MRI of sports-related muscle injuries of the lower extremity

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Learning objectives

Magnetic resonance imaging (MRI) is increasingly being used to evaluate sports-related muscle injuries because of its unparalleled anatomic resolution and high sensitivity in detecting acute and chronic soft-tissue abnormalities.

Background

110 patients (76 males and 34 females, age range 17-39, mean age 28) who sustained muscle injuries of the pelvis and lower extremities during sports activities underwent MRI at 1,5 T between July 2007 and August 2009. The imaging protocol consisted of axial, sagittal and coronal T1-W FSE, Fat-suppressed (FS) PD-W FSE and STIR sequences. FS T1-W FSE images after intravenous administration of gadolinium were obtained in 12 cases to establish the diagnosis.

Imaging findings OR Procedure details

NORMAL MUSCLE MORPHOLOGY

Skeletal muscle represents the largest tissue in the body, making up to 40 to 45% of total body weight. The muscle fiber is the basic structural unit of skeletal muscle. The muscle cell is a long cell connected to the related tendon or bone. There are no end-to-end connections between muscle fibers. In MRI examination, skeletal muscle has an intermediate to long T1 and short T2 relaxation time; thus, it has intermediate signal on both T1- and T2-W images. Normal muscle bellies are separated from each other by fat-containing septa. The presence of this high signal fat gives the muscle a marbled appearance on non-fat suppressed images.

ACUTE MUSCLE INJURIES
**Muscle Contusion**

Muscle contusion occurs as a result of blunt trauma. Edema and hemorrhage produce diffuse increased signal intensity on long TR/long TE images (Fig. 1, 2).

**Muscle Strain**

Muscle strain injury results from excessive force or stress beyond the capabilities of a strongly contracting muscle. Strains occur during eccentric muscle contraction. Pain is sudden and injury can be identified at the myotendinous junction. It is important to keep in mind that the myotendinous junction actually extends a long distance within the muscle belly. Muscle strains can be classified into the following three categories.

**Grade I**

First-degree strain describes a microscopic injury to myotendinous unit. MR imaging findings are edematous changes at the muscle or myotendinous junction resulting in high signal intensity on T2-W images (Fig. 3-5, 8, 11). Perifascial fluid might be present as well (Fig. 6, 7, 9, 10).

**Grade II**

Grade II is characterized by a partial-thickness macroscopic tear that is subclassified as low-grade, moderate, or high-grade injury. Low-grade lesions involve up to one-third of the cross-sectional area of the myotendinous unit (Fig. 12); moderate injuries involve up to two-thirds (Fig. 13, 14), and high-grade injuries involve more than two-thirds (Fig. 15). MR imaging findings are hematoma and edematous changes resulting in high signal intensity on T2-W images. Perifascial fluid is commonly seen.

**Grade IIIA**

Grade IIIA refers to complete disruption of the myotendinous junction with complete functional loss. On MR images, there is complete dissociation of the muscle from its associated tendon (Fig. 16-18). Grade III injuries may require surgical repair.

**Grade IIIB-Avulsion Injuries**
Grade IIIB refers to acute avulsion injury at the tendinous insertion site resulting from forceful eccentric muscle contraction or excessive passive lengthening. Loss of function and severe tenderness are frequent presenting symptoms. Avulsion fractures are generally diagnosed by radiography. Cortical fracture fragments that do not contain marrow can be missed on MRI. Acute avulsion injury is manifested on MRI as a hematoma and periosteal stripping at the tendinous attachment site. Waviness and retraction of the torn end of the tendon, along with a fragment of bone or cartilage, may be present (Fig. 19-22).

Muscle Laceration

Muscle laceration injury results from penetrating trauma. High signal discontinuity on long TR imaging at the affected site is the typical finding on MR. Over time, these lesions may have scar and fatty infiltration with lower T2 signal intensity.

Complications of Acute Injuries

Hematoma

Hematomas typically are heterogeneous in appearance and may occur with muscle tear or laceration injury (Fig. 23-28). Subacute hemorrhage often has characteristics of methemoglobin with moderately increased signal on T1-W imaging and high signal intensity on T2-W imaging. Muscle hematomas resolve completely in 6 to 8 weeks. In some cases, after the blood products resorb, a seroma may develop and persist. Seromas will have fluid attenuation signal on MR images. The presence of blood products beyond several weeks suggests recurrent hemorrhage.

Acute Compartment Syndrome

Compartment syndrome refers to increased pressure within a confined muscle compartment with associated neurovascular compromise. Fractures and crush injuries can lead to acute compartment syndrome. The condition is a surgical emergency requiring emergent fasciotomy. MRI is only indicated when the diagnosis is unclear clinically. The MR findings are petechial hemorrhage in the muscles on T1-W images, diffuse muscle edema on T2-W images, and enlargement of the affected compartments.

Fibrosis
Occasionally, muscle injuries may heal with fibrous scar. This may lead to a fixed deformity of the affected muscle. In some patients, fibrosis can cause a palpable mass. Fibrous scar has characteristic low signal intensity on all pulse sequences.

**Delayed Onset Muscle Soreness**

Delayed onset muscle soreness describes muscle pain which occurs several hours after unusually vigorous eccentric exercise. Pain is most severe for the first 48 hours. High signal on T2-W and STIR imaging after exercise, which represents edema, may last up to 80 days.

**CHRONIC MUSCLE INJURIES**

**Muscle Denervation**

Acute denervation injury as a result of trauma might result in normal MRI findings. Later, high signal intensity is seen on T2-W images of denervated muscular tissue, without associated perifascial edema. On a chronic basis, fatty infiltration and muscle volume loss are noted (Fig. 29). These findings affect the muscles enervated by the injured nerve.

**Myositis Ossificans**

Myositis ossificans is a heterotopic muscular calcification as a possible complication of a muscular contusion, typically affecting the large muscles in the extremities. Myositis ossificans develops in three phases: acute, subacute, and chronic phases. MR imaging findings are relatively nonspecific in the acute and subacute phase. The involved muscular tissue appears ill defined. Edematous changes and hemorrhage with diffusely increased signal intensity on T2-W and intermediate signal on T1-W images are seen. The lesion demonstrates enhancement after contrast administration. In the subacute stages, the edematous changes as observed in the MRI findings of the acute phase are decreased. Fatty transformation and ossification occur, demonstrated by high signal intensity on T1-W images and intermediate signal intensity on T2-W images. In the chronic phase, a well-defined ossific structure within the muscular soft tissue is typically seen. The structure is not in continuity with a bony structure and its size decreases over time (Fig. 30, 31).

**Chronic Compartment Syndrome**
Elevated pressure within a compartment may occur over time causing chronic exertional compartment syndrome. Increased interstitial fluid leads to elevated tissue pressures. Increased T2-W signal intensity occurs in the affected compartment after exercise, and this edema signal characteristically persists for more than 15 minutes after the cessation of exercise. Provocative exercise and repeated scans demonstrating prolonged muscular edema on delayed images might improve diagnostic performance.

**Muscle Herniation**

Muscle herniation is a protrusion of muscular tissue through a fascial defect. MR images may demonstrate the location of fascial defect and the bulging muscular tissue. Muscle herniation is thought to be the result of local blunt trauma with a subsequent rent within overlying fascia allowing muscle protrusion. Alternatively, muscle hypertrophy may be the underlying etiology in herniation. MRI, possibly with dynamic imaging, should be considered if clinical findings are inconclusive. MR images may demonstrate the location of fascial defect and the bulging muscular tissue.

**Images for this section:**
Fig. 1: Muscle contusion of medial head of gastrocnemius muscle due to severe injury. The muscle is swollen and has a diffuse edematous appearance (arrows). (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (a). (c) Coronal STIR image. (d) Coronal T1-W FSE image at the same level to (c). (e) Sagittal STIR image. (f) Adjacent STIR image to (e).
**Fig. 2:** Muscle contusion of popliteus muscle as a result of blunt trauma. Edema and hemorrhage produce diffuse increased signal intensity (arrows). (a), (b), (c) Adjacent axial STIR images. (d), (e) Adjacent coronal STIR images. (f) Sagittal FS PD-W FSE image.
Fig. 3: Grade I quadratus femoris muscle strain with subtle edematous changes (arrows). (a) Axial STIR image. (b) Coronal STIR image.
**Fig. 4:** Grade I strain of both gemelli and obturator internus muscles with microscopic edematous changes (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c) Coronal STIR image. (d) Adjacent coronal STIR image to (c).
Fig. 5: Grade I strain of adductor magnus muscle with microscopic edematous changes (arrows). (a) Axial STIR image. (b) Coronal STIR image. (c) Sagittal STIR image.
Fig. 6: Grade I strain with feathery edema pattern of both semitendinosus and biceps femoris muscles. Perifascial fluid is also present (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c) Coronal STIR image. (d) Sagittal STIR image.
Fig. 7: Grade I strain of distal biceps femoris muscle with subtle edematous changes. A small amount of perifascial fluid is also present (arrows). (a) Coronal STIR image. (b) Adjacent coronal STIR image to (a). (c) Sagittal STIR image. (d) Adjacent sagittal STIR image to (c). (e) Axial STIR image.
Fig. 8: Grade I strain of proximal and mid rectus femoris muscle with subtle edematous changes (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c) Coronal STIR image. (d) Sagittal STIR image. (e) Adjacent sagittal STIR image to (d).
Fig. 9: Grade I strain of mid and distal rectus femoris muscle with edematous changes. A small amount of perifascial fluid is also present (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c) Coronal STIR image. (d) Adjacent coronal STIR image to (c). (e) Sagittal STIR image. (f) Adjacent sagittal STIR image to (e).
Fig. 10: Grade I strain of distal semimembranosus muscle with microscopic edematous changes at the muscle-tendon unit. A tiny amount of perifascial fluid is also present (arrows). (a), (b), (c) Adjacent axial STIR images. (d), (e), (f) Adjacent sagittal FS PD-W FSE images.
Fig. 11: Grade I strain of soleus muscle with subtle edematous changes at the muscle-tendon unit (arrows). (a) Axial STIR image. (b) Sagittal STIR image. (c) Coronal STIR image.
**Fig. 12:** Low-grade II muscle strain characterized by a partial muscle tear of distal rectus femoris with intramuscular hematoma (arrows). (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (b). (c) Coronal STIR image. (d) Adjacent coronal STIR image at the same level to (c).
Fig. 13: Moderate II muscle strain characterized by a partial muscle tear of vastus medialis with intramuscular hematoma. Perifascial fluid is also present (arrows). (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (b). (c) Coronal STIR image. (d) Adjacent coronal STIR image at the same level to (c). (e) Sagittal STIR image. (f) Adjacent sagittal STIR image at the same level to (e).
Fig. 14: Moderate II muscle strain of gluteus maximus with hemorrhagic collection and grade I muscle strain of adductor magnus (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image at the same level to (a). (c) Coronal STIR image.
Fig. 15: High-grade II muscle strain of distal vastus medialis. A complete rupture of medial collateral ligament as well as knee joint effusion is present. An enchondroma in distal femur diaphysis is also demonstrated (arrows). (a), (b), (c) Adjacent axial STIR images. (d) Sagittal FS PD-W FSE image. (e) Coronal FS PD-W FSE image.
Fig. 16: Avulsed and retracted rectus femoris tendon with hemorrhagic fluid collection in tendinous gap (arrows). (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c), (d) Axial T1-W FSE images at the same level to (a) and (b) images respectively.
**Fig. 17:** Continued (e) Coronal STIR image. (f) Adjacent coronal STIR image to (e). (g), (h) Coronal T1-W FSE images at the same level to (e) and (f) images respectively.
**Fig. 18:** Avulsed and retracted adductor longus tendon with hemorrhagic fluid collection in tendinous gap. (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (a). (c) Coronal STIR image. (d) Coronal T1-W FSE image at the same level to (c).
**Fig. 19:** Double-avulsion of hamstrings tendons (semimembranosus, conjoined tendon of biceps femoris and semitendinosus) from right ischial tuberosity and rectus femoris (direct and indirect heads) from left anterior inferior iliac spine in a 15-year-old boy (arrows). (a), (b) Coronal STIR images. (c), (d) Coronal T1-W FSE images at the same level to (a) and (b) images respectively.
**Fig. 20:** Continued (e), (f) Axial T1-W FSE images. (g), (h) Sagittal T1-W FSE images. (i), (j) Sagittal STIR images at the same level to (g) and (h) images respectively.
Fig. 21: Continued (k) AP radiograph demonstrates the cortical fracture fragments at the right ischial tuberosity and the left anterior inferior iliac spine.
**Fig. 22:** Sports-related osteitis pubis as a result of the pull of adductor magnus muscle (arrows). (a) Coronal T1-W FSE image demonstrates cortical erosion of left inferior pubic ramus. (b) Coronal STIR image depicts hyperintensity in the symphysis pubis (secondary cleft sign).
**Fig. 23:** Hemorrhagic fluid collection between soleus and medial head of gastrocnemius in tennis leg. Feathery edema pattern of grade I muscle strain of medial head of gastrocnemius. The plantaris tendon is not disrupted (arrows). (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (b). (c) Coronal FS PD FSE image. (d) Adjacent coronal FS PD FSE image to (c). (e) Sagittal FS PD FSE image. (f) Adjacent sagittal FS PD FSE image to (e).
Fig. 24: Extensive hemorrhagic fluid collection between soleus and medial head of gastrocnemius in tennis leg. Feathery edema pattern of a grade I muscle strain of medial head of gastrocnemius. The plantaris tendon is not disrupted (arrows). (a), (b), (c) Adjacent axial STIR images. (d), (e), (f) Axial T1-W FSE images at the same level to (a), (b) and (c) images respectively.
**Fig. 25:** Continued (g) Coronal T1-W FSE image. (h) Coronal FS PD FSE image at the same level to (g). (i) Sagittal FS PD FSE image. (j) Adjacent sagittal FS PD FSE image to (i). (k) Axial FS T1-W FSE image after i.v. administration of gadolinium. The hemorrhagic fluid collection shows peripheral enhancement. (l) Sagittal FS T1-W FSE image after i.v. administration of gadolinium. Associated synovitis in knee joint is also depicted.
Fig. 26: Acute intramuscular hematomas are observed as foci of high signal intensity on both FS PD FSE and T1-W FSE images. Associated grade II muscle strain of medial head of gastrocnemius. Hemorrhagic fluid collection between soleus and medial head of gastrocnemius is also present. (a) Axial FS PD FSE image. (b) Adjacent axial FS PD FSE image to (a). (c) Coronal FS PD FSE image. (d), (e), (f) T1-W FSE images at the same level to (a), (b) and (c) images respectively.
Fig. 27: Grade II muscle strain characterized by partial muscle tear of medial head of gastrocnemius with hemorrhage and fascial tearing of the muscle-tendon unit. Intramuscular edema is identified. The subacute hematoma with low signal intensity rim of hemosiderin may be mistaken for a retracted plantaris tendon (arrows). (a) Axial STIR image. (b) Axial T1-W FSE image at the same level to (b). (c) Coronal STIR image. (d) Coronal T1-W FSE image at the same level to (c). (e) Sagittal STIR image. (f) Sagittal T1-W FSE image at the same level to (e).
Fig. 28: Acute rupture of plantaris muscle-tendon unit with intermuscular hemorrhage (arrows) identified in the plane between soleus and medial head of gastrocnemius. Hemorrhage is hyperintense on STIR images and isointense to slightly hyperintense on T1-W FSE images. (a) Axial STIR image. (b) Axial T1-W image at the same level to (a). (c) Sagittal STIR image. (d) Adjacent sagittal STIR image to (c).
Fig. 29: Chronic denervation injury of medial heads of gastrocnemius muscles in both legs. The muscles present with high signal intensity on both STIR and T1-W FSE images without associated perifascial edema. This MRI signal is characteristic for fatty infiltration. (a) Axial STIR image. (b) Adjacent axial STIR image to (a). (c), (d) Axial T1-W images at the same level to (a) and (b) images respectively. (e) Coronal STIR image.
Fig. 30: Myositis ossificans. A well-defined heterotopic ossific structure of low signal intensity is demonstrated within adductor magnus muscle after muscular contusion. The structure is not in continuity with a bony structure and is surrounded by soft-tissue edema (arrows). (a) Axial T1-W FSE image. (b) Axial STIR image at the same level to (a). (c), (d) Adjacent sagittal FS PD-W FSE images. (e), (f) Sagittal STIR images at the same level to (c) and (d) images respectively.
Fig. 31: Continued (g) AP radiograph of left hip depicts a rounded ossification below the level of lesser trochanter.
Conclusion

MRI is the ideal noninvasive method to assess the extent and severity of sports-related muscle injuries of the pelvis and lower extremities, which impacts therapy and influences prognosis.

Personal Information

References