

# *The virtuoso foot*

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## **Clinical Rheumatology**

Journal of the International League of  
Associations for Rheumatology

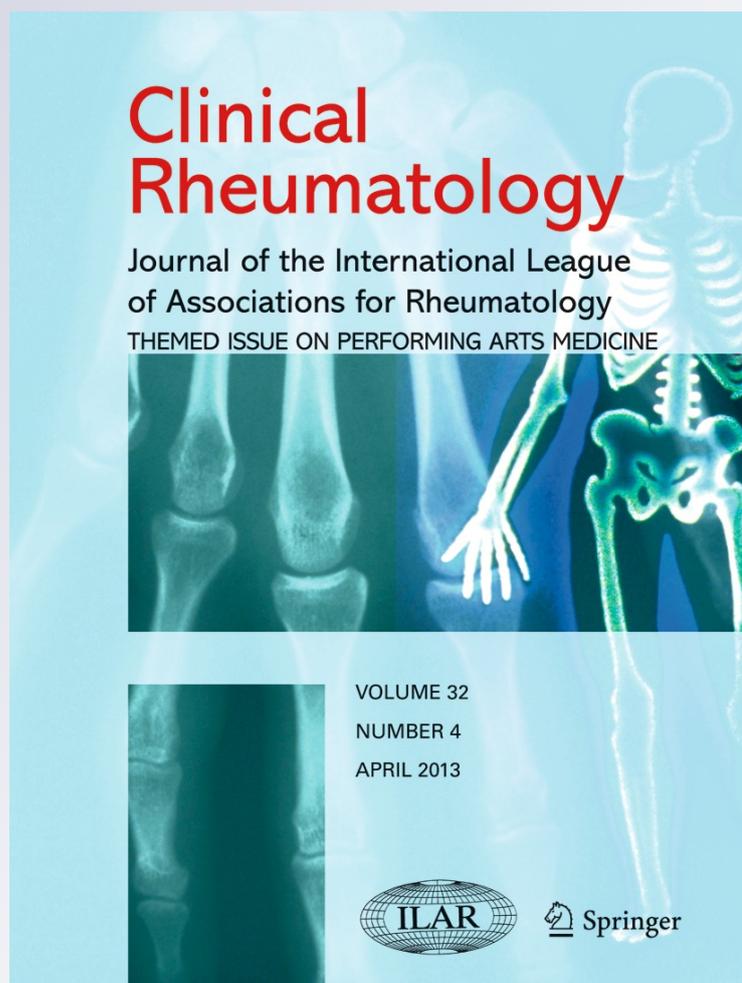
ISSN 0770-3198

Volume 32

Number 4

Clin Rheumatol (2013) 32:439-447

DOI 10.1007/s10067-013-2187-5



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# The virtuoso foot

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Received: 12 January 2013 / Accepted: 25 January 2013 / Published online: 13 February 2013  
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**Abstract** The foot and ankle are prone to injury in the performing arts population, not least amongst dancers who require extreme ranges of movement in this area. This is a complex anatomical area which can be vulnerable to wide array of injuries. Many of these injuries stem from the dancer's posture, technique and environmental factors such as footwear and flooring; therefore, a thorough understanding of these by the clinician is important to ensure full rehabilitation and to prevent recurrence. This article presents an overview of the most common injuries seen in the dancer population and explores the underlying postural, technical and environmental factors that need to be addressed for full recovery.

**Keywords** Dancers · Foot and ankle injuries · Performing arts · Virtuoso

In the world of the performing arts, the foot often represents one of the main tools of the performer's trade. Not only will it usually be providing the main base of support and functioning as a primary shock absorber and lever for often very intricate movement, but in the case of a dancer, it will also be required to be expressive of the particular movement style and be the crowning glory of the dancer's "line". This article will focus primarily on the dancer's foot and ankle, but it should not be overlooked that musicians such as drummers, pianists, keyboard players, organists and harpists also use their feet on the instrument pedals and are therefore also prone to injuries in this anatomical area.

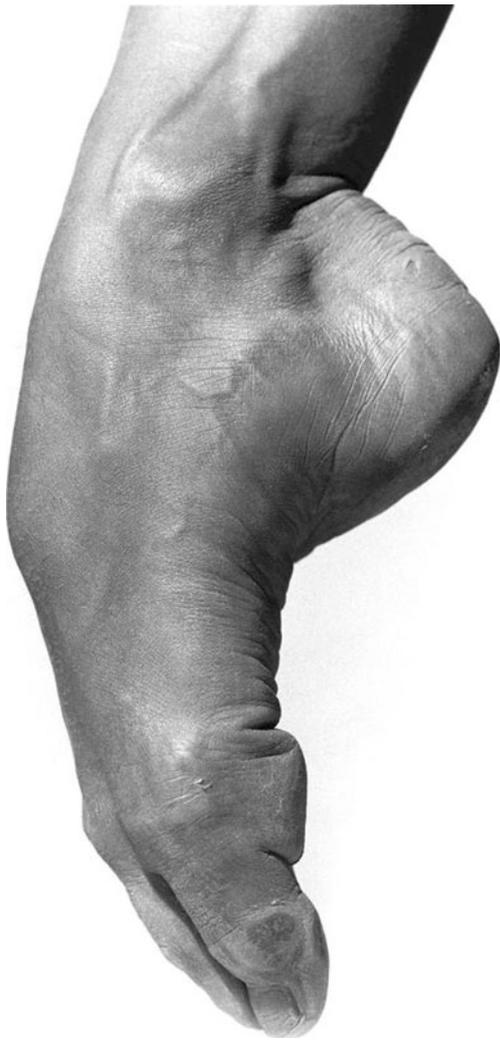
A dancer's foot and ankle complex is required at the same time to be both extremely flexible and extremely strong. Injuries can often occur in the discrepancy between these extremes. The incidence of foot and ankle injuries in classical ballet has been reported at up to 42.4 % [1]. In a study of injuries in 184 professional modern dancers, the foot and ankle represented 40 % of the reported injuries [2]. Dance styles are many and varied from classical ballet to street jazz, Irish dancing to Flamenco and tap dance to contemporary dance and each will have different aesthetic requirements. The extrinsic factors acting on the foot will also vary with these differing styles in the form of footwear (hard shoes, soft shoes, pointe shoes, bare feet, jazz sneakers, etc.) and also floor surfaces. This article will explore both the intrinsic and extrinsic factors in relation to injury risk in this elite population.

For a dancer's foot to achieve the required aesthetics, it must be able to achieve extreme ranges of motion, particularly in plantar flexion for the classical dancer where 90° to 100° is optimal (Fig. 1) [3]. As hyperextension of the knees is also aesthetically favoured (this can be up to 10°) [3], this must be countered with extreme plantar flexion in order to bring the foot back under the centre of gravity for balance when "en pointe" (Fig. 2).

The dancer will move repeatedly between this full plantar flexion and full dorsiflexion with knee flexion (known as the demi-plie) during movement phrases. In the dorsiflexed position, the talus will be stabilised between the malleoli of the tibia and fibula, and in full plantar flexion, the posterior tibial plafond locks against the posterior talus and the superior calcaneus, also providing stability [4]. It is in the movement between these extremes (known as the demi-pointe) that the foot becomes less stable and more prone to injury. The demi-pointe position requires 90° to 100° of dorsiflexion in the first metatarsophalangeal joint and is used in static

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**Fig. 1** Plantar flexion

balance poses as well as forming the transition phase when taking off and landing from jumps (Figs. 3 and 4).

Another factor of note which affects the loading patterns in the dancer's foot as compared to other elite athletes is the use of external hip rotation (known as "turnout" in dance), again mainly within the classical ballet population. There is an aesthetic requirement for a 180° alignment of the feet in the standard ballet positions as depicted below (Figs. 5 and 6).

If this maximal external rotation is not anatomically available to the dancer at the hip, there will usually be a resultant overpronation in the foot causing torsional strain. This is known in dance as "rolling" which can be seen in the left foot in Fig. 7. This can increase the risk of midfoot injuries and may lead to a hallux valgus and bunion formation in a dancer with this familial tendency [3].

Injuries in the foot and ankle area should always be viewed from a global perspective as the predisposing factors may lie in technique and placement errors further up the



**Fig. 2** En pointe

kinetic chain, so without addressing these, injuries may become recalcitrant or recurrent. Conversely, foot and ankle injuries may themselves become the predisposing factors to issues in the more proximal anatomy.

### Common injuries

#### Ankle sprains

The dancer shares a similar frequency of acute ankle injuries to that which is found in the sporting population with lateral inversion ankle sprains being the most common [5]. This occurs most frequently in the landing phase of jumps and when rolling towards the lateral aspect of the foot whilst in the less stable "demi-pointe" position [6].



**Fig. 3** Demi-pointe position



**Fig. 4** Demi-pointe transitioning to full pointe

The anterior talo-fibular ligament is particularly vulnerable to injury in the dancer population due to the extremes of plantar flexion, as previously referred to. This ligament is the weaker of the lateral ankle group and will be put on increased strain as the talus moves away from the fibula when reaching the near vertical position en pointe [4]. This vulnerability can be mediated by the relative strength of the lower leg musculature, particularly the peroneal muscle group during the landing phase of jumps, but any weakness of these muscles along with the ipsilateral hip abductors and knee flexors may increase injury risk in this area. A more significant injury may also involve the calcaneo-fibular ligament and rarely the posterior talo-fibular ligament. Avulsion fractures of the tip of the fibula and extensor digitorum brevis origin (anterior process of the os calcis) should also be considered along with lateral talar process fractures, sinus tarsi syndrome and cuboid syndrome in the symptomatic dancer.



**Fig. 5** First position



**Fig. 6** Fifth position

A high ankle sprain or syndesmosis injury should also be considered in this population as the mechanism of this injury most commonly involves external rotation of the foot. This injures the structures of the syndesmosis (anterior and inferior tibiofibular ligaments and interosseous membrane) and may cause a fibular (Maisonneuve) fracture [7].

Acute medial deltoid ligament sprains are rare, but if the dancer's turnout is poorly controlled at the hip, then chronic pain may occur in this area due to the rolling of the feet (as shown in Fig. 7) causing a chronic strain of the anterior aspect of the deltoid ligament.



**Fig. 7** Rolling of the feet

### Posterior ankle impingement

This occurs as a result of weight bearing in the demi and full pointe positions and causes pain and tenderness in the posterior and lateral area behind the peroneal tendons as well as stiffness and inability to achieve full plantar flexion. Either a large posterior talar tubercle or an os trigonum can cause this syndrome and the pain is usually due to impingement of these structures on the soft tissues rather than the bone itself [8]. An os trigonum is present in up to 10 % of the population and is bilateral 50 % of the time [3] and is rarely symptomatic outside the ballet dancing population (Fig. 8).

Posterior impingement can often occur as a sequela to a lateral ankle sprain where the resultant ligamentous laxity allows the talus to move forwards during plantar flexion leading to impingement of the posterior tibial lip on the os calcis. A concurrent flexor hallucis longus (FHL) tenosynovitis may sometimes occur due to the proximity of the fibro-osseous tunnel of this tendon to the lateral tubercle of the talus. This will be described later.

Treatment should begin conservatively with avoidance of pain-producing activities along with physical therapy and technique adaptation if necessary. In the younger dancer age group, the clinician should be aware of the common practice of forcing the foot into plantar flexion by levering the foot under pianos or pushing the feet into equinus from a



**Fig. 8** Os trigonum impingement en pointe

kneeling position and forcing the body weight through the heels in order to achieve the desired range of movement. Clearly this should be avoided if an os trigonum is suspected. If conservative treatment fails, then surgical excision may be warranted in the serious pre-professional or professional dancer.

### Flexor hallucis tendinitis (dancer's tendinitis)

This condition is seen frequently in dancers and has therefore been termed “dancer's tendinitis” [9]. It is most common in the female ballet dancer due to the repetitive transitional movement from the dorsiflexed position in demi-plie to the en pointe position. Both the FHL and flexor digitorum longus (FDL) cross both the ankle and the metatarsophalangeal joints. These muscles have been shown to be working 2.5 to 3 times harder than those plantar flexors which cross only the ankle joint during the rise to the full pointe position, increasing their risk of overuse injuries [10]. The FHL passes through a fibro-osseous tunnel along the posteromedial talus and under the sustentaculum tali of the calcaneus, and if it becomes strained, it can begin to bind causing further friction and irritation. This may also result in triggering causing a pseudohallux rigidus. Pain is most commonly felt at the posteromedial ankle with concurrent crepitus and “popping”, but symptoms may also present at the knot of Henry (intersection of FHL and FDL tendons at the base of the first metatarsal) and where the tendons pass the sesamoid bones.

Conservative treatment is usually effective with cessation of pointe work and rest, but in recurrent cases in professional dancers who fail to respond to conservative treatment, tenolysis may be indicated. Post-operative results for 41 dancers recorded by Hamilton in 1996 reported an excellent or good outcome for 73 % and a poor outcome for 12 % with amateur dancers accounting for a disproportionate number of the poor results [11].

### Achilles tendinopathy

This can be seen in both male and female dancers and in many different dance genres. Predisposing factors include:

- Forcing the turnout at the feet leading to overpronation with a resultant oblique force being applied to the Achilles tendon causing micro tears
- Failure to contact the ground with the heels when landing from jumps causing shortening of the tendon
- A cavus foot

The cavus foot is favoured in dance but leads to an increased risk of Haglund's disease where the prominence of the posterosuperior calcaneus causes irritation of the bursa and overlying tendon. An extrinsic irritant can also

be the pointe shoe ribbons if they are tied too tightly around the tendon. This can be alleviated by sewing elastic into the ribbons where they cross the Achilles and ensuring that the dancer ties the ribbons with the foot in maximal dorsiflexion where the ankle is at its widest rather than in the plantar flexed position (Figs. 9 and 10).

Achilles tendinopathy may involve just the pseudosheath causing pain, crepitus and potential thickening or, in more chronic cases, can involve nodule formation around the tendon which may also lead to adhesions between the tendon and sheath. Fusiform swelling may be apparent in more severe cases.

Conservative management with rest and physical therapy is again recommended and must include correction of any technical issues (such as turnout control at the hip) and adaptation of footwear as appropriate. Active stretching of the Achilles and triceps surae is necessary and many dance companies have stretch boxes available backstage to facilitate this (Fig. 11).

Achilles tendon rupture occurs more frequently in the male dancer population over 30 years of age when tendon vascularity and elasticity are decreased. This usually occurs during the take-off and landing from jumps with eccentric loading. This is generally treated surgically and needs not be career ending if tendon length can be preserved, but



**Fig. 9** Ribbons crossing the Achilles



**Fig. 10** Elastic sewn into ribbons

rehabilitation may take a year and patient compliance is key. Occasionally, this results from an extraneous factor, sometimes drug therapy, the collagen-weakening effect of ciprofloxacin especially pertinent.

#### Midfoot injuries—Lisfranc fracture

The midfoot in dancers can become vulnerable to injury during jumping and spinning movements, particularly if the floor surface is uneven or sticky. In pirouettes (multiple turns on one leg in the demi-pointe or full pointe position), there needs to be sufficient glide between the shoe and the



**Fig. 11** The stretch box

floor surface to facilitate the movement, but too much frictional force may cause the contact point of the foot to stick as the leg begins to rotate leading to the potential for mid-foot torsional strain. The plantar flexed position combined with a degree of valgus during these movements leaves the first and second tarsometatarsal joints particularly vulnerable. Injuries can range from a mild sprain of the Lisfranc ligament connecting the second metatarsal to the medial cuneiform to a fracture–dislocation of the first and second tarsometatarsal joint. Midfoot pain and significant swelling would be present and an inability to bear weight following the injury would raise the index of suspicion of a fracture. A radiograph may show a diastasis between the first and second metatarsal cuneiform joints and potentially an avulsion fracture from the Lisfranc ligament.

Mild sprains without instability can be treated conservatively, but most Lisfranc's injuries will require surgical fixation [6]. Recovery is prolonged and a return to professional level dancing may not be possible. A case study of a male professional ballet dancer who sustained a Lisfranc fracture in 2004 reported that, despite a prompt diagnosis, surgical reduction and reacquisition of full range of movement post-surgically, the subject was unable to return to professional level dancing. They also recommended that footwear and floor surfaces should be routinely checked as irregularities in these are possible risk factors for a Lisfranc injury [12].

#### Hallux valgus/bunion formation

It is often thought that hallux valgus and bunion formation are caused by dancing; however, in a Swedish study [13], it was found that they are no more common in dancers than in the general population. It is more related to the foot type with a Simian foot being more bunion-prone, so it is the dancers with this familial tendency who are likely to develop the issue. A pes planus and also poor control of turnout leading to overpronation will exacerbate the problem as well as pointe work in the bunion-prone dancer.

Bunions should be managed conservatively in the dancer population with the use of padding over the first metatarsophalangeal joint (MTP) and the use of toe spacers between the first and second toes. Pointe shoes should also be fitted carefully with a high vamp and wing block to prevent friction of the toe box over the bunion area (Figs. 12, 13 and 14).

As previously mentioned, a dancer requires 90–100° of first MTP joint dorsiflexion, so any surgical intervention, which may adversely affect this range of movement, would most likely be career ending.

#### Hallux rigidus

This is a degenerative condition of the first MTP joint which causes pain and stiffness, preventing the dancer



**Fig. 12** The pointe shoe toe box

from achieving the full demi-pointe position previously mentioned. The tendency is then to move the weight toward the lateral rays (known as “sickling”) which cannot only predispose lateral ankle instability, but may also have negative effects further up the kinetic chain (Fig. 15).

Mild, early cases with few radiographic changes can be managed with physical therapy and intrinsic muscle strengthening [6], but more severe cases with osteophyte formation may require surgical intervention. This may not restore full range of movement and may be career limiting.



**Fig. 13** Bunion guard



**Fig. 14** Toe spacers

#### Sesamoid injuries

Due to the repetitive rolling from demi-pointe to full pointe and taking off and landing from jumps, the sesamoid bones of the first MTP joint can become vulnerable to injury in the dancer population. Errors in the technique such as rolling and poor turnout control can cause excessive loading of the sesamoids and the classical ballet dancer's tendency to walk with a toe-out gait can also be a contributory factor.

There are commonly two sesamoid bones (medial and lateral) which are held within the two tendon slips of the flexor hallucis brevis muscle. The repetitive loading during dance may result in inflammation (sesamoiditis), but differentials may also include stress fractures, avulsion fractures, bursitis, neural entrapment, osteonecrosis



#### Sickling

**Fig. 15** A “sickled” foot with weight bearing on the lateral rays

and osteoarthritis. Conservative management would include the use of a felt pad over the area for protection, curtailing of activities involving the full demi-pointe position and correction of any predisposing technical errors. In cases of persistent pain, surgical removal may be necessary which, if done carefully, may allow a return to a professional career [3].

#### Fifth metatarsal fractures

Spiral shaft fractures of the fifth metatarsal are common acute fractures in dancers and have hence been named the “dancer’s fracture” [3]. This is usually due to a missed landing from a jump or falling laterally from the demi-pointe position (Fig. 16).

Treatment usually involves a walking cast or boot for approximately 6 weeks until walking is pain-free, followed by gradual return to dance class under physical therapy guidance. An average of 19 weeks for return to full performance has been reported in classical dancers [14]. It is rare for nonunion of this fracture to occur.

Avulsion fractures involving the peroneus brevis muscle and proximal fifth metatarsal may also be seen, usually in conjunction with a lateral ankle inversion sprain. These will also usually respond well to symptomatic treatment with a removable boot.

Jones fractures at the metaphyseal–diaphyseal junction are more serious due to the poor blood supply in this area and resultant risk of nonunion. These are seen more within the



**Fig. 16** Spiral or dancer’s fracture of the fifth metatarsal

modern dance population where less extreme plantar flexion is used but more pivoting and lateral and adduction foot movements occur. This is generally treated in a short leg, non-weight-bearing cast and can take anything from 6 to 12 weeks to heal.

### Stress fractures

The most common sites for stress fractures in ballet dancers are the metatarsals (63 %) as found in a survey of two professional ballet companies [15]. In this study, risk factors were found to be dancing for more than 5 h per day and amenorrhea greater than 90 days. The aesthetic drive for a slim body in the world of professional dance coupled with the high levels of training required makes female dancers at risk of developing the female athlete triad. This is a triad of anorexia or disordered eating, amenorrhea and osteoporosis. Eating disorders can start as early as age 13 and pre-professional dancers are at increased risk, as compared to the general public, due to the slim body aesthetic and high performance pressures [16].

When muscles become fatigued, more load can be transmitted to the bones and when bones are repeatedly stressed and have underlying low bone mineral density levels, the result can be a stress reaction. This can further be compounded if a dancer is working on a hard floor surface which can cause repetitive shock and overuse injuries [17].

The dancer usually presents with dull, diffuse pain which may be present at night. Swelling is not usually evident and initial radiographs are often normal. Diagnosis would be by bone scan or MRI.

A common site of stress fractures in dancers which is not seen as frequently in other athletes is the base of the second metatarsal. The first and second metatarsals bear most of the weight in the demi- and full pointe positions making this area particularly vulnerable. Treatment is usually symptomatic with some requiring a walking cast. In a study of 51 ballet dancers with this fracture, all returned to performance at an average of 6.2 weeks [18].

### Plantar fasciitis

Plantar fascia pain is most commonly felt at the medial attachment to the os calcis. This can be an overuse syndrome but may also be predisposed by the rolling or overpronating foot, tight triceps surae or Achilles tendon and working on hard, non-sprung dance floors. Pain is often worse first thing in the morning during to overnight contracture of the tissues and can sometimes ease with exercise and increased blood flow. Pain will often be experienced again post-exercise.

Management can involve the use of rest, ice, anti-inflammatory medication, rolling a firm rubber ball under the sole of the foot and, in more chronic cases, the use of a

night splint for prolonged stretching may be helpful. Technique correction and addressing any extrinsic factors such as footwear and floor surfaces will also be key. Multiple steroid injections should be avoided due to the increased risk of plantar fascia rupture [3].

### Summary

The dancer's foot is required to be strong, supple, durable, expressive, beautiful and dynamic—a difficult combination to achieve without occasional compromise to its health. As the main point of contact with the surface and primary base of support for the dancer (arms and hands may sometimes perform this role in modern dance), any injury to the foot and ankle will have a ripple effect further up the kinetic chain. Therefore, any clinical examination should involve a global perspective. As a fundamental tool of their trade, the dancer's foot also represents their source of income; therefore, correct early diagnosis and treatment is vital to their physical, psychological and financial well-being. When treating a dancer, the clinician should also be aware of the high tolerance for pain in this elite group of athletes. It is considered “normal” to be experiencing some level of pain at any given time; therefore, there is often a reluctance to present for treatment unless the symptoms have reached a significant level. With some 26 bones and 34 joints in the foot alone, this can be a challenging area for the clinician, but by taking the time to truly understand the incredible virtuosity of this dancer's tool and how best to support it, you will ensure your place in the heart of any dancer you treat.

**Disclosures** None.

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