

The Influence of the Windlass Mechanism on Plantar Fasciitis

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Plantar fasciitis, inflammation of the plantar fascia and perifascial structures, is a common problem requiring treatment by chiropractors. Chandler and Kibler reported a [10 percent occurrence rate in runners](#), while Kwong classified plantar fasciitis as a syndrome resulting from [repeated trauma to the plantar fascia at its origin](#) on the medial tubercle of the calcaneus.^{1,2}

A literature review attributes plantar fasciitis to [faulty biomechanics, including excessive pronation](#).³ Excessive pronation can result from structural deformities such as a forefoot varus that can contribute to excessive foot mobility. The resulting stresses are absorbed by muscle, fascia and other soft-tissue structures as fascia elongates and tissue stresses increase.⁴

Increased stress along the medial joint capsule and ligamentous structures causes the foot joints to be strained beyond their normal motion. The tibialis posterior muscle becomes lengthened, which results in excessive muscle fatigue as it tries to control the excessive motion. It has been determined that plantar fasciitis can be attributed to the [disproportionate duration of motion](#), as opposed to the motion itself.⁵ To appreciate the effect different biomechanical stresses have on the foot, one must understand and appreciate the function of the *windlass mechanism* as it applies to foot mechanics and gait. The windlass mechanism is a model that explains biomechanical factors and stresses as they relate to foot pronation and plantar fasciitis.

A windlass is a [device designed to lift a heavy object](#) by tightening a rope or cable.⁹ The plantar fascia simulates a cable attached to the calcaneus and the metatarsophalangeal joints. Dorsiflexion during the propulsive phase of gait winds the plantar fascia around the head of the metatarsals. This shortens the distance between the calcaneus and the metatarsals, and results in elevation of the medial longitudinal arch.

The crux of the windlass mechanism principle is the shortening of the plantar fascia resulting from hallux dorsiflexion.^{2,6,7} The medial longitudinal arch raising is synchronous with subtalar joint supination and external leg rotation. Without correct windlass function, the foot will not act as an efficient lever and effective push-off power cannot be achieved.

A [reverse windlass mechanism](#) has also been proposed.²¹ During the early single-support phase of gait, the leg internally rotates and the subtalar joint pronates. This unwinds the windlass, and the arch lowers as the foot elongates. In this situation, the plantar fascia becomes tight and applies a plantar flexion moment to the phalanges, stabilizing them against the ground. This applies a compressive force longitudinally and resists excessive pronation movements.

Prolonged reverse windlass occurs as a result of excessive pronation at the subtalar joint. This movement impedes hallux dorsiflexion, prevents the arch from rising and reduces the ability of the foot to efficiently move the body forward, resulting in inefficient propulsion. Understanding this

mechanism will enhance the decision-making process in the [evaluation and treatment](#) of patients with plantar fasciitis.⁶

Hicks originally described the foot and its ligaments as an [arch-like triangular structure](#).⁶ The calcaneus, midtarsal joints and metatarsals, including the medial longitudinal arch, form the truss' arch. The plantar fascia form the tie-rod that runs from the calcaneus to the phalanges. Vertical forces from the body weight travel downward along the tibia and have a tendency to flatten the medial longitudinal arch. At the same time, ground-reaction forces push up on the calcaneus and metatarsal heads, which further the flattening effect because these forces fall both [anterior and posterior to the tibia](#).⁷

The plantar fascia prevents foot collapse due to its anatomic location and tensile strength as it runs from the base of the calcaneus to the phalanges. Stretch tension from the plantar fascia [prevents spreading](#) of the calcaneus and the metatarsals, which maintains the medial longitudinal arch.⁸

There are [several phases of gait](#), as described by Donatelli.¹⁰ The stance phase of gait includes heel contact, weight acceptance, midstance, push-off, propulsion and toe-off. The gait cycle begins with the foot in a supinated position at heel strike. The subtalar joint then immediately pronates when going from heel strike to weight acceptance. This period of pronation results in the increased foot mobility needed to [absorb ground-reaction forces](#) and adapt to uneven terrain.¹¹

The foot reaches maximum pronation following the weight-acceptance phase, and the subtalar joint supinates the foot from [midstance through toe-off](#).¹² Supination transforms the foot into a rigid lever necessary for propulsion. Without a mechanism to maintain the arch, we would not be capable of overcoming the many forces that stress the foot and result in disruption of the medial longitudinal arch. This results in inefficient and nonsystematic gait patterns. The orientation of the plantar fascia helps maintain the arch throughout gait and significantly contributes to appropriate timing of pronation and supination during the gait cycle.

From heel strike to weight acceptance, pronation increases the relative distance between the calcaneus and the metatarsals, and applies a tension stress to the plantar fascia. From midstance through the propulsive phase, supination occurs so the foot can become a rigid lever using the windlass mechanism to propel the body forward. Forces that are generated during supination also apply tension to the plantar fascia, just as in pronation.^{6,9} The forces generated during pronation and supination increase plantar fascia tension. Inefficient foot function can lead to increased tissue stress.^{2,3}

The foot must have a [balance between pronation and supination](#). Too much or too little of either motion at the wrong time of gait in a prolonged fashion leads to foot dysfunction.⁵ The previous discussion illustrates how vertical and ground-reaction forces stress the plantar fascia tissues. Plantar fascia pain results from increased tension and excessive traction forces applied to the calcaneus. High tension in the fascia can result in periosteal lifting at its insertion on the calcaneus, and bone healing could cause growth of a spur commonly seen at the calcaneus. The explanation of traction stress describes why bone spur growth occurs horizontal to the ground. It should also be clear that [fascial stretching causes pain](#) either to the fascia itself or to its bony attachment on the calcaneus.⁶

There are a number of studies that support the belief that heel pain [does not occur from the bone](#)

spur itself, but from excessive tension applied to the plantar fascia.^{2,3,13} Excessive tension causes tissue irritation to the plantar fascia, as well as to its origin at the medial calcaneal tubercle.

Clinicians can reproduce the symptom by applying the windlass test.¹⁴

In a weight-bearing position, the clinician forcefully extends the great toe. A positive test reproduces pain at the medial calcaneal tubercle. Researchers have reported 100 percent specificity, but only 31.8 percent sensitivity with this test. However, clinicians may find it useful in determining plantar-fascial tissue irritation. Decreasing tension in the plantar fascia will decrease the pain. Therefore, successful management depends on the clinician's ability to reverse the forces that lead to excessive strain and the resulting pain and discomfort that bring patients in for management.

Patients with pronation problems have a more flexible, lower-arched foot. Factors that contribute to excessive pronation include muscle weakness, heel-cord tightness and structural foot deformities.^{2,3,15} Thordarson found that the posterior tibialis muscle provided the most significant dynamic arch support during the stance phase of gait.¹⁵ This muscle eccentrically lengthens to control pronation and reduces tension applied to the plantar fascia during weight acceptance. With excessive pronation, the plantar fascia elongates and weakens the tibialis posterior muscle. This reduces the effectiveness of the foot's windlass mechanism because of instability during the propulsive phase of gait.^{2,17} Subsequently, controlled pronation provides for the appropriate timing of supination during gait.

The combined effects of the flexor digitorum longus, flexor hallucis longus, peroneus longus and Achilles tendons permit the supination needed to enhance the windlass mechanism.¹⁶ The plantar flexors enhance supination so the cuboid pulley system can plantar-flex the first ray and promote efficient use of the windlass mechanism. Proximal muscle weakness from the gluteus medius, gluteus minimus, tensor fascia latae or quadriceps muscle can contribute to plantar fascia abnormalities. Weakness in these muscles inhibits their ability to assist with the lower-extremity load response, which results in greater transmission of shock to the supporting foot structures.¹⁸ Furthermore, gluteus medius, gluteus minimus, tensor fascia latae weakness can accelerate lower-extremity pronation.¹⁹

A tight Achilles tendon limits the amount of dorsiflexion available during gait. A person with a flexible foot can compensate for this by unlocking the midtarsal joint, because dorsiflexion and abduction are movements allowed at the midtarsal joints axis. This increased motion results in excessive pronation that can lead to stress of the plantar fascia.^{10,18} Structural deformities such as an excessive subtalar or forefoot varus can contribute to plantar fascia problems. When the heel hits the ground, the foot must pronate excessively to allow the forefoot to contact the ground. This excessive pronation stresses the plantar fascia and inhibits efficient use of the windlass mechanism. A subtalar varus deformity of more than 10 degrees can also contribute to excessive pronation.¹⁹

A rehabilitation plan should relieve inflammation and correct the mechanical factors.²⁻⁴ Treatment goals should focus on restoring normal muscle strength, improving muscle flexibility and normalizing biomechanical influences. Strengthening should center on muscles involved in controlling pronation and facilitating the windlass mechanism. This should encompass tibialis posterior, ankle plantar flexors, the peroneus muscles as well as proximal hip and knee musculature. Rehabilitation should also include calf stretching, chiropractic manipulative therapy

for the foot and ankle and biomechanical control of excessive pronation.

Orthotics are commonly prescribed to control pronation.^{1-3, 20} An orthotic device applies a supinatory moment at the subtalar joint. Orthotics allow an appropriately timed windlass mechanism and initiation of autosupportive mechanisms. This facilitates supination in coordination with external leg rotation and stabilizes the foot, leading to efficient toe-off.²² Plantar fasciitis is the most common musculoskeletal injury presenting to the podiatrist for treatment with orthotics.²³

Functional hallux limitus has been restored by the use of foot orthoses. The orthoses controlled abnormal subtalar pronation by restoring dorsiflexion at the first metatarsal phalangeal joint, thereby eliciting a more functional windlass mechanism. This led to decreased stress, increased healing and a more efficient gait pattern.²⁴

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