A PAIN IN THE MIDFOOT; BUT WHY?

A BRIEF ANATOMICAL RECAP

The midfoot or lesser tarsus is defined as the section of the foot bordered proximally by the midtarsal joint, and distally by the tarsometatarsal joints (Chopart’s and Lisfranc’s respectively). The bones of the midfoot are the navicular, cuboid and the three cuneiforms. These osseous structures can be further divided into two groups, those that are part of the medial column and contribute to the medial longitudinal arch, which includes the talus and medial three metatarsals. The cuboid is also part of the lesser tarsus, which with the two lateral metatarsals makes up the lateral column, and therefore lateral longitudinal arch. The latter has much the lower profile. The two “key stone” bones of each arch lie in the lesser tarsus, the navicular and cuboid. Both of these bones make up part of the functional unit of the midtarsal joint, which is of course two joints, the calcaneo-cuboid and talo-navicular joints. However although we like to divide the foot into sections and functional units the foot is a far more complex structure, as there are structure affiliations from the talus to the cuboid, and the lateral and medial columns as a whole. Our need for convenience of descriptions perhaps blinds us to the complexity of this region.

THE ARTICULATIONS

MIDTARSAL JOINT

The talonavicular joint is possibly the most important articulation of the foot and it has been shown to be very influential of other articulations of the foot (Savory, 1998). The navicular also demonstrates the greatest motion in the lesser tarsus, although there is great variation (Rathleff et al, 2010). With the calcaneocuboid joint, they make up the midtarsal joint. The calcaneocuboid is opened packed in supination of the joint and closed in pronation (Böjsen-Møller, 1979). This means the calcaneocuboid joint need to be in its pronated position to be a stable point for the peroneals to act on during late midstance and terminal stance.

Both of these joints are prone to degenerative changes, and greatly influence the total motion of the lesser tarsus. There has been some debate over whether the midtarsal joint has one or two axis, on the grounds that no joint can have more than one axis. It is of course a two joint ‘man-constructed’ functional single joint, so why not more than one axis for actually two joints? Also all joints have a degree of play, and although a joint axis concept is useful in learning to
understand joint motion, the reality of the situation is no joint has a single axis. For ease of understanding the midtarsal joint motion can be considered to produce eversion and inversion around a longitudinal axis and, abduction/adduction and dorsiflexion/plantarflexion around an oblique axis. In reality the subtle motion in the rest of the lesser tarsus effects these movements of the midtarsal joint.

THE GREAT TARSAL JOINT.

Palpate and range of motion test enough lesser tarsal regions and you will soon start to note a great deal of variation in mobility and direction of motion within the human population. The reasons for this are not least the variation in the type of joint present in the central lesser tarsus. For most people the distal articular surface of the navicular, the proximal and lateral articular surface of the medial cuneiform, all the articular surfaces of the intermediate and lateral cuneiform, plus the medial articular surface of the cuboid share the same articular cavity. Synovial fluid and membrane are therefore continuous in these joints. Often the 2nd intermetatarsal joint also shares this joint space.

Some people have continuations of this joint with the 3rd and 4th metatarsal bases, the cuboid navicular articulation and (rarely) the first intermetatarsal joint. However, interrossei ligaments rather than the normal synovial joints are often found in these locations (Draves, 1986 p.165-166).

Primarily the plantar ligaments maintain the integrity of the lesser tarsus with neurodynamic relationship with the muscle tone of the plantar intrinsics, and
tendon tension from the plantar extrinsics. The long and short plantar ligaments and the spring ligament (calcaneonavicular ligament) are crucial to maintenance of the lesser tarsus and the stretch-shortening cycle of the foot. The effect of muscles, such as tibialis posterior have been shown to function abnormally without these ligaments even in cadavers that have no neurodynamic effect (Imhauser, et al, 2004) so the mechanical integrity of the ligaments can't be overlooked. These plantar structures are under stain during midstance, with compressive plantar directed forces producing dorsiflexion moments on the proximal and distal foot segments. This causes dorsal compression and plantar strain on the lesser tarsus.

During late terminal stance with plantarflexion of the foot, the dorsal ligaments are under strain, but not nearly as great as the tension the plantar ligaments experience. Hardly surprising then, that these ligaments are thin and weak. A forced plantarflexion force can therefore easily cause an injury, and usually it is the tarsometatarsal joints that suffer first in such an injury.

THE TARSO METARSAL JOINTS

Also know as Lisfranc's joint after the Napoleonic surgeon, the integrity of these joints again is ligament and muscle tension dependant. The joints primarily offer dorsal and plantar displacement, with most occurring at the 1st metatarsal and medial cuneiform and the least at the 2nd (Mizel, 1993). My clinical experience is that most problems occur with dorsal displacement of the 1st cuneo-metatarsal joint and between the 4th metatarsal and cuboid. Degenerative changes seem common in both locations, I suspect as a consequence.
As mentioned before the dorsal ligaments of these joints are generally not under much strain during gait, so it isn’t a surprise to find that the plantar ligaments are more extensive. There are also assisting interosseous ligaments to help prevent spreading of these joints in the transverse plane.

**Biomechanics**

It will probably come as no big surprise that there is far less research and understanding of the motion in the midfoot than any other region of the foot. One reason is that unlike other areas it is far less accessible. At first the foot was often modeled as a single segment, but as sensors got smaller and technology better more skin markers could be applied for 3D kinematic study. As a result much of the kinematics of the midfoot is taken purely on the arch height, and that from navicular motion. The midfoot itself is often modeled as a 3D rigid body and given one skin marker, like the shank and the calcaneus. The difference of course is this rigidly modeled structure is actually made up of 5 bones 13 joints, unlike the tibia and the calcaneus!

What mathematical modeling has been attempted in the region supports the idea of dorsal compression and plantar strains (Shanti et al, 1996). So there is a lot of midtarsal motion that remains unknown. For example, because force coupling of movement between the forefoot and rearfoot is weak (Pohl et al, 2007), there must be a lot of capacity for the midfoot to have independent motion.

So what is the lesser tarsus for? Essentially, it has two rudimental roles. The first is the give the foot the ability to make subtle variations in the in phase and out phase motions of the foot. The second role is to contribute in the stretch-shortening cycle of the foot.
In phase movements occur when the rearfoot everts and the forefoot inverts. These movements tend to flatten the foot, with an inversion and dorsiflexion torque occurring through the lesser tarsus. This movement is the most common movement to occur when we walk on flat surfaces. It is common for people to overuse in phase, which is why I believe restrictions of out phase and forefoot invertus is common.

Out phase motion occurs with rearfoot inversion and forefoot eversion. Again the torque occurs through the lesser tarsus with an eversion and plantarflexion motion. Generally this movement is usually occurring more when we walk on uneven ground, mixed with in phase. Some people do overutilise out phase, usually cavoid feet with lateral instability. This tends to drive a forefoot valgus type foot. In summary the lesser tarsus thrives on variability of motion. It doesn’t like the same old motion all the time. Pronated feet generally show too little variation (Yates & White, 2004), while supinated (pronation limited) feet too much variation (Rathleff, 2010).

The other major function of the lesser tarsus is to allow passage of the Centre of Mass (CoM) over the top of the foot during the stance phase. If the arch remains high, then the ankle has to produce greater dorsiflexion. Therefore to allow the leg smooth passage over the foot, the midfoot drops.

This allows the soft tissues under the foot to be stretched. Stretched soft tissues, and muscles particularly under their eccentric
contraction, store potential energy just like an elastic band. Once this midfoot plantarflexion directed stretch is released the soft tissues can release that stored energy, helping to propel the arches up and to propel the proximal CoM of the foot forward during terminal stance. This is known as a stretch shortening cycle. Combined with the Achilles tendon stretch-shortening cycle that occurs at the same time, it is a great energy saving mechanism.

The whole of midstance can be thought of like a hump back bridge. At first the arch works against you, as you have to climb the hill. Once you've reached the top it is all down hill and it's easy to accelerate. But the lesser tarsus is a damn smart hump back bridge because it lowers itself to make it easier to pass to the top of the bridge, then starts to spring back up once you are going down the slope.

Of course a bridge that did that is going to increase compression to the top bricks and increase the gap between the lower bricks. And that essentially is what happens to the lesser tarsus. Get it wrong and the compression causes damage to the spongy bone at the top, and strains the ligaments below. If the neurodynamic control from the ligaments is lost, this spells trouble.

What complicates the picture is foot morphology. Those with cavoid feet of whatever type need more arch drop, but generally can't give very much because of the joint angles leading to dorsal joint compression. This increases the risk on injury and reduces the stretch-shortening energy storage available. Planus foot types need less arch drop to allow CoM to pass over them, but because of that they are likely to offer less effective stretch-shortening cycles.
However, any lesser tarsus hypermobility in these feet is punished harshly, because there is less elastic recoil to utilize and more drop in the arch, causing greater dorsal compression and plantar strain. The same dorsal compression, and plantar strain can therefore occur in these feet too because of too much plantar motion.

**PSEUDO_EQUINUS**

One strong predisposition to insidious degeneration in the lesser tarsus is in people demonstrating a pseudo-equinus, also known as forefoot or anterior equinus. This is where the forefoot is pitched lower than the rearfoot. Quite what drives this particular morphology is unknown and it certain seems to have an inherited tendency in shod populations. My own feeling it is an environmental adaptation occurring in shod populations to heeled shoes. Indeed it works well in the corrected pitched heeled shoe. But get the heel height wrong and it can lead to lesser tarsus degeneration.

Whitley and Green (1982), described 4 different forms of the deformity depending on the location in the increase in declination:

1. Metatarsus cavus (at the midtarsal joint)
2. Lesser tarsus cavus (at the lesser tarsus)
3. Forefoot cavus (at the tarsometatarsal joint)
4. Combined anterior cavus (at all three areas)

What is different in these feet from a standard pes cavus is that with the ankle in neutral there is no increase in the calcaneal inclination angle. Fortunately, this condition can be sorted just by getting the patient in a torsion stable shoe with the correct heel height to match the degree on declination.

I will take this opportunity to remind you that all cavoid feet should be considered neurological until evidence doesn’t support it. Increasing cavoid feet should always be investigated further.
References


