In several hundred years of ballet history, it has been the lightness of movement of the ballet dancers that has captivated audiences and made dancers famous. The lighter and more magical it appears when their bodies are en-ponté and pirouetting on stage, the more hard training they have gone through, exposing their heels, toes and balls of their feet to extensive repetitive loading.

The variety of statically challenging and non-physiological positions of the ballet dancer’s lower extremities is large compared to most other types of dance and sport activities. Therefore dance-related injuries are common in the ankle and foot. In addition, ballet dancers may suffer stress-related injuries of the lower leg, particularly the tibia. The knee, hip and groin are also commonly affected.

The ankle and foot of ballet dancers are exposed to atypical high-load forces and repetitive stress more than any other part of their bodies. Continuous training over many years, often decades, starting in early childhood and performing in a highly competitive environment make both chronic and acute injuries common in ballet dancers.

THE ANKLE AND HINDFOOT

Injuries around the ankle and hindfoot are very common in ballet dancers. As in other professional settings this includes both non-specific and specific activity-related injuries.

Ankle sprain

Probably the most common non-sport-specific injury of the ankle is the lateral ankle sprain. Typically the anterior talofibular ligament is initially involved (Figure 1). With increasing severity of the trauma, the calcaneofibular ligament, the posterior talofibular ligament and the tibiofibular syndesmosis may subsequently be injured. Anterior and anterolateral impingement may occur primarily or secondary with associated anterolateral gutter synovitis and scarring (Figure 2). However, it may occur, as in any other trauma setting leading to lateral ankle sprain, that forced supination causes medial ligamentous compression between the medial malleolus and the medial surface of the talus. Medial ankle sprain due to pronation trauma within ballet dancers can also occur, but is very rare.

Dancer’s heel

A more specific ballet-related injury is what is known as dancer’s heel, os trigonum syndrome or the nutcracker lesion. All of these refer to posterior ankle impingement and may or may not be associated with an os trigonum or prominent posterolateral talar process (a.k.a. Stieda process).

When en ponte, the foot goes into extreme plantar flexion. In this position, the posterior tibial limbus and the superior posterior surface of the calcaneus come into close contact. A normal variant os trigonum or prominent Stieda process lie within this...
space of close bony approximation. Often chronic, and sometimes acute, traumatic compression of the interposed soft tissues and osseous structures is the result. Besides the aforementioned os trigonum (Figure 3) and Stieda process, the posterior capsule, the posterior intermalleolar ligament, the posterior talocalcaneal ligament and the posterior talofibular ligament may be impinged and injured (Figure 4). As a result, on MRI soft tissue oedema, bone marrow oedema pattern and posterior ankle recess synovitis may be seen.

Osseous stress reactions and stress fractures

Osseous stress to the hind-foot is common in ballet dancers and may result in an osseous stress reaction or, if the stress is continued, a stress fracture of the talus or calcaneus. Both are easily diagnosed with MRI. A stress reaction is shown as bone marrow oedema without a linear component whereas a stress fracture manifests as bone marrow oedema with a central linear component (Figure 5). Early detection of a stress reaction is the key because once a stress fracture has developed, recovery time and therefore time off training will increase. Note that in professional ballet dancers with ankle pain, associated oedema of the talus can be present, which may be related to biomechanical stress reactions due to their frequently performed unique manoeuvres.

Tibial stress injuries such as shin splints, stress reactions and, rarely, stress fractures, may occur in ballet dancers. Symptomatology and imaging findings are not ballet-specific and therefore will not be discussed in detail. However, typical pain resulting from such injuries appears to be most prominent during running and in jumping, particularly during deceleration and in the landing phase of the affected leg.

Subtalar subluxation

Generally uncommon, subtalar subluxation has rarely been reported in ballet dancers. The few cases found in the literature usually seem to occur after a grand plié en pointe or landing en demi-pointe. This almost exclusively acute injury manifests with tremendous pain below the ankle, the immediate inability to put any weight on the affected foot and is therefore ‘la fin’ of any performance or training. The diagnosis may be made clinically or with MRI, but is easily proven radiographically – lateral views show subtalar malalignment and widening.
Figure 4 (left): 10-year-old female. Impingement of the posterior talocalcaneal ligament. In this young dancer hindfoot pain occurred during an intense training period. Two consecutive fat-suppressed intermediate PD-w images (a and b) reveal fraying of the posterior talocalcaneal ligament (arrow). Note the surrounding hyperintense tissue and fluid signal intensity.

Figure 3: 28-year-old male. Posterior impingement syndrome. Sagittal fat-suppressed intermediate PD-w image (a) shows an accessory ossicle (arrow) at the posterior aspect of the talus. Cortical erosions and bone marrow oedema at the surface of the talus articulating with the os trigonum are seen (arrow). Axial T1-w (b) and fat-suppressed intermediate PD-w images (c) in another patient show a bipartite os trigonum (arrow) with surrounding synovitis.

Figure 5: (a) 11-year-old female; (b) 18-year-old female. Subchondral stress reaction and stress fracture of the talus. Sagittal fat-suppressed intermediate PD-w image (a) show subchondral high signal in the talar dome (arrow). Note that there is no fracture line. Sagittal T1-w (b) and fat-suppressed intermediate PD-w images (c) depict the marrow oedema and hypointense fracture line (arrow) running through the inferior aspect of the talus.
TENDON ABNORMALITIES

Tendon abnormalities of the distal lower extremity and foot are frequently found as the cause of ankle pain and foot malfunction in ballet dancers. Due to the unique pathway of the tendons, their bony insertions and associated muscle bellies, the pain may radiate deep into the foot or rise up the lower leg. Often, a thorough clinical examination can determine the affected tendon. Further therapy-relevant investigation and differentiation of tendinopathy/tendinosis, tenosynovitis, subluxation and tear is easily depicted with MRI or ultrasound. Since tendon abnormalities are often an intermittent and dynamic process, dynamic ultrasound assessment is recommend to be included in the diagnostic work-up in many cases. In ballet dancers the tibialis posterior, flexor hallucis longus, peroneus longus and brevis and Achilles tendons are the most commonly involved.

Flexor hallucis longus tendon
One of the most frequent complaints is tenosynovitis of the flexor hallucis longus (FHL). One must keep in mind that due to a normal communication of the FHL tendon sheath with the ankle joint, peritendinous fluid often can be seen in the asymptomatic tendon sheath in proportion to the amount of fluid in the ankle joint. In symptomatic tenosynovitis of the FHL the amount of fluid in the tendon sheath becomes significantly greater, entirely surrounding the tendon and there may be little or no fluid in the ankle joint (Figure 6). Stenosing tenosynovitis, resulting in the so-called ‘trigger toe’, may be associated with septae within the FHL tendon sheath and should be differentiated from a normal mesotenon.

Peroneus brevis and longus tendon
The short and long peroneal tendons are located behind the fibular tip and held within the retrofibular groove by the peroneal retinaculum. This primarily tight juxtamalleolar pathway makes the tendons susceptible to high friction, early degeneration, split tears and subluxation, particularly in the coexistence of any anatomical normal variant or previous lateral ligament injury (Figure 7). The peroneal tendons with their high flexion and pronation actions are especially critical for ankle stability when going en pointe. Therefore, normal function of the peroneal tendons is crucial for ballet dancers and abnormalities of these tendons must be subject to correct and early diagnosis, particularly if there has been previous injury of lateral ankle ligaments and thus an ‘at risk’ ankle is present.

Achilles tendon and plantar fascia
Pain typically located in the posterior upper hind-foot, with or without radiation in the calf, may be related to an Achilles injury, which occurs in approximately 9% of ballet dancers. This includes tendinosis/tendinopathy, tendinitis, retrocalcaneal/pre-Achilles bursitis and peritenonitis. Note that it does not include tenosynovitis, because the Achilles tendon is a sheathless tendon and has no synovial lining (Figure 8). Tears or partial thickness tears of the Achilles tendon may be seen in ballet dancers, but remain very rare and, if present, are mostly small. Tenderness and gradually increasing focal pain in the distal lower heel is likely to be caused by a chronic plantar fasciitis.
Relatively common in ballet dancers, this type of fasciitis, as opposed to the rare acute fasciitis, is frequently caused by repetitive tensile overload. It presents with focal pain at the calcaneal attachment of the fascia at the anterior inferior surface of the calcaneus and usually involves its thicker, medial cord. MRI can depict the focal to diffusely enlarged fascia and associated soft tissue and/or marrow oedema (Figure 9). Note that calcaneal spurs are not located in the plantar fascia but are found at the origin of the short flexor muscles

**Jones fracture and Dancer’s fracture**

A common acute fracture of the mid-foot is the transverse fracture at the base of the fifth metatarsal, also known as a Jones fracture (Figure 10). When the ballet dancer lands with the foot in inversion, forces may lead to a transverse detachment of the base of the fifth metatarsal through the proximal metaphysis. Sudden pain and swelling in the lateral foot are the result and plain radiographs will easily depict the diagnosis. The Jones fracture can be treated conservatively and operatively, although intra-medullary screw fixation is more likely to lead to successful union of all types of Jones fractures compared to non-operative treatments. In contrastinction, the Dancer’s fracture, an acute avulsion fracture of the insertion of the peroneus brevis tendon at the base of the fifth metatarsal, typically heals with conservative treatment.

**Stress fractures**

Stress fractures may occur in almost any bone of the foot. The metatarsals, the cuboid and the sesamoids, especially those at the plantar aspect of first metatarsal head, are particularly susceptible to stress injuries in ballet dancers. Compared to the normal population, where the most common sites of stress fractures are the base or neck of the second or fifth metatarsal, in ballet dancers a stress fracture is more likely to occur at the base of the second and third metatarsal (Figure 11). This has been related to the rather non-physiological extreme plantarflexion when the ballet dancer is en pointe, also referred to as ‘over pointe’.

As described in the hindfoot, any stress-related bony injury progresses from a simple non-fractured stress reaction to a stress fracture with a steady increase of symptoms. MRI in an early stage of stress injuries (stress reactions and stress fractures) can detect and accurately localise the lesion when radiographs are still normal and therefore may help to prevent an early stress reaction from becoming an actual stress fracture.
Lesions of the Lisfranc ligament

Pain within the mid-foot may be caused by a lesion of the Lisfranc ligament, a tight double-layered ligament which holds the base of the second metatarsal to the medial cuneiform. In ballet dancers the Lisfranc joint is particularly stressed when going en pointe. An acute injury of the ligament may present with sudden onset of pain at the medial aspect of the mid-foot, whereas chronic repetitive injuries of the Lisfranc ligament may only lead to vague discomfort or tenderness and therefore may not be clinically suspected. MRI can clearly visualise the normal anatomy and any fraying or tear of the ligament (Figure 12).

THE FOREFOOT

Due to the very specific foot positions, especially when dancing en pointe or demi-pointe, the forefoot in ballet dancers seems to be involved in dance-related osseous or soft tissue injuries more often than the mid-foot. Note that while standing or landing in demi-pointe, the metatarsophalangeal joints extend up to 90°. At this moment high load forces are applied to the metatarsal heads and necks as well as the plantar aspect of the joint. Common lesions of the fore-foot are hallux rigidus, hallux valgus, chondral or subchondral injuries of the metatarsal heads and the so-called sesamoiditis.

Hallux rigidus and hallux valgus are well known and can easily be diagnosed with clinical examination and plain radiographs. Whereas chondral and subchondral lesions of the metatarsal heads can be missed on radiographs, they are much better visualised with MRI (Figure 13). Sesamoiditis describes the clinical condition of pain and tenderness in the ball of the foot, focally located at the first metatarsophalangeal joint. In most cases there are two sesamoids, of which one is located medially and the other one laterally at the plantar aspect of the joint. Both sesamoids directly articulate with the head of the first metatarsal. Intimately related...
to the joint capsule and held together by the inter-sesamoid ligament, they allow the tendon of the FHL to pass between them. Note that even if sesamoiditis may originate from many different pathologies within the plantar aspect of first metatarsophalangeal joint, the two most common lesions are stress reactions and stress fractures of the sesamoid bone. Those and all associated structures described above can be well depicted with MRI (Figure 14).

CONCLUSION

MRI is an excellent tool to dismantle the large spectrum of ankle and foot injuries found in ballet dancers. Thorough knowledge of the biomechanics and common injuries leads to a fast and precise diagnosis so the right therapy can be tailored immediately. For the ballet dancer this results in less time off from training and performing and ultimately results in cost savings for professional ballet companies.

References


Figure 14: 23-year-old female. Sesamoid fracture at the first metatarsal head. Sagittal fat-suppressed intermediate PD-w (Fig. 14a), axial T1-w (Fig. 14b) and coronal T2-w images (Fig. 14c) clearly depict the fracture line (arrows) running transversally through the tibial sesamoid, which, apart from partly hypointense signal close to the fracture, shows hyperintense signal on PD-w and T2-w images. The surrounding tissue shows mild oedema and the first metatarsophalangeal joint mild effusion.

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