If the big toe cannot be brought back sufficiently to create a right angle, the big toe stretch (table 6.8G) should be carefully added to the dancer’s regular stretching routine. This exercise involves stretching not only the flexors of the great toe but also often the joint capsule and ligaments. Hence, it should be performed slowly and gently. If pain and limitation is experienced, the dancer should stretch only in a pain-free range and seek a medical evaluation to rule out arthritis or other conditions that could be worsened by overzealous stretching.

### Ankle and Foot Injuries in Dancers

Very large forces are generated and absorbed in the ankle-foot complex in dance. For example, ankle joint compression forces have been calculated to reach 5 times body weight during walking and 9 to 13 times body weight during running (Hamill and Knutzen, 1995). Considering these high forces and the complex structure and demands of the foot, it is not surprising that the ankle-foot complex is the site most frequently injured in dance. In three extensive studies of ballet dancers, 38% (Garrick and Requa, 1988), 42.4% (Quirk, 1983), and 48.5% (Garrick, 1999) of all injuries involved the ankle-foot complex. Studies involving modern dancers showed that 26.6% (Solomon and Micheli, 1986), 36% (Schaffle, Requa, and Garrick, 1990), and 38% (Hardaker and Mooreman, 1986) of injuries were in the ankle and foot. Studies of flamenco dancers indicated incidences of injury to the ankle-foot complex of 45% and 40% (Salter-Pedersen and Wilmerding, 1998), and a study of tap dancers showed that 36% of all injuries occurred in the ankle and foot (Mayers, Judelson, and Bronner, 2003). So, despite differing demands of varied dance forms, all of the dance forms studied showed a high incidence of injury to the ankle and foot, although at least in ballet, with a higher incidence in female versus male dancers (Liederbach, 2000).

### Prevention of Ankle and Foot Injuries

Considering the high incidence of injury involving the ankle and foot, prevention of injuries to this region should be a priority for dancers. Preventive conditioning measures include trying to avoid abrupt
increases in dance training by maintaining condition during layoffs or breaks, performing supplemental strengthening exercises for the ankle-foot two to three times per week, and performing daily stretching to maintain adequate ankle-foot dorsiflexion to foster shock absorption and help avoid excessive foot pronation. Preventive technique considerations include utilizing appropriate placement of the body weight over the axis of the foot to avoid excessive inversion or eversion, utilizing the stirrup muscles to facilitate balance and a high demi-pointe or pointe position with less Achilles stress, maintaining turnout at the hip to prevent compensatory foot pronation, and “going through the foot” (emphasizing a toeheel contact pattern) and using adequate plié depth to help lessen impact when landing from jumps (Devita and Skelly, 1992; Dutek and Bates, 1990). In terms of equipment considerations, careful selection of well-fitting shoes and use of floors with good resiliency and friction characteristics (Fiolkowski and Bauer, 1997) whenever possible can also help prevent injuries to the ankle and foot.

Rehabilitation of Ankle and Foot Injuries

As with injuries to other regions of the body, initial recommended treatment usually utilizes ice and anti-inflammatory medications to control pain and swelling. For dancers, many physicians recommend using nonsteroidal anti-inflammatory medications for many injuries such as tendinitis or plantar fasciitis, reserving corticosteroids for select conditions with unresponsive pain, as the repetitive use of steroids has been implicated in tissue weakening and rupture (Hardaker, 1982; Weiker, 1988)—particularly if activity is not adequately controlled immediately following-injection (Roberts, 1999). Various other physical therapy modalities such as contrast baths, massage, ultrasound, electrical stimulation, or phonophoresis (ultrasound used to deliver hydrocortisone cream) are often used to reduce pain, increase range of motion, and promote healing.

As soon as symptoms allow, stretching and range of motion exercises are added in a pain-free range to help restore normal range of motion. Again, as symptoms allow, strengthening exercises are added, often progressing from isolation exercises to functional exercises and proprioceptive exercises as permitted by healing. Due to the fact that weight bearing can often aggravate more severe ankle and foot injuries, functional exercises are frequently initially performed where loading can be reduced, such as in a swimming pool or on a Pilates-based Reformer (Brown and Clippinger, 1996; Henderson et al., 1993), and then gradually progressed to normal weight bearing on land.

Proprioceptive exercises are also key in the rehabilitation process, as many injuries have been shown to impair reflex responses and subtle aspects of movement coordination that can interfere with full return to dance and increase the risk of injury recurrence. Last, as symptoms allow, specific dance movements that originally aggravated the condition, such as jumps or turns, are gradually re-introduced in a progressive manner, with particular care taken to correct any technique problems that could contribute to reinjury.

Because altered foot mechanics play an important role in many injuries of the ankle and foot, particular care should be paid to correcting any underlying technique problems. In some cases, assistive devices such as tape, arch supports, heel cups, and shock-absorbing inserts may be incorporated into the rehabilitation process. Potential mechanisms by which these supports work are still controversial and may relate to very slight changes in skeletal movement, shock absorption, or minimizing muscle work (Marshall, 1988; Nigg, Nusrse, and Stefanyszyn, 1999, Scranton, Pedegana, and Whitesel, 1982; Yakut et al., 1997).

Common Ankle and Foot Injuries in Dancers

Given the large number of joints and ligaments composing the ankle-foot complex, it is not surprising that a vast number of different types of injuries can occur in this region. A discussion of selected key injuries follows, and interested dancers are referred to the writings of Hamilton (1988), Malone and Hardaker (1990), Norris (1990), Spilken (1990), and other authors cited in this section for a more detailed presentation of injuries to the ankle and foot.

Ankle Sprains

The ankle sprain is one of the most common acute (traumatic) injuries seen in dancers. Although termed an ankle sprain, technically this injury involves injury to ligaments of both the ankle joint and the subtalar joint. About 85% of ankle sprains involve inversion (Whiting and Zernicke, 1998) and tend to occur when the ankle is in a less stable position of relative plantar flexion, during loading or unloading of the foot such as in landing poorly from a jump, falling out of a turn, or miscalculating a step.

Ankle sprains are classically put into three grades based on the degree of damage. Hamilton (1988) describes Grade I as a mild sprain involving partial
treatment of the ATFL and occasionally the anterior talofibular ligament with little or no resultant instability. Grade II sprains are moderate sprains generally involving complete tears of the ATFL with minimal damage to the calcaneofibular ligament. A moderately positive anterior drawer sign is present, but a normal or minimally abnormal talar tilt is seen on stress X-ray films (Tests and Measurements 6.1, p. 205). Hamilton holds that this is the type of sprain most commonly seen in dancers. In the demi-pointe or pointe position, the ATFL is almost vertical and so is easily torn when an abduction-inversion force is applied, while the calcaneofibular ligament is in a position almost parallel to the floor where it will likely avoid large disruptive forces (figure 6.43A). Grade III injuries are severe ankle sprains and are rare. Grade III injuries involve a complete rupture of the lateral ligament complex and result in gross instability, with grossly positive drawer sign and stress films (figure 6.43B).

When the ankle is sprained, dancers will often hear a pop or experience a tearing sensation with immediate pain. However, it is important to realize that the extent of pain is not necessarily a good indicator of the seriousness of the injury. Swelling occurs quickly around the ligaments (lateral malleolus); and if the sprain is sufficiently serious, the dancer feels that the ankle is unstable and is unable to continue dancing or to walk normally. Depending on the severity, after several hours, swelling progresses, range of motion becomes limited, and discoloration may appear. On examination, both passive inversion of the foot and ankle-foot plantar flexion will tend to produce discomfort.

In terms of treatment, many dance medicine physicians recommend surgical repair for Grade III sprains in professional dancers to achieve adequate ankle-foot stability and avoid early joint degeneration that can be associated with instability (Hamilton, 1988; Hardaker, 1989; Safran, Benedetti, et al., 1999). However, for Grade I and Grade II ankle sprains, a conservative treatment approach is generally recommended. Because this is a traumatic versus an overuse injury, initial treatment is aimed at limiting damage; and this is one injury for which RICE (Rest [relative], Ice, Compression [elastic ankle wrap], Elevation) is particularly relevant. Early protection such as taping, strapping, an air cast, functional walking orthosis, or a walking plaster cast may also be utilized in accordance with the injury severity.

As symptoms allow, a comprehensive rehabilitation program should be followed that includes stretches to help restore normal motion, strengthening exercises with a particular emphasis on the peroneals, functional exercises such as relevés while holding dumbbells, and proprioceptive exercises such as side-to-side or fondu développé performed on balance boards and foam rollers. Proprioceptive exercises are key for reestablishment of reflexes necessary for regaining a sense of the joint’s feeling stable and prevention of reinjury (Eils and Rosenbaum, 2001). Impaired reflex response of the peroneals and increased postural sway have been shown to persist for weeks or even months after the

**FIGURE 6.43** In plantar flexion (right foot), (A) the anterior talofibular ligament (ATFL) is almost vertical and can be readily sprained when (B) inversion-adduction force is applied.
initial injury (Nawoczenski et al., 1985), and in some populations the likelihood of lateral ankle sprain recurrence is as high as 70% to 80% (Hertel et al., 1999). However, one study of soccer players showed only a 5% recurrence of ankle sprains in athletes performing regular proprioceptive exercises versus 25% seen in controls (Tropp, Asking, and Gillquist, 1985). Hence dancers with ankle sprains are encouraged to undergo comprehensive rehabilitation (Sammarco and Tablante, 1997), consider the use of dance-specific ankle taping or braces (Rovere et al., 1988) with the initial return to dance, and continue select peroneal and proprioceptive exercises well after full return to dance.

**Plantar Fasciitis**

**Plantar fasciitis** is an inflammation of the plantar fascia, often involving microscopic tears in the fascia that, if persistent, can lead to degeneration of collagen in the fascia (Shea and Fields, 2002). Because of the key role the plantar fascia plays in supporting the longitudinal arch, jumping is commonly implicated with this injury. Anatomical and biomechanical factors that can heighten injury risk include pes planus or pes cavus foot types, a tight triceps surae, and excessive foot pronation (Hall, 1999; Hamill and Knutzen, 1995; Kreighbaum and Barthels, 1996). In some cases a bone spur develops in conjunction with the plantar fasciitis, and on occasion the plantar fascia can rupture, often in association with impact loading after it has already been weakened from chronic inflammation, repeated cortisone injections, or both (Howse and Hancock, 1988; Roberts, 1999).

Plantar fasciitis is characterized by pain and tenderness on the underside of the calcaneus at the medial or central area (Figure 6.44) where the plantar fascia attaches to the calcaneus. Surprisingly, only a relatively small percentage of individuals complain of pain extending distally along the plantar fascia itself, and this may occur more in dancers with chronic cases. Generally, pain can be accentuated through passively extending the MTP joints, which in effect stretches the plantar fascia. A hallmark of this condition is morning stiffness. Some dancers complain that while taking the first few steps in the morning, it feels as though their feet are as stiff as boards.

In addition to ice, friction massage, and other physical therapy modalities, recommended rehabilitation focuses on heel raises done on a step to strengthen the triceps surae and eccentrically load the Achilles tendon (Shea and Fields, 2002), as well as strengthening the intrinsic muscles and extrinsic muscles that help support the longitudinal arch. Because of associated risk from pronation, efforts to control pronation including orthotics, arch supports, and taping, as well as technique modification and triceps surae stretching (when indicated), can be helpful. Adding viscoelastic inserts or a heel cup to reduce shock can also sometimes offer relief (Marshall, 1988; Warren, 1983).

**Ankle-Foot Tendinitis**

**Tendinitis** (tendon + G. itis, inflammation) is an inflammation of a tendon or its covering/sheath (or both) due to microscopic tearing of collagen fibers secondary to overload (Fernández-Palazzi, Rivas, and Mujica, 1990). Although tendons have a tensile strength that is about twice that of muscle (Frey and Shereff, 1988), their collagen fibers have poor elasticity and so can be injured when forces are applied rapidly, obliquely, or during high-level eccentric contractions of their associated muscles.

When a tendon becomes injured, the surface becomes roughened and it will no longer move smoothly, but instead will tend to bind as it moves in its sheath or covering, causing further pain, swelling, tenderness, and sometimes crepitus. Furthermore, the new collagen that the body tries to lay down for

![Common site of pain with plantar fasciitis (left foot, posterolateral view).](image-url)
“healing” the tendon can be damaged by enzymes associated with inflammation, and so the inflammatory response must be limited through such modes as ice, anti-inflammatory medication (Frey and Shereff, 1988), and adequate relative rest. Additionally, it appears that these new collagen fibers orient in accordance with the forces applied to the tendon, suggesting that the high forces associated with eccentric contractions may help the fibers align in the desired longitudinal direction. However, one must take care when performing eccentric contractions that the movement is very slow and controlled, or injuries can sometimes be aggravated.

Tendinitis can occur in any of the tendons that cross the ankle. However, the Achilles tendon and tendon of the flexor hallucis longus are most commonly involved in ballet dancers.

**Achilles Tendinitis** The Achilles tendon is not surrounded by the typical synovial tendon sheath, but rather by a sheath composed of fascia that is termed a paratendon. Inflammation and injury can occur to the paratendon, the tendon itself, or both. It is not surprising that this tendon is commonly injured when one considers that the triceps surae is responsible for generating a majority of the force used in plantar flexion and that this tendon has been estimated to bear forces 4 to 10 times body weight in running and jumping (Hamilton, 1988; Whiting and Zernicke, 1998).

Factors that have been theorized to increase risk of injury include a tight triceps surae, congenitally small or thin Achilles tendons, excessive pronation, rolling in or out when on demi-pointe or relevé, limited range in ankle-foot plantar flexion or presence of an os trigonum such that the triceps surae has to contract very hard in an effort to achieve adequate height in relevé/pointe, inadequate triceps surae strength and endurance, cavus foot type, and prominence of the posterior superior portion of the calcaneus (Ende and Wickstrom, 1982; Frey and Shereff, 1988; Hall, 1999; Hamilton, 1988; Hardaker, 1989; Howse and Hancock, 1988; Norris, 1990). Further research will be necessary to show which of these factors actually are predictive of Achilles tendinitis and to what degree. A study with runners showed that runners with Achilles tendinitis had more of a cavus foot type, greater maximum pronation magnitude and velocity, and lower plantar flexion strength and that they performed less stretching (McCrory et al., 1999). Floors also appear to be an important factor. In one study, 45% of cases of Achilles tendinitis occurred when dancing was on cement, while only 4% of cases started when dancing was on wood surfaces (Fernández-Palazzi, Rivas, and Mujica, 1990).

**Achilles tendinitis** is characterized by pain, tenderness, and swelling, most commonly about 0.8 to 2.4 inches (2.6 centimeters) above its attachment onto the heel (figure 6.45). This is an area where the tendon is narrower and where blood supply is poor (Frey and Shereff, 1988; McCrory et al., 1999). Dancers will also often complain of a feeling of tightness and stiffness, particularly when awakening in the morning, and decreased range of motion in pliés and other movements involving ankle-foot dorsiflexion. Sometimes a feeling of weakness is present. There may also be crepitus associated with active motion. Pain is generally reproduced or increased with resisted ankle-foot plantar flexion such as in relevés or jumps. Pain also tends to occur when the triceps surae is working eccentrically or the tendon is stretched, as in landing from jumps or the bottom of a plié.

Treatment is particularly challenging because healing and remodeling of the tendon are slow due to its relative avascularity, and it is often difficult for the dancer to stop long enough for it to heal. However, if the dancer continues dancing with Achilles tendinitis, it can lead to scar formation, areas of tissue death (necrosis) within the tendon itself, and sometimes rupture (Weiker, 1988). Hence, it is very important for the dancer to heed tendinitis in its early acute stages while tendon damage is minimal and to follow a well-supervised, comprehensive rehabilitation program that can appropriately progress exercises so that further tendon damage is avoided. Earlier stages of rehabilitation generally focus on the use of medications and modalities to limit the inflammatory response and reduce symptoms. Wearing 1/2-inch (1.3-centimeter) heel lifts or shoes with slight heels, viscoelastic heel inserts, Achilles taping,
control of excessive pronation (where indicated), and correction of related technique errors can also sometimes help reduce symptoms. Later stages of rehabilitation generally focus on restoring adequate and symmetrical flexibility and strength of the triceps surae. The desired inclusion of eccentric contractions can be achieved by performing calf raises while holding weights on a step or platform, where the lowering phase is emphasized by performing it more slowly.

When Achilles tendinitis does not respond to conservative treatment or an actual rupture of the Achilles tendon occurs, surgery may be recommended. Rupture usually occurs in male dancers over the age of 30 (Hamilton, 1988). The rupture commonly occurs in rigorous movements such as jumping or a quick change in direction, and the dancer classically feels as if he has been “shot” or “kicked in the back of the leg” (Teitz, 1986). Surgical repair of the tendon is often recommended for professional dancers because it has been shown to better restore plantar flexion strength (Scheller, Kasser, and Quigley, 1980).

Flexor Hallucis Longus Tendinitis  Flexor hallucis longus tendinitis has a uniquely high prevalence in ballet dancers (Hardaker, 1989). Its high occurrence in dancers is thought to relate to its important functions of stabilizing the foot and preventing excessive eversion in demi-pointe and pointe, as well as pressing the big toe down against the ground to help go from demi-pointe to a full pointe position, and helping to stabilize the big toe in full pointe when it is in a very shortened position. This muscle may also be particularly prone to tendinitis for anatomical reasons. The flexor hallucis longus tendon passes through a fibro-osseous tunnel at the back of the ankle just behind the medial malleolus (figure 6.46); and when strained or thickened, it will tend to bind rather than move smoothly. Because it crosses the ankle joint and toe joints, an excursion of 2 to 3 inches (5-7.6 centimeters) (Conti and Wong, 2001) of the tendon may be required when going from a plié to pointe, giving ample opportunity for irritation if it is not sliding smoothly in its fibro-osseous tunnel.

Flexor hallucis longus tendinitis is characterized by pain on the posterior medial aspect of the ankle, deeper than experienced with Achilles tendinitis (Fond, 1983). Tenderness, mild swelling, and in some cases crepitus may be present that are generally aggravated by flexion and extension of the great toe. Weakness of flexion of the great toe may be present with manual testing, and dancers may complain of a sense of weakness in the big toe on pointe. In more advanced cases, fusiform thickening of the tendon (nodules) can occur that can get stuck within the tendon sheath or canal and cause pain, popping, and impaired ability to move the big toe (“triggering of the big toe”) as seen in figure 6.46. Affected dancers may complain of having the big toe get stuck in flexion or extension, and the release of the halluc is generally accompanied by a pop or snap on the posterior medial aspect of the ankle (Sammarco and Miller, 1979).

Recommended treatment for flexor hallucis longus tendinitis includes anti-inflammatory medications, deep friction massage, ice massage, and other modalities, as well as stretching and strengthening the flexor hallucis longus and related muscles in pain-free ranges as inflammation subsides (Fond, 1983; Norris, 1990). Temporary avoidance of relevé or pointe work is often recommended. Correction of any relevant technique errors such as excessive pronation or having the body weight too far medial or back (such that the toes tend to “grab” the floor) can also often be beneficial.

Nonsurgical treatment is usually successful in alleviating symptoms. When conservative treatment fails, surgery may be recommended in accordance with the particular case to remove dead areas of the tendon, reinforce the tendon, free the tendon from adhesions, open the tendon sheath or flexor retinaculum, remove a bony block, or do a combination of these (Hamilton, Geppert, and Thompson, 1996).

Shin Splints and Tibial Stress Syndrome

This text will use the term shin splints, also termed tibial stress syndrome, to refer to activity-related pain and generalized tenderness on the anterior or medial

![Shin Splints and Tibial Stress Syndrome](image)

FIGURE 6.46  Chronic flexor hallucis longus tendinitis with a nodule near the entrance of the fibro-osseous canal (right foot, medial view).
shin (figure 6.47), from traction of muscles on their attachments onto the tibia that results in injury to and inflammation of the membrane covering the bone (periosteum), fascial inflammation, a stress reaction of the bone, or a combination of these. While the anterior shin pain was originally believed to involve the tibialis anterior and tibialis posterior muscles, there is evidence that the soleus (Hutchinson, Cahoon, and Atkins, 1998; Michael and Holder, 1985) and flexor hallucis (Kortebain et al., 2000) may also be responsible in some cases.

Shin splints often relate to too fast an increase or change in overload such as beginning to dance after a long layoff, participating in intensive workshops, working with a choreographer with an unaccustomed style, or changing to less resilient or raked floors as can happen on tour. Shin splints also have been postulated to be related to abnormal pronation since the muscles commonly involved in shin splints are all inverters that work eccentrically to control pronation. Theoretically, abnormal pronation could put excessive stress on these inverters and their proximal attachments onto the tibia (Brukner, 2000). Various studies, primarily involving runners, have shown an association of increased pronation with increased risk for shin splints (Kortebain et al., 2000; Soderberg, 1986; Sommer and Vallentine, 1995). In the dance world, one study also found that dancers with shin splints tended to demonstrate more double heel strikes during jumps (Gans, 1985). A double heel strike occurs when a dancer places the heel on the floor upon landing, lifts it off the floor unintentionally, and then replaces the heel to push off for the next jump.

Shin splints are evidenced by regular aching or long-lasting shin pain that is associated with repetitive exercise such as dance. At first, pain tends to lessen or disappear after warm-up and return only with rigorous movements such as repetitive jumping, or with fatigue such as toward the end of class or rehearsal. However, if not heeded, over time the pain often increases in severity, does not disappear so readily with warm-up, and is brought on by less intense activity. This shin pain is usually accompanied by generalized tenderness along the lateral border and crest of the tibia (figure 6.47A) or the posteromedial border of the lower tibia (figure 6.47B).

Recommended treatment for shin splints often includes ice after activity and sufficient decrease in activity to allow a pain-free status. In dance, this often means removing movements like jumps and sometimes also limiting the duration of dance. When symptoms allow, strengthening of the involved muscles and developing a balance of strength between the dorsiflexors and plantar flexors of the foot are key, as low levels of dorsiflexor strength relative to plantar flexor strength may increase risk for shin splints (Gehlsen and Seger, 1980). Arch or shin taping, use of shock-absorbing insoles (Thacker et al., 2002), and use of arch supports or orthotics in street shoes to try to control excessive pronation (Michael and Holder, 1985) can also sometimes provide relief.

For many dancers, technique modification involving maintaining turnout at the hips to limit pronation versus using the foot inverters to “hold up the arches” is essential for successful rehabilitation and prevention of shin splint recurrence. However, if despite conservative treatment pain persists or becomes severe, it is important that the dancer see a physician to rule out more serious conditions such as a stress fracture or compartment syndrome.

Exertional Compartment Syndromes of the Lower Leg

Compartment syndromes involve an activity-related marked increase in pressure within one or more of the compartments of the lower leg, producing pain and potentially interfering with the blood flow to the muscles so that they do not receive adequate oxygen (Blackman, 2000; Martens et al., 1984). While in the more common chronic or recurrent form (Geary and Kelly, 1997) the pressures drop rapidly when exercise stops, in rare instances and for reasons poorly understood, the condition progresses to an acute form in which pressures continue to increase and then stay elevated. If the rise is severe enough

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FIGURE 6.47 Pain associated with shin splints thought to reflect involvement of the (A) tibialis anterior and (B) tibialis posterior, flexor hallucis longus, or soleus.
and stays elevated long enough, it can lead to death of the involved muscle tissue and injury to the nerves unless the compartment is decompressed via surgical opening of the fascia (Mercier, 1995; Whit- ing and Zernicke, 1998). Although this condition occurs infrequently in dancers (Lokicic, Siev-Ner, and Pritsch, 1991), dancers should be aware of it because it can be a medical emergency with permanent dire consequences if medical treatment is not pursued quickly.

Recurrent compartment syndromes are classically associated with leg pain described as ill-defined deep cramping, aching, or burning that generally has a characteristic point of onset relative to exercise intensity or duration and that classically disappears shortly after activity is stopped. Some individuals, however, primarily experience ankle weakness, the inability to control the ankle when fatigued, and numbness of the foot. Shortly after exercise, a tenderness and tenseness over the muscle mass of the involved compartment may be present. For example, the anterior compartment is the compartment most commonly involved, and the condition may be evidenced by weakness of ankle-foot dorsiflexion and toe extension; pain in the anterior compartment when the toes are extended; diminished sensation of the first dorsal web space; and tenseness, swelling, and tenderness in the anterior compartment (Geary and Kelly, 1997; Korkola and Amendola, 2001; Leach and Corbett, 1979) as shown in figure 6.48. When compartment syndromes are suspected, techniques can be used to allow pressures in the desired compartments to be measured during exercise.

Unfortunately at this time, there has been little success with conservative treatment (Martens et al., 1984); and common recommendations are to adjust training to a level below the level where pain and pressure become evident or to have surgery. Surgical approaches are directed at cutting the fascia in various ways so that pressures are prohibited from rising to dangerous levels, and these approaches have a reported high success rate.

**Stress Fractures of the Lower Leg and Foot**

The risk of lower leg and foot stress fractures can also be increased by factors that tend to heighten

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**Associated nerves and blood vessels:**

1. Anterior tibial artery, deep peroneal nerve
2. Superficial peroneal nerve
3. Posterior tibial artery
4. Small saphenous vein, sural nerve
5. Great saphenous vein, saphenous nerve

**FIGURE 6.48** Exertional compartment syndrome of the lower leg involving the anterior compartment (right foot). (A) Transverse section of the lower leg showing the anterior compartment, and (B) common complaints.
the stress borne by these bones during activity, such as muscle fatigue or muscle weakness (Bruckner, Bradshaw, and Bennell, 1998; Couture and Karbon, 2002; Hockenbury, 1999), a pes cavus foot type (Nigg, Nursae, and Stefanyshyn, 1999), and a pes planus foot type and other factors associated with excessive pronation (Hughes, 1985; Matheson et al., 1987; Taunton, Clement, and Webber, 1981). Studies of military recruits and runners suggest that factors related to excessive pronation are particularly important predisposing factors for stress fractures.

A stress fracture can occur in any of the bones of the lower leg or foot. In ballet dancers, the most common site is the metatarsals (Bruckner et al., 1996), and the metatarsal most commonly affected is the second metatarsal, at its base (Harrington et al., 1998; O'Malley et al., 1996; Sammarco, 1982), as seen in Figure 6.49. According to one study of elite ballet students, 45% of stress fractures occurred in the metatarsals, followed by 26% in the fibula, 13% in the tibia, and 3% in the cuboid (Lundon, Melcher, and Bray, 1999). Another study of professional ballet dancers showed 65% of stress fractures in the metatarsals and 22% in the tibia.

A stress fracture is generally associated with pain and tenderness, localized to the site of the fracture, that is aggravated by weight bearing or impact. The pain typically has a gradual onset and initially is often a low-grade acheing associated with certain movements (such as jumps) or the duration of dance (e.g., the dancer hurts toward the end of class or rehearsal). However, if not heeded and dance is continued, the pain may progress such that it becomes more severe and more persistent and is more easily initiated. Abnormal changes often do not show up on an X-ray for at least two weeks (Bruckner, 2000), although other diagnostic techniques such as bone scans and magnetic resonance imaging can be helpful for establishing a definitive diagnosis at a much earlier stage (Hutchinson, Cahoon, and Atkins, 1998).

A cornerstone to successful treatment for a stress fracture is to temporarily unload and in some cases immobilize the bone sufficiently to allow completion of the remodeling process so that the bone is stronger and better able to handle loads (Hershman and Mailly, 1990). The limitation of activity necessary to achieve a pain-free situation will vary greatly by the site, severity, and length of injury. For example, a small stress fracture that is treated very early may require discontinuing only high-impact movements such as jumps and using viscoelastic inserts to reduce shock. In contrast, a more serious or long-standing stress fracture or a stress fracture in a site such as the tibia, noted for poor healing, may require not only total temporary stopping of dance but also immobilization with a brace, a wooden-soled shoe, crutches, or casting to even allow pain-free walking (Martire, 1994). Electrical stimulation may also have a positive effect on stimulating osteoblasts to lay down new bone (Bruckner, 2000).

When healing is sufficient, a very gradual and progressive resumption of impact activity is initiated. There are many different approaches, but one approach is to have the athlete pain free 10 to 14 days before this gradual reintroduction begins (Matheson et al., 1987). Reintroduction of activity on an alternate-day basis may be beneficial, as rest days have been shown to reduce stress fracture incidence. Although the goal is to remain pain free, even well-designed progressions often have points at which bone pain recurs. If this should happen, an often effective approach is to rest one to two days until no pain occurs with walking and then resume activity at the pace below the level at which pain occurred (Bruckner, 2000).

During rehabilitation, other stress fracture risk factors should also be addressed, including pain-free strengthening of associated muscles for better shock absorbency, correction of any underlying technique issues such as excessive pronation, stretching of the triceps surae if inadequate dorsiflexion is present, and addressing hormonal and dietary factors as discussed in Chapter 1, if indicated. Adequate correction of risk factors is important not only to promote successful full return to dance but also to prevent recurrence. One study of stress fractures in

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**FIGURE 6.49** Common site of stress fractures in dancers (right foot, superior view).
professional dancers reported eight refractures out of the original 51 dancers studied (O’Malley et al., 1996). To have another stress fracture occur after prolonged rehabilitation not only is very discouraging for the dancer but also may jeopardize the dancer’s career.

**Impingement Syndromes of the Ankle**

With pointing and flexing of the foot, the talus changes its position in the mortise. With the extreme range of motion utilized in dance, the talus can come into contact with the tibia either anteriorly or posteriorly; this contact is termed anterior or posterior impingement.

**Anterior Ankle Impingement** When the ankle-foot is dorsiflexed as in walking, the front of the lower tibia normally is accommodated by a depression, called a sulcus, on the talar neck. However, with the extreme dorsiflexion used in dance, such as in demi-plié, some dancers can reach a point where the tibia actually comes directly in contact with the talus, and this contact between the bones is termed impingement. With repetitive impingement the bone itself can respond to the trauma by producing small outgrowths (osteophytes or bone spurs). These osteophytes then make impingement occur at an earlier degree of dorsiflexion, causing larger osteophytes and a vicious cycle (Hamilton, 1988). Anterior impingement tends to occur in sports involving jumping, and it is seen more commonly in male versus female dancers, perhaps due to the greater jumping demands that tend to be imposed on men.

Dancers with anterior impingement syndrome will often complain of dull, chronic aching anterior ankle pain that tends to be exacerbated with ankle-foot dorsiflexion. They will also commonly note that there is a decrease in the depth of their plié, and that they are stopping because of discomfort or the feeling of a block on the front of the ankle, well before they feel a stretch in their calf. Tenderness and swelling may also be present in this anterior aspect of the ankle (Hardaker and Moorman, 1986). Suspected anterior ankle impingement syndrome can be confirmed by the presence of exostoses where the front of the talus makes contact with the front of the tibia on X rays.

Recommended symptomatic treatment for this condition includes anti-inflammatory medications and a decrease in ankle-foot dorsiflexion through consciously making the plié shallower and using heel lifts (bilaterally) in street shoes (Malone and Hardaker, 1990), and if possible in dance shoes (e.g., jazz shoes). Unlike many other injury situations in which increasing strength and flexibility can improve the condition, this is often not the case with impingement; and forced stretching of the calf to try to improve the plié depth will generally only aggravate the condition. While reduction in inflammation and technique modifications may sometimes offer some relief, if and when symptoms become severe enough to limit dance to an unacceptable degree, surgery is usually recommended to excise the exostoses. Although this is the only definitive treatment, in some cases exostoses recur, and repeat excision may be required, usually within three to four years (Hardaker, 1989).

**Posterior Ankle Impingement and the Os Trigonum Syndrome** In contrast to anterior impingement syndrome, posterior impingement has a unique high occurrence in dance, probably due to the repetitive use of extreme ankle-foot plantar flexion. For the female ballet dancer, there is a particularly strong emphasis on maximizing plantar flexion to meet both aesthetic and biomechanical criteria in pointe work; and not surprisingly, posterior impingement occurs more frequently in female versus male ballet dancers. During extreme plantar flexion, the posterior portion of the talus is brought in approximation with the posterior aspect of the tibia. The posterior border of the talus has a lateral tubercle (termed the posterior process) that normally fuses with the body of the talus between 9 and 12 years of age (Kadel, Micheli, and Solomon, 2000). However, in some cases this process fails to fuse and remains a separate little bone, termed an os trigonum.

While some hold that the os trigonum actually represents a stress fracture of the posterior process (Howse and Hancock, 1988) and that failure to unite is due to repetitive trauma, this conjecture is still an area of controversy. If such an os trigonum is present, or if the posterior process is particularly long (Stieda’s process), adjacent capsular and synovial tissues can be readily compressed or impinged against the posterior tibia as shown in figure 6.50. With repeated pinching and inflammation, these soft tissues can become thickened and fibrotic. In addition to posterior ankle impingement syndrome, this condition is called by other names including os trigonum syndrome.

With posterior ankle impingement syndrome, pain, tenderness, and sometimes swelling are generally experienced at the back of the ankle, behind the lateral malleolus and deep to the Achilles tendon. This pain tends to be reproduced when the ankle-foot is brought into full plantar flexion, such as in tendu, demi-pointe, and particularly pointe work. Passive plantar flexion may also reveal the feeling of a sudden hard stop or endpoint to the motion. A decreased passive range in plantar flexion and
decreased ability to point the foot (active range of plantar flexion) are often present. Weakness and numbness may also be present. The diagnosis is often confirmed by taking a lateral-view X ray with the ankle-foot in full plantar flexion, such as in standing on pointe or demi-pointe, and the use of other imaging techniques to ascertain soft tissue involvement (Hamilton, 1988; Marotta and Micheli, 1992).

Recommended initial treatment often includes nonsteroidal anti-inflammatories; limitation of ankle-foot plantar flexion in dance to pain-free limits; and physical therapy that includes an emphasis on restoring plantar flexion range of motion, strengthening ankle-foot plantar flexors, and correction in any technique errors such as insufficient use of the stirrup muscles on releve, which could decrease stress to this area. If there is dual involvement of the flexor hallucis longus, which runs in the groove just medial to the posterior process, this condition must also be addressed. However, the great plantar flexion demands of dance training may preclude successful conservative treatment; and if conservative treatment fails, surgical excision of the os trigonum is often recommended for professional and other serious dancers and tends to allow the ability to return to full dance (Brodsy and Khalil, 1986; Marotta and Micheli, 1992; Weiker, 1988).

Sesamoiditis

Sesamoiditis is an inflammation of the sesamoid bones that lie within the flexor hallucis brevis. Because of their location under the base of the big toe, these sesamoids bear large forces during movements such as going on demi-pointe or pushing off or landing in jumps. Hard floors, a cavus foot type (Spilken, 1990), and bunions have also been conjectured to increase the risk for sesamoiditis. In the case of inflamed bunions, the tendency to shift the body weight more medially or laterally to reduce pain puts undue stress on the sesamoid on that side, while with more advanced bunions, the angulation of the first metatarsal can displace the sesamoids from their normal positioning and produce excessive stress.

Sesamoiditis is characterized by pain and tenderness over one or both sesamoids (figure 6.51). One can readily locate the sesamoids by passively hyperextending the great toe (MTP extension) with one hand and palpating them over the head of the first metatarsal with the opposite hand. Pain is also often reproduced or exaggerated with demi-pointe.

In addition to the normal ice, anti-inflammatory medications, and physical therapy modalities, treatment is aimed at reducing the load borne by the sesamoids through various padding techniques. However, sesamoiditis often is difficult to treat in dancers because the hallux extension accompanying movements such as demi-pointe and the push-off in locomotor movements tends to aggravate the condition. Restriction of demi-pointe in and out of dance class and use of a felt pad in relatively rigid athletic shoes, or taping to limit hallux hyperextension (Dyal
and Thompson, 1997), can sometimes be temporarily used to control symptoms. However if pain persists, other potential causes of pain including stress fractures or fractures of the sesamoids need to be evaluated. Detecting a fracture or stress fracture is not always as straightforward as one would expect, as approximately 6% to 30% of feet have sesamoids that are in two or more parts from birth (bipartite or multipartite sesamoids) and are asymptomatic (Van Hal et al., 1982). Sequential X rays or a bone scan, or both, are often used to help make the specific diagnosis. In some persistent cases, surgical treatment is required (Conti and Wong, 2001).

Morton’s Neuroma

Morton’s neuroma involves fibrous tissue growth that is fusiform in shape (small benign tumor) and forms around a sensory nerve in the foot as shown in figure 6.52. This nerve runs between each pair of metatarsals and divides near the end of the metatarsals to go to the adjacent side of the two adjacent toes. Due to their placement between the metatarsals and the ligaments that run between the metatarsals, these sensory nerves are vulnerable to being compressed, and it is this repeated compression that is believed to cause the outgrowth of the lining of the nerve and neuroma (Dyal and Thompson, 1997). This neuroma occurs most commonly in the third interspace (space between the third and fourth metatarsals), followed in frequency by the second interspace (between the second and third metatarsals).

Morton’s neuroma is associated with a sharp, electrical or burning pain in the region of the third (or second) interspace that may radiate down into the adjacent toes. Numbness or tingling may also be evident in the adjacent toes. This pain can generally be reproduced or aggravated by gently squeezing the forefoot together or pressing between the appropriate metatarsals. The pain is also often aggravated by the wearing of narrow shoes, particularly narrow high-heeled shoes, and relieved by removal of the shoes.

Treatment involves anti-inflammatories and wearing wider dance and street shoes. Use of a felt metatarsal pad behind the metatarsal heads (Ryan and Stephens, 1987) and correction of any technique problems that could aggravate the condition, such as shifting the weight too far laterally, can sometimes alleviate compression. Interestingly, this condition often tends to clear after several years even when no treatment is performed (Weiker, 1988), but pain can often be limiting and surgery is often curative (Brown, 2002, personal correspondence).

Summary

The ankle joint proper is a hinge joint that primarily allows dorsiflexion and plantar flexion. This joint has a very strong bony structure that is enhanced by strong medial and lateral collateral ligaments. Below and in front of the ankle joint, the subtalar joint and transverse tarsal joints can contribute slightly more

![FIGURE 6.51] Common site of pain and tenderness with injury to the sesamoids (right foot, inferior view).

![FIGURE 6.52] Morton’s neuroma (right foot, superior view).