IMAGING EVALUATION OF HANDBALL INJURIES

– Written by Paulo Victor Partezani Helito, Maria Lua Sampaio Gulde, Marcelo Bordalo, Qatar, and Affonso Cardoso de Oliveira Neto, Brazil

INTRODUCTION

Involving rapid changes in direction, jumps, throws, and robust physical contact among players, handball stands out as a high-intensity team sport distinguished by its dynamic nature. Beyond its status as a globally popular professional sport, handball has transcended into a widely practiced activity among amateur adults and children worldwide.

Nevertheless, the elements that make handball such a thrilling sport also contribute to high risk of injury. These injuries affect the lower and upper limbs, joints and muscles.

Accurate diagnosis and staging of musculoskeletal injuries in handball players are fundamental for adequate treatment. In addition to recognizing the nuanced nature, incidence rates, and severity of handball injuries, imaging evaluation is crucial in the development of a comprehensive, high-level, and multidisciplinary therapeutic plan.

This article aims to provide healthcare professionals in sports medicine and science, and rehabilitation with essential information on imaging of handball injuries. We discuss imaging findings of handball related musculoskeletal injuries, in parallel with the epidemiologic and biomechanical features.

EPIDEMIOLOGY OF INJURIES

Data collected from elite handball players in Brazil, Denmark, and Iceland reveal injury incidences leading to loss of training sessions or games ranging from 11 to 14 per 1000 hours of play and 0.6 to 2.4 per 1000 hours of training[1-3]. Moreover, statistics from the German Statutory Accident Insurance (Verwaltungs-Berufsgenossenschaft, VBG) for professional male handball players contracted with first or second league teams between 2010 and 2013 indicate that, out of 1194 players, 930 sustained 5456 injuries[4]. This equates to a prevalence rate of 77.9% and an incidence rate of 4.3 injuries per 1000 hours per player over the entire observation period.

International handball tournaments have also reported a high prevalence of injuries, with 1.5 injuries per match (or 108 injuries per 1000 player hours). More importantly, the incidence of injuries leading to loss of training sessions or games was recorded at 27 injuries per 1000 player hours[5]. The 24th Men's Handball World Championship 2015 in Qatar injury and illness surveillance protocol also reported a high incidence of injuries; a total of 104.5 per 1000 player-hour, affecting 27.1% of the players, and 40% of those being time-loss injuries[6]. In line with this data, during the 2012 London Summer Olympic Games, handball had one of the highest injury rates (5%), ranking among the sports with the greatest number of injuries leading to more than 7 days of absence from training or competition[7].

Pooled data from a 2022 meta-analysis[8] has revealed that the primary cause of injuries in handball is contact with another player, with traumatic injuries being the most prevalent, followed closely by overuse injuries. Moreover, a comprehensive study involving video analysis of 580 injuries[9] concluded that, while not constituting foul play, contact emerged as the predominant mechanism associated with moderate and severe injuries. Notably, injuries to the head, hand, shoulder, and ankle were predominantly sustained during direct contact situations.

In terms of gender differences, men have a higher incidence of injuries compared to women. Women, however, have a higher rate of recurrent injuries[8]. Additional studies indicate a greater incidence of injuries in competitive handball settings for women compared to men, whereas during training, this trend is reversed. Furthermore, women players recorded a higher number of injuries resulting in more than 7 days of lost playing time.

When considering the occurrence of injuries in relation to playing positions, there is great variability in the reports. However, the pivot position trends as the one in greatest risk of injury, specially from contact[8].

IMAGING MODALITIES

The diagnostic toolkit for assessing musculoskeletal injuries in athletes is diverse, encompassing radiographs, computed tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI).

Radiographs are typically the first imaging modality employed due to their wide availability and low cost. They are primarily used to evaluate osseous morphology and to rule out fractures. While limited in assessing soft tissues, radiographs can indicate soft tissue injuries indirectly by showing asymmetry or enlargement of joint spaces. Radiographs can also be performed with the patient in weight-bearing positions, providing additional functional information.

CT scans utilize X-rays to produce tomographic images with high spatial resolution, making them ideal for evaluating areas with complex anatomy and bony overlap, such as the spine. CT is particularly useful for detecting small or non-displaced fractures. Although CT is less effective than US and MRI, it can still provide valuable information on soft tissue abnormalities.

It is important to be mindful that both radiographs and CT scans expose patients to ionizing radiation, so their use should be judicious to minimize unnecessary exposure.

Ultrasound uses mechanical waves to create images and excels in evaluating soft tissue injuries, especially in superficial tissues. Modern ultrasound machines with high-frequency probes produce high-resolution images, making them ideal for diagnosing injuries in shoulder tendons, elbow joints, muscles and tendons, ankle ligaments, and the knee's peripheral ligaments and extensor mechanism. However, ultrasound is less effective for examining deeper structures or those behind bones, such as knee cartilage surfaces, cruciate ligaments, and menisci. Other disadvantages of this method are the dependency on high-quality machines and probes, as well as experienced examiners.

MRI is highly effective for evaluating bone, joint, and soft tissue injuries, offering superior contrast resolution. Although it is less widely available, more expensive, and typically more time-consuming, MRI remains the preferred modality for diagnosing a wide range of musculoskeletal injuries.

Illustration

MRI imaging is based on the spins of protons in the body's tissues. When subjected to a strong magnetic field, these protons align, and upon exposure to radiofrequency pulses, they produce signals that are converted into detailed images. This process allows healthcare practitioners to visualize both osseous and soft tissue structures with exceptional clarity on MRI.

In athletes, MRI is particularly valuable for diagnosing soft tissue injuries (such as muscle and ligament tears), intra-articular pathologies, and early stages of bone stress injuries. T2-weighted sequences with fat saturation are frequently used for injury diagnosis, as they highlight injuries with bright (high signal) areas. Conversely, T1-weighted sequences are beneficial for evaluating anatomical details, bone marrow, and hematomas.

LOWER EXTREMITY INJURIES

A 2022 systematic review[10], which specifically focused on lower limb injuries, highlighted the knee (30%) and ankle (24%) as the most frequently reported locations of injuries. These were closely followed by the thigh (15%), feet (9%), and hip/groin (8%). While most of the included studies did not provide information on specific structures affected in each location, the majority of knee and ankle injuries involved ligaments, whereas thigh and hip/groin injuries were primarily muscular in nature. Additionally, foot injuries were mostly bony injuries, particularly metatarsal fractures. It's important to mention that, despite the results of this study, there is a heterogeneity of data in the literature regarding the most prevalent injury sites, whether in the knee, ankle, or thigh.

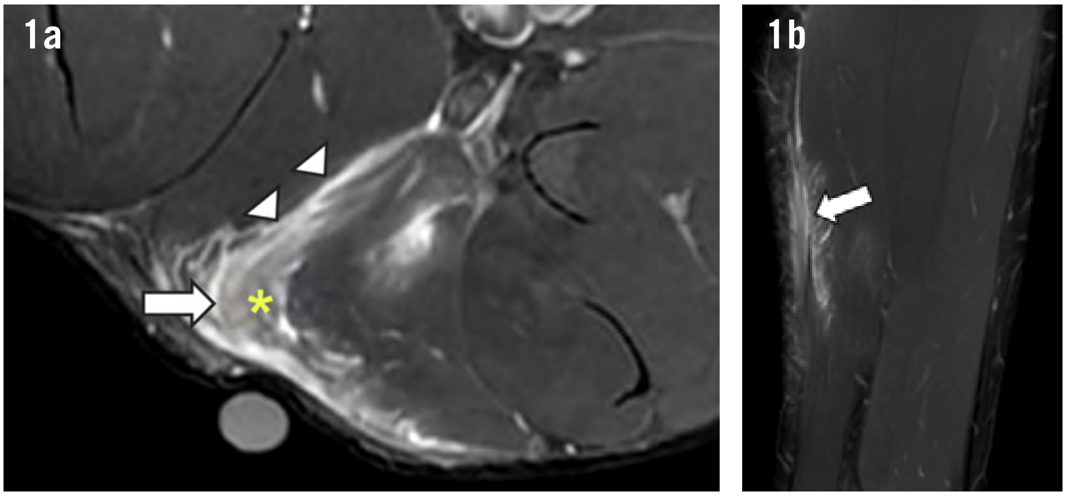


Figure 1: Magnetic resonance imaging of a hamstring injury affecting the distal biceps femoris. Axial (a) and coronal (b) T2 weighted images with fat saturation. There is edema (asterisk) and architectural disruption of the muscle fibers and intramuscular tendon (arrows) in the distal myotendinous junction of the long head of the biceps femoris, also involving the T-junction in the interface with the short head (arrowheads). Coronal images are useful to determine the longitudinal extent of the injury and loss of tension.

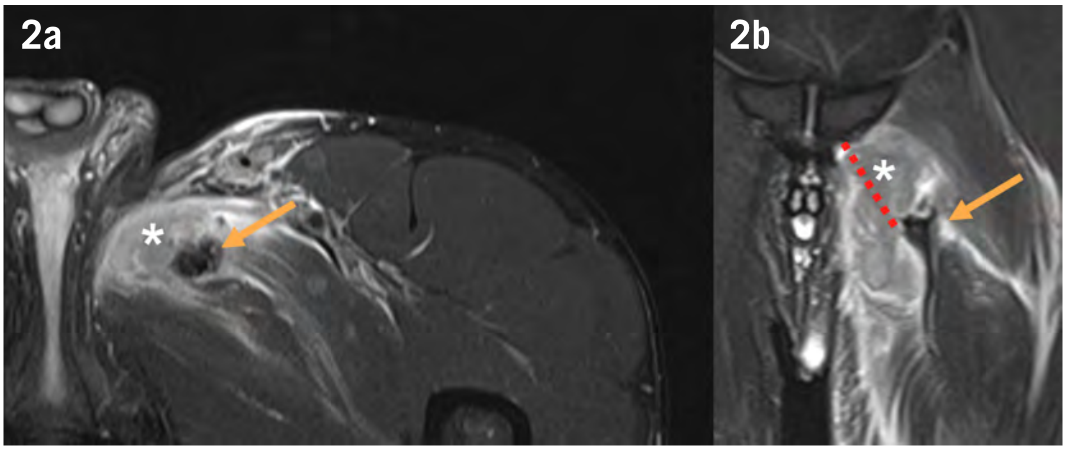


Figure 2: Magnetic resonance imaging of an adductor longus proximal tendon tear. Axial (a) and coronal (b) T2 weighted images with fat saturation show adductor tendon proximal avulsion with interposed heterogeneous hematoma (*) and distal retraction (dotted red line) of the tendon stump (yellow arrow). There is edema and fluid in the surrounding muscle and fat tissues due to infiltrative hematoma and local inflammation.

Imaging of Hip and Thigh Injuries

The vulnerability of this muscle group to injury is not surprising, given the rapid accelerations, pivots, and feints performed by handball players. The imaging assessment of muscular injuries focuses not only on providing an accurate diagnosis but also on offering tailored treatment to each player, thereby minimizing training and match absence.

US and MRI are the main tools for evaluating muscle injuries. Both methods are used to identify the presence of a muscle injury, as well as to characterize its location, parts of the muscle involved, and the size of the injury.

On ultrasound scans, injuries may appear as areas of increased echogenicity, sometimes accompanied by fiber disruption. Fiber disruption is characterized by focal or extensive discontinuity of fibers with interposed fluid or hematoma. The echogenicity of the fluid may vary depending on the time of the injury, ranging from anechoic to heterogeneous. Passive or active dynamic maneuvers are often used to increase the sensitivity of the method.

On the other hand, MRI is highly sensitive to muscle injuries, revealing areas of edema (increased signal on T2-weighted images), as well as disruptions in muscle fibers and interposed hematomas (Figure 1).

While there is controversy regarding the prognostic value of imaging for estimating return to play in indirect muscle injuries[11], common evaluated injury characteristics include the longitudinal and cross-sectional dimensions of the injury, the presence of architectural fiber disruption, the site of the injury (myofascial vs. myotendinous), and the involvement of the tendon itself, and associated loss of tension. Several classifications can also be applied, including the simpler and widely used three-grade scale and the BAMIC classification.

In cases of groin and hip pain, imaging serves as a valuable diagnostic tool, particularly due to the wide range of conditions that can cause pain in these areas in athletes[12]. Specifically, MRI can be used to diagnose conditions such as osteitis pubis, piriformis-anterior pubic ligament-adductor longus complex injuries (PLAC injuries)[13] (Figure 2), inguinal hernias, iliopsoas tendinopathy and bursitis, and intra-articular hip injuries, among others. Since dynamic maneuvers are easily performed during an US scan, this method is often the modality of choice for evaluating inguinal hernias.

Knee Joint Injuries

The knee stands out as the most injured joint in handball. Most injuries involve the anterior cruciate and medial collateral ligaments. These passive stabilizers are often sprained during practice, particularly when there is postural imbalance, such as during feints and landings. Such actions can overload secondary stabilizers, thereby increasing the risk of injury.

Anterior cruciate ligament (ACL) tears are typically suspected based on the mechanism of trauma and clinical examination. MRI is requested to confirm and assess the extent of an ACL injury, as well as to evaluate other intra-articular injuries such as peripheral ligamentous tears, meniscal tears, and cartilage injuries.

MRI is commonly used to evaluate ACL injuries (Figure 3), with direct signs

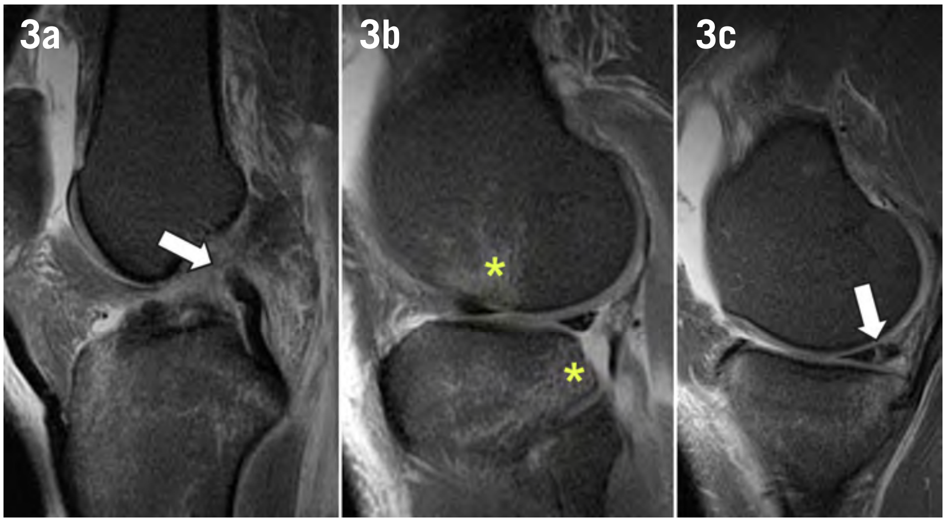


Figure 3: Magnetic resonance imaging of complete tear of the anterior cruciate ligament. Sagittal T2 weighted images with fat saturation from the intercondylar region (a), lateral compartment (b) and medial compartment (c) show complete discontinuity and absence of the ACL (arrow in a), the typical contusions in the lateral compartment (asterisks in b) and a vertical tear in the posterior horn of the medial meniscus (arrow in c).

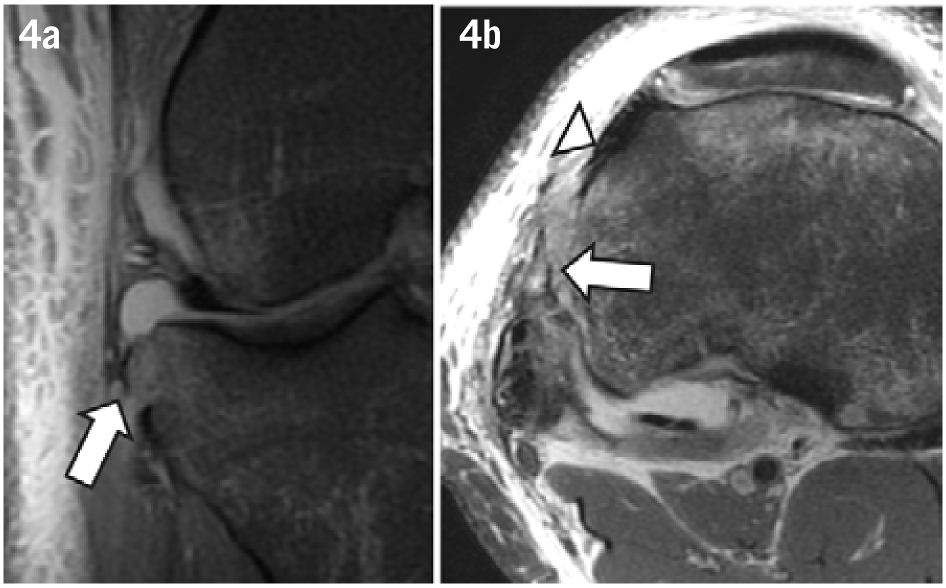


Figure 4: Magnetic resonance imaging of a patient with an ACL tear and a Segond Fracture. Coronal (a) and axial (b) T2 weighted images with fat saturation depicting a small cortical avulsion (arrows) in the lateral side of the tibia, posterior to the Gerdy's tubercle (arrowhead in b), consistent with a Segond fracture, an avulsion of the anterolateral ligament.

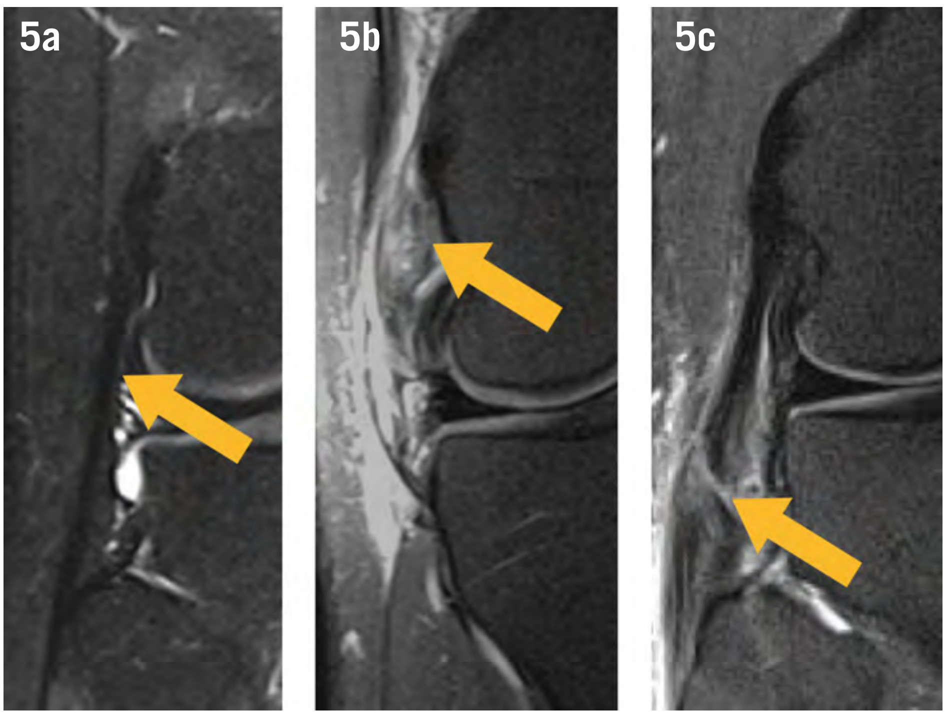


Figure 5: Magnetic resonance imaging of the lateral collateral ligament. Three cropped coronal T2 weighted images of the lateral collateral ligament of different patients depicting a normal (a), partially torn (b) and completely torn (c) ligaments. The normal ligament shows homogeneous low signal and regular morphology. The partially torn ligament shows increased signal and irregularity of the fibers, but no complete discontinuity. The completely torn ligament shows a full-thickness tear, pointed by the arrow.

including partial or complete discontinuity of ligament fibers, increased signal, thickening, and heterogeneity of the ligament, as well as abnormal orientation and loss of tension. Indirect signs may include anterior translation of the tibia, bony contusions, Segond fracture (Figure 4), meniscal tears, and verticalization of the posterior cruciate ligament.

Peripheral ligament injuries are common in handball players, often occurring in isolation or accompanying cruciate ligament tears. These injuries are typically classified into grades based on MRI finding. Grade 0 signifies a normal ligament, while grade 1 involves minor injury with peripheral edema. Grade 2 denotes partial tearing of ligament fibers, represented as a thickened edematous ligament, with partial discontinuity of fibers. Grade 3 indicates a complete tear (Figure 5).

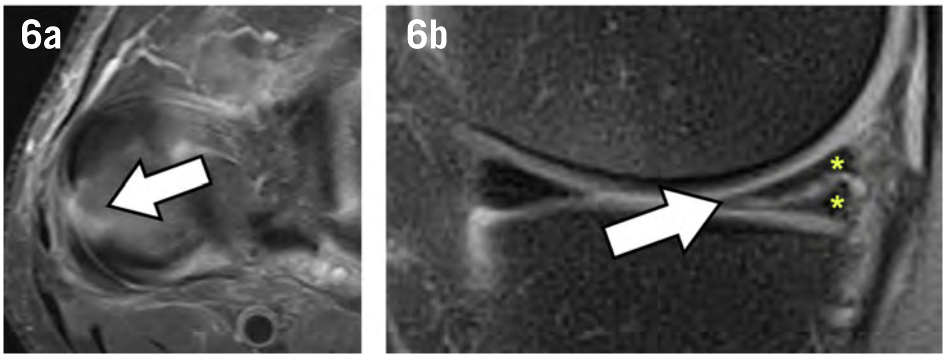


Figure 6: Magnetic resonance imaging of meniscal tears. Axial T2 weighted image (a) of the lateral femorotibial compartment showing a complete radial tear in the body of the lateral meniscus, as a complete discontinuity perpendicular to the long axis of the meniscus (arrow). Cropped sagittal T2 weighted image (b) of the medial femorotibial compartment showing a horizontal tear in the posterior horn of the medial meniscus, as a linear high-signal abnormality (arrow) along the long axis of the meniscus that divides the meniscus in one superior and one inferior fragments (asterisks).

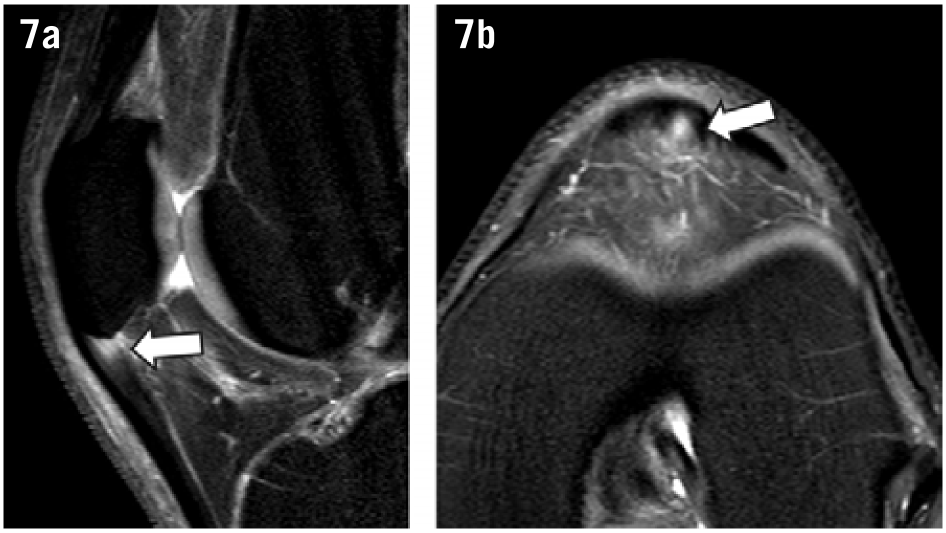


Figure 7: Magnetic resonance imaging indicating patellar tendon tendinopathy with a small partial tear at the origin. Sagittal (a) and axial (b) T2 weighted images with fat saturation depicting increased signal at the origin of the patellar tendon (arrow in a), consistent with tendinopathy, associated with a small area with fluid signal intensity in the deep fibers (arrow in b), related to a focal partial tear.

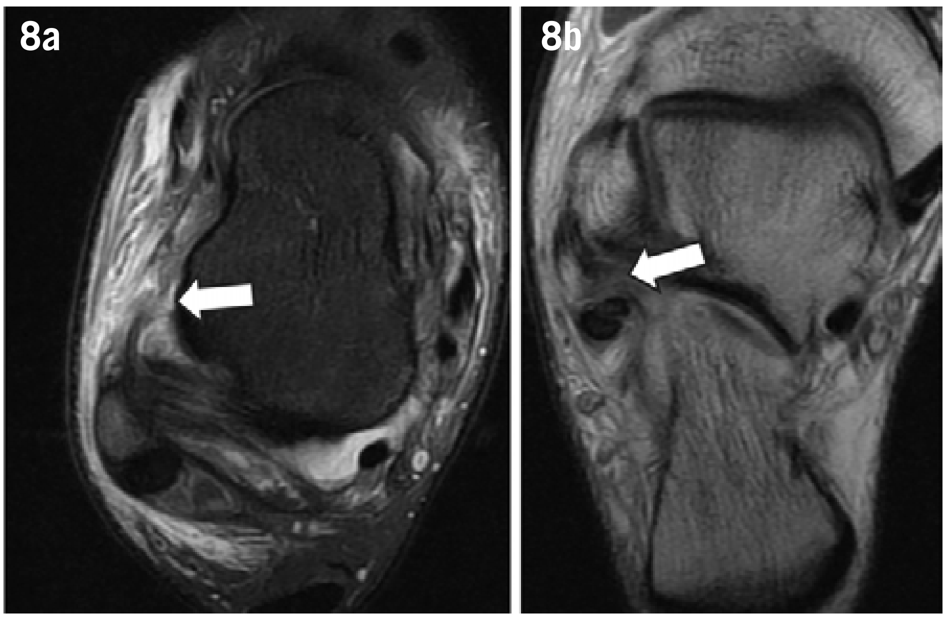


Figure 8: Magnetic resonance imaging of an injury affecting the lateral ligaments of the ankle. Axial T2 weighted image with fat saturation depicting a complete discontinuity of the anterior talofibular ligament near the talar attachment (arrow) and coronal oblique PD weighted image (b) depicting a nearly complete tear of the calcaneofibular ligament (arrow).

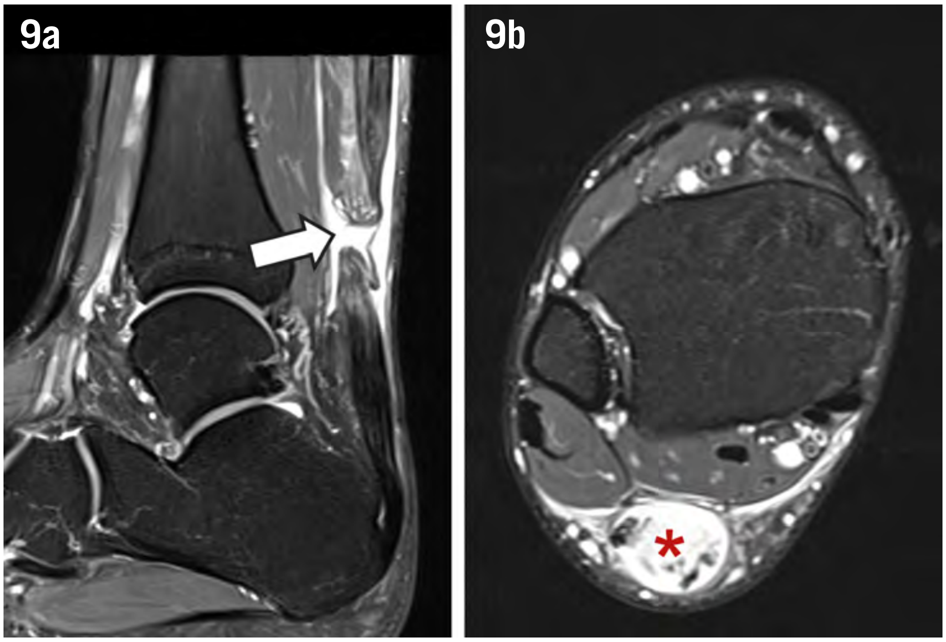
MRI is also applied to assess meniscal tears, which can occur independently or in conjunction with ligamentous or other traumatic injuries. Meniscal tears are visualized as fluid signal within the meniscus that extends to one of the articular surfaces (Figure 6). The tears are classified according to standardized criteria, describing the injury's orientation (in relation to the meniscal short and long axis) and the affected part of the meniscus[15].

Furthermore, a variety of injuries can affect the extensor mechanism, often related to overuse. These include patellar (Figure 7) and quadriceps tendinopathies and ruptures, jumper's knee, Osgood-Schlatter disease, and Hoffa's fat pad impingement syndrome. Imaging plays a crucial role in diagnosing and staging these injuries, assessing tendon tears, and evaluating osseous involvement.

Ankle and Foot Injuries

The feet and ankles of handball players are frequently subjected to high stress and therefore at risk of injury. Ankle injuries are a significant cause of time loss among handball players. Similar to the knee, ankle ligaments are commonly injured passive stabilizers, with the anterior talofibular ligament being a frequent site of injury. MRI is often utilized to diagnose and assess the severity of ankle ligament injuries, as well as any concomitant injuries.

Ankle ligament injuries can involve various structures, including the distal tibiofibular syndesmosis, the lateral ligament complex (especially the anterior talofibular ligament), and the medial



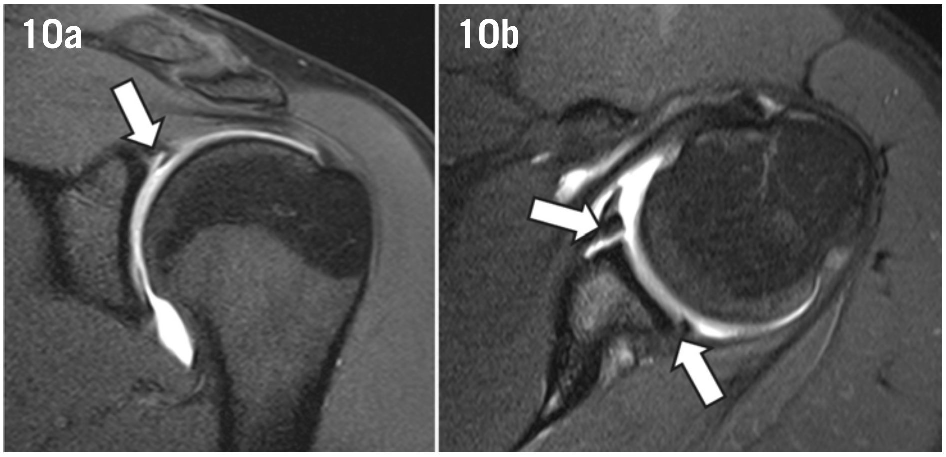


Figure 9: Magnetic resonance imaging of a complete tear of the Achilles tendon. Sagittal (a) and axial (b) T2 weighted images with fat saturation depicting a full-thickness tear of the Achilles tendon in the non-insertional segment (arrow) with a hematoma (asterisk) interposed in the tear and limited by the paratenon.

Figure 10: Magnetic resonance imaging arthrography of a shoulder with a SLAP labral tear. Sagittal (a) and axial (b) T1 weighted images with fat saturation and intra-articular contrast depicting a linear area of increased signal in the superior labrum (arrows in a and b) due to extension of the intra-articular fluid inside the tears.

ligaments (deltoid complex). These injuries can manifest as sprains, partial tears, or complete tears, which can be assessed by MRI (Figure 8) or ultrasound scans. Furthermore, the injuries can be associated with fractures or bony avulsions at the ligament attachments, more easily visualized by X-ray and computed tomography evaluation.

The Achilles tendon is the most injured tendon in handball players, often due to repetitive stress and jumping. Injuries can affect both the insertional and non-insertional segments of the tendon. Tendinopathy or tendinosis is characterized by thickening of the tendon with increased T2 signal intensity on MRI or decreased echogenicity on ultrasound scans. Partial or complete tears of the tendon may also occur, with imaging used to assess the affected area, degree of retraction, and site of injury (Figure 9).

Foot injuries in handball players frequently include metatarsal bone stress injuries, which are considered one of the most-injured osseous structures in these athletes. Stress reactions are preferably evaluated using MRI, which can detect subtle changes ranging from bone marrow and periosteal edema (Figure 10), to actual fracture lines. Radiographs, on the other hand, can depict the fracture lines or cortical thickening; however, early stress reaction can often present with normal x-rays. The Fredericson classification is often employed to describe stress injuries, categorizing them based on findings such as periosteal and bone marrow edema, cortical signal changes, and the presence of fracture lines[16].

UPPER EXTREMITY INJURIES

Upper extremity injuries involve predominantly the shoulder, followed by wrist, hands and fingers. The shoulder, as well as the elbow, is involved in throwing movements, which is inherently repeated during sports practice; the reason why most shoulder injuries are chronic. Overuse problems were most prevalent in the shoulder of a cohort of elite junior handball players, with the majority affecting the dominant shoulder[17]. Hand and finger injuries are often related to acute trauma.

Shoulder Injuries

Shoulder injuries in handball players often result from overuse and the repetitive throwing motion, predominantly affecting the rotator cuff tendons, labrum, and humeral head. Unlike the throwing motion in baseball players, handball throws are characterized by variability, shorter duration, faster speed, less predictability, and frequent contact during or after the movement[18]. Moreover, handball players are susceptible to various types of contact that can impart load on the shoulder joints during offensive and defensive maneuvers.

Despite prevalent structural abnormalities in dominant handball shoulders, caution is warranted when interpreting abnormal scans. A study involving elite handball players indicated that 93% of throwing shoulders exhibit MRI abnormalities, yet only 37% are symptomatic[19]. The correlation between pain and MRI findings was weak, emphasizing the need for meticulous symptom evaluation in handball and overhead throwing athletes.

Rotator cuff injuries, including tendinopathy and partial thickness

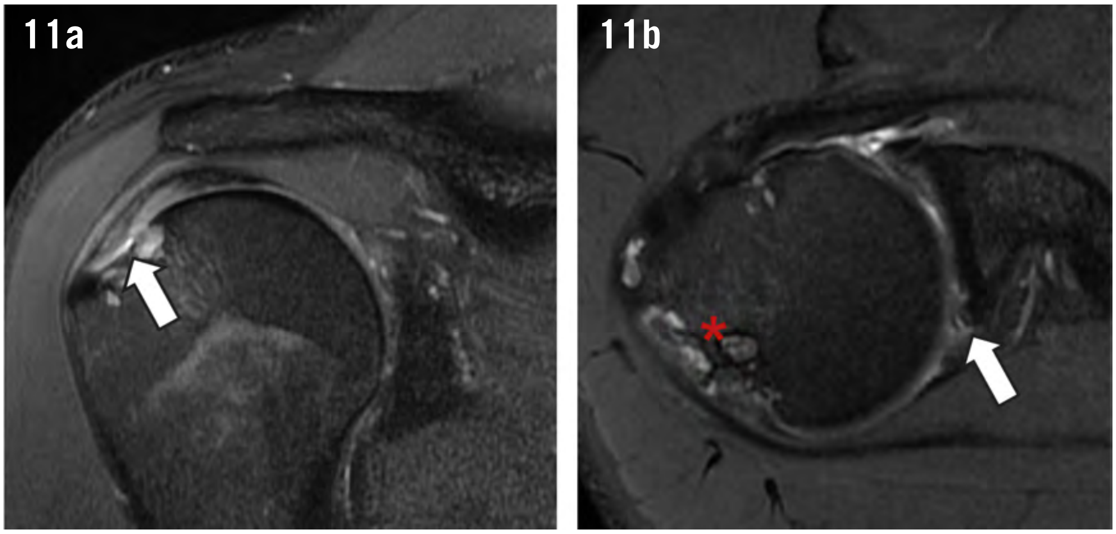


Figure 11: Magnetic resonance imaging of a shoulder with internal impingement syndrome. Sagittal (a) and axial (b) T2 weighted images with fat saturation depicting a tendinopathy and a partial-thickness tear of infraspinatus tendon near the humeral attachment (arrow in a), osseous remodeling and cysts in the posterosuperior aspect of the humeral head (asterisk) and an injury in the posterosuperior labrum (arrow in b).

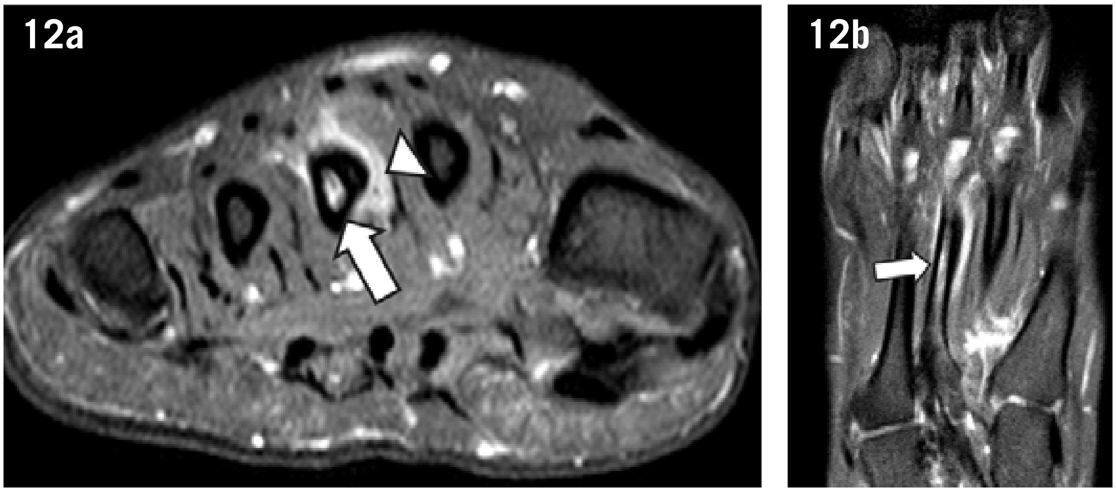


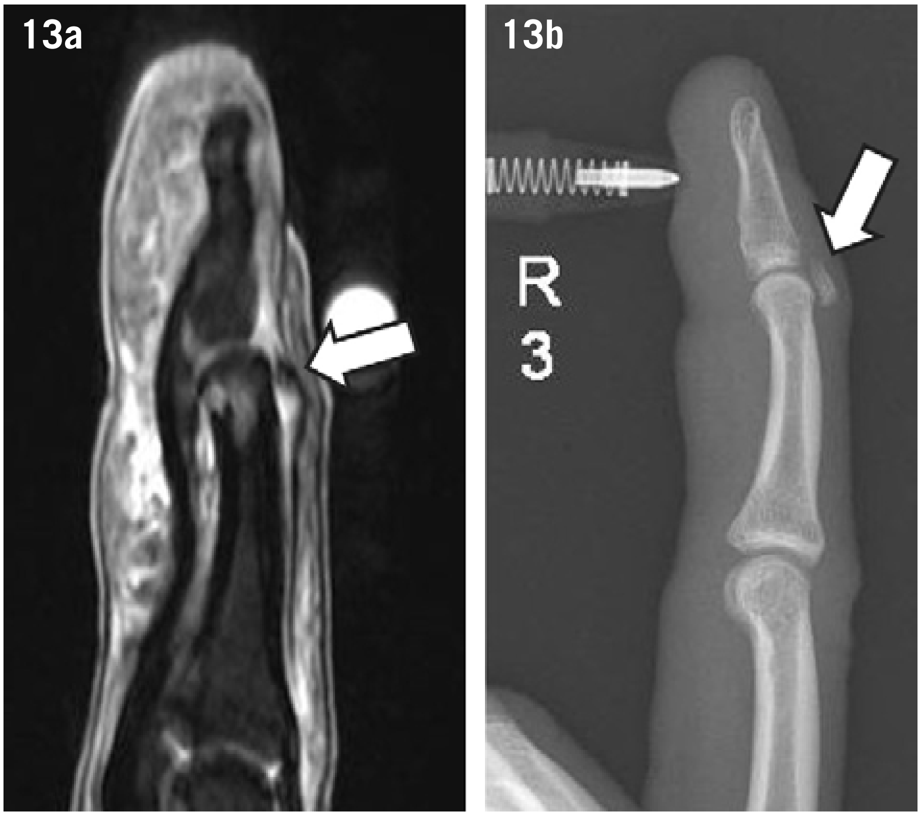
Figure 12: Magnetic resonance imaging of a stress reaction in the third metatarsal bone. Short (a) and long (b) axis T2 weighted images with fat saturation depicting bone marrow edema in the diaphysis of the third metatarsal bone (arrows) as well as periosteal edema (arrowhead) consistent with a stress reaction. No fracture line is seen.

tears, are common in handball players, particularly in the dominant throwing arm. However, full-thickness tears are relatively uncommon[20,21]. Both ultrasound and MRI are effective imaging modalities for assessing rotator cuff injuries. Ultrasound reveals thickened, hypoechoic, and heterogeneous tendons in tendinopathy, while tears appear as focal areas of anechoic material with accompanying tendon thinning. Similarly, MRI depicts tendinopathy as thickening and hypersignal of the tendon on T2-weighted images, whereas tears manifest as areas of discontinuity and interposed fluid with marked hypersignal on T2-weighted images. Nonetheless, interpretation of images should consider potential artifacts due to the curved morphology of the rotator cuff tendons, such as anisotropy in ultrasound scans and 'magic angle effect' on MRI. In these situations, the curvature of the tendon fibers, typically of the supraspinatus tendon, can create an angle between the tendon and the ultrasound beam or MRI magnetic field, leading to areas of hypoechogenicity or increased signal intensity that do not reflect actual tendon pathology.

The glenoid labrum is another common site of injury in handball players, with labral injuries slightly more prevalent in the dominant shoulder but also affecting the non-dominant arm[19]. Types of labral injuries include superior labrum anterior to posterior (SLAP) lesions, labral tears related to internal impingement, and posteroinferior labral tears. SLAP tears are believed to result from strain exerted on the bicipital-labral complex during the throwing motion. In imaging studies, a SLAP tear can be recognized by the presence of articular fluid or intra-articular contrast medium extending into the superior labrum (Figure 11). Additionally, SLAP tears may extend to involve other adjacent structures, such as the biceps tendon and other quadrants of the labrum.

Internal impingement, also known as posterosuperior impingement, arises from the abduction and external rotation of the shoulder during throwing motions. This movement pattern leads to the compression of the posterosuperior labrum and rotator cuff between the humerus and the glenoid. Consequently, this impingement results in: (i) degeneration and tears of the posterosuperior glenoid labrum; (ii) tendinopathy and articular sided partial tears of the rotator cuff in the transition zone between the supraspinatus and infraspinatus tendons; and (iii) remodeling and the formation of subcortical cysts in the posterosuperior aspect of the humeral head near the insertion of the infraspinatus tendon (Figure 12).

Handball players' shoulders, especially symptomatic ones, may exhibit glenohumeral internal rotation deficit (GIRD) and increased external rotation[22] likely occurring due to microtraumas



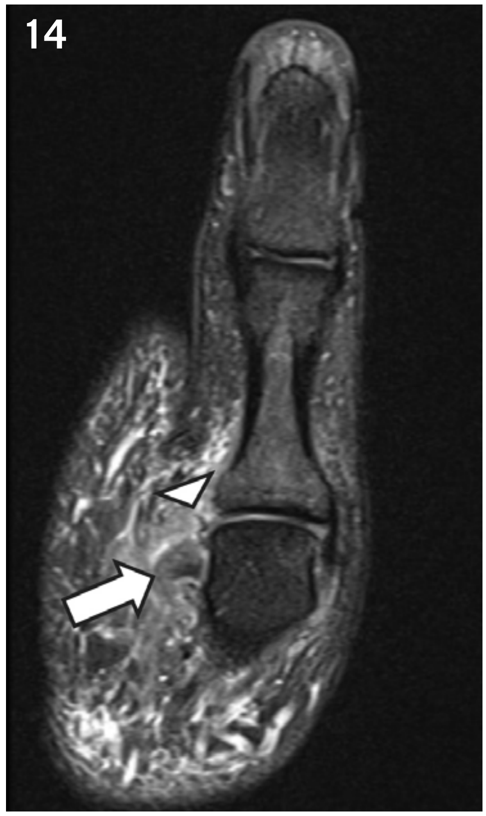


Figure 13: Magnetic resonance imaging and radiography of a mallet finger. Sagittal T2 weighted image (a) and radiography - lateral view (b) depict an avulsion of the terminal tendon of the extensor mechanism (arrow in a) with an osseous fragment from the dorsal aspect of the base of the distal phalanx, easily identified in the radiograph (arrow in b).

Figure 14: Magnetic resonance imaging of a Stener lesion. Coronal T2 weighted image with fat saturation of the thumb showing a complete tear and proximal retraction of the ulnar collateral ligament (arrow) of the metacarpophalangeal joint, with interposition of the adductor aponeurosis (arrowhead) between the ligament stump and the proximal phalanx.

related to abduction and external rotation during throwing. Clinically relevant GIRD may occur when the internal rotation loss exceeds the internal rotation gain, creating a deficit in the arc of motion[23] associated with stiffness of the rotator cuff and posterior capsule.

Hand and Finger Injuries

As previously mentioned, hand and finger injuries in handball players are most often caused by acute trauma, such as direct axial impact by a ball, contact trauma to the hand or falls onto the upper extremity. Less frequently, they are associated with overuse.

Traumatic injuries of the hand and wrist can include scaphoid fractures and tears of the scapholunate ligament. Scaphoid fractures represent about 70% of all carpal fractures[24], and are detectable using various imaging modalities, with MRI offering higher accuracy. In an MRI scan, a fractured scaphoid will exhibit edematous signal changes in the bone marrow, with a visible fracture line in both T1 and T2 weighted sequences. Another bone disorder associated with repetitive wrist loading in handball is osteonecrosis of the lunate, also known as Kienböck disease[24].

Hand and finger injuries may also involve the flexor and extensor tendons (e.g., mallet and boutonniere injuries, jersey finger) (Figure 13), collateral ligaments, flexor pulley and volar plate. Both MRI and high-frequency ultrasound scans can offer precise diagnoses of these injuries. MRI provides superior contrast resolution, while modern ultrasound probes offer excellent spatial resolution, and allow for dynamic maneuvers to be performed. Special attention should be paid to injuries of the ulnar collateral ligament at the thumb metacarpophalangeal joint, where identifying the injury location, presence of retraction, and potential interposition of the adductor aponeurosis between the tendon stump and the distal phalanx is crucial, as this indicates a Stener lesion (Figure 14).

CONCLUSION

In conclusion, handball players are at significant risk for a variety of injuries, particularly to the lower and upper extremities. This is due to the sport's high-intensity nature and frequent physical contact. Accurate diagnosis and appropriate treatment are essential to manage these injuries effectively and minimize time away from play. Utilizing advanced imaging techniques, such as MRI and ultrasound, allows for precise identification of injury extent and augments tailored treatment strategies.

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Paulo Victor Partezani Helito MD, PhD

Consultant Radiologist

Aspetar Orthopaedic and Sports Medicine Hospital

Doha, Qatar

Maria Lua Sampaio Gulde

Clinical Specialist Fellow (Sports Imaging)

Aspetar Orthopaedic and Sports Medicine Hospital

Doha, Qatar

Marcelo Bordalo MD, PhD

Chief of Radiology

Aspetar Orthopaedic and Sports Medicine Hospital

Doha, Qatar

Affonso Cardoso de Oliveira Neto MD

Musculoskeletal Radiologist

Hospital das Clinicas FMUSP

Sao Paolo, Brazil

Contact: paulo.helito@aspetar.com