Thigh muscles injuries in professional football players: from diagnosis to follow-up

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Aims and objectives

Illustrate the normal anatomical appearance of thigh muscles, producing detailed didactical schemes correlating with dHRUS-MR imaging findings and providing a systematic technique for the evaluation of such structures.

Provide a clear standardization of muscles injuries in order to facilitate interdisciplinary collaboration.

Describe a detailed, integrated dHRUS-MR appearance of thigh most common soccer-related injuries.
Methods and materials

1. BACKGROUND

Thigh muscles injuries represent one of the most common diagnosis in athletes. Over the past years, there has been a gradual evolution in our understanding and management of thigh muscles injuries, but the challenge of optimising the management of the injured muscle remains. In professional soccer, 9 out of 10 muscular injuries affect the 3 major muscle groups of the thigh: hamstrings, adductors and quadriceps in order of prevalence, demonstrating their high relevance for professional athletes as well as for the clubs. Clinical evaluation has consistently been shown to have a high false positive rate when compared with imaging findings and in particular with MRI; clinicians are now turning to imaging examinations to confirm injury as well as to provide information about a proposed period of convalescence. Generous remuneration and desire to play at the professional level intensify the pressure to return to competition rapidly and may undermine the healing process. However, a premature return to competition may result in recurrent injury and a more prolonged period of convalescence. Thigh muscles injuries are responsible for a large proportion of time lost to competition, and for all professional athletes rapid return to training and competition is a priority, but not too soon, when the risk of recurrent injury is still high: MR imaging and ultrasound are necessary complements to the clinical assessment of these lesions in professional athletes.

2. ANATOMY AND BIOMECHANICS

Thigh could be divided in three major fascial compartments: the anterior compartment including quadriceps (rectus femoris, vastus lateralis, vastus intermedius and vastus medialis) and sartorius muscles; the posterior compartment consisting of hamstrings muscles (semimembranous, semitendinous and biceps femoris); the medial compartment including gracilis, pectineus, adductor longus, brevis and magnus muscles. Muscles that perform eccentric, rather than concentric contraction, and muscles that cross two joints (hamstrings, sartorius, gracilis and rectus femoris) are most susceptible to strain injury.

The anterior thigh muscles

Of the quadriceps muscles, the rectus femoris muscle is the most commonly injured; this is thought to be because it crosses both the hip and knee joints, contains a high percentage of type II fibres, and has a complex musculo-tendinous architecture.
**Fig. 1:** Anterior compartment of the thigh.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT

**Quadriceps femoris:** This muscle includes four heads that originate in different locations but all share the quadriceps tendon, which inserts onto the patella. The continuation of the quadriceps tendon that extends from the patella and inserts onto the tibial tuberosity of the tibia is called the patellar ligament. All four parts of the muscle are innervated by the femoral nerve, and they extend the knee. The rectus femoris, however, also flexes the hip.

- **Rectus femoris** forms the middle portion of the quadriceps. It originates at the anterior inferior iliac spine and just above the acetabulum of the hip bone.
- **Vastus lateralis** is the lateral-most head. It originates at the greater trochanter and the linea aspera of the femur.
- **Vastus medialis** is the most medial of the heads. It originates on the intertrochanteric line and linea aspera.
- **Vastus intermedius** lies behind the rectus femoris. It originates on the shaft of the femur.
**Pectineus:** This muscle originates on the superior ramus of the pubis portion of the hip bone and inserts on the pectineal line of the femur. It’s innervated by the femoral nerve and adducts and flexes the thigh.

**Sartorius:** Originating on the anterior superior iliac spine, this muscle inserts on the medial surface of the tibia. It’s innervated by the femoral nerve, and it flexes, abducts, and laterally rotates the thigh. It also flexes the leg at the knee.

**Iliopsoas:** The iliopsoas is made up of two muscles that flex the thigh. One of those muscles, the psoas major, is also important for posture: psoas major originates on the 12th thoracic and the five lumbar vertebrae. It inserts onto the lesser trochanter of the femur and is innervated by the first three lumbar spinal nerves. Iliacus originates on the iliac crest, sacrum, and sacroiliac ligaments. It inserts onto the tendons of the psoas major and the lesser trochanter of the femur. It’s innervated by the femoral nerve.

**The medial thigh muscles**

The muscles of the medial part of the thigh include muscles that bring the thigh toward the midline and rotate it, the adductor longus is the most commonly injured:
Fig. 2: Medial compartment of the thigh.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT

**Adductor longus:** This muscle originates on the pubis and inserts onto the middle of the linea aspera of the femur. It’s innervated by the obturator nerve and adducts the thigh.

**Adductor brevis:** Originating on the pubis and inserting on the pectineal line and linea aspera of the femur, this muscle is innervated by the obturator nerve. It adducts the thigh.

**Adductor magnus:** This muscle originates on the pubis and the ischial tuberosity. It inserts onto the gluteal tuberosity, linea aspera, and the adductor tubercle of the femur. It’s innervated by the obturator nerve and the sciatic nerve. It adducts the thigh and assists in both flexion and extension of the thigh.
**Gracilis:** This muscle originates on the pubis and inserts on the medial tibia. It's innervated by the obturator nerve. It adducts the thigh and flexes the leg at the knee.

**Obturator externus:** Originating at the obturator foramen and membrane of the hip bone, this muscle inserts onto the femur. It's innervated by the obturator nerve and laterally rotates the thigh.

**The posterior thigh muscles**

The three muscles of the posterior thigh are known as the hamstring muscles. Hamstrings cross both hip and knee joints, and integrate extension at the hip with flexion at the knee. Biceps femoris is the most commonly injured muscle in the hamstring muscle group. The semitendinosus muscle is a thin, band-like muscle with a long tendon distally, which may predispose the muscle to lesion. The semimembranosus arises from the superolateral part of the ischial tuberosity, its tendon has to be distinguished from the semitendinosus tendon.
Fig. 3: Posterior compartment of the thigh.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT

Semimembranosus: The most medial of the three hamstring muscles, this muscle originates on the ischial tuberosity and inserts on the medial condyle of the tibia. It functions with the semitendinosus to extend the thigh and flex and medially rotate the leg. It’s innervated by the tibial portion of the sciatic nerve.

Semitendinosus: This muscle originates on the ischial tuberosity and inserts onto the superior part of the medial tibia. It’s innervated by the tibial portion of the sciatic nerve and extends the thigh and flexes and medially rotates the leg.

Biceps femoris: The most lateral of the hamstrings, the biceps femoris has two heads: the long and the short. The long head originates on the ischial tuberosity, and the short head originates on the linea aspera of the femur. They insert onto the lateral side of the fibula. The long head is innervated by the tibial portion of the sciatic nerve, and the short head is innervated by the fibular portion of the sciatic nerve. It extends the thigh and flexes and laterally rotates the leg.

Cross-sectional thigh anatomy
Fig. 4: Cross-sectional anatomy of the thigh

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 5: TSE T1W axial scan of the thigh at a upper level. S: Sartorius; P: Pectineus; PS: IlioPsoas; V: Vastus Intermedius; R: Rectus femoris; T: Tensor fasciae latae; OE: Obturator externus; QF: Quadratus femoris; G: Gluteus magnus; H: Proximal insertion of hamstrings on the posterior ischiatic tubercle; AL, AB, AM: Proximal insertions of adductor longus, brevis and magnus respectively.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 6: TSE T1W axial scan of the thigh at an intermediate level. S: Sartorius; V: Vastus Intermedius; VM: Vastus medialis; VL: Vastus lateralis; R: Rectus femoris; femoris; AL: Adductor longus; AB: Adductor brevis; AM: Adductor magnus; G: Gracilis; SM: Semimembranosus; ST: Semitendinosus; BF: Biceps femoris.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 7: TSE T1W axial scan of the thigh at a lower level. S: Sartorius; V: Vastus Intermedius; VM: Vastus medialis; VL: Vastus lateralis; R: Rectus femoris; femoris; AM: Adductor magnus; G: Gracilis; SM: Semimembranosus; ST: Semitendinosus; BF: Biceps femoris.

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3. TERMINOLOGY AND CLASSIFICATION

The combination of diagnostic modalities such as medical history, inspection, clinical examination and imaging will most likely lead to an accurate diagnosis. History and clinical examination will help in diagnosing muscles injury in most cases. The athlete typically describes sudden pain in a determined point of thigh, resulting in the immediate cessation of the activity. However, not all muscular lesions manifest with this classic history. Differentiating between injury and muscle soreness, identifying recurrent tears in the rehabilitating athlete, or diagnosing an acute injury against a background of prior chronic strain can be difficult clinically. The goals of imaging are to confirm injury, provide a comprehensive assessment of the nature of the injury, and identify
which patients may benefit from surgery. Furthermore, referred pain, most commonly from the lumbar spine and the hip, may further complicate the clinical picture in the professional soccer player.

Many previous muscle injury classification systems had been presented, the currently most widely used classification is an MRI-based graduation defining four grades: grade 0 with no pathological findings, grade 1 with a muscle oedema only but without evidence of tissue damage, grade 2 as partial muscle tear and grade 3 with a complete muscle tear. In a professional soccer club the majority of muscular injuries are classified as grade I- II lesions.

It is very important to have a clear definition of each type of muscle injury, a differentiation according to symptoms, clinical signs, location and imaging in order to get a better collaboration between specialists of different fields and, further, to have better management of the injured athletes.

**Classification of acute muscle injuries**

A. Indirect muscle disorder/injury
   • Functional muscle disorder
      - Fatigue-induced muscle disorder
      - Delayed-onset muscle soreness (DOMS)#
      - Spine-related neuromuscular Muscle disorder - Muscle-related neuromuscular Muscle disorder

   • Structural muscle injury
      - Minor partial muscle tear(grade1)
      - Moderate partial muscle tear#(grade2)
      - Subtotal or complete muscle tear(grade3) - Tendinous avulsion

B. Direct muscle injury - Contusion
   - Laceration

**FOCUS ON FOOTBALL PLAYERS MOST COMMON INJURIES**

**Minor partial muscle tear (Grade 1 tear)**

Tear with a maximum diameter of less than muscle fascicle/bundle.

Clinical: Sharp, needle-like or stabbing pain at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain; Well-defined localised pain. Stretch-induced pain aggravation
Imaging: Positive for feathery pattern edema on high resolution MRI and possible fibers disomogeneity on dHRUS.

**Moderate partial muscle tear (Grade 2 tear)**

Tear with a diameter of greater than a fascicle/bundle

Clinical: Stabbing, sharp pain, often noticeable tearing at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain. Possible fall of athlete; Well-defined localised pain. Probably palpable defect in muscle structure, often haematoma, fascial injury. Stretch-induced pain aggravation

Imaging: Positive for fibre disruption. Possible fascial injury and intermuscular haematoma.

**(Sub)total muscle tear/tendinous avulsion (Grade 3 tear)**

Tear involving the subtotal/ complete muscle diameter/ tendinous injury involving the bone-tendon junction

Clinical:Dull pain at time of injury. Noticeable tearing. Athlete experiences a 'snap' followed by a sudden onset of localised pain. Often fall; Large defect in muscle, haematoma, palpable gap, haematoma, muscle retraction, pain with movement, loss of function, haematoma

Imaging: Subtotal/complete discontinuity of muscle/ tendon. Possible wavy tendon morphology and retraction. With fascial injury and intermuscular haematoma

**Direct injury (Contusion)**

Direct muscle trauma, caused by blunt external force. Leading to diffuse or circumscribed haematoma within the muscle causing pain and loss of motion

Clinical: Dull pain at time of injury, possibly increasing due to increasing haematoma. Athlete often reports definite external mechanism; Dull, diffuse pain, haematoma, pain on movement, swelling, decreased range of motion, tenderness to palpation depending on the severity of impact. Athlete may be able to continue sport activity rather than in indirect structural injury

Site: Any muscle, mostly vastus intermedius and rectus femoris Imaging: Diffuse or circumscribed haematoma in varying dimensions
Scar tissue

The great majority of muscle injuries don’t heal with the formation of scar tissue. However, greater muscle tears can result in a scar formation which has to be considered in the diagnosis and prognosis of a muscle injury. Usually partial tears of less than a muscle fascicle heal completely while moderate partial tears can result in a fibrous scar. Recurrent muscle injuries, more severe than the first injury, could occur for the premature return to full activity due to an underestimated injury. Healing of muscle and other soft tissue is a gradual process: the connective tissue constituting the scar produced at the injury site is the weakest point of the injured skeletal muscle; full strength of the injured tissue needs time to return depending on the size and localisation of the injury.
Fig. 1: Anterior compartment of the thigh.

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Fig. 2: Medial compartment of the thigh.

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Fig. 3: Posterior compartment of the thigh.

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Fig. 4: Cross-sectional anatomy of the thigh

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Results

1. Imaging protocol

It is very important to start with a precise injury circumstances investigation followed by a careful clinical examination of the muscles. An early post-injury d-HRUS between 2 and 48 h after the muscle trauma provides helpful information about any existing disturbance of the muscle structure, particularly if there is any haematoma or if clinical examination points towards a functional disorder without evidence of structural damage. MRI (after 48-72 hours post-injury) is mandatory for every injury which is suspicious for structural muscle injury. MRI is helpful in determining whether oedema is present, in what pattern, and if there is a structural lesion including its approximate size. Furthermore, MRI is helpful in confirming the site of injury and any tendon involvement. Then in our protocol an intermediate combined MRI - dHRUS follow-up has to be performed at about 2 weeks from the time of injury (monitoring the evolution of the healing process); in the end, a last combined follow-up is performed at about 4-6 weeks from the injury time (assessing whether or not there is a complete healing of the lesion and if scar tissue is present or not). Commonly additional d-HRUS evaluation could be executed through the whole rehabilitation time in case of particular needs of the team medical staff.

Dynamic-HRUS

The US evaluation has to be conducted with high-quality linear transducers for the musculoskeletal study; it consists in multiple long-axis and short-axis scans of the region of interest of the injured muscle (corresponding to the region of pain), assessing the potential structural damage, the presence of intramuscular and/or intrafascial haematoma, the status of the tendons, the size of the tear and the possible scar tissue formation. It is important not to make too much compression with the probe on the skin because a possible deep intramuscular haematoma could be masked by the tissues mechanical compression and because a minor muscle injury could results less detectable. Further a dynamic evaluation, making the patient perform an isometric contraction of the muscle against appropriate resistance, could be very useful in assessing minor injuries, in appropriately giving the size of the lesion and, particularly, in evaluating the true stabilisation of the scar tissue during the follow-up of the lesion.

MRI

Fluid-sensitive sequences play an important role in our protocol for muscle injuries detection:

- Long axis plane: TSE T2W fat saturated, STIR(long TE)
- sagittal if evaluating abnormalities in the anterior or posterior aspect of the thigh
- coronal if evaluating abnormalities in the medial or lateral aspect of the thigh
  - Axial plane: TSE T1W and T2W or intermediate weighted (fat suppression increases sensitivity).
  - Additional sequences:

- GE if looking for metallic foreign bodies, gas, hemosiderin - IV gadolinium in detecting early very subtle muscle injuries
- IV gadolinium in detecting early very subtle muscle injuries

2. Soccer-related Imaging Findings

   - DOMS (Delayed Onset Muscle Soreness)

     MR: Diffuse hyprintensity of the whole muscle without signs of fibers tear
     US: No signs of fiber disruption or tissue disomogeneity

       - Grade 1

     MR: Intramuscular ‘feathery' hyperintensity on fluid-sensitive sequences without muscle fiber or tendon disruption

     US: Areas of intramuscular hyperechogenicity and/or fibers focal disomogeneity
     Symptoms: Pain

       - Grade 2

     MR: Hyperintensity (oedema and haemorrhage) intramuscularly or at the MTJ, with extension along the fascial planes between muscle groups; Irregularity and mild laxity of tendon fibres; haematoma at the MTJ is pathognomonic

     US: Discontinuity of muscle fibres with hypervascularity around disrupted muscle fibres; altered echogenicity and loss of perimysial striation adjacent to the MTJ; intramuscular fluid collection (hypoechochogenicity) with a surrounding hyperechoic halo

     Symptoms: Weakness

       - Grade 3

     MR: Complete discontinuity of muscle fibres (at the MTJ) associated with extensive oedema and haematoma, and possible retraction of tendon

     US: Ill-defined area of hyperechogenicity in the muscle, which may cross fascial planes
     Symptoms: Loss of function
• Contusion

MR: T1-weighted and fluid-sensitive sequences may show hypo- to hyperintensity US: Area of intramuscular hyperechogenicity
Symptoms: Pain

• Avulsion

MR: Redundant tendon edge lying within large fluid collection/haematoma; a small bony fragment
US: Evaluation is difficult due to the presence of mixed echogenicity haematoma with similar echogenicity to the avulsed tendon
Symptoms: Loss of function

• Scar tissue

MR: Scar tissue formation appears hypointense on all pulse sequences with progressively reduction of the nearby oedema signal intensity
US: Areas of scar tissue have irregular morphological features and display heterogeneous echo texture(mostly hyperechoic)
Symptoms: Normal function

• Hematoma

- Acute (<48 h)

MR: typically isointense to muscles on T1-weighted images
US: Appears as a hypoechoic fluid collection and may contain debris

- Subacute

MR: higher signal intensity than muscle on both T1-weighted and fluid-sensitive sequences; variable signal intensities within hematoma
US: Variable appearance (anechoic, hypoechoic or hyperechoic) within 24 h of injury; appearance changes over the next few days becoming hypoechoic or anechoic

- Chronic
MR: Dark signal intensity rim seen on all pulse sequences due to hemosiderin US: hypoechoic or anechoic.
**Fig. 8:** DOMS. 25-year-old football player with delayed onset muscle soreness: diffuse hyperintensity is visible in the left adductor longus muscle. A and B: STIR long TE coronal scans; C: TSE T2W FATSAT axial scan. Notice the associated intraosseous hyperaemia against the pubic symphysis in A.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 9:** I-II grade injury of the rectus femoris. 31-year-old football player with fibers disruption along the MTJ of the proximal tendon of the left rectus femoris muscle, surrounding intramuscular oedema and fascial hematoma. A: TSE T2 axial scan; B: STIR long TE coronal scan; C: STIR long TE sagittal scan.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 10**: Rectus Femoris Grade II. A: TSE T2W axial scan of the upper-middle third of the thigh showing muscular tear at the rectus femoris MTJ and the intramuscular hematoma. B: Corresponding HRUS axial scan showing the hypoechoic tear, the intramuscular hematoma and the fascial involvement. C: Corresponding longitudinal scan highlighting in particular the extension of the hematoma and the fibers architecture alteration.

**References**: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 11: II grade lesion of the vastus intermedius. 28-year-old football player with fibers disruption and intramuscular hematoma in the deep portion of the left vastus intermedius. A: STIR long TE coronal scan; B: TSE T2W axial scan; C: TSE T2W FATSAT axial scan

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 12: Vastus intermedius Grade II. A: TSE T2W FATSAT axial scan of the upper-middle thigh; II grade vastus intermedius muscle tear with intramuscular hematoma seen as hyperintensity around the lesion. B: Corresponding HRUS axial scan through the deep portion of the vastus intermedius showing the hypoechoic fibers interruption with hematoma and adjacent fibers disomogeneity.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 13:** I-II grade lesions of the vastus lateralis muscle. 25-year-old football player with myofascial oedema at the upper-middle third of the left vastus lateralis muscle. MR performed 24h post-trauma. A: STIR long TE coronal scan; B: TSE T2W FATSAT axial scan C: TSE T2W axial scan

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 14: II grade lesion of the Iliopsoas muscle. Fibers disruption with intramuscular oedema visible at the MTJ of the right ilio-psoas muscle. A: STIR long TE coronal scan; B: STIR long TE sagittal scan. C: TSE T2W FATSAT axial scan

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 15: Grade II lesion of the Gracilis muscle. 31-year-old football player with fibers disruption on the middle-distal third of the left gracilis muscle with intramuscular oedema and fascial involvement. A: STIR long TE coronal scan B: TSE T2W axial scan C: TSE T2W FATSAT axial scan

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 16:** II grade adductor longus tear. 29-year-old football player with re-injury of the left adductor longus muscle. Images show the hyperintense hematoma extending from the previous myofascial tear superficial site, through the myofascial plane (between adductor longus and brevis), into the deep portion of the thigh. A: STIR long TE sagittal scan; B: TSE T2W FATSAT upper axial scan; C: TSE T2W FATSAT lower axial scan. 

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 17:** Adductor longus Grade II. A: TSE T2W FATSAT axial scan of the upper portion of the thigh. Grade II tear on a previous myofascial lesion of the adductor longus muscle. The tear appears as a loss of signal image and the intra- and intermuscular hematoma as a hyperintense signal on this scan. B: Corresponding HRUS scan showing the hypoechoic fibers tear, the more superficial scar tissue formation at the previous lesion site, the hyperechoic intramuscular hematoma and the hypoechoic fascial hematoma.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 18:** II grade lesion of the hamstrings. 24-year-old football player with laceration of the fibers at the MTJ of the right biceps femoris/semitendineous muscle with intra- and inter-muscular hematoma extending along the fascia and surrounding the sciatic nerve. A: TSE T2W axial scan; B: STIR long TE sagittal scan; C: STIR long TE coronal scan. 

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 19:** Hamstrings Grade II tear. A: TSE T2W axial scan of the upper-middle thigh. Fibers tear at the proximal MTJ of the right biceps femoris/semitendineous muscle with intra- and inter-muscular hematoma extended along the fascia and surrounding the sciatic nerve. B: Corresponding HRUS axial scan showing the hypoechoic fibers tear with intramuscular hematoma extending towards the fascia and the surrounding muscular fibers disomogeneity.

**References:** Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 20: Hamstrings Grade II. A: TSE T2W axial scan passing through the middle third of the thigh; the image shows a partial tear of the fibers at the MTJ of the right semitendinosus muscle with associated intramuscular oedema. B: Corresponding HRUS axial scan showing the tear on the lateral side of the semitendinosus muscle with surrounding hyperechoic oedema; * : sciatic nerve.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
Fig. 21: Hamstrings conjoined tendon avulsion. A) Coronal STIR long TE SENSE sequence showing diffuse muscle edema and conjoined tendon avulsion from the ischial tuberosity (1) and the tendon stump at the middle third of the thigh (2). B) Axial T1W TSE HR SENSE sequence at ischial tuberosity level. C) Axial T1W TSE HR SENSE at middle third of the thigh.

References: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
**Fig. 22**: Rectus femurs scar. A: TSE T2W FS axial scan of the upper-middle portion of the thigh shows the formation of hypointense scar tissue of an old II grade tear into the deep part of the right rectus femoris muscle; B: Corresponding HRUS axial scan of the same region showing the scar tissue into the deep part of the rectus femoris muscle as a hyperechoic focal tissue disomogeneity.

**References**: Department of Radiodiagnostic, University of Medicine Genova, San Martino University Hospital Genova - Genoa/IT
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Fig. 10: Rectus Femoris Grade II. A: TSE T2W axial scan of the upper-middle third of the thigh showing muscular tear at the rectus femoris MTJ and the intramuscular hematoma. B: Corresponding HRUS axial scan showing the hypoechoic tear, the intramuscular hematoma and the fascial involvement. C: Corresponding longitudinal scan highlighting in particular the extension of the hematoma and the fibers architecture alteration.

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Fig. 11: II grade lesion of the vastus intermedius. 28-year-old football player with fibers disruption and intramuscular hematoma in the deep portion of the left vastus intermedius. A: STIR long TE coronal scan; B: TSE T2W axial scan; C: TSE T2W FATSAT axial scan

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Fig. 12: Vastus intermedius Grade II. A: TSE T2W FATSAT axial scan of the upper-middle thigh; II grade vastus intermedius muscle tear with intramuscular hematoma seen as hyperintensity around the lesion. B: Corresponding HRUS axial scan through the deep portion of the vastus intermedius showing the hypoechoic fibers interruption with hematoma and adjacent fibers disomogeneity.

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Fig. 13: I-II grade lesions of the vastus lateralis muscle. 25-year-old football player with myofascial oedema at the upper-middle third of the left vastus lateralis muscle. MR performed 24h post-trauma. A: STIR long TE coronal scan; B: TSE T2W FATSAT axial scan C: TSE T2W axial scan

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Fig. 14: II grade lesion of the Iliopsoas muscle. Fibers disruption with intramuscular oedema visible at the MTJ of the right ilio-psoas muscle. A: STIR long TE coronal scan; B: STIR long TE sagittal scan. C: TSE T2W FATSAT axial scan

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**Fig. 15:** Grade II lesion of the Gracilis muscle. 31-year-old football player with fibers disruption on the middle-distal third of the left gracilis muscle with intramuscular oedema and fascial involvement. A: STIR long TE coronal scan B: TSE T2W axial scan C: TSE T2W FATSAT axial scan

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**Fig. 16**: II grade adductor longus tear. 29-year-old football player with re-injury of the left adductor longus muscle. Images show the hyperintense hematoma extending from the previous myofascial tear superficial site, through the myofascial plane (between adductor longus and brevis), into the deep portion of the thigh. A: STIR long TE sagittal scan; B: TSE T2W FATSAT upper axial scan; C: TSE T2W FATSAT lower axial scan.

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Fig. 17: Adductor longus Grade II. A: TSE T2W FATSAT axial scan of the upper portion of the thigh. Grade II tear on a previous myofascial lesion of the adductor longus muscle. The tear appears as a loss of signal image and the intra- and inter- muscular hematoma as a hyperintense signal on this scan. B: Corresponding HRUS scan showing the hypoechoic fibers tear, the more superficial scar tissue formation at the previous lesion site, the hyperechoic intramuscular hematoma and the hypoechoic fascial hematoma.

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Fig. 18: II grade lesion of the hamstrings. 24-year-old football player with laceration of the fibers at the MTJ of the right biceps femoris/semitendineous muscle with intra- and inter-muscular hematoma extending along the fascia and surrounding the sciatic nerve. A: TSE T2W axial scan; B: STIR long TE sagittal scan; C: STIR long TE coronal scan.

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Fig. 19: Hamstrings Grade II tear. A: TSE T2W axial scan of the upper-middle thigh. Fibers tear at the proximal MTJ of the right biceps femoris/semitendineous muscle with intra- and inter-muscular hematoma extended along the fascia and surrounding the sciatic nerve. B: Corresponding HRUS axial scan showing the hypoechoic fibers tear with intramuscular hematoma extending towards the fascia and the surrounding muscular fibers disomogeneity.

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**Fig. 20:** Hamstrings Grade II. A: TSE T2W axial scan passing through the middle third of the thigh; the image shows a partial tear of the fibers at the MTJ of the right semitendinosus muscle with associated intramuscular oedema. B: Corresponding HRUS axial scan showing the tear on the lateral side of the semitendinosus muscle with surrounding hyperechoic oedema; *: sciatic nerve.

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Fig. 21: Hamstrings conjoined tendon avulsion. A) Coronal STIR long TE SENSE sequence showing diffuse muscle edema and conjoined tendon avulsion from the ischial tuberosity (1) and the tendon stump at the middle third of the thigh (2). B) Axial T1W TSE HR SENSE sequence at ischial tuberosity level. C) Axial T1W TSE HR SENSE at middle third of the thigh.

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Fig. 22: Rectus femurs scar. A: TSE T2W FS axial scan of the upper-middle portion of the thigh shows the formation of hypointense scar tissue of an old II grade tear into the deep part of the right rectus femoris muscle; B: Corresponding HRUS axial scan of the same region showing the scar tissue into the deep part of the rectus femoris muscle as a hyperechoic focal tissue disomogeneity.

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Conclusion

Combined d-HRUS-MR imaging allows to better evaluate thigh muscles providing a comprehensive anatomical representation of such structures and, at the same time, a detailed analysis of their internal architecture. US is easily available, is quick and has low costs, allows a dynamic assessment of muscles and provides reliable assessment of the extent of damage. Disadvantages of US are that its resolution is limited to the tertiary bundle and cannot visualise deep muscle planes as well as superficial ones. It may provide negative results in lesions with only slight muscle alterations, such as DOMS and grade 0-1 injuries. Dynamic US evaluation adds to normal US-examination several important informations about biomechanics of muscular structures and helps to better determine the extention of a fibres tear and the stability of healing tissue. MRI allows to recognize those lesions undetectable with US evaluation. MRI has many advantages, including multiplanar capabilities, panoramic views, ability to evaluate deep muscle planes and to detect lesions missed by US. Combined d-HRUS and MR imaging allow to cover all diagnostic steps that follows through the athlete's injury and rehabilitation, helping clinicians to more accurately estimate the time required before an athlete can return to competition as well as the related risk of recurrent injury. Experience, in combination with a deep knowledge of the anatomy, will assist the musculoskeletal radiologist in making an accurate and useful contribution to the treatment of high-level professional soccer players. Another important thing to remember is that many of the injuries seen in professional soccer show no signs of fibre disruption even on MRI, but still cause the majority of absence days. Further, it is very important to use high-quality imaging technology and to collaborate with the team medical staff in order to plan and guide athlete rehabilitation and have the shortest return-to-play time with the minimum risk for the athlete. In our experience, only a combination of high-level imaging and accurate clinical examination makes it possible to achieve correct management of injured elite soccer players.
References


