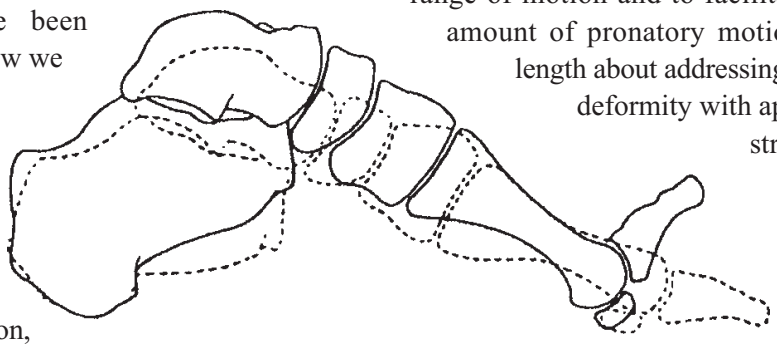
Motion Control or Motion Enhancement:

Traditional Root Paradigm vs. Sagittal Plane Facilitation Model

Introduction

We often shy away from the things that we don't know or clearly understand. In our education we learn the facts, and then try to critically dissect them based on our experience and what we have learned through our continuing education and practice.

Without question, the contributions of Merton Root have been colossal. The theoretical models proposed by Root and colleagues on podiatric biomechanics have guided us to design decades of effective orthotic devices. However, like all theoretical models, many of Root's contentions have been scrutinized and now we find that there are new proposed theoretical models that are coming into practice.



For whatever reason, many jump on the "new model bandwagon" or, conversely, many ignore the new proposed ideas and stick to those that they are most comfortable with. I believe that it is important to think critically about all new ideas and to gather from them the information that can help you increase your knowledge about a specific issue.

Craig Payne has thoroughly described these and many other issues in his articles so there is no need to review them here. What is interesting is the proposal that foot orthotic function should be thought of as being **motion enhancing** rather than **motion controlling**. This concept has been put forward by Dananberg and Payne in the *Sagittal Plane Facilitation Model*.

This *Bulletin* will look at the Root model of functional foot orthotic design that concentrates on motion control in the frontal plane and then will review the *Sagittal Plane Facilitation Model* that focuses on motion enhancement in the sagittal plane.

Review of Root's Development of the Functional Orthosis

Clinics in Podiatric Medicine and Surgery, v.11, n.2, 1994

If you carefully read through the Root (1994) article you'll find that the author primarily discusses controlling frontal plane foot deformity with functional orthoses. The goal of the orthotic therapy is to control the foot, ensure a healthy subtalar joint range of motion and to facilitate the necessary amount of pronatory motion. He speaks at length about addressing varus and valgus deformity with appropriate posting strategies.

The main premise is to balance the negative cast to calcaneal vertical to capture the forefoot: rearfoot relationship. The positive cast is measured and compared to the prescribing practitioner's measures. The cast is then balanced or intrinsically posted to calcaneal vertical. In essence, what you are doing is balancing the rear foot and forefoot.

Root recommends pressing the shell and adding an extrinsic rearfoot post that allows for 4° of motion. He explains that for individuals whose STJ axis sits at an orientation of approximately 42° from the transverse plane (Root definition of normal) requires 4° of motion. For individuals whose STJ axis orientation sits significantly greater than 42°, requires less post motion and for those who have a significantly lower inclination no post may be indicated.

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Without question, this technique has been effective over the years. At Paris Orthotics, we employ this technique to some extent at our lab and balance forefoot anomalies up to 4° of either a varus or valgus persuasion. We do not incorporate motion into the design unless specifically requested by the prescriber. Laboratories have employed the Root technique, either partially or fully, for decades.

More recently, there have been several alternate models discussed. The work of Kirby is certainly an extension of Root and his colleagues' ideas. It too, focuses on motion control and specifically on controlling supinatory and pronatory moments about the subtalar joint axis. The Kirby model of foot mechanics is described in terms of basic principles of physics and has made a significant contribution to explaining how subtalar joint motion is influenced by ground reaction force.

Dananberg and Payne have written about another model that concentrates on motion enhancement in the sagittal plane. This is an interesting model and presents an added dimension (pardon the pun) to what happens in the sagittal plane during locomotion.

Sagittal Plane Facilitation Model

Australian Journal of Podiatric Medicine, v.31, n.1, 1997

Many of us at one time or another have heard of the work of Dr. Howard Dananberg. Many of us have struggled with it because it's different from what we were taught or because it is based on things that are not easily observed in clinical practice. However, there is a great deal of valuable and interesting information that has come from Dananberg's work.

All of the currently employed models of podiatric biomechanics seem to have some degree of validity. I think it is those who study each and that put them all together as a whole will be the most successful.

In the Payne and Dananberg article the focus is on sagittal plane motion. They report that the Root based model has limitations and a lack of scientific support. It is their belief that the Root model concentrates on controlling the foot in the frontal plane and that this comprises approximately 15% of the total range of motion. The Sagittal Plane Facilitation Model, on the other hand, concentrates on the sagittal plane and 70% of the total range of motion. Their premise is that foot orthotic design should be based on motion enhancement rather than motion control.

The Sagittal Plane Facilitation Model suggests that in order for the foot to function efficiently through the sagittal plane there has to be a coordinated effort between the action of the foot's *autosupportive mechanisms* and the *creation of power for efficient forward motion*.

Payne and Dananberg outline three *autosupportive mechanisms* that are essential to enabling the foot to resist applied forces during gait and to ensure that the foot becomes stable from midstance to toe-off. All of these mechanisms depend on the complete range of motion of the 1st metatarsophalangeal joint.

The first mechanism is the *Windlass Mechanism* that was first described by Hicks in 1954 (figure 1). It is the mechanism by which the hallux acts as a winch and by dorsiflexing pulls on the plantar aponeurosis shortening the distance between the 1st metatarsal head and calcaneus.

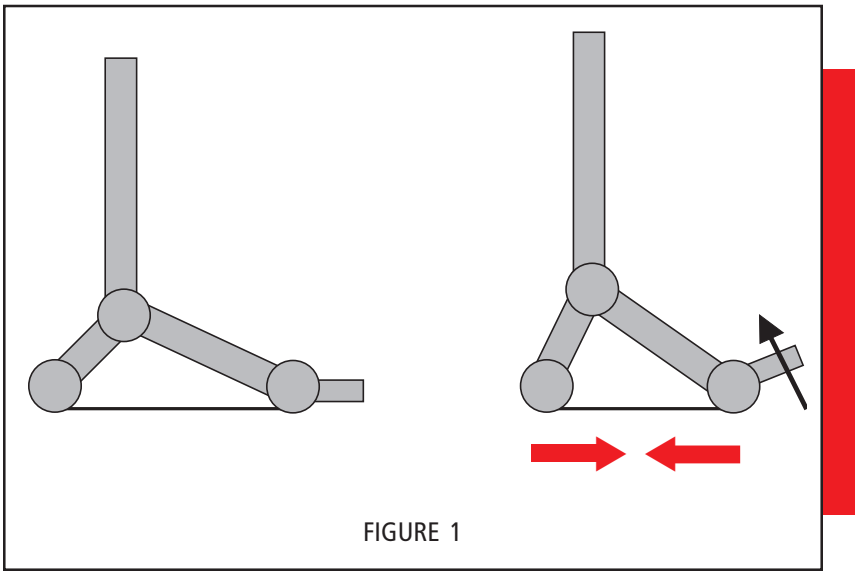

FIGURE 1

This action supinates the foot and the tightening of the plantar aponeurosis helps to ensure the 2nd *autosupportive mechanism* that facilitates a close-packing of the calcaneocuboid joint. Close-packing of the calcaneocuboid joint compresses the joint prior to heel off and requires that weight flow be directed through the1st interspace. Here again, full 1st metatarsophalangeal joint motion (>65° dorsiflexion) is necessary for this to occur (figure 2). Lastly, the 3rd *autosupportive mechanism* involves the *Locked Wedge Effect* that is a compressive loading of the osseous structures of the foot.

Autosupportive Mechanisms

- Windlass Mechanism (Hicks, 1954);
- Calcaneocuboid joint locking (Bojsen-Moller, 1979); and
- Locking wedge effect (Dananberg, 1993).

The three *autosupportive mechanisms* need to be coordinated with the creation of power, which comes from four sources:

- The swing limb's pull that acts on the body's center of mass;
- Momentum;
- Gravity; and
- Elastic tissue response.

Payne and Dananberg suggest in this model that it is the coordinated nature of the *Autosupportive Mechanisms* and *Creation of Power* that ensures stable and efficient foot function in the sagittal plane. If there is a breakdown in this synergy a sagittal plane block may occur. One such block is functional hallux limitus, a momentary failure of the 1st metatarsophalangeal joint to dorsiflex secondary to inadequate 1st ray plantarflexion. Functional hallux limitus has been highly scrutinized by the podiatric community as a clinical phenomenon. Due in part to its very difficult positive identification without the use of slow motion video.

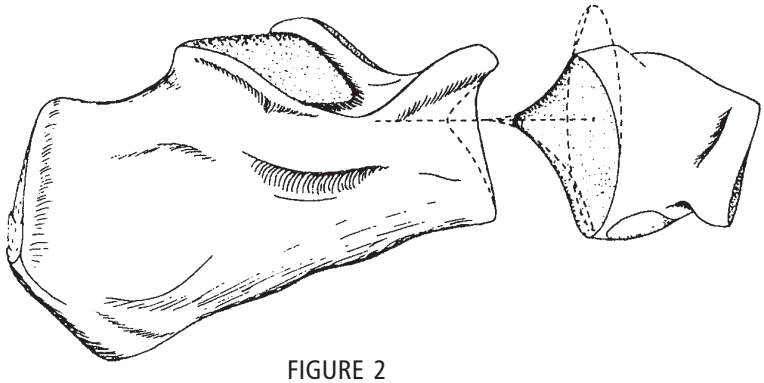

FIGURE 2

However, a functional hallux limitus can lead to a total breakdown in the foot's ability to maintain the *autosupportive mechanisms* and Payne et al. report that there are several compensatory signs that may indicate a sagittal plane block. When there is a sagittal plane block, or deficiency, the foot and ankle complex must compensate somewhere along the kinetic chain. Whether there is a gastrocnemius equinus present or functional hallux limitus, dorsiflexion must occur elsewhere. It is believed that this most often occurs at the midtarsus and, more specifically, at the oblique axis of the midtarsal joint(s).

A common compensatory mechanism is *altered heel lift* with *apparent late midstance pronation*. Payne describes that this is a sign of compensatory midtarsal oblique axis dorsiflexion that occurs secondary to a sagittal block. Continuing from the *altered or delayed heel off* is a *vertical toe off*. There appears to be a delayed heel off and the foot tends to be lifted straight off the ground. The person will walk with an apropulsive and laborious gait.

The third compensatory movement is referred to as the *inverted step* where the weight flow shifts laterally rather than through the 1st interspace prior to heel off. These patients will often stand in a pronated position during static stance but show excessive lateral shoe wear. The mechanism is that the foot is unable to establish its autosupportive mechanisms, the 1st metatarsophalangeal joint does not dorsiflex and, hence, the weight flow cannot pass through the 1st interspace. Essentially, weight flow passes through the path of least resistance.

Abducted or adducted toe off can also be present with someone who has a functional hallux limitus. The hip may internally or externally rotate inorder to detour around a functional hallux limitus and here again the path of least resistance is followed. Lastly, *flexion compensation of the body* is another compensatory action that has been confirmed by 3-D slow motion video. Dananberg attributes postural malalignment and low back pain to this particular compensatory motion.

Sagittal Plane Blockage Compensation

- Altered heel lift;
- Vertical toe off;
- Inverted step;
- Abducted and adducted toe off; and
- Flexion compensation of the body.

Foot Orthoses Management

In the Payne et al. (1993) article the authors describe their recommendations for foot orthotic design to help address

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sagittal plane blockage with special attention paid to managing functional hallux limitus. Payne describes that the goal in designing such an orthoses is to facilitate sagittal plane motion. To accomplish this it is essential to ensure that the 1st ray is allowed to plantarflex and this will prevent functional hallux limitus from occurring. This, in turn, will allow the foot to establish the *autosupportive mechanisms* necessary for integral foot stability. The device is designed to ensure the correct timing and direction of weight flow.

Like many functional deficits that we see in our industry, there are many different effective solutions to managing the problem. Many different prescriptions that are designed to address this very issue:

- Functional orthoses with a first ray cutout;
- Functional orthoses with a first ray cutout and a 2-5 extension; or
- Functional orthoses with a Kinetic Wedge®.

Whatever the practitioner prefers the functional goals that Payne describes are to ensure 1st ray plantarflexion and eversion so that weight flow can pass directly through the 1st interspace at precise timing.

Critics argue that the Root functional orthotic design is one that only addresses frontal plane deformity. They criticize that its design is based on clinical assumptions that have not been subject to exhaustive research. However, for many patients it has been and continues to be an effective methodology. When I spoke with Craig Payne about this and other articles that he has published, we agreed that it is important to employ ideas from all models that are available to us. We also agree that it is always important to remember that foot mechanics are triplanar and that to consider only motion in one plane would be faulty.

It is my belief that there are three main reasons why the Root methodology has not been exhaustively researched for its efficacy and theoretical support. This technique was founded in an era when we weren't as concerned with evidence based medicine as we are today. It is true that most of what Root claims is based on clinical observation and not proven by exhaustive research. For most us, that is not as important as the fact that it works, plain and simple.

Another reason why this field has lagged behind in the research world is because of the nature and complexity of foot and ankle mechanics. It is not an easy part of the anatomy to assess, even with today's technology. One day we will be able to measure precise navicular, midtarsal, subtalar and calcaneal motion but for now there are technological limitations that are limiting increased understanding.

Lastly, there are only a limited number of podiatric colleges. Traditionally, they have been centers for research along with other academic institutions with significant contributions from other allied health care professionals. There is simply a lack of foot and ankle research being conducted and not enough facilities where it can be conducted.

An analogy is the sports medicine community; many sport medicine physicians are affiliated with an academic institution and have research facilities and resources at their disposal. There are hundreds of universities in North America that have the ability to conduct research. Generally speaking, most have focussed on the knee, ankle and shoulder.

The main objective of this *Bulletin* from the outset has been to create a means by which information and food for thought can be shared. We hope that you find this topic interesting and if anyone wants these articles or any other information that we have, please do not hesitate to contact Christopher MacLean at 800-848-0838.

Suggested Readings

1. Bojsen-Moller, F. Calcaneocuboid joint and stability of the longitudinal arch of the foot at high and low gear push off. *Journal of the Anatomy,* 1979: 165-176.
2. Dananberg, HJ. Gait Style as an Etiology to Chronic Postural Pain. *Journal of the American Podiatric Medical Association,* 1993; 83(8): 443-441.
3. Hickes, JH. The Mechanics of the Foot II. The Plantar Aponeurosis and The Arch. *Journal of the Anatomy,* 1954; 88: 25-31.
4. Payne, CB and Dananberg, HJ. Sagittal plane facilitation of the foot. *Australian Journal of Podiatric Medical Association* 1997; 31(1): 7-11.
5. Roukis, TS, Scherer, PR and Anderson, CF. Position of the First Ray and Motion of the First Metatarsophalangeal Joint. *Journal of the American Podiatric Medical Association.,* 1996; 86(11): 538-546.