Current Concepts In Orthotic Therapy For Pes Cavus

Despite the prevalence of pes cavus, questions abound about etiology, classifications and appropriate treatment. Accordingly, these authors sort through the various classification systems, offer insights on the pathomechanics and share their thoughts on the role of orthoses for managing symptoms of pes cavus.

Pes cavus occurs in about 8 to 15 percent of the population but it does not get nearly as much attention in the medical literature as its counterpart pes planus. Sixty percent of the population with cavus feet develop foot pain.

Why does this chronically painful condition with such a large prevalence remain somewhat of an unsolved mystery in terms of its etiology and development? Although medical knowledge regarding pes cavus exists, the research and treatment options, as well as any theory or hypothesis as to why humans develop this deformity, are quite limited. Traditionally, we have considered pes cavus a neuromuscular problem with a surgical answer. By combining what is known with what we can hypothesize, perhaps we can establish a new and more successful approach to pes cavus.

Pes cavus has a variety of classifications. However, many of these overlap and lead to confusion. The most common classification system categorizes pes cavus as neuromuscular, congenital or traumatic. (See “A Guide To The Classification Of Pes Cavus Etiology”) Researchers often separate an idiopathic category from congenital when they classify pes cavus. A large retrospective survey reviewed 465 patients with pes cavus and found that 81 percent were classified as having idiopathic pes cavus and 19 percent had neuromuscular pes cavus. Another study reviewed 77 patients in a pes cavus clinic and found that 33.8 percent were idiopathic and 66.2 percent were neuromuscular. Despite this discrepancy, a significant portion of the pes cavus patients in these studies had no known etiologic source of deformity (idiopathic classification).

The identification of the high arched foot has also been classified by way of footprint morphology, radiography, visual inspection and, most recently, by a foot posture index (FPI) system is the most comprehensive method since it distinguishes all foot types (not just the cavus foot) by point criteria. This validated and consistent observation identifies the cavus foot as any foot that has a FPI score of -2 to -12 on a scale of -12 to +12. A normal foot has a score of -5 to +5.

The structure of pes cavus falls into anterior, posterior and global categories. The anterior cavus is either total (indicating plantarflexion of the entire forefoot) or local (plantarflexion of the first ray only). The posterior type has a high calcaneal inclination angle but no forefoot equinus. The global type is a combination of both deformities.

The pes cavus foot has also been classified by variations of function, either flexible or rigid. Although this classification is often the least emphasized, function may prove to be the most important consideration when considering orthotic therapy. These two variations of functioning cavus feet, though similar in appearance, act very differently. Anecdotally, there is an assumption that pes cavus deformity begins as a flexible entity and will become rigid if it is not treated. However, no evidence supports this speculation.

Understanding The Pathomechanics Of Pes Cavus
The classification of pes cavus with so many different parameters may signal that the true etiology of pes cavus may have escaped the medical community. The tradition of classifying pes cavus does not help the situation and circumvents the investigation into the possible true cause which probably lies in imbalance in muscle forces and strength.

Originally, researchers thought posterior tibial tendon dysfunction (PTTD), which is now referred to as adult-acquired flatfoot (AAF), was idiopathic unless it was associated with a specific traumatic incident. We learned to test the tibialis posterior and found there was a progressive character to the weakness imbalance pathology and resulting deformity, which changes the morphology of the foot.

We began to evaluate adolescent flatfoot based on the strength of the tibialis posterior and the overpowering of the peroneus brevis. This evolution of thought became a focus of investigation simply because several people pursued the obvious rationale: there must be a mechanical origin of flatfoot, not just a convenient category called idiopathic. Can muscle imbalance, the progression of deformity and the resultant symptoms be the basis of a theory of the mechanical origin of pes cavus?

If the tibialis anterior muscle is weak at birth, then the peroneus longus muscle would not have a strong enough antagonist. This would disrupt Kirby’s rotational equilibrium concept, leading to progressive plantarflexion of the first ray during osseous development. The plantarflexion of the first ray from the overpowering peroneus longus would force the talus into a more dorsiflexed position. This would increase arch height and calcaneal inclination. This pattern is the same as the muscle imbalances and reactions that occur with AAF. The increased arch height would lead to a smaller contact area on the ground. Accordingly, there would be more pressure on the metatarsal heads and heel.

The tilting back of the talus in the ankle joint would deplete most available dorsiflexion of the ankle joint and lead to an equinus. This equinus of the ankle joint would lead to gastroc-soleus contraction. The extensor muscles would compensate in stance and swing for the gastrocnemius contracture, producing extensor substitution. There would also be more pressure for a greater time on the metatarsal heads as the tibia moves forward in gait due to the small contact area produced from the higher arch combined with limited ankle joint dorsiflexion. This would all eventually result in a patient suffering from metatarsalgia, ankle joint pain, heel pain and antalgic gait changes.

Would early evaluation and intervention with orthotic therapy improve the midlife outcome clinically? Could early intervention slow down the progression of the deformities that result from a lifetime of compensation and metatarsalgia? Forward looking investigation and studies may prove this to be true as more investigators recognize that cavus foot is a mirror image of posterior dysfunction in the child and adult.

What The Literature Reveals About Pes Cavus

Most early studies on the pes cavus foot type attempted to determine the etiology. Recent clinical studies have focused more on the function and symptoms of the deformity. Some have suggested that the structure of the rigid cavus foot leads to less shock absorption, reduced contact area and the development of hammertoes and resultant metatarsalgia. Most contemporary research has attempted to answer more clinically relevant questions that deal with gait changes, peak pressures, pressure-time integrals, injuries and mechanical intervention with orthotics.

A 1997 paper analyzed the gait patterns in patients with pes cavus. The researchers noted the presence of two different types of pes cavus: compensated pes cavus and non-compensated pes cavus, which are now considered functional variations. The compensated pes cavus foot had enough laxity to allow the metatarsal depression to be compensated by ankle joint and midtarsal joint dorsiflexion. Researchers generally found these patients to be asymptomatic and not in need of medical intervention.

The non-compensated type could not compensate at the ankle joint or midtarsal joint because of a genetic limitation of dorsiflexion. During gait analysis, the compensated group had increased flexion of the knee and increased ankle joint dorsiflexion coupled with prolonged firing of the anterior tibialis muscle into late stance. This partially validates a portion of the previously proposed hypothesis. The
non-compensated group, which was more symptomatic, had hyperextension of the knee during stance and an inability of the anterior tibialis muscle to overcome the plantigrade position of the forefoot. Researchers found the use of insoles helped redistribute ground reactive force on the plantar surface of the forefoot and allowed metatarsal unloading and less painful gait. This study is perhaps a confirmation that an imbalanced anterior tibialis/peroneus longus complex may compensate in two different ways, depending on joint motion availability, and subsequently produce two different morphologies of pes cavus.8

A 2001 study took a different approach, dealing with differences in foot types and related sports injuries.9 Researchers studied two groups of runners with flat or high arched feet to determine the differences in their injury patterns. They screened patients based on an arch ratio system.10 The lower arch runners had more medial and soft tissue injuries while the high arch runners had more lateral and bony injuries. The most common injuries in high arch runners were plantar fasciitis, iliotibial band friction syndrome and lateral ankle sprains. All the stress fractures in the high arch group were at the fifth metatarsal. This group had increased lateral loading and the center of pressure of the foot remained more lateral throughout stance. This has been one of the few studies to differentiate a true set of injuries that are experienced by people with cavus feet.9

Orthotic Therapy: Can It Have An Impact For Pes Cavus?

Remarkably, only since 2000 have we started to see research studies focused on orthotic therapy and symptoms related to pes cavus, specifically metatarsalgia. Considering that metatarsalgia is the most common symptom in patients with pes cavus, a review of studies on the effect of orthoses on metatarsalgia is relevant.

In one study conducted on rheumatoid arthritis patients with metatarsalgia, researchers assessed the use soft orthotics, shoes alone and semi-rigid orthotics.11 The semi-rigid orthoses worn in supportive shoes were much more effective than soft orthotics or shoes alone at attenuating the metatarsal pain. In another study, researchers measured peak pressure and pressure-time integrals in patients with diabetes and a history of plantar ulcers. They looked at the use of shoes alone, shoes with custom-molded total contact inserts, and shoes with total contact inserts and metatarsal pads.12 The orthoses with the total contact insert lowered peak plantar pressure and pressure time integrals by 16 to 24 percent in comparison to the control (shoe only) group. When patients wore the metatarsal pad with the total contact device, pressure reduced by 29 to 47 percent in comparison to the control group. This study has applications in many patient groups but especially in the patient with pes cavus feet.

Most recently, a group from Australia published three landmark studies on the cavus foot.2 The first study attempted to determine the relationship among pes cavus, pain and foot deformity. Sixty percent of pes cavus patients complained of pain in comparison to 23 percent of patients without the deformity. Pressure-time integrals in all three areas of the foot (rearfoot, midfoot and forefoot) were higher in the pes cavus group than in normal patients. There was also a significant correlation between higher pressure-time integrals and pain.

The second study from the Australian group concerned 130 patients who all had idiopathic painful pes cavus deformity.13 About 75 percent of the patients studied had bilateral pain, including metatarsalgia, plantar heel pain, midfoot soreness and ankle pain. The study showed that the pain severity was not linked to the severity of the cavus deformity.

The Foot Health Status Questionnaire revealed that cavus feet had a substantial impact on the quality of life.14 The data further demonstrated that rearfoot and forefoot pressures were again much higher than midfoot pressures in cavus feet. Participants with pain limited to the rearfoot avoided loading that area and had higher plantar pressures in the forefoot. Those same patients had a more cautious gait pattern. The data regarding the effect of rearfoot pain is interesting since most treatment data has been focused on the symptoms of the forefoot.
This paper was also the first randomized controlled trial to investigate the effectiveness of custom orthoses for the treatment of painful pes cavus deformity. The patients received either custom molded orthoses made of 3 mm polypropylene with a Poron top cover or sham insoles of 3 mm foam. Researchers evaluated patients for both quality of life changes using the Foot Health Status Questionnaire and for changes in plantar pressure measurements.  

The foot pain scores after three months of insole use improved by 43 percent with sham insoles and 74 percent with custom-molded orthotics. The peak pressure was 9 percent less with the sham insole and 26 percent less with the custom-molded orthoses. Overall, the custom orthoses had a greater effect on quality of life, including increasing activity and decreasing pain. One cannot overlook the value of improvement for both physical and mental health in cases of chronic pain and disability.

Although the clinical studies concerning pes cavus are limited, the information is applicable to clinical scenarios. Cavus gait is specific and often limited by the amount of compensation available at the ankle joint. The runner study revealed that the injury pattern is somewhat predictable and can help with orthotic fabrication details. The studies by the Australian group revealed that custom orthoses could relieve pain and decrease pressure time integrals. The positive information gained from this research acknowledges the value in biomechanical intervention for patients with pes cavus.

**Essential Prescription Insights For Optimal Orthotic Solutions**

The typical complaints associated with pes cavus are pain, shoe fit issues and lateral ankle sprains. By focusing on the pathomechanics of these issues and applying the evidence in the literature, we can compile a list of prescription components for the ideal custom orthoses.

**Overload on the metatarsal heads.** The overload on the metatarsal heads is due to limited contact area of the plantar surface of the foot because of the high arch. There is also a domino effect from a weak anterior tibialis muscle, tight gastrocsoleus complex, overactive extensors for ground clearance and extensor substitution or clawtoe contractures resulting in metatarsalgia. Increasing plantar surface contact with an orthosis ensures that more of the foot is bearing weight in the arch and the metatarsal heads are bearing less weight for less time. One can accomplish this via a minimal fill cast correction and a semi-rigid or rigid device.

Adding a metatarsal bar or a metatarsal pad will shift ground reactive forces more proximally away from the metatarsal heads. Overload on the metatarsal heads is due to limited contact area of the plantar surface of the foot because of the high arch. There is also a domino effect from a weak anterior tibialis muscle, tight gastrocsoleus complex, overactive extensors for ground clearance and extensor substitution or clawtoe contractures resulting in metatarsalgia. Increasing plantar surface contact with an orthosis ensures that more of the foot is bearing weight in the arch and the metatarsal heads are bearing less weight for less time. One can accomplish this via a minimal fill cast correction and a semi-rigid or rigid device.

Laterally deviated subtalar joint axis. Lateral ankle instability and a laterally deviated subtalar joint axis (STJ) are frequently associated with high arched feet. The STJ axis lays more laterally and exits the foot at a different angle than the average STJ axis.

The result of this axis deviation leaves the pes cavus foot with more inversion as well as more plantar surface medial to the STJ axis. This leads to more ground reactive force area available for supinatory moments across the STJ axis. As a result, the peroneus brevis has a shorter and less efficient moment arm to fight supination, leading to lateral ankle sprains. The muscle imbalance inherent in the cavus foot leads to a plantarflexed first ray, subsequent rearfoot inversion and lateral ankle sprains by leaving the foot in an inverted position.

Leaving the lateral side of the rearfoot post unbeveled increases the surface area and effectiveness of the post by providing a more stable platform to resist inversion of the device. Adding a reverse Morton’s extension or a slight valgus forefoot extension creates a pronatory moment that counteracts the excessive supinatory moment. This makes the cavus foot more stable.

Rearfoot instability due to flexible forefoot valgus. Rearfoot instability is an extension of the laterally deviated subtalar axis. However, in flexible pes cavus feet, midtarsal flexibility complicates the later portion of the stance phase of gait. The forefoot pathology produces midtarsal joint supination that leads to excessive pronation of the rearfoot. Some pes cavus feet suffer from both lateral ankle instability and...
mid stance and rear foot pronation at late mid stance. Adding a flat rear foot post and a deep heel cup, over 16 mm, helps stabilize the rear foot by limiting rear foot motion in relationship to the supporting surface.

Gait changes. Multiple problems contribute to the apropulsive, antalgic gait of the pes cavus foot. Pain in the metatarsal heads or rear foot can cause shorter strides, which can lead to excessive use of extensor tendons and eventually result in tendinitis, tendon fatigue and even shin splints. Limited ankle joint motion also leads to shorter strides and limited propulsion, and is often associated with pes cavus.

Adding a 4 mm heel lift to the rear foot post actually increases available ankle joint dorsiflexion by plantarflexing the talus. Also bear in mind that making a wide orthosis increases the surface area that contacts the arch of the foot and distributes more ground reactive force to the midfoot, and away from the forefoot and rear foot.

In Conclusion

One must understand that early in treatment, the morphology and pathomechanics of cavus feet are likely to be progressive. Frequent reevaluation and recasting is essential to chase the continually rising arch and shifting of symptoms. Orthotic and shoe intervention are likely to change on a regular basis. The patient with pes cavus will be a lifetime patient. These patients are often difficult to treat due to the ongoing complexity of their lower extremity issues and our lack of knowledge of the pathomechanics.

The true etiology of pes cavus remains one of our unsolved mysteries. We have proposed a pathomechanical model that future trials can test. Recent research is both enlightening and encouraging. However, it is apparent that more studies need to be completed.

There is a congenital and familial component to these feet but there is much more to be studied about the progression. We need to recognize patients with cavus feet early in life and studies need to find means of early intervention to affect midlife outcomes and avoid symptoms. One should incorporate effective orthotic intervention into treatment plans.

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References: