

BIOMECHANICAL FUNCTIONS OF THE PLANTAR FASCIA

The plantar aponeurosis consists of three components, the central, medial and lateral components. The biomechanical functions of the central component, commonly known as the *plantar fascia*, will be the topic of this newsletter. The plantar fascia is the most superficial of the plantar tension load-bearing structures of the Longitudinal Arch Load-Sharing System (LALSS) of the Foot in which the plantar fascia, plantar intrinsic muscles, deep flexor muscles and plantar ligaments all work together to stiffen the longitudinal arch and prevent longitudinal arch flattening and longitudinal arch elongation during weightbearing activities (Kirby KA: Longitudinal arch load-sharing system of the foot. Revista Española de Podología, 28(2), 2017).

Since the plantar fascia (i.e., central component of plantar aponeurosis) originates proximally from the medial calcaneal tubercle and inserts distally into the plantar plates, sesamoids and then onto the bases of the proximal phalanges of all five digits, the plantar fascia plantarly spans all the joints of the foot other than the digital interphalangeal joints. As such, the plantar fascia has many important functions other than simply helping prevent longitudinal arch flattening and preventing longitudinal arch elongation.

One of the most well-known functions of the plantar fascia was first described by Hicks in 1954 in which he used the mechanical analogy of a *windlass* to describe his experimental observations that hallux dorsiflexion would produce longitudinal arch-raising of the foot in both living and cadaver feet. Hicks noted that dorsiflexion of the hallux also produced supination of the subtalar joint (STJ) and external rotation of the leg during weightbearing examination of the subject. He likewise noted that a *reverse windlass* effect occurred when the longitudinal arch was flattened, causing the hallux to plantarflex more forcefully into the ground (Hicks JH: The mechanics of the foot. II. The plantar aponeurosis and the arch. J Anatomy. 88:24-31, 1954).

During propulsion, as the heel lifts and the hallux dorsiflexes, the plantar fascia and windlass actively increase the height of the medial longitudinal arch (MLA) causing STJ supination. The ability of the plantar fascia to assist in resupination of the STJ during propulsion was confirmed by a novel experiment by Ward et al using a *dynamic gait replicator* which allowed a cadaver foot to “walk”. These researchers found that before the plantar fascia was sectioned, the cadaver feet resupinated normally during propulsion. However, as the plantar fascia was sectioned progressively from medial to lateral, STJ supination was found to lessen, which suggests the plantar fascia assists in STJ supination during propulsion (Ward ED et al.: In vivo forces in plantar fascia during stance phase of gait. Sequential release of plantar fascia. JAPMA, 93:429-442, 2003).

Because of the ability of the plantar fascia to help prevent MLA flattening and help cause STJ supination during propulsion, the plantar fascia also has the ability to actively assist the muscles of the deep posterior compartment in decelerating STJ pronation during early stance phase and accelerating STJ pronation during propulsion. In assisting the deep posterior compartment muscles, and especially the posterior tibial muscle, in helping to decelerate STJ pronation and helping to supinate the STJ, an intact plantar fascia likely has a preventative role in reducing the risk of pronation-related pathologies, such as posterior tibial tendon dysfunction, from developing over time (Kirby KA: Conservative treatment of posterior tibial dysfunction. Pod Management, 19:73-82, 2000).

In addition, using the biomechanical

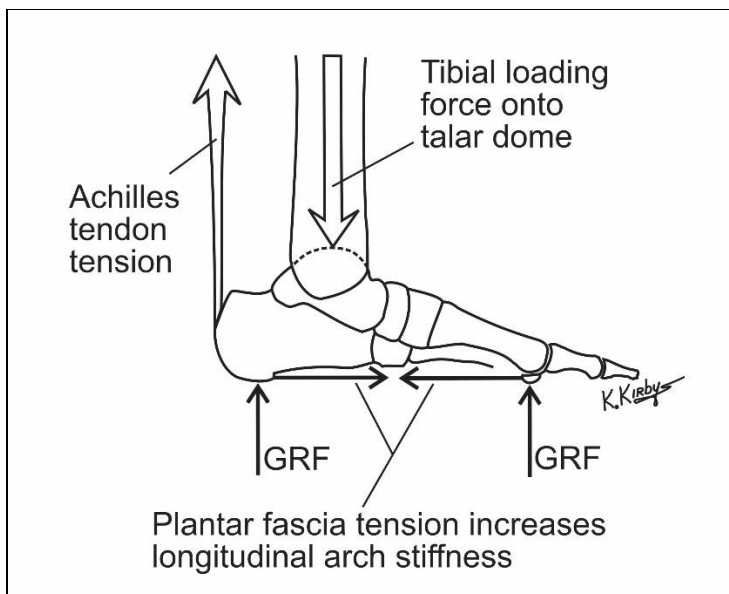


Figure 1. The plantar fascia stiffens the longitudinal arch of the foot when the forefoot is subjected to ground reaction force (GRF), when Achilles tendon tension acts on the calcaneus and when tibial loading forces act on the talus.

concepts embodied by the LALSS concepts, another unique function of the plantar fascia is to assist the plantar intrinsic muscles and the plantar ligaments of the foot in helping to stiffen the longitudinal arch and prevent excessive flattening and elongation of the longitudinal arch during weightbearing activities. Since the plantar intrinsic muscles of the foot are active in the latter half of midstance and throughout the propulsive phase of walking gait, their contractile activity can actively stiffen the longitudinal arch of the foot and work along with the plantar fascia to reduce longitudinal arch flattening during weightbearing activities (Headlee DL et al.: Fatigue of the plantar intrinsic foot muscles increases navicular drop. J Electro Kinesiology. 18:420-426. 2008). Likewise, the tension force within the plantar ligaments of the longitudinal arch is also reduced by the tension load-bearing function of the plantar fascia. In support of this theory, in an experimental study published by Crary et al in 2003, the average strain in the spring ligament increased by 52% and the average strain in the long plantar ligament increased by 94% after plantar fasciotomy on cadaver feet (Crary JL et al.: The effect of plantar fascia release on strain in the spring and long plantar ligaments. Foot Ankle Intl, 24:245-250, 2003).

Due to its ability to help prevent longitudinal arch flattening and elongation, the tension forces within the plantar fascia which, overall, help to support the structure of the longitudinal arch also help to prevent the midfoot joints of the longitudinal arch from being subjected to excessive dorsal interosseous compression forces during weightbearing activities. The large magnitudes of ground reaction force (GRF) acting on the plantar forefoot during the latter half of the stance phase of gait, combined with Achilles tendon tension force and downward-directed tibial forces on the talar dome create large magnitudes of longitudinal arch flattening moments, which the passive tension forces within the plantar fascia help resist (Fig. 1). As a result, these plantar fascia tension forces also help reduce the dorsal midfoot interosseous compression forces during the late midstance phase of gait. Therefore, the plantar fascia, by helping to prevent excessive dorsiflexion motion of the midfoot joints and longitudinal arch flattening, will help prevent the pathological levels of dorsal midfoot joint compression forces which can ultimately lead to chronic dorsal midfoot pain (Kirby KA: Understanding ten key biomechanical functions of the plantar fascia. Podiatry Today, 29(7):62-71, 2016).

Because of its insertions into the sesamoids, lesser MPJ plantar plates, the bases of the digital proximal phalanges, the plantar fascia also acts to help reduce metatarsal bending moments which can cause metatarsal stress fractures and/or stress reactions. Plantar fascia tension force pulls the proximal phalanx bases more forcefully into the distal aspects of the metatarsal heads which, in turn, creates a plantarflexion bending moment on the metatarsal, or, put another way, tends to prevent the distal metatarsal shaft from excessive dorsiflexion bending due to GRF. This effect has been confirmed by cadaver studies using simulated weightbearing conditions which showed that both dorsiflexion bending moments and dorsal metatarsal strains were significantly increased with plantar fasciotomy (Donahue SW, Sharkey NA: Strains in the metatarsals during the stance phase of gait: implications for stress fractures. JBJS (A): 1:81 (9):1236-1244, 1999).

Finally, due to the passive increase in plantar fascia tension force that occurs with flattening and elongation of the longitudinal arch, plantar fascia tension also produces a digital plantarflexion moment which causes the digit to plantarflex into the ground, creating a *digital purchase force*. In support of this function of the plantar fascia, Donahue et al. demonstrated a significant reduction in plantar digital pressure and plantar digital contact force with plantar fasciotomy of cadaver feet in simulated weightbearing conditions. In this same study, Sharkey and colleagues demonstrated that progressive transection of the plantar fascia also caused significant increases in plantar pressure and plantar GRF at the metatarsal heads, which the authors thought would decrease the risk of excessive compression forces from GRF acting on the metatarsal heads during weightbearing activities (Sharkey NA, Donahue SW, Ferris L: Biomechanical consequences of plantar fascial release or rupture during gait. Part II: Alterations in forefoot loading. Foot Ankle Intl, 20:86-96, 1999).



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