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MUSCULOSKELETAL IMAGING

REVIEW

MRI of lower extremity impingement and friction syndromes in children

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ABSTRACT
Although generally more common in adults, lower extremity impingement and friction syndromes are also observed in the pediatric age group. Encompassing femoroacetabular impingement, iliopsoas impingement, subspine impingement, and ischiofemoral impingement around the hip; patellar tendon–lateral femoral condyle friction syndrome; iliotibial band friction syndrome; and medial synovial plica syndrome in the knee as well as talocalcaneal impingement on the hindfoot, these syndromes frequently cause pain and may mimic other, and occasionally more ominous, conditions in children. Magnetic resonance imaging (MRI) plays a key role in the diagnosis of musculoskeletal impingement and friction syndromes. Iliopsoas, subspine, and ischiofemoral impingements have been recently described, while some features of femoroacetabular and talocalcaneal impingements have recently gained increased relevance in the pediatric population. Fellowship-trained pediatric radiologists and radiologists with imaging workloads of exclusively or overwhelmingly pediatric patients (particularly those without a structured musculoskeletal imaging program as part of their imaging training) specifically need to be aware of these rare syndromes that mostly have quite characteristic imaging findings. This review highlights MRI features of lower extremity impingement and friction syndromes in children and provides updated pertinent pathophysiologic and clinical data.

Impingement and friction syndromes occur when soft tissues are repetitively compressed by other musculoskeletal structures. A bone is part of the mechanism at least on one side and frequently on both sides of the involved soft tissue. Although generally more common in adults, these syndromes are sometimes observed around the hip, knee, or hindfoot in the pediatric population. They include femoroacetabular impingement, iliopsoas impingement, subspine impingement, and ischiofemoral impingement around the hip; patellar tendon-lateral femoral condyle friction syndrome; iliotibial band friction syndrome; and medial synovial plica syndrome in the knee as well as talocalcaneal impingement of the hindfoot (Table). Variant or pathologic anatomical conditions underlie many of these impingement or friction syndromes. Impingement or friction syndromes may be the only or primary explanation for symptoms of some patients. Pain is a common symptom with such an impingement or friction. Magnetic resonance imaging (MRI) is an excellent tool to detect soft tissue abnormalities and also the osseous background and/or changes in such impingement or friction syndromes. Biomechanical alterations following corrective or tumor removal surgery may be a reason for the development of some impingement syndromes, and it is important to be familiar with their MRI findings as these syndromes may explain persistent or new onset pain following such surgeries.

Most lower extremity impingement and friction syndromes are more commonly encountered in young adults. However, they have been increasingly recognized in the pediatric population, particularly during adolescence. We aimed to review the MRI features of lower extremity impingement syndromes along with current and pertinent pathophysiologic and clinical data regarding these abnormalities with respect to pediatric patients. In addition to radiology residents and general radiologists, our target population of radiologists particularly included fellows at the pediatric radiology training programs, where MRI of such musculoskeletal conditions may not be reviewed in a routine setting, and radiologists at the musculoskeletal imaging fellowship programs, where the pediatric population may not be covered during routine MRI procedures.

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Table. Lower extremity impingement and friction syndromes in children			
Pathologic entity	Impinging structures	Impinged structure	Underlying condition
Femoroacetabular impingement	Femoral neck and acetabulum	Acetabular labrum±joint cartilage± subchondral bone at the opposite side of the femoral head	Variable (e.g., bony protuberance at the anterolateral femoral head-neck junction; acetabular retroversion; abnormal femoral torsion; developmental dysplasia of the hip; Legg-Calvé-Perthes disease; slipped capital femoral epiphysis; etc.)
Iliopsoas impingement	Iliopsoas (and/or iliocapsularis) tendon and femoral head-neck	Acetabular labrum (anterior capsulolabral complex)	Not clear; possibly a tight, spastic, scarred/adherent or hypertrophic iliopsoas (and/or iliocapsularis) tendon
Subspine impingement	Anterior inferior iliac spine and femoral neck	Acetabular labrum, rectus femoris tendon, and surrounding soft tissues	Low-lying anterior inferior iliac spine
Ischiofemoral impingement	Lesser trochanter and ischial tuberosity	Quadratus femoris and surrounding soft tissues	Coxa valga, increased ischial angle
Patellar tendon-lateral femoral condyle friction syndrome	Lateral femoral condyle, patella, and patellar tendon	Superolateral aspect of Hoffa fat pad	High-riding patella and other patellofemoral malalignment/maltracking features
Iliotibial band friction syndrome	Iliotibial band and lateral femoral epicondyle	Lateral synovial recess of the knee joint and surrounding soft tissues	None definitely established
Medial synovial plica syndrome	Patella, prefemoral fat pad, and medial femoral condyle	Medial synovial plica	Interposition of the medial plica within the patellofemoral compartment of the knee joint
Talocalcaneal impingement	Lateral aspects of talus and calcaneus at the critical angle of Gissane	Talus, calcaneus, overlying joint cartilage, and lateral aspect of sinus tarsi	Flat-foot, hindfoot valgus, and accessory anterolateral talar facet

Femoroacetabular impingement

In this impingement type, which has been increasingly recognized during the last 10–15 years, acetabular labrum and sometimes joint cartilage is compressed between the acetabulum and proximal femur usually during flexion. Classically, two morphologic types of femoroacetabular impingement (and their combination) were described: cam type (characterized by an osseous protuberance usually at the anterosuperior aspect of the femoral neck close to the growth plate) and pincer type (with usually anterosuperior overcoverage of the femoral head by the acetabulum that is also referred to as "acetabular retroversion") (1). Femoroacetabular impingement, which is more commonly observed in young adults, is also encountered in children (2), sometimes in the presence of preexisting conditions like sequelae from developmental dysplasia of the hip (Fig. 1) (3), Legg-Calvé-Perthes disease (Fig. 2) (4), and slipped capital femoral epiphysis (5). An increased prevalence of a cam-type deformity in the anterosuperior head-neck quadrant of elite adolescent basketball players versus an age-matched control group was reported (6). This cam-type deformity was later suggested to be a consequence of an alteration of the growth plate (in the form of a larger extension of the femoral capital growth plate toward the neck in the entire cranial femoral head hemisphere in young basketball athletes) rather than reactive bone formation (7).

Shown to be highly accurate in detecting acetabular labral lesions (8), MR arthrography is used in patients who are suspected to have labral tears in association with femoroacetabular impingement in whom conventional MRI is indeterminate or has equivocal findings. Paralabral cysts on conventional MRI are considered to be an indirect sign of acetabular labral tears (9), even if such a tear is not discretely visualized; in such a setting, MR arthrography is usually recommended to further investigate for a labral tear. A recent study showed that 3.0 T conventional MRI and 3.0 T MR arthrography are nearly equivalent for diagnosing acetabular labral tears, while 3.0 T MR arthrography is more sensitive for detecting acetabular chondral defects (10).

Femoroacetabular impingement can also be observed beyond the two major morphologic types (and their combination). Supraphysiologic use of hip joints, such as in excessive sports (e.g., bicycling) activity or ballet dancing (11), and femoral antetorsion abnormalities (12) may effectively cause such an impingement without cam or pincer type of morphology.

Main points

- Impingement and friction syndromes occur when some soft tissues are compressed by other musculoskeletal structures; a bone is part of the mechanism at least on one side, and commonly on both sides, of the involved soft tissue.
- Impingement or friction syndromes may be the only or primary explanation for some children's symptoms.
- Variant anatomic conditions may underlie some of these impingement or friction syndromes.
- MRI is an excellent tool to depict soft tissue abnormalities, and sometimes osseous background and/or changes, in such impingement or friction syndromes.
- Biomechanical alterations following corrective or tumor-removal surgery may be a reason for the development of some impingement syndromes; it is important to become familiar with their MRI findings as they might explain persistent or new onset pain following such surgery.

Iliopsoas impingement

First proposed in 2011 (13), iliopsoas impingement is currently considered to be an extra-articular type of hip impingement syndrome (14), which is being increasingly recognized. Iliopsoas impingement is considered to arise in patients in whom there is an intimate relationship between the il-

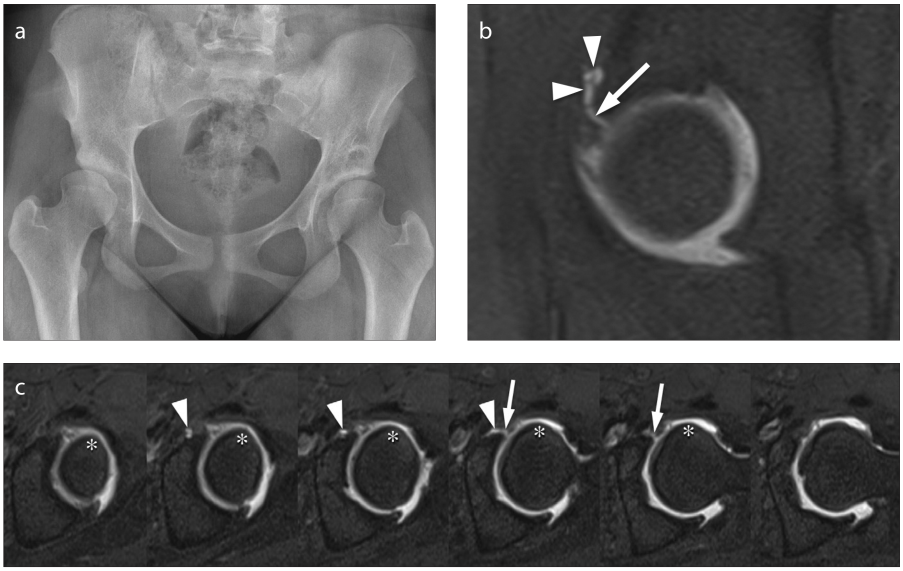

Figure 1. a–c. Left hip pain in a 14-year-old girl with developmental dysplasia of the hip who had bilateral pelvic osteotomies 12 years earlier. Frontal radiograph of the pelvis **(a)** shows incomplete coverage of bilateral femoral heads. Sagittal **(b)** and consecutive oblique axial **(c)** fat-saturated T1-weighted MR arthrography images show a basilar tear *(arrows)* at the anterosuperior aspect of the acetabulum that extends to a paralabral cyst *(arrowheads)*. The tear is likely secondary to an impingement from the malformed femoral head undercovered by the hypoplastic acetabulum. Note the bony protuberance-like configuration (*asterisks,* **c**) at the anterior aspect of the femoral head effectively causing a cam type of femoroacetabular impingement.

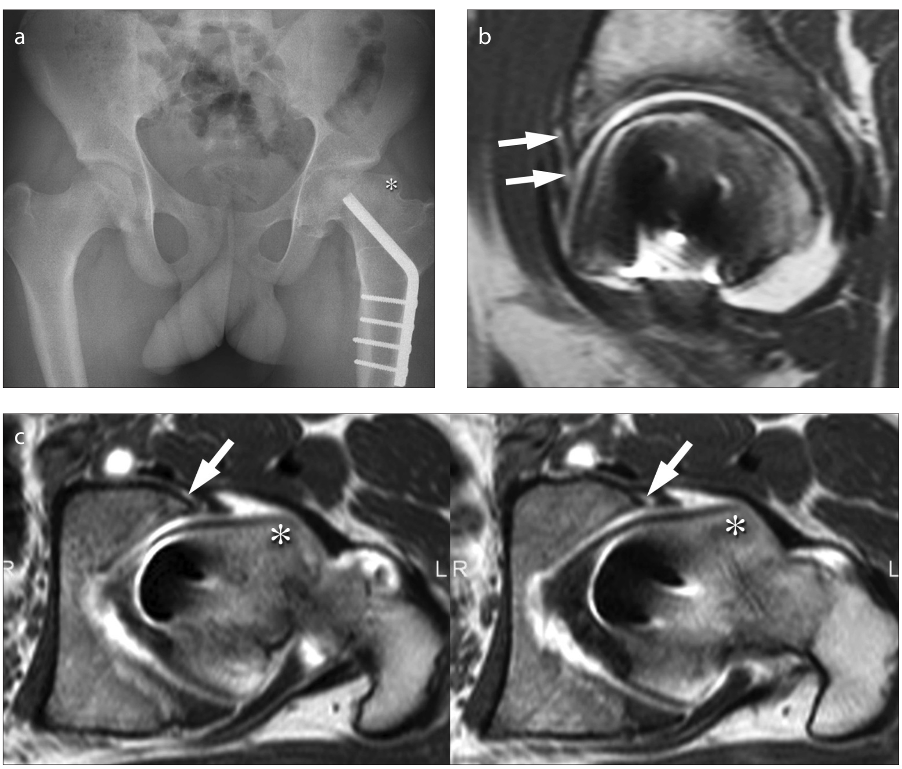

Figure 2. a–c. Left hip pain in a 15-year-old boy with Legg-Calvé-Perthes disease. Frontal radiograph of the hips **(a)** shows a blade plate with screws from left femoral valgus osteotomy performed for Legg-Calvé-Perthes disease (adductor tenotomy was also performed during surgery). Sagittal **(b)** and consecutive oblique axial **(c)** T1-weighted MR arthrography images show a labral base tear *(arrows)* at the anterosuperior aspect of the acetabulum. The tear is likely secondary to an impingement from the deformed femoral head. Note the bony protuberance (*asterisks,* **a** and **c**) at the anterior and lateral aspect of the femoral head-neck junction effectively causing a cam type of femoroacetabular impingement). Further, note that MR arthrography images could show the labral tear despite paramagnetic artifacts from surgical hardware (fat saturation was deliberately avoided in T1-weighted sequences).

iopsoas tendon and anterior aspect of the acetabular labrum, with focal injury at the latter (13). The labral tear/injury does not characteristically extend to an anterosuperior location (which is usually the site of injury with femoroacetabular impingement) in iliopsoas impingement. Tightness, spasticity, scarring/adherence, or hypertrophy of the iliopsoas or the immediately adjacent iliocapsularis tendons may be contributing factors to this kind of impingement (13). Few studies regarding iliopsoas impingement existing in the literature reveal a strong female predominance, wherein patients' age ranged between 12 and 57 years (13, 15–17). Retroversion of the lesser trochanter, which is the attachment site of the iliopsoas tendon, with respect to the distal femur was recently found to be significantly increased in symptomatic patients with iliopsoas impingement (17), likely contributing to the tightness of the iliopsoas tendon in these patients. Although there is no strict MRI criterion for the diagnosis of this particular type of impingement, close proximity of the iliopsoas tendon to an isolated anterior labral tear suggests iliopsoas impingement in patients without characteristic imaging features of cam or pincer type of femoroacetabular impingement (Fig. 3).

Subspine impingement

"Spine" in the "subspine" impingement refers to the anterior inferior iliac spine (AIIS). In this condition, which was first described in 2011 (18), the variable morphology of AIIS is such that the spine's lower position causes an impingement of the intervening soft tissues (including the acetabular labrum) against the spine, rectus femoris tendon, and distal femoral neck during flexion (18, 19). Such a configuration of AIIS may be developmental or can be observed secondary to prior AIIS avulsions or following pelvic osteotomies (Fig. 4), which may effectively result in subspine impingement by lowering or inferiorly rotating AIIS level. Subspine impingement causes hip pain and limits terminal hip flexion and internal rotation. In a recent study (19), all 21 patients with hip pain and a low AIIS had labral tears with an injured labrum congested and hyperemic anteriorly at AIIS level during surgery; anterosuperior labrocartilaginous disruption was also evident in 17 of 21 patients.

No established MRI criteria exist for subspine impingement yet. As with femoroacetabular impingement, MR arthrography exquisitely shows labral and/or labrocar-

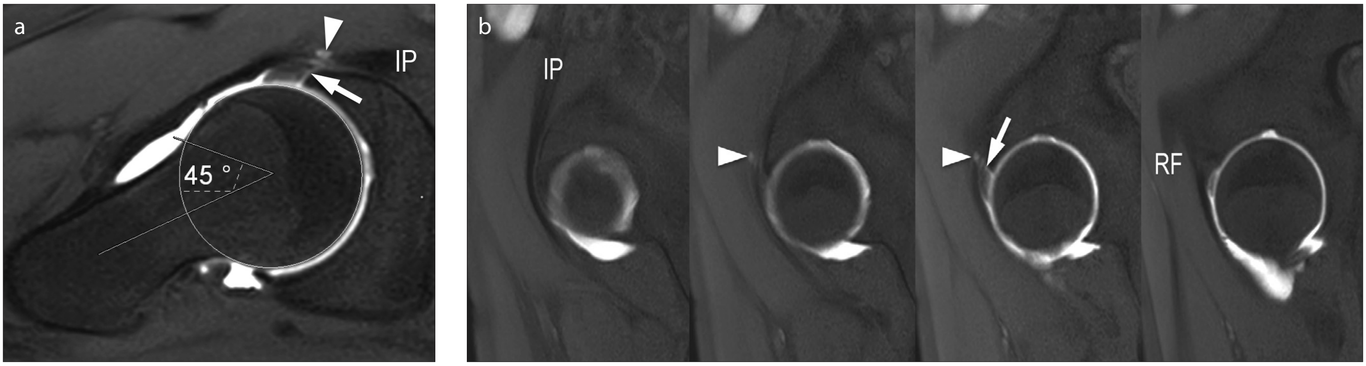

Figure 3. a, b. Pain and limited internal rotation of the right hip in a 15-year-old active football player boy. Oblique axial **(a)** and consecutive sagittal **(b)** fat-saturated T1-weighted images show a focal basilar tear *(arrows)* at the anterior aspect of the acetabular labrum with an anterior paralabral cyst *(arrowheads)*; note the close proximity of the iliopsoas tendon to the tear (IP, iliopsoas tendon; RF, rectus femoris tendon). There is no cam type of deformity on the oblique axial fat-saturated T1-weighted image (**a,** Nötzli's alpha angle is 45°).

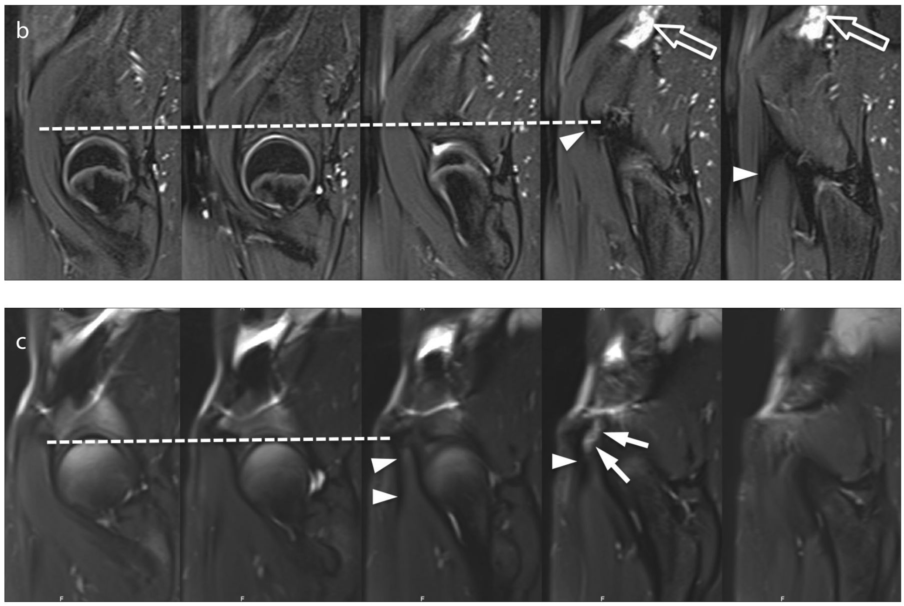

Figure 4. a–c. Left hip pain in a 13-year-old girl who was operated for a left iliac wing Ewing sarcoma. Frontal radiograph of the pelvis **(a)** shows left partial hemipelvectomy. Consecutive medial-to-lateral sagittal fat-saturated T2-weighted images before **(b)** and after **(c)** surgery display inferior displacement of the anterior inferior iliac spine (AIIS) following surgery in this girl, shown by the level of the AIIS *(dashed lines)* with respect to the acetabular roof. Peritendinous cysts *(arrows,* **c**) just lateral and posterior to the rectus femoris tendon (*arrowheads,* **b** and **c**) insertion to AIIS are likely caused by subspine impingement after surgery. Note residual Ewing sarcoma (*open arrows,* **b**) after the reduction of the tumor size by chemotherapy before surgery. There was no evidence of tumor recurrence in the postoperative MRI.

tilaginous tears that may be associated with subspine impingement. However, one distinguishing MRI feature of subspine impingement from femoroacetabular impingement is that paracapsular cysts, when present, are not usually paralabral as in femoroacetabular impingement but rather immediately adjacent to the rectus femoris tendon in subspine impingement (Fig. 4). However, in the presence of a labral tear associated with low-lying AIIS, paralabral cysts may also be observed on MRI or MR arthrography. Unfortunately, normative measurements of the size of AIIS and its location in reference to the acetabulum have not been reported in the pediatric age group. Currently, only patients with alterations of AIIS level and rectus femoris tendon and/or peritendinous soft tissue signal alterations on MRI can be considered to have this condition with some reliability.

Ischiofemoral impingement

Ischiofemoral impingement is a condition wherein the quadratus femoris muscle and soft tissues in its immediate vicinity are compressed in the space between the ischial tuberosity and lesser trochanter. Although initially described as a condition following hip surgery, it was later recognized on MRI as an entity that might occur without such a history (20).

Patients with this type of an impingement are usually adults and are older than patients with other types of impingement around the hip. However, children as young as four years may display MRI evidence of ischiofemoral impingement (Fig. 5) (21, 22). Coxa valga (22, 23) and an increased ischial angle (which is between the long axis of the ischiopubic ramus in reference to the horizontal plane) (23) have been recently implicated as predisposing factors for ischiofemoral impingement, which may also occur following surgery that causes anatomical and biomechanical alterations about the hip (Fig. 6). Ischiofemoral impingement is not necessarily symptomatic (21); however, it may well be the only positive MRI finding in some patients and may help explain symptoms. Although an impingement involves

Figure 5. a–d. Mild bilateral hip pain in a four-year-old boy under treatment for acute lymphoblastic leukemia; MRI was requested to investigate for avascular necrosis. There was no evidence of avascular necrosis on the frontal radiograph of the hips **(a)** and coronal fat-saturated T2-weighted images (**b, c**; I, ischium; F, femur). MRI of the hips, which also included axial fat-saturated T2-weighted sequence (**d**), was only positive for bilateral quadratus femoris edema/inflammation (*arrows,* **c** and **d**) in the ischiofemoral space, which is consistent with ischiofemoral impingement.

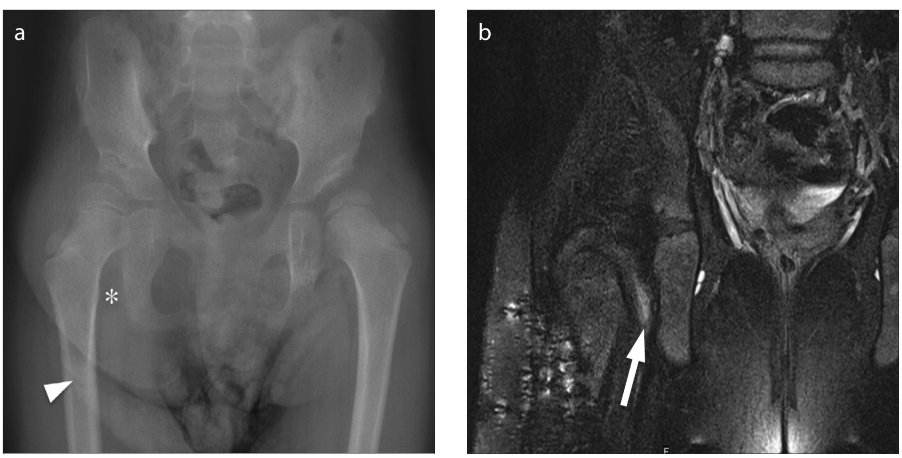

Figure 6. a, b. Right hip pain in a five-year-old girl who was operated on for congenital dysplasia of the hip. Frontal radiograph of the hips **(a)** shows the asymmetrically narrowed right ischiofemoral space *(asterisk)*. Coronal fat-saturated T2-weighted image **(b)** shows soft tissue edema in the right ischiofemoral space *(arrows)*, likely because of biomechanical alterations following rotational osteotomy of the right proximal femur (*arrowhead,* **a**; note paramagnetic artifacts from surgery on **b**) in addition to bilateral supra-acetabular osteotomies.

anatomical structures that are relatively posterior and inferior with respect to the hip, pain that is attributable to ischiofemoral impingement is not present at a specific location; anterior or posterior hip or groin pain may be reported by patients with MRI findings of this condition in whom imaging is otherwise unremarkable. There is no established clinical examination test suggesting ischiofemoral impingement; however, external rotation of the hip with extension and adduction decreases the ischiofemoral space (24) and such a maneuver may elicit or increase pain in persons with this condition.

Patellar tendon–lateral femoral condyle friction syndrome

First described in 2001 using MRI (25), patellar tendon-lateral femoral condyle friction syndrome is characterized by an impingement between the lateral femoral condyle and posterior aspect of the patellar tendon, resulting in superolateral infrapatellar (Hoffa) fat pad edema on MRI (26). This condition is associated with focal tendonopathy at the lateral aspect of the patellar tendon, a high-riding patella (Fig. 7); other patellofemoral malalignment/maltracking features such as a short distance between the patellar ligament and lateral femoral condyle; and an increased distance from the tibial tubercle to the trochlear groove (26). In other words, when edema at the superolateral aspect of the infrapatellar fat pad is identified using MRI, patellofemoral malalignment and maltracking need to be scrutinized (27, 28).

Iliotibial band friction syndrome

Iliotibial band friction syndrome results from the compression of the distal iliotibial band against the lateral femoral epicondyle during intense physical activity (i.e., repetitive knee flexion and extension as in running, cycling, rowing, and skiing) (29). Any sports activity that involves a lot of running (such as soccer, basketball, and field hockey) also has the risk for this condition. Local tenderness at the lateral knee inferior to the femoral epicondyle and superior to the knee joint line is a characteristic finding. MRI shows soft tissue edema (Fig. 8) between the lateral femoral epicondyle and overlying distal iliotibial band, which is a thickened fascia that inserts on the Gerdy's tubercle at the lateral aspect of the proximal tibia (30). The lateral synovial recess of the anterior aspect of the knee joint should not be mistaken for edema representing iliotibial band friction syndrome on MRI. This fluid-containing recess, however, does not extend posterior to the lateral epicondyle, as does the soft tissue edema (which extends

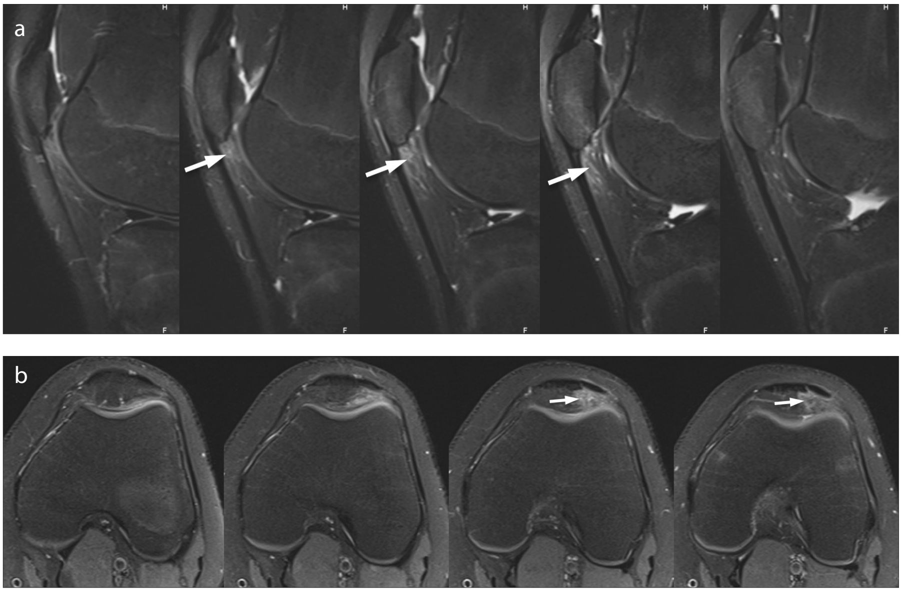

Figure 7. a, b. A 15-year-old girl with bilateral knee pain, greater on the left, for the last two years. Consecutive fat-saturated T2-weighted sagittal **(a)** and fat-saturated proton-density axial **(b)** images of the left knee show soft tissue edema *(arrows)* at the superolateral aspect of the Hoffa's fat pad, likely because of an impingement between the lateral femoral condyle, patellar tendon, and patella. She had the same condition on the right knee MRI *(not shown)*. Her patellae were bilaterally high riding (Insall-Salvati indices >1.4 for both knees). There were no other positive knee MRI findings.

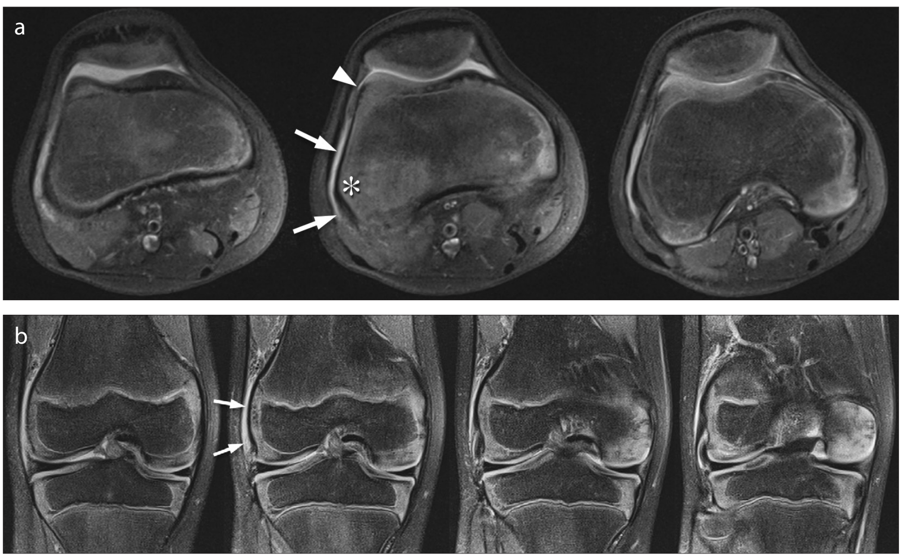

Figure 8. a, b. A seven-year-old boy who "plays a lot of soccer" with right lateral knee pain; MRI was requested to investigate for a discoid meniscus. Consecutive axial **(a)** and coronal **(b)** fat-saturated proton-density images show soft tissue edema *(arrows)* between the iliotibial band and lateral femur passing posterior and inferior to the lateral epicondyle (*asterisk,* **a**) that is characteristic of iliotibial band friction syndrome. There is no discoid meniscus. Note that soft tissue edema **(a)**, presumably from the friction of the iliotibial band against the lateral femoral epicondyle, extends posterior to the lateral gutter (*arrowhead,* **a**) of the anterior aspect of the knee joint, turning posteriorly around the lateral epicondyle. Lateral gutter (*arrowhead,* **a**), which is a synovial recess, would not turn posteriorly around the lateral epicondyle.

posterior to the lateral femoral epicondyle under the iliotibial band) in iliotibial band friction syndrome. Such an extension of fluid-signal on MRI should alert the radiologist for the possibility of this overuse injury.

From an imaging evaluation standpoint, it is important to realize that MRI findings in iliotibial band friction syndrome, which is a chronic injury, are different from acute injury to the iliotibial band, which is usually associated with a significant internal derangement of the knee (particularly cruciate ligament rupture, posterolateral corner injury, and patellar dislocation) (31). In rare cases where isolated acute "sprain" of the iliotibial band is present, edema usually surrounds both the superficial and deep sides of the iliotibial band, whereas with iliotibial band friction syndrome, edema is usually observed only deep in the iliotibial band (31).

Medial synovial plica syndrome

Symptomatic medial plica is a cause of anterior knee pain (32, 33). In this condition, medial synovial plica is interposed between the patella and prefemoral fat pad or medial femoral condyle within the patellofemoral compartment of the knee joint space. Medial synovial plica syndrome is well recognized in adolescent athletes (33). MRI is very helpful in distinguishing plica syndrome from other causes of anterior knee pain such as patellar chondromalacia and patellar maltracking. Characteristic MRI finding in medial synovial plica syndrome is the thickening of an interposed medial plica (34) with or without edema in the plica itself or the adjacent prefemoral fat pad (Fig. 9). It is important to note the mediolateral extent of the interposition of an otherwise normal (i.e., not thickened and/or edematous) plica between the patella and prefemoral fat pad or femur in the MRI report, as such an interposition may predispose the patient to medial synovial plica syndrome that may develop later. In MRI reports, such extension may be given in millimeters from the level of the medial edge of the patella on axial images.

Talocalcaneal impingement

Talocalcaneal impingement, between the lateral talus and calcaneus, is considered to be one of the two entities constituting the so-called "extra-articular lateral hindfoot impingement" (the other is a subfibular impingement that occurs between the calcaneus and fibula) (35). Typically, talocalcaneal impingement occurs before subfibular or combined talocalcaneal subfibular impingement, which is characteristically observed in adults (36). Talocalcaneal impingement is usually observed in patients with a painful flatfoot and is associated with the presence of an accessory anterolateral talar facet (37, 38). The presence of this facet is associated with sinus tarsi pain in adolescents with peroneal spastic flatfoot (37). Covered with a joint cartilage as the contiguous anterior spread from the posterior facet of the subtalar joint cartilage, this accessory facet was reported to be present in one-third of cadaveric speci-

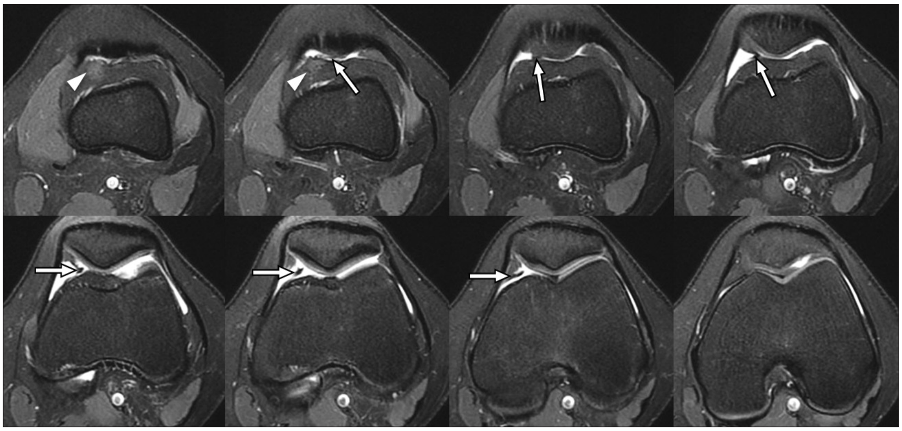

Figure 9. A 17-year-old girl with left anterior knee pain for the last five years. Consecutive axial fat-saturated proton-density images show the mildly thickened medial synovial plica *(arrows)* interposed between the patella and prefemoral fat pad, which is mildly edematous *(arrowheads)*. Several prior MRI examinations of the patient dating back to as early as five years ago also showed these findings, albeit to a lesser degree.

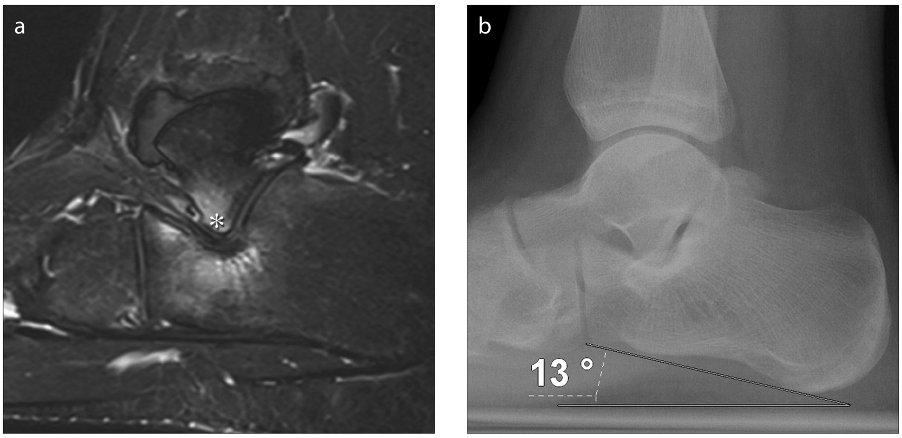

Figure 10. a, b. A 16-year-old boy with ankle pain; MR arthrography was requested to investigate for an osteochondral lesion. Although MR arthrography of the ankle did not reveal any osteochondral lesion, sagittal short tau inversion recovery **(a)** image from routine MR arthrography series displays subcortical bone marrow edema-like changes in the talus and calcaneus centered at the calcaneal Gissane angle, which is consistent with talocalcaneal impingement. Calcaneal pitch angle is 13° on the standing lateral radiograph **(b)**, which is consistent with the flatfoot deformity. Note the accessory anterolateral talar facet (*asterisk*, **a**). This facet is associated with painful talocalcaneal impingement in the presence of flatfoot deformity.

mens from a pediatric osteologic collection (38). MRI readily shows talar and calcaneal bone marrow edema-like changes of talocalcaneal impingement centered at the critical angle of Gissane and the accessory anterolateral talar facet itself (Fig. 10). It should be realized that MRI is not suitable to diagnose the flatfoot deformity, which requires weight-bearing ankle radiographs for proper identification.

Conclusion

It is important to consider impingement or friction syndromes in children to explain some lower extremity problems. Because clinical diagnosis is not often straightforward, MRI is very useful in this regard, with edema-like signal intensity in the soft tissues and/or bones at some specific locations around the hip and knee and in the hindfoot. Fluid-sensitive MRI sequences, such as fat-saturated proton-density-weighted or T2-weighted imaging, or short tau inversion recovery in routine imaging planes are usually sufficient to ascertain the presence of such edema-like changes. MR arthrography is a highly accurate tool for identifying acetabular labral tears that may be associated with some of these impingement syndromes. Some anatomical variants or conditions that might have predisposed the child to these impingement or friction syndromes also need to be considered for correct diagnosis while evaluating MRI examinations of the lower extremities in children.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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