Musculoskeletal MRI in Football Medicine – essential, useful or too much information?

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In the higher echelons of professional football, where financial resources are greater, the use of MRI as a diagnostic aid has been prevalent for the past 20 years. However, it has not always been employed as part of a validated clinical process with scans being requested sometimes for political reasons or simply in response to player/coach demand. The potential ramifications of MRI findings can go far beyond clinical management and affect transfer fees, player asset value, contract terms and conditions, insurability and medicolegal matters.

Radiologists reporting 'abnormal' findings can have detrimental effects on player wellbeing or confidence (or that of his/her therapist) leading to over-caution in training or rehabilitation and subsequent reduction in performance or athletic development. Clinical experience and scientific research show that many such 'abnormal' findings are in fact adaptive or developmental in response to the physical and biomechanical stresses of the sport and whilst they need to be recorded and noted once a player has been subjected to MRI examination, the interpretation by the referring practitioner is key as is subsequent communication to the player.

When interpreted within context by experienced sports physicians, therapists and radiologists working as a team, MRI can add great value if applied at appropriate times and situations as an adjunct alongside good clinical management. The advent of newer MRI techniques has increased diagnostic and screening/profiling possibilities and the development of functionally relevant protocols and sequences could enhance player care even further. Caution will be needed in how imaging information may be interpreted and potentially misused by those with business interests rather than patient welfare. This article will give an overview of musculoskeletal MRI as utilised in professional football though MRI is also becoming more widely used in the assessment of players from a cardiological and neurological perspective.

Clinical Relevance

Injury diagnosis

The majority of clinicians in professional football will not refer a player for MRI in the early stages of injury assessment partly because it is unlikely to change their immediate clinical management and also because their budgetary resources will not permit it. Amateur and recreational players are only likely to be referred for MRI if they have a significant injury and have been referred on to secondary care specialists such as orthopaedic surgeons.

Conversely, at top professional levels there is often increased pressure from the player and the manager/coach to give an immediate prognosis for an injury ('when will I be back, Doc?') and MRI has become fashionable as having a key role in that diagnostic and prognostic decision-making process. I have experienced situations where players have demanded a scan within minutes of leaving the pitch with muscle pain and whilst there are some infrequent indications for early MRI following a significant trauma it is often

Figure 1: Coronal oblique PD FS image of a 17 year old footballer's pelvis showing typical functional stress-related bone oedema in the pubic body bilaterally.

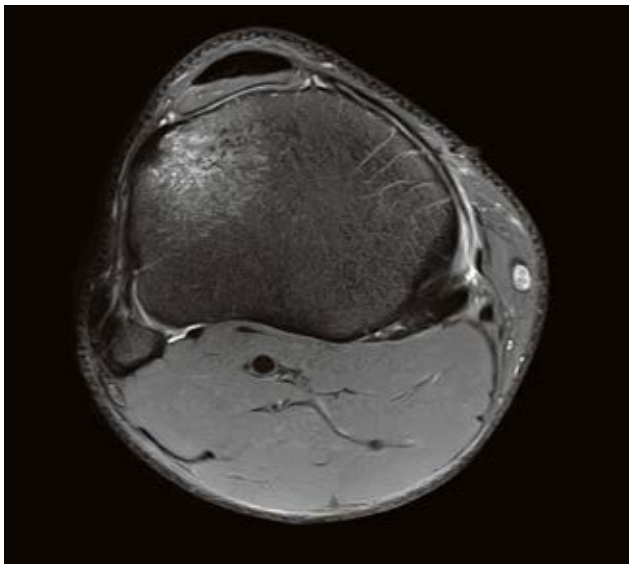

Figure 2: Axial PD FS image of a footballer's right knee showing a bony contusion in the medial proximal tibia due to a stud impact injury.

better to wait for the clinical picture to evolve and to allow the necessary physiological response to injury to occur in order that MRI can detect relevant pathological findings (oedema/haemorrhage, etc.). The timing and sequences applied will therefore depend on many factors such as player age, nature of trauma, time since trauma and suspected tissues involved. Player and coach education in these aspects is important as a means of managing the immediate situation which understandably causes anxiety in highly driven and motivated individuals who will be anxious about future results, performances, careers and the financial and personal implications of an injury. The more widespread use of ultrasound scanning by sports team physicians over recent years has been very helpful in appeasing players/coaches and in alleviating such anxieties whilst also being clinically useful as it is easily applied, relatively cheap and allows daily monitoring of injury evolution. MRI added to that combination at the right time with the right sequences and the right interpretation within context is often very valuable.

Joints (bone, cartilage ligament)

Traumatic injuries to the knee, ankle and midfoot joints are very common in football, predominantly in the form of ligament sprains/ruptures; overuse injuries can affect those joints but also the lumbar spine, hips and pubic symphysis. Shoulder, elbow and wrist injuries are less common but are often significant when present, including dislocations, subluxations, fractures and loose bodies. Whilst X-rays still play a role as the primary investigation for the suspected fracture and ultrasound can be of use in superficial bony and ligamentous lesions, MRI is the go-to modality for the complete assessment from an imaging perspective in joint injury, particularly if there is associated joint swelling (effusion or haemarthrosis) and/or clinical signs of instability.

As football is an inherently 'traumatic' sport in terms of mechanical joint loading and from contacts with the ball and other players, a diligent radiologist will report many 'positive' findings on MRI scans many of which may be noted but disregarded by the team physician when evaluating a player. Many such MRI findings represent normal adaptation responses to the demands of the sport or the stage of skeletal maturity of the player and are not necessarily pathological. Examples include transient marrow oedema in the pubic bones of an adolescent player (Fig. 1) or thickening of the medial collateral ligament of the knee in response to repetitive kicking and tackling actions. Other findings previously thought to be less significant radiologically such as 'bone bruises' following contact trauma are now taken more seriously and have been re-termed as micro-trabecular fractures in recognition of the underlying pathology (Fig. 2).

In my experience, MRI appearances 'over-grade' the severity of superficial ligament injuries when compared to a combination of clinical and ultrasound examination findings. Nevertheless MRI is essential to confirm the severity of deeper or internal joint ligament injuries such as knee cruciate ligament injury, particularly if the clinical signs are inconclusive (Fig. 3). MRI is the gold standard for imaging articular cartilage and meniscal cartilage injury, both of which may be acutely traumatic or chronically degenerative in origin in footballers or may occur in combination with ligament injury (Fig. 4). Bone marrow oedema on T2 or STIR sequences may indicate metabolic activity in an injured region such as the pars interarticularis of a lumbar vertebra or proximal shaft of a 5th metatarsal bone

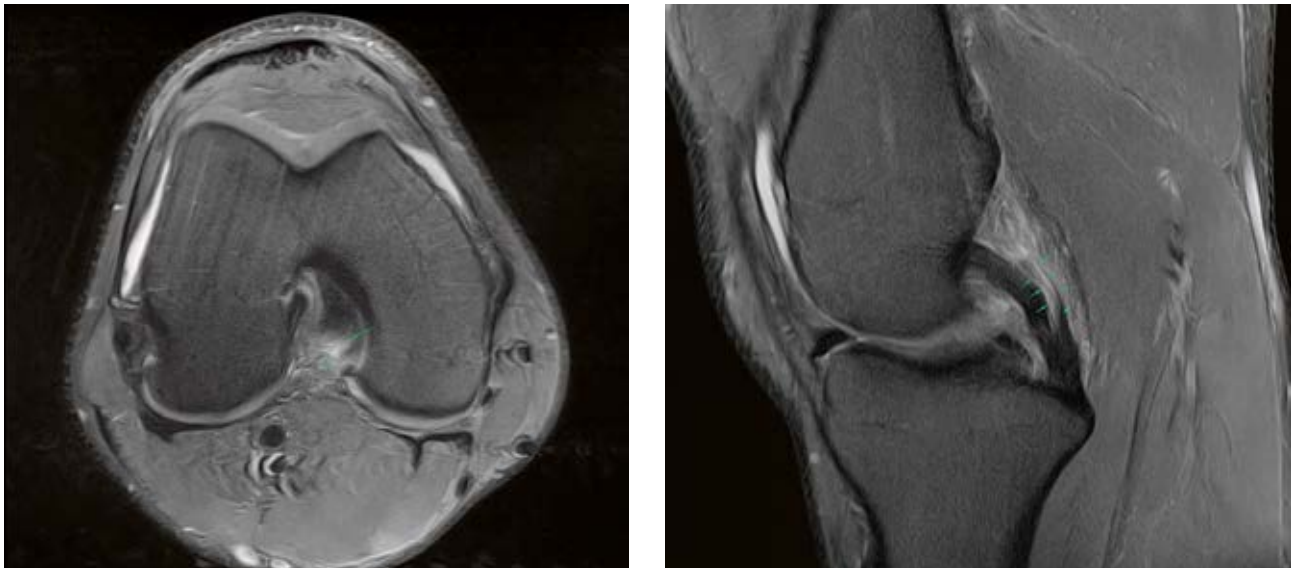

Figure 3: Axial & sagittal PD FS images of a footballer's right knee showing subtle oedema in the posteromedial bundle of the posterior cruciate ligament in keeping with a grade 1 sprain (green arrows).

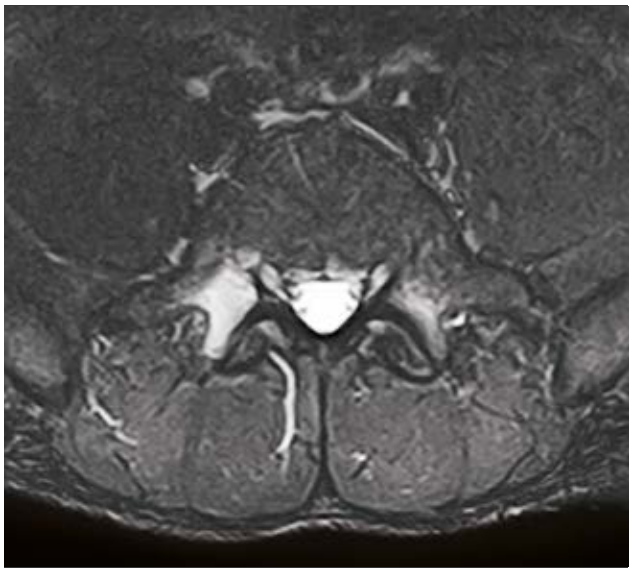

Figure 4: Axial STIR images of the 5th lumbar vertebra in a 20 year old footballer showing bilateral bone marrow oedema in the pars/pedicle region preceding eventual stress fracture formation.

Figure 5: Localised residual oedema in the same player's right pars/pedicle region 8 months later (2 months after a return to full training).

in the foot (common stress fracture sites in footballers). Marrow oedema may persist long after functional recovery and bone loading capacity has returned so its presence must not be the sole arbiter of a return to training activities (Fig. 5).

CT scanning has some advantages over MRI when assessing certain bone and joint injuries and both may be needed in combination to fully evaluate a hip impingement or lumbar spine stress fracture. The increasing image resolution afforded via 3T MRI imaging, however, is of great value when safely screening or profiling young footballers for anatomical factors that might predispose them to typical football injuries, e.g. hip adductor muscle strains associated with pubic symphiseal or sacroiliac degeneration or CAM/pincer-type hip dysplasia (Fig. 6).

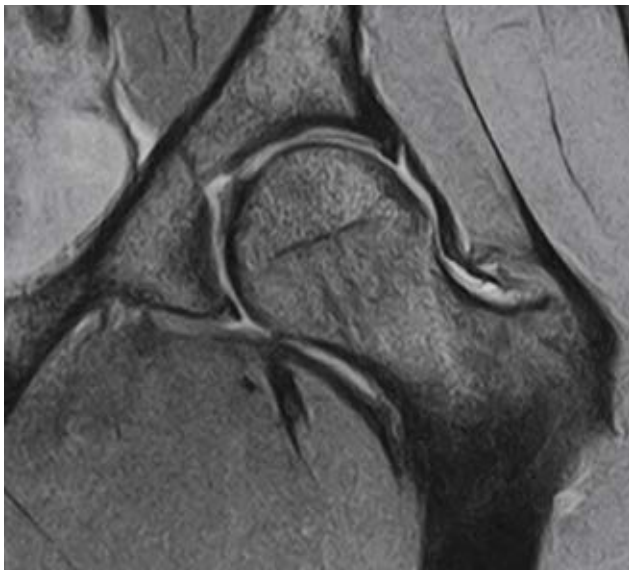

Figure 6: Coronal PD FS image of an 18 year old footballer's left hip showing CAM-type femoral head configuration with associated labral tear from repetitive impingement during kicking and running actions. Note the presence of pubic symphiseal degenerative changes, a common associated finding.

Muscle/tendon

MRI is most useful for differentiating between the 'MRI-positive' (i.e. oedema, haemorrhage +/- structural disruption) and the 'MRI-negative' (i.e. no oedema, haemorrhage or structural disruption). High resolution ultrasound scanning in combination with clinical history and examination is sufficient in most cases to confirm structural injury but can be less helpful in confirming a functional injury where subtle muscle oedema may be present. MRI can be 'over-sensitive' with regard to muscle oedema causing dilemmas for the treating practitioner when determining the pathological from the normal reactive increase in lymphatic and vascular fluid post-exercise.

Timing of MRI examination after clinical presentation is therefore important. 24 to 48 hours is generally accepted as sensible practice to reduce the risk of false negatives or positives by scanning too soon. The widely used Peetron's grading system to describe muscle oedema and structural disruption is being superseded by alternative classification systems bespoke to athlete muscle evaluation as they are deemed to be more specific or relevant to clinical decision making. These include classifications based on MRI appearances alone1 or those based on combining clinical presentations and examination findings with ultrasound and/or MRI appearances2 (Fig. 7 & 8).

Debate exists as to the validity of MRI in determining key factors for the player, therapist and coach such as prognosis and return to play decisions3,4 and there is no doubt that injured muscles can remain 'MRI-positive' for some time after functional recovery and return to play has been achieved6. Whilst the scientific research may not always be conclusive, experiential practice supports the use of MRI for accurate anatomical location and structural integrity assessment in key muscle injuries such as quadriceps, hamstrings and calf as the information gleaned can influence rehabilitation programmes in order to restore full performance whilst minimising re-injury risk. MRI may be the only way of identify deep groin/pelvic muscle injury in footballers that is beyond the depth of view of ultrasound scanning.

Footballers' tendon injuries are readily amenable to assessment by ultrasound in view of their relatively superficial location (patellar, Achilles, peroneal, tibialis posterior being those most often affected). The higher spatial resolution, the ability to assess dynamically

and with Doppler/Microvascular Imaging and Elastography/Tissue Characterisation make ultrasound the modality of choice in most cases but MRI can add value when assessing the musculotendinous junction particularly if structural injury is very subtle or when examining longer tendons that follow a convoluted course (e.g. peroneus longus/flexor hallucis longus). Newer MRI techniques (ultra-short TE sequencing) may begin to tilt the balance more in favour of MRI.

Screening/profiling

It is difficult in many clinical settings to justify the use of MRI as a screening tool if the word 'screening' is utilised correctly within context of the Wilson-Jungner criteria (see below).

1. The condition sought should be an important health problem.
2. There should be an accepted treatment for patients with recognized disease.
3. Facilities for diagnosis and treatment should be available.
4. There should be a recognizable latent or early symptomatic stage.
5. There should be a suitable test or examination.
6. The test should be acceptable to the population.
7. The natural history of the condition, including development from latent to declared disease, should be adequately understood.
8. There should be an agreed policy on whom to treat as patients.
9. The cost of case finding (including diagnosis and treatment of patients diagnosed) should be economically balanced in relation to possible expenditure on medical care as a whole.
10. Case finding should be a continuing process and a not "once for all" project.

In an elite football club setting, however, the relative definitions of terms such as 'important health problem' and 'economically balanced in relation to medical care as a whole' will be viewed differently and MRI becomes a more acceptable screening tool for certain conditions. In reality there is insufficient scientific evidence to meet some of the other criteria such as 'latent/asymptomatic early stages' and 'recognised treatment pathways' and the players expect their healthcare and performance optimisation to be managed on an individual basis albeit within a team 'population' setting. In view of that I prefer to avoid the term 'screening' and replace it with 'profiling' as that enables the individual player to be compared to himself over time (injury surveillance) or against a group which can be defined in many ways (age, ability, playing position, etc.). MRI can be a powerful addition to all the other aspects of health and performance profiling that medical & science professionals can undertake on footballers.

Examples of such profiling include body composition assessment, muscle length, cross-sectional area and volume, skeletal maturity that can be specific to areas relevant to football such as pelvis and knee joints as opposed to standardised wrist imaging for skeletal age estimation. Emerging techniques utilising 3T MRI can assist with profiling muscle fibre type and joint cartilage composition via non-invasive means which makes the assessment very acceptable to the athlete patient.

Since access to players for screening/profiling purposes can be difficult to obtain, having a dedicated MRI facility close to hand is essential. However, there is usually one opportunity to profile a player when he/she joins the club (although the nature of the transfer system can also make that very difficult at times).

The 'Signing/Transfer' medical

The common perception portrayed by the media is that footballers either 'pass' or 'fail' their transfer medicals when joining a new club. As there are no legislative or industry-defined criteria for fitness to play professionally this is not strictly true. Each scenario will be different depending on the context of the transfer and this might be influenced by the duration of the proposed contract, the size of the transfer fee, the terms and conditions of the contract and financial aspects such as salaries and agent's fees. The process is more one of risk assessment and an opportunity to gather baseline information in order to assist with the player's subsequent medical care should he/she join the club. Whilst a transfer medical can be likened to a pre-employment medical where the initial duty of care is to the employer, a duty of care is also assumed towards the player whether

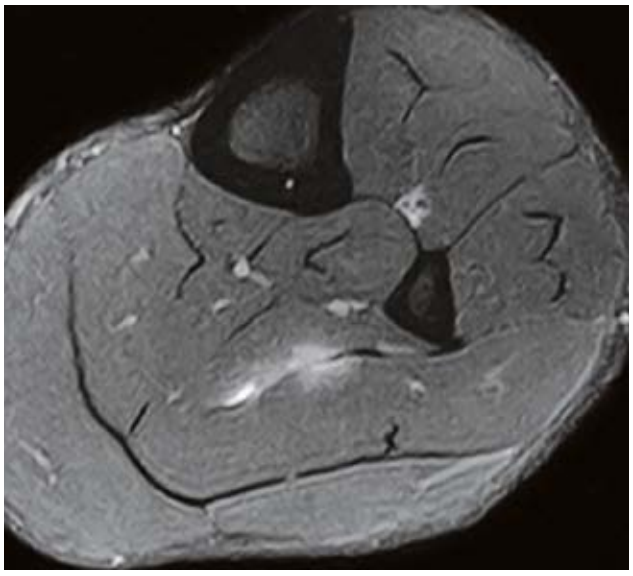

Figure 7: Axial PD FS image of a footballer's left calf muscle showing subtle oedema in the deep lateral soleus musculotendinous junction consistent with minor functional or very low grade structural injury.

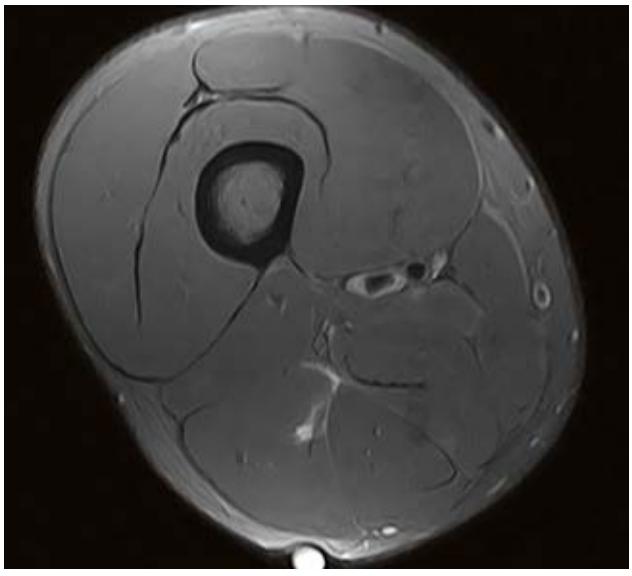

Figure 8: Axial PD FS image of a footballer's right thigh showing a localised structural defect at the biceps femoris musculotendinous junction with high signal extending from that into the myofascial space consistent with a moderate partial muscle tear (Munich Classification Type 3B).

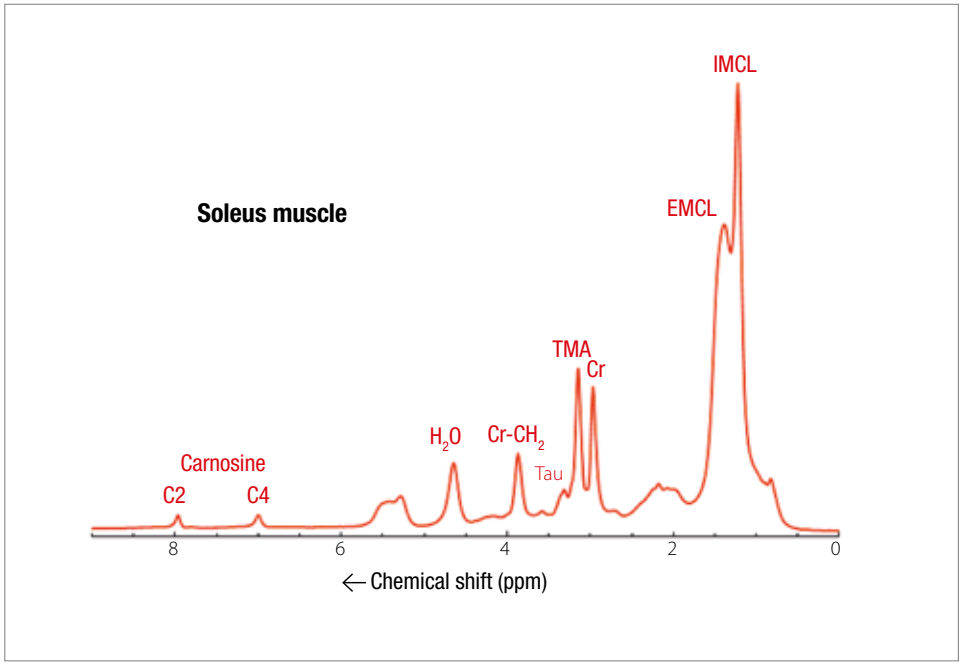

Figure 9: Spectroscopy of soleus muscle to assess carnosine content as an indicator of type 2 'fast-twitch' muscle fibre proportion.

he eventually signs or not, particularly if adverse findings are detected. MRI scanning can therefore be very informative but also fraught with ethical and medicolegal issues in such circumstances.

One of the major limiting factors in transfer medicals is time available, particularly if it takes place near the end of the transfer window periods. MRI scanning is usually the most time- consuming aspect of the medical assessment, even if limited sequence protocols are employed, and it might be impossible to include MRI if a transfer takes place in the final hours of 'deadline day'. Wherever possible it is our policy to include a limited sequence protocol examining lumbar spine, pelvis, hips, knees and ankles with additional sequences if clinically indicated from history and physical/functional examination. The scanning time needed is around 2.5 hours plus any transport time if this has to be undertaken at a remote facility. It's a long time for a player to be on the scanner table so maximising comfort and minimising sequence time is essential for full compliance and a positive 'first experience' for the player at his/her intended new club.

Although there is no consensus amongst football medics regarding the value of transfer medical MRI and many medicals take place without them being performed, it seems logical that the more information one is aware of when investing in a high value player the better, especially with regard to the detection of asymptomatic or subclinical pathology. Evolving articular cartilage lesions in joints or painless degenerative tendinosis might not cause a problem but could also be performance-limiting and potentially career-threatening; knowing about their presence in advance can help by modification of training loads and initiation of preventative programmes as part of asset management. MRI provides a baseline checkpoint which can be referred back to for comparison if needed.

As decisions, risk assessments and recommendations are usually required immediately after completion of the medical examinations it's vital to have experienced radiologists available 24/7 to report and discuss within clinical and functional context. In high value transfers it is not unusual to undertake 'double reporting' to seek a range of unbiased opinion.

'Performance' imaging

In addition to standard anatomical MRI, post-processing applications can visualise structures in a more impactful manner (e.g. fat and lean mass) and quantify muscle tissue dimensions and volume. This can be very important for monitoring results of conditioning or rehabilitation programmes when comparing the player to him/herself or to a population of players who have been profiled in a similar manner.

MRI spectroscopy can be utilised to measure amounts of substances key to muscle function or fibre type composition, e.g. carnosine content is closely related to the proportion of fast-twitch fibres a player has within the muscle5. This can have implications for his/her genetically-determined performance potential, prescription of training programmes and recovery strategies post exercise (Fig. 9).

Compositional assessment of joint cartilage7 is an exciting new development for football medicine as it has the capacity to detect microstructural and biochemical changes within the articular cartilage before eventual structural defects become apparent on standard MRI. Whilst many players are able to play professionally with established articular cartilage defects this pathology is one of the major career-limiting factors for a footballer if hip, knee or ankle are affected. Even if able to play without recurring joint pain, swelling or mechanical dysfunction, secondary injury or performance impairment is likely due to associated muscle inhibition or protective hypertonicity. The ability to detect pre-symptomatic changes in the cartilage by quantitative T2 mapping may facilitate early implementation of preventative strategies thereby prolonging athletic performance and the long-term health of the joint beyond the playing career.

1.5T v 3T

Although scanning with a 3T rather than a 1.5T scanner will not alter the subsequent clinical management in the majority of cases of typical football injury[8], 3T does offer advantages in terms of reduced scanning time (and hence patient comfort and acceptability). If time is no issue, better image quality is possible particularly for smaller joints such as the foot or wrist where subtle ligament or joint injury might otherwise go undetected. The radiographer and radiologist

will need to amend their 1.5T techniques and some time may be required to fine-tune a 3T scanner to the area under examination. The effort will be worthwhile leading as it leads to beautiful images. Findings that previously were impossible to detect need to be interpreted carefully in conjunction with the treating sports physician. Another advantage of 3T MRI in the sports medicine setting is that emerging technologies such as those described above for performance profiling are more readily applicable in higher field strengths.

Summary

As the physical demands of professional football and the financial investments in the industry continue to increase year on year, the pressure on club medical & science teams to maintain their players in top condition also increases. Some injuries are inevitable and the aim then is to return the player to the pitch at the required performance level with minimised risk of re-injury in the shortest possible time. MRI has a role to play in that overall process and it will continue to evolve as technologies develop and practitioners become familiar and confident in applying them within this unique area of sports medicine. //

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