

The Foot Orthotics Laboratory

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The Unified Theory

The Unified Theory was first published by Paul Harradine et al in 2003, and has continued to be published and taught since this date. This theory on foot function incorporates and unifies previous foot function theory with new research to make a cohesive and logical step in our knowledge of foot function and the treatment of foot based gait dysfunction and symptoms. Below is a basic explanation of the unified theory, if you would like a more detailed scientific paper these can be requested from The Foot Orthotics Laboratory or obtained from various scientific journal access websites.

The Basic underpinning requirements of the foot for normal function are:

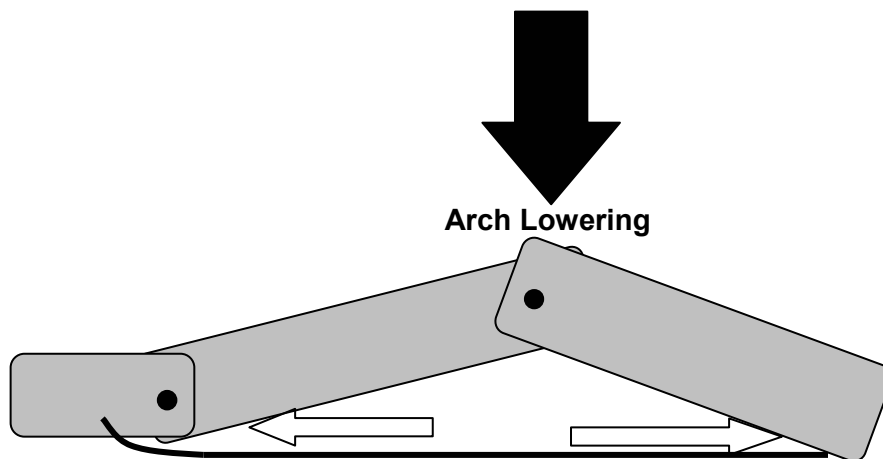
- To be stable and maintain a congruent structure through the stance phase.
- To allow the leg to pivot over the point of ground contact, permitting a normal stride.
- To allow internal and then external rotation of the leg in relation to the ground via STJ pronation and supination

Normal Foot Function

As the foot hits the ground the lower limb internally rotates. To allow this internal rotation the subtalar joint (STJ) pronates and the arch lowers. As the arch lowers the plantar fascia becomes more taut, applying a longitudinal compressive force through the convex and concave joints of the midtarsus,

theoretically 'close-packing' these joints and increasing the congruent stability of the foot. This increase in plantar fascia tightness with pronation has been called 'the reverse windlass mechanism' and is demonstrated below in figure 1:

Figure 1: The Reverse Windlass Mechanism. With pronation the foot lengthens and increased tension in the plantar fascia creates stability



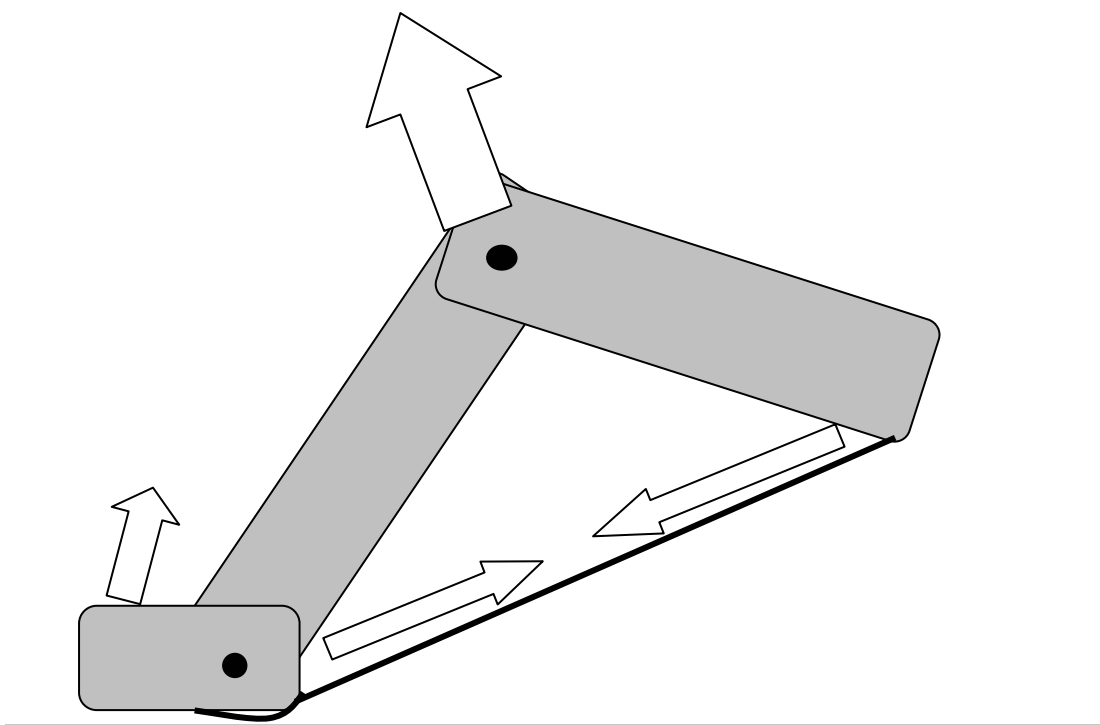
The normal amount of pronation that occurs with internal leg rotation at contact phase therefore supplies stability of the foot essential for a normal gait cycle.

Through midstance the leg begins to externally rotate in relation to the ground. For this to happen STJ supination must occur. With this supination the arch begins to rise and therefore the origin and insertion of the plantar fascia become closer and tension is lost. This occurs with heel lift, a stage in gait where as the bodies' centre of mass progresses anterior to the ankle over the Midtarsal joint. This progression of centre of mass creates a peak moment attempting to lower the arch. The ability of the foot to resist these bending moments and so maintain arch raising is essential, but unless the slack in the plantar fascia can be taken up, stability may be lost.

The windlass effect was first described by Hick's, a British anatomist, in 1954. During closed kinetic chain in a foot with a normal structure, dorsiflexion of the

hallux will tighten the plantar fascia, due to the plantar fascia being wound around the first metatarsal head. This is analogous to a cable being wound around a windlass. This effectively draws the head of the 1st metatarsal and calcaneus together 'shortening' the foot and raising the arch (figure 2). During propulsion most of the weight bearing is borne through the medial column of the foot while the leg is externally rotating and arch is rising and shortening. For the heel to lift, the hallux therefore should dorsiflex. This winds the windlass maintaining tension in the plantar fascia and so a compressive force across the foot.

Figure 2 – The Windlass Mechanism. As the hallux is dorsiflexed the plantar fascia is 'wound' tighter raising the arch.



To summarise, the foot therefore uses the internal rotation of the leg to aid in its own stability via increasing plantar fascia tension with pronation through contact and early midstance. As the foot pivots over the hallux the leg is externally rotating and midfoot stability is maintained via the windlass mechanism. Although the plantar fascia may only be one of the many structures involved in maintaining foot structure in relaxed bipedal stance, it is

theoretically essential in maintaining midtarsus stability during resupination at heel lift.

Theoretical Mechanism for abnormal foot function

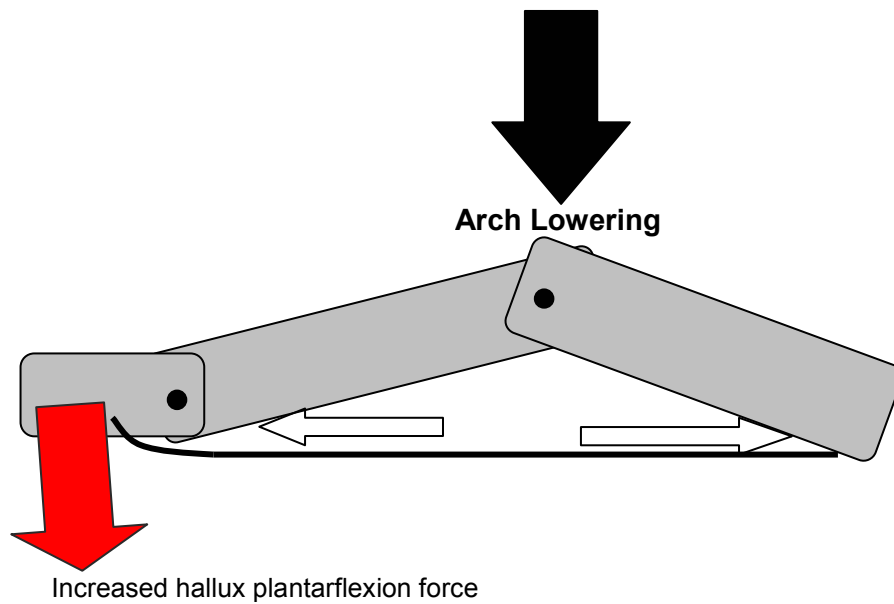
- **Failure to be stable through stance phase**

If moments resisting STJ pronation and so arch lowering are not of significant magnitude, abnormal pronation may occur and the midtarsus may move to a position of poor congruency through malalignment.

In addition, for stability to be maintained after heel lift the windlass mechanism needs to be applying tension to the plantar fascia. If this fails, the midtarsus will be unstable at heel lift and unable to resist the bending moment applied as the heel is pulled off the floor. The lowering of the arch at heel lift is analogous to STJ pronation, rather than the required supination. For the windlass to function effectively, dorsiflexion of the hallux via medial column propulsion must occur. If a limitation of 1st MTPJ dorsiflexion is present, whether structural or functional, a lack of windlass mechanism may arise with resultant compensation. Although causes of a structural hallux limitus are well discussed in literature, the aetiology of functional hallux limitus is less reported. The two main causes are theorised below:

1) A prolonged reverse windlass. This occurs as a result of excessive pronation moments at the STJ. These excessive moments may be due to a myriad of causes, such as a forefoot varus, tibial varum or weak lateral hip rotators. The resultant prolonged reverse windlass results in drawn out plantarflexory moments at the 1st MTPJ when dorsiflexion should be occurring (Figure 3)

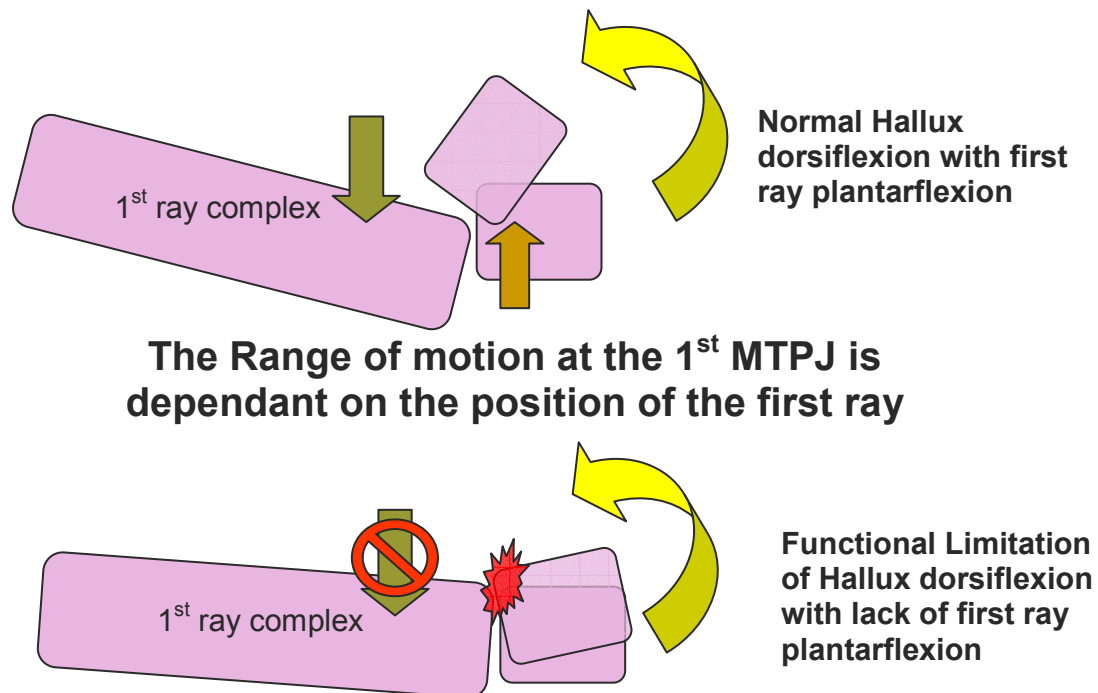
Figure 3 – The pathological reverse windlass mechanism. If too much pronation occurs, tension in the plantar fascia pulls the hallux down and prevents normal dorsiflexion in gait.



Such increased plantarflexory moments will therefore impede hallux dorsiflexion and so reduce the ability of the foot to propulse through the 1st MTPJ. Pressure may remain lateral, engaging the foot in inefficient propulsion. This in turn inhibits the arch rising due to the lack of a windlass mechanism

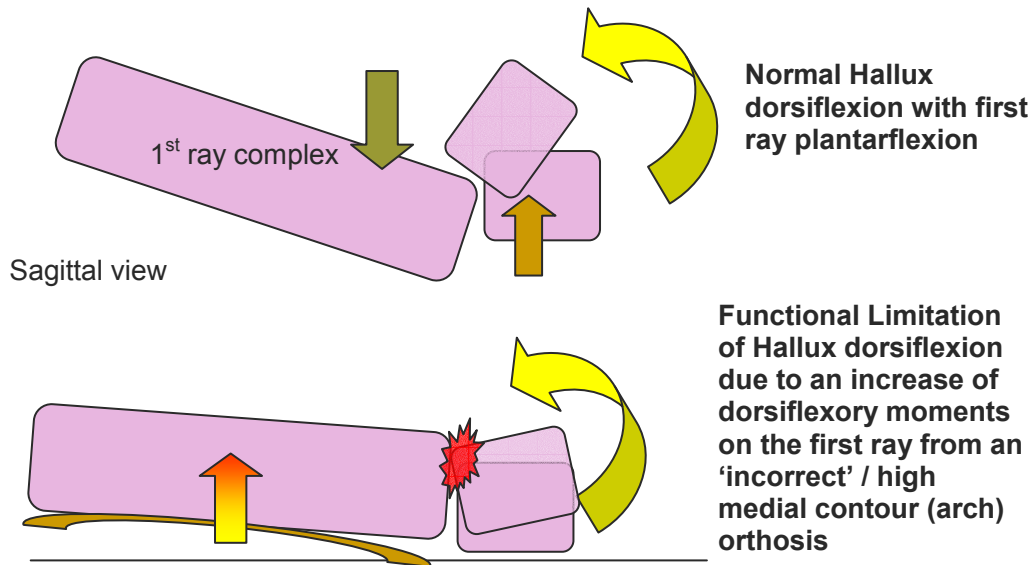
2) Functional bony restriction of the 1st MTPJ. For the hallux to dorsiflex the first ray must be able to plantarflex, as demonstrated in figure 4:

Figure 4 – A Sagittal view of the first ray. For the hallux to dorsiflex, the first ray must plantarflex.



Dorsiflexion of the first ray impedes the ability of the 1st MTPJ to extend. Pronation will lead to dorsiflexion of the first ray via increased ground reaction forces to the medial column of the foot. This will limit the foot's ability to pivot over the 1st MTPJ leading to abnormal compensation. The resultant effect is similar to that of a structural hallux limitus. Unfortunately many custom and prefabricated orthoses are high in the arch under the first ray. These dorsiflex the first ray and inhibit normal hallux dorsiflexion (Figure 5). Although original symptoms may improve, symptoms may be moved elsewhere, such as lower back pain and knee pains. The Foot Orthotics laboratory appliances are specially designed in the USA and UK to encourage normal first ray function and help the foot to work normally to resolve symptoms, rather than move the problem elsewhere.

Figure 5 – Some prefabricated and custom orthoses dorsiflex the first ray by being high in the arch, leading to a functional hallux limitus and an abnormal change in gait.



- **Failure to allow the foot to pivot and so permit a normal stride.**

The hallux dorsiflexing allows for normal extension of the hip by the body pivoting over the foot. If the hallux cannot dorsiflex, due to either a structure or functional hallux limitus (see above), compensation pathways may occur. Common examples are a flattened lordosis and lack of hip and knee extension

- **Failure to allow external rotation of the leg via STJ pronation during midstance and propulsion**

From Midstance, in relation to the ground, the leg externally rotates and applies supinatory moment to the STJ. For the leg to externally rotate the foot must supinate, and so the supinatory moment must be greater than the pronatory moment across the STJ. In abnormal situations this may not occur and can be due to a lack of applied supinatory moments or increased pronatory moments. There are several methods by which compensation may occur. The leg may simply remain internally rotated, or if the friction coefficient between the floor and the foot is overcome the foot may be seen to rapidly

abduct and so allow external hip rotation without resupination. This has been called an 'abductory twist'.

It is worth noting here that If the STJ has an inadequate range of pronation to allow normal internal leg rotation at the hip at contact phase (e.g. Triple arthrodesis), normal lumbar and pelvic mechanics will not occur. An orthotic which reduced too much pronation can therefore be detrimental to a patient.

Orthotic Prescription Utilising the Unified Theory

The fundamental reason to prescribe functional foot orthoses is to improve symptomatic gait dysfunction. This may be caused by one or a combination of factors resulting in a failure of the foot to function as a stable pivot or to allow normal external rotation of the hip in midstance and propulsion. The Foot Orthotic Laboratory range are designed to aid first ray plantarflexion and reduce pronatory moments, addressing each of the above issues in a low bulk appliance.

For further details on orthoses prescription please feel free to call or e-mail us, or attend one of our training courses.