White Paper

Orthotic Management of the Cavovarus Foot

Introduction

Human feet are incredibly complex structures. There are 26 bones, 33 Joints and more than 100 ligaments, tendons and muscles in each foot. On average, we (should) walk 10000 steps per day, 1000000 steps per year and 115000 miles in our lifetime[1]. The normally functioning foot is even more complex in that it becomes a flexible adapter to the terrain during the first rocker and transforms into a rigid propulsive lever arm in the 4th rocker. Of all the variations from normal, high arch foot deformities are perhaps the most challenging to treat. It is perceived as easier to manage excessive motion associated with over-pronation than managing the foot with a significant lack of motion.

Nomenclature

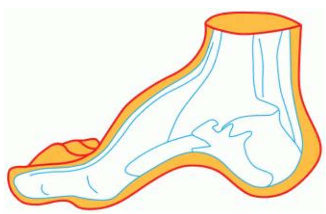

Figure 1
https://treadlabs.com

A number of terms are used in literature to describe this foot, (figure 1) including cavo-varus, equinovarus, pes cavus, cavus foot, cavusvarus and cavovarus. Alexander in 1989[2] was the first to use the descriptive and distinct terms anterior cavus and posterior cavus. The most commonly used term throughout orthopedics is "cavovarus foot" which, classically, is a three-dimensional deformity characterized by plantar flexion of the first ray, forefoot pronation, and hindfoot varus[3].

Cause

In general, any condition that produces muscle imbalance of the foot may result in a pes cavovarus[4]. This results in clawing toes and an increase in the height of the foot's arch as well as an equinus deformity of the forefoot over the hindfoot[4]. The most common etiologies for this deformity are neurologic, traumatic, residual clubfoot, and, when a cause can't be found, the deformity is labeled as idiopathic[4,5]. Hereditary motor and sensory neuropathies including Charcot-Marie-Tooth (CMT) disease are frequently expressed with an acquired cavusvarus foot[3,4,6,7]. Two-thirds of adults with symptomatic cavus foot have an underlying neurological condition with Charcot–Marie–Tooth (CMT) disease the most frequently reported[7]. The probability of a patient who has bilateral cavovarus feet being diagnosed with CMT is 78%[6]. CMT typically has an anterior cavus presentation whereby a specific and predictable sequence of muscle loss creates muscle imbalances which result in plantar flexion of the first metatarsal and or global plantar flexion of all the metatarsals. Consequently, weight bearing x rays will reveal a normal calcaneal inclination angle of less than 30 degrees[2].The increased medial longitudinal arch causes lower mobility of the foot and shock absorption mechanism weakness which predisposes the patient to injuries[8].

Symptoms

Lower limb afflictions associated with CMT are often the earliest ones to arise, including distal muscle atrophy and weakness, which could result in foot drop, sensory loss, absent tendon reflexes, muscle cramps, and cavo-varus foot deformity[9,10]. A study involving 172 children found that symptoms included: foot pain in 66 (38%); leg cramps in 68 (40%); ankle instability during walking in 84 (49%); daily trips/falls in 82 (48%); sensory symptoms in 54 (31%). Foot drop was evident in 104 (60%) cases, difficulty heel walking in 146 (85%) and difficulty toe-walking was evident in 65 (38%) children. Sixteen (9%) children required Ankle-Foot-Orthoses to walk[6]. Additional challenges faced by patients with the diagnosis include metatarsal pain, fifth metatarsal stress fracture, plantar fasciitis, medial longitudinal arch pain, and even iliotibial band syndrome[7].

Prevalence

There is an estimated high arch prevalence of 10% among adults[5,7]. Others put the incidence a little higher at approximately 10% to 15% [11,12] of the population, with one reporting the incidence to up to 25%[4]. Whatever the incidence, these feet lack the mobility to pronate and adapt to the terrain during gait, creating a whole host of challenges.

It has been suggested that the simple presence of bilateral cavovarus feet denotes a 76% chance of having CMT disease[4], so taking a family history is important. The prevalence of cavus foot without an identifiable underlying deficit has steadily increased in recent years so the mechanisms underlying this foot deformity are not fully understood[11].

About 66% of cavovarus feet are the result of subtle neurological diseases, which only become evident later in life[4]. Primary pes cavus (idiopathic) is diagnosed by elimination in more than half the cases and most authors believe that it is the consequence of a latent neurological disorder[13].

Presentation

Supination and pronation are triplanar movements[1]. Pronation is thought to act as a mechanism that dampens impact forces from the foot up the lower limb and to the rest of the musculoskeletal system[14]. Conversely, pes cavus presents with an increase of normal plantar concavity, where the anterior and posterior weight-bearing areas of the foot are brought closer together. This is accompanied by a wide spectrum of foot deformities including a plantarflexed first ray, forefoot pronation and adduction, and hindfoot varus or high calcaneal pitch[13]. These feet walk on the lateral border[1] and are incapable of absorbing shock or adapting to the terrain in advanced stages. The deformity can be mild, flexible, and painless, or severe, disabling, and rigid, with plantar calluses and lateral ankle instability[3,13]. These patients with painful foot deformities alter their gait strategy by reducing gait speed or limiting the time spent in certain phases of stance in order to reduce pain and/or pressure in symptomatic regions of the foot[5]. Typical clinical presentation of cavus foot includes unstable gait, ankle pain, plantar painful callus, loss of sensation in the metatarsal head, and occasional knee and hip pain[7].

Progression

The deformed forefoot is flexible at first. As the deformity of the forefoot becomes stiff, the hindfoot begins to develop compensatory varus, which leads to plantar fascia and Achilles tendon contracture[7,13].

The average age of onset is between 10 and 20 years of age. The cavo-varus foot deformity usually represents the first clinical symptom of the disease. Consequently, the presence of bilateral cavus foot deformity in a healthy subject should be investigated for CMT when other etiologies have already been excluded. The development of stiffness, pain and even dysfunction in the weight-bearing area may occur, seriously affecting the patient's quality of life[4,6,7].

There is increasing evidence supporting the link between heel impact forces, once excessive, and the development of a number of pathological conditions, including degenerative joint disease such as osteoarthritis, plantar fasciitis, headaches, prosthetic joint loosening, muscle tears, and lower back pain[14] and stress fractures[3].

It's not surprising then that the most common complaints in this population are ankle instability during walking (63%), and frequent falls (47%). Pain has been reported in up to 60% of patients[4,8]. 70% of the subjects with pes cavus reported musculoskeletal foot pain compared to the 23% of individuals with a normal foot type[8,11].

Pathomechanics

Differences in timing and severity of muscle involvement cause an imbalance between agonistic and antagonistic muscles, resulting in a vicious circle of ensuing denervation and biomechanical alterations[10]. The initial pattern of imbalance commonly found in CMT disease is the weakness of the peroneus brevis muscle, which does not balance the inverting power of the posterior tibial muscle, and muscle weakness of the tibialis anterior, with relative preservation of muscle strength of the strong peroneus longus and triceps surae[3,7]. Thus, the peroneus longus muscle flexes the first metatarsal plantarly, causes forefoot pronation, and thus causes secondary hindfoot varus[3].

A "tripod effect" has been described, when the plantar flexed first ray lengthens the anterior medial leg of the tripod and thereby creating an inversion twist to the hind foot, (varus deformity) which shifts the weight line lateral to the base of support[2]. This results in lateral ankle instability that leads to progressive chronic lateral ankle sprains.

Additional contracture of the plantar fascia will accentuate the windlass mechanism and further depress the metatarsal heads[13]. Because of hindfoot inversion, the Achilles tendon will shift medially and act as a secondary invertor[13]. In pes cavus it is anatomically thicker and stronger in its medial portion, its retraction not only maintains the accentuation of the plantar arch, but also contributes to adduction of the forefoot[3].

In people with cavus type feet, the lack of motion has been shown to result in increased lower leg muscle activity[15]. Higher up the chain, the cavus foot may display higher levels of gluteus medius muscle activity during gait compared to neutral and planus type feet[15]. This muscle activity indicates proximal functional instabilities associated with the cavovarus condition.

The calcaneal pitch angle (or calcaneal inclination angle) is formed by a line along the plantar surface of the os calcis and a line that goes through the floor. The normal value is < 25°. A calcaneal pitch > 30° is indicative of posterior cavus (calcaneocavus)[3,4,13].

Global observational assessment

The deformities involved in cavus foot are complex and include the abnormal elevation of the medial arch, varus hindfoot, high calcaneal pitch, high-pitched midfoot, plantarflexed, claw toe, and adducted forefoot[7,8]. Different patterns of shoe wear indicate abnormal contact of the foot with the ground. Early lateral, proximal, and mid shoe wear, indicates a supination deformity[1].

Hindfoot varus is confirmed through the 'peek-a-boo' heel sign which is the clinical condition whereby the heel is visible on the medial side when viewing the patient from the front with the feet in neutral rotation[13]. Calluses are also usually present, mostly at head of the first and fifth and base of the fifth metatarsals[4].

An evaluation of the entire lower limb is mandatory and calf-wasting or hypertrophy should be noted[1,13]. The gait examination should analyze the contact of the foot with the ground and verify whether there is a tendency to "drop foot" in the swing phase[3].

Quantify cavovarus condition

In a study of all tests used to quantify the foot, the conclusion suggests the adoption of the six-item version of the Foot Posture Index scale (FPI-6) for foot assessment in the CMT population. FPI-6 is the only scale specifically developed for CMT patients being the most widely used scale assessing foot deformity and was employed in 27 studies included in the current review[9]. The total score can vary from -12 to 12, with 0 to 5 (normal foot), from 6 to 9 (pronated foot), from 10 to 12 (very pronated foot), from -1 to—4 (supinated foot) and from -5 to -12 (very supinated foot)[16].

Flexibility assessment

The cavus deformity may present as an isolated deformity of the forefoot, hindfoot, or it may be a combination of both[3]. The most frequent anterior pes cavus is characterized by lowering of the forefoot in plantarflexion[13]. The posterior cavus or calcaneocavus is characterized by an isolated high calcaneal pitch of greater than 30°[13].

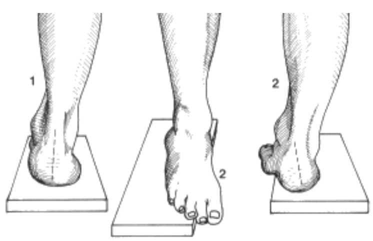

Figure 2. blogspot.com

The Coleman block test (Figure 2) is used to assess the flexibility of the hindfoot, i.e., whether the cavus foot is caused by the forefoot or the hindfoot, and to determine if it is flexible or fixed. A block is placed under the lateral aspect of the patient's foot while the first ray is allowed to hang over the side. If the hindfoot varus remains, then the deformity is fixed. However, if the hindfoot corrects to (or towards) physiologic valgus, then the deformity is flexible and driven by the forefoot deformity[1,3,7,13]. There is clinical evidence that hindfoot correction of as little as 10° towards neutral can benefit from orthotic intervention resulting in higher levels of function with less pain.

Intervention goals

There is a lack of consensus about what constitutes the ideal treatment for pes cavovarus[4]. Some suggest that nonoperative treatment of both neuromuscular and non-neuromuscular cavus foot should be tried first in order to prevent or slow down the further development of the deformity and to provide comfort and stability during gait, and relieve fatigue in the lower extremities[7,11]. Others state that conservative treatment plays no role[4] and these feet should go to surgery before more rigid deformities are formed. The aim of [surgical] treatment is to preserve a painless, plantigrade, mobile foot. Management consists of correcting bone deformity while preserving movement, and the wise use of rebalancing techniques. Arthrodesis should only be a salvage procedure[4]. Because correction of cavus foot can be difficult with regard to both the decision-making and the execution of the surgery[7], it is reasonable that the same goals would apply to conservative management in that a byproduct of surgical intervention includes scar tissue that can complicate return to function.

Local (foot orthotic) intervention

Although there are no high-level studies proving that conservative treatment is effective, it is still reasonable to undergo nonoperative treatment in an attempt to avoid operative intervention[5,11,12]. The problem is that little is known about the effects of custom foot orthotics (CFOs) in individuals with cavus feet.

There are two schools of thought on what a proper CFO should look like. One school proposes CFOs should be designed with lower durometer materials to act as a shock absorber for the rigid cavus foot. Grech[14] states that the cavovarus foot necessitates the wider utilization of shock-absorbing materials in those foot orthotic devices prescribed once supinated, or cavus, feet are diagnosed.

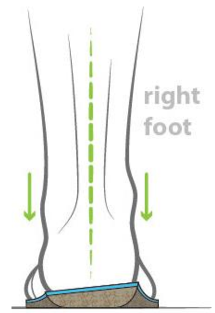

Figure 3
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The other school of thought is to use higher durometer materials in a biomechanical CFO (Figure 3) to mobilize the foot and therefore make the foot a more functional shock absorber. In a forefoot-driven cavus with a supple hindfoot, correction of the plantarflexed first ray will allow the hindfoot varus to correct by way of a first ray recess or cut-out associated with a metatarsal bar and lateral forefoot post. Furthermore, in front of a hindfoot-driven cavus, the appropriate orthosis includes a lateral hindfoot-to-midfoot heel wedge with a first metatarsal recess and *minimal or absent* (added for emphasis) medial arch support[13]. In order to accomplish that, CFOs were made of a 3.2 mm thick polypropylene shell, cut proximal to the metatarsal heads. A straight extrinsic ethylene-vinyl-acetate (EVA, Durometer: 55) rearfoot post, commonly used in clinical practice, was glued under the 14 mm heel cup and a lateral bar was glued under the lateral part of the CFOs in the gap between the rearfoot post and the anterior edge[3,12]. CFOs with a lateral bar decreased the EMG amplitudes of the peroneus longus and gastrocnemius lateralis compared to a control condition, thereby limiting pain and plantar pressures while also limiting ankle inversion and external tibial rotation associated with the cavus foot[12].

It has been suggested that conservative measures may slow the progression of the deformity or even cause its reversal. There have also been suggestions that surgical treatment could be delayed because surgery is not always necessary and many patients could be treated conservatively. This is especially true in mild cases[3].

Global (AFO) intervention

Conservative management of the cavovarus foot involves a CFO for local (foot/ankle) intervention as described above, as well as a more global (gait and AFO) perspective. Given the number of concurrent muscle imbalances including deficit ankle dorsiflexors, one cannot succeed without the other.

In managing the cavovarus foot that already lacks some mobility, using molded plastic AFOs is contraindicated in that they would further limit mobility of the foot/ankle complex and further decrease power crossing the ankle.

Energy Return carbon composite AFOs (ERAFO) are considered to be better than plastic AFOs in terms of energy return capacity, light weight, and durability. In addition, the overall satisfaction of users is high, as the appearance is more modern and the function is superior to the existing orthoses[17]. For management of the more rigid cavovarus foot, CMT related or not, a more supportive version of an ERAFO is the Blue Rocker carbon composite AFO made by Allard USA.

Figure 4
Allard USA

The Blue Rocker ERAFOs (Figure 4) assist with correcting foot drop during swing phase of gait for individuals with anterior tibialis weakness, but also assist stance phase by controlling the forward motion of the tibia for individuals with plantarflexion weakness. They also assist with push off at terminal stance, which can improve balance, stride length, and gait speed[18]. In addition they likely improve the proprioceptive input in the lower legs, and improve tibial progression and ankle dorsiflexion during stance phase[17]. In a -pilot study, there was an immediate improvement in dynamic balance during ambulation with the use of ERAFOs[18]. The improved tibial progress can contribute to improved push off at terminal stance, improved balance, stride length, gait velocity, and overall improved gait efficiency. There were no custom foot orthoses provided, which would have optimized the foot position in the shoe and on the AFO[17], noting the necessity of combining CFOs with the right AFOs. These spring-like ankle-foot-orthosis (ERAFOs) can reduce walking energy cost[19] and usually allow patients greater walking distance capacity.

Soft, low durometer footwear can negate the function of the CFO/AFO combination described above, so shoes worn with these devices should have a rocker toe, and feature a higher durometer sole for firm support to facilitate function of the orthotic intervention.

Summary

Cavovarus foot can be challenging in that they generally lack mobility and concurrently present with muscle weaknesses and imbalances. The foot can present as either mild, flexible, and painless, or severe, disabling, and rigid. It is the prior rather than the latter that is usually appropriate for conservative management. Foot orthotic intervention is a bottom-up approach designed to help maintain or even increase flexibility of the foot to make it a better shock absorber. Energy Return AFOs are then included to provide top-down support to augment weak plantarflexor and dorsiflexor muscles and provide enhanced proximal stability during gait.

Cavovarus Foot References

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Robert Meier, CO, has been active in the fields of orthotics, therapeutic exercise and biomechanics since 1978, and has been conducting education programs since 1982. His special interest is in applied closed chain biomechanics and muscle function. He has developed and taught numerous courses across North and South America, Australia and Europe on gait assessment, rehabilitation and orthotics. He holds six patents applying functional biomechanics to lower extremity and spinal interventions.

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