PROLAB ORTHOTICS
Evidence-Based Medicine

Biomechanics & Orthotic Therapy Newsletter
July 2025

BIOMECHANICS OF FLATFOOT DEFORMITY – PART 1

Flatfoot deformity is characterized by a flatter than normal medial longitudinal arch (MLA) and can be a painful and disabling condition for some individuals. Pediatric patients with flatfoot deformity may suffer from frequent pain in their foot and lower extremities which intensifies with prolonged standing, walking and/or running activities and which may cause them to prefer to be more sedentary than other children their age. Adult patients with flatfoot deformity may complain of pain in their foot, ankle, tibia, knee or lower back. Because of the relatively common occurrence of flatfoot deformity within the population, it will be helpful to discuss in detail how the structural decrease in MLA height in individuals with flatfoot deformity may affect the overall biomechanics of the foot and lower extremity during weightbearing activities

From clinical examination of literally thousands of patients over the past four decades of podiatric practice, it has become evident that individuals with flatfoot deformity share some common structural issues which can lead to abnormal biomechanical function. First of all, the height of the MLA of the individual with flatfoot deformity may range from being only slightly lowered or to being so severe that the whole plantar aspect of the MLA contacts the ground, becoming a fully weightbearing area of the foot. Many times, the individual with flatfoot deformity may appear to have a more normal MLA height during standing examination of their feet, but will exhibit abnormal flattening of the MLA only during walking gait, especially at the late midstance phase of gait. Therefore, it is always important to do a gait examination of patients with suspected flatfoot deformity to determine how much their MLA does collapse during walking activities.

Secondly, all individuals that I have examined with a flatfoot deformity have a subtalar joint (STJ) axis that is more medially deviated than normal. The STJ axis location may be clinically determined using the STJ axis palpation technique (Kirby KA: Methods for determination of positional variations in the subtalar joint axis. JAPMA, 77: 228-234, 1987). The STJ axis is always medially deviated in flatfoot deformity because, in the maximally pronated foot, the talar head and neck are more internally rotated and plantarflexed than would be present within the foot standing closer to the STJ neutral position (Fig. 1). Since the best biomechanical studies to date have demonstrated that the STJ axis exits the foot distally at the dorsal aspect of the talar neck (Van Langelaan EJ: A kinematical analysis of the tarsal joints: An x-ray photogrammetric study. Acta Orthop. Scand.,54: Suppl. 204, 135-229, 1983), any internal rotation and plantarflexion of the talus relative to the ground which occurs with STJ pronation will result in a foot with a medially deviated STJ axis.

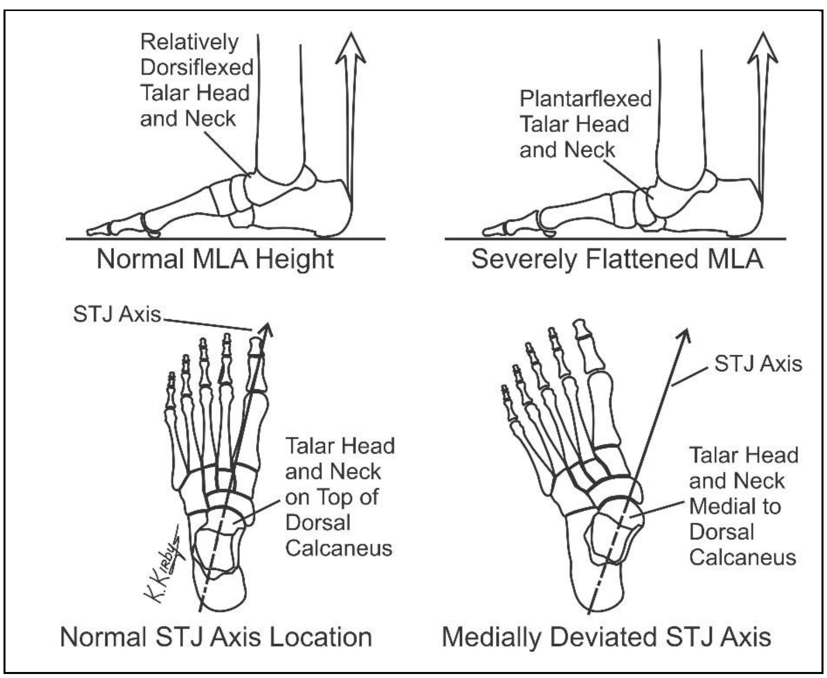

Figure 1. In the foot with a normal medial longitudinal arch (MLA) height, the talar head and neck are relatively dorsiflexed and on top of the anterior calcaneus with the subtalar joint (STJ) axis pointing toward the first metatarsal head (left). However, in the foot with a severely flattened MLA (right), the talar head and neck are much more plantarflexed and medial relative to the anterior calcaneus with the STJ axis pointing well medial to the first metatarsal head. The result of this abnormally medial STJ axis location is greatly increased STJ pronation moments in the flatfoot deformity.

To briefly review the mechanics of STJ pronation, when the STJ undergoes closed kinetic chain (CKC) pronation, the talar head plantarflexes and adducts (i.e., internally rotates) relative to the calcaneus and the ground. As a result of this plantarflexion of the talus relative to the ground, the MLA will decrease in height since the navicular drops with the talar head, while the other distal segments of the medial column (i.e., cuneiforms and medial three metatarsals) dorsiflex due increased ground reaction force (GRF) acting plantar to the medial three metatarsals. In other words, when the talar head plantarflexes relative to the ground, the medial column dorsiflexes relative to the ground during CKC pronation of the STJ. The result is a decrease in MLA height with CKC pronation of the STJ.

It is important to note here that in the foot with a more normal MLA height, the talar head and neck are positioned directly superior to the distal calcaneus, pointing more toward the first metatarsal head than in the flatfoot deformity with excessive STJ pronation where the talar head and neck point medially (Fig. 1). This increased medial talar head and neck position seen in the flatfoot deformity with an excessively pronated STJ will cause an increased medial deviation of the STJ axis. The biomechanical result of increased STJ axis medial deviation is increased magnitudes of STJ pronation moments due to the reduction of STJ supination moment arms from the actions of GRF and extrinsic foot muscles during weightbearing activities (Kirby KA: Subtalar joint axis location and rotational equilibrium theory of foot function. JAPMA, 91:465-488, 2001).

Many flatfoot deformities are congenital in nature. The congenital cause of flatfoot deformity may be osseous in nature, such as in the case of congenital forefoot varus deformity, but, from my clinical observations, most flat-footed individuals have increased ligament laxity within their feet (i.e., decreased tensile stiffness in their ligaments). Decreased ligamentous tensile stiffness may occur in hereditary connective tissue disorders such as the more serious and less common Ehler's Danlos and Marfan's Syndrome, or the less serious and much more common Joint Hypermobility Syndrome (JHS). Simmons and Keer reported that JHS is more prevalent in children than in adults, more common in people of African or Asian descent, and more common in females than in males. The incidence of JHS within the adult population ranges from 5% in the USA to 43% in the Noruba tribe in Nigeria (Simmonds JV, Keer RJ: Hypermobility and the hypermobility syndrome. Manual Therapy, 12(4):298-309, 2007).

Flatfoot deformities may also be acquired in adulthood, and not congenital in nature. Conditions such as calcaneal fractures, crush injuries of the foot, and ligament or tendon injuries are common causes of acquired flatfoot deformities. For example, isolated tears of the posterior tibial tendon or isolated tears of the spring ligament complex can cause relative rapid development of flatfoot deformity in adults due to the lack of adequate support from these soft tissue retraining structures to the MLA of the foot (Borton DC, Saxby TS: Tear of the plantar calcaneo-navicular (spring) ligament causing flatfoot. A case report. JBJS, 79-B(4):641-643, 1997). In addition, some types of seropositive and seronegative arthritis may cause sufficient intra-articular swelling to cause weakening of the supportive ligaments within the STJ and MLA which can, over time, destabilize the pedal joints and lead to flatfoot deformity (Pinney SJ, Lin SS: Current concept review: acquired adult flatfoot deformity. Foot Ankle Int, 27(1):66-75, 2006).

If the MLA of the foot is flattened during weightbearing activities, regardless of whether the resulting flatfoot is congenital or acquired in nature, the resulting decrease in MLA height and corresponding medial deviation of the STJ axis (i.e., due to medial deviation of the talar head and neck) will cause significant and profound alterations within the biomechanical function of the foot and lower extremity. For example, individuals with significant flatfoot deformity and medial STJ deviation will nearly always be maximally pronated at the STJ during bipedal standing and walking. These feet will also be less likely to undergo normal STJ supination in late midstance and propulsion, may have a decreased stride length during walking and may be more abducted in walking gait than normal. In addition, since the posterior tibial tendon in the more severe flatfoot deformity has a reduced moment arm to produce STJ supination due to the medially deviated STJ axis, the posterior tibial muscle will be, in effect, weaker than normal at producing STJ supination during walking. My next newsletter will further discuss the biomechanics and treatment of flatfoot deformities.

Kevin

Kevin A. Kirby, D.P.M.
Biomechanics Director