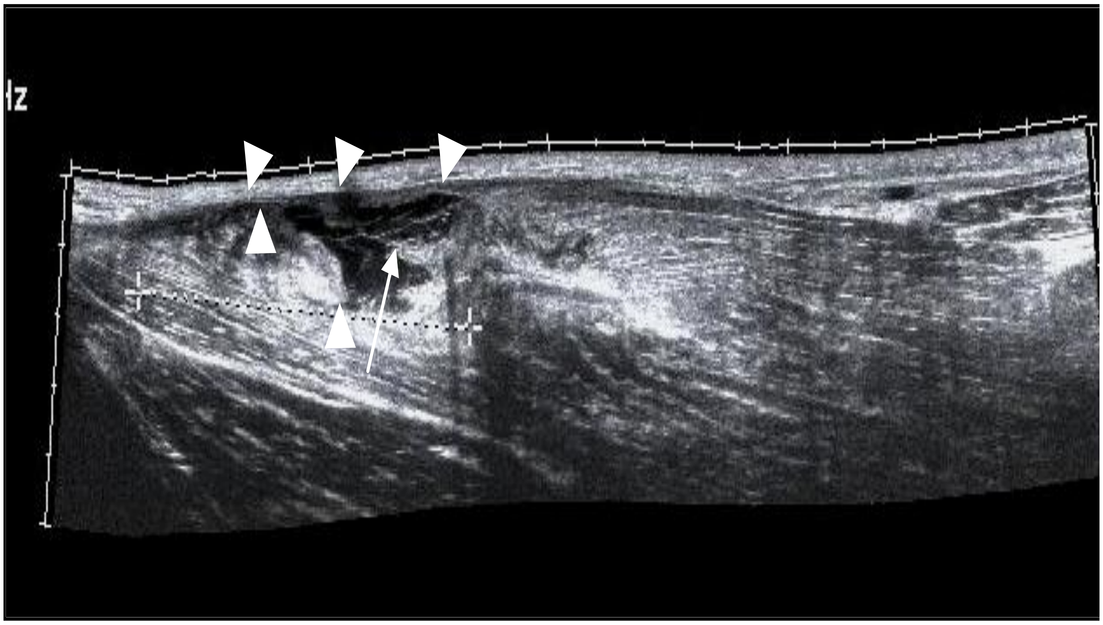


*Figure 8: Acute muscle tear of the biceps femoris muscle*
Acute biceps femoris muscle tear at the proximal musculotendinous junction. The retracted distal part of the muscle (arrow) is surrounded by assonant fluid (arrowheads).

US performed shortly after a direct or indirect muscle trauma may be confusing. The extent of a muscle tear can be difficult to assess because of oedema, intramuscular haematomas and red infarct. Krol et al.[26] compared standard B-mode US examinations and gray-scale contrast-enhanced US after administration of Sonovue (Altana Pharma, Konstanz, Germany) to evaluate the margins and size of the post-traumatic lesions in a small number of patients (n = 8). Following administration of the contrast agent, the borders of the muscle lesions, which are otherwise poorly or non-enhanced areas, were better delineated. These preliminary results indicate that gray-scale contrast-enhanced US of muscle may be helpful to determine the extent of muscle trauma in the early post-injury period[26].

**Hip**
Leg complaints at maximal exercise in endurance athletes may have many causes, including arterial flow limitations in the iliac arteries. Simple sports-specific tests accurately diagnose iliac artery obstruction in endurance athletes[27]. A fall of ankle brachial index (ABI) after exercise proves the presence of a significant stenosis in symptomatic athletes. Colour-coded duplex ultrasonography is a non-invasive method to document suspected endofibrotic stenosis in young athletes that can reliably detect both iliac artery stenosis and elongation. In the detection of external and common iliac artery stenosis, the sensitivities of the US vs. digital substraction angiography (DSA) were 84.6 and 53.8% vs. 53.8 and 12.5%, respectively. For the detection of excessive external iliac artery length, the sensitivity of US was 85.7% with a 57.1% specificity[28].

**Ankle**
Ultrasound is accurate in detecting synovial lesions within the antero-lateral gutter (anterolateral impingement) (Figure 9), demonstrating associated ligamentous injuries, and differentiating soft tissue from osseous impingement. Synovial lesions in excess of 10mm were associated with clinical symptoms. Ultrasound will not demonstrate osteocartilaginous lesions or stress fractures and may overlook some loose bodies. Ultrasound findings together with clinical correlation can be used to direct arthroscopic examination and surgical debridement of anterolateral impingement symptoms[29]. US may be used in a dynamic way to demonstrate dislocation of peroneal tendons during extension-eversion movement at the hind foot. Clinically and ultrasonographically the extension-eversion

manoeuvre produces anterior tendon dislocation in case of ruptured superior peroneal retinaculum. If the retinaculum is not ruptured, a dynamic ultrasound may also accurately demonstrate the peroneal tendons to switch their relative positions (the peroneus longus came to lie deep to the peroneus brevis tendon) with a reproducible painful click. This condition is called intrasheat dislocation by Raikin[30].

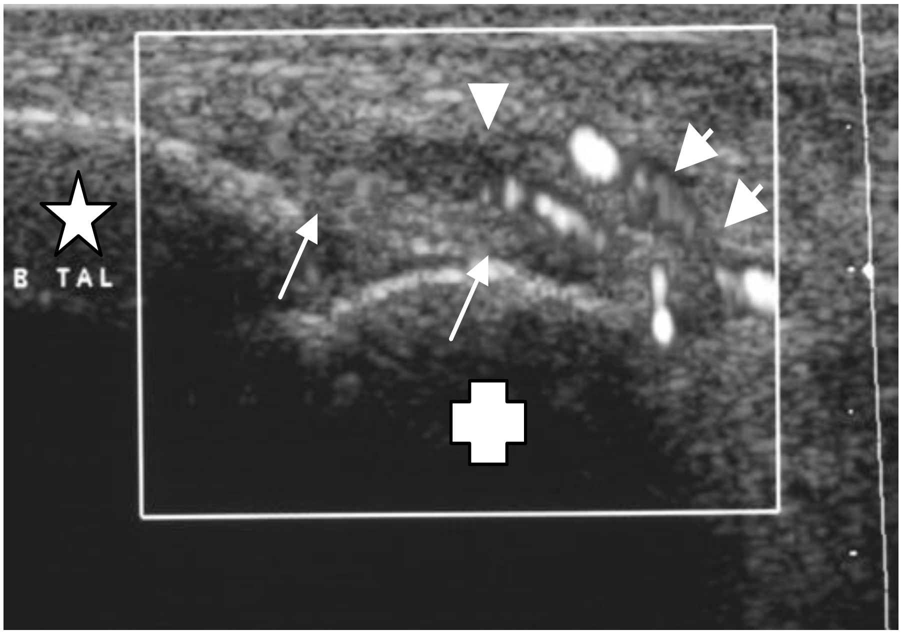


*Figure 9: Ankle anterior lateral impingement*
The anterior talofibular ligament is thickened (arrows) but has a normal continuity from the distal fibula (asterisk) to the talus (plus). Superficial to the anterior talofibular ligament non-homogeneous hypo-hyperreflective additional tissue is visualised (pseudomeniscus, arrowheads) with marked hypervascularity on power Doppler

## Summary

Despite the rather small number of high quality scientific studies, US is widely accepted and used in diagnosis and early detection of soft tissue lesions in sports. It is expected that in coming years more controlled studies covering many more sports lesions will become available. US imaging has become the gold standard for detection of abnormalities in superficial tendons (i.e. Achilles and patellar tendons). Both power Doppler and colour Doppler play an important role in the detection of angiogenesis in tendon overuse.

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