The Tissue Stress Model:
Justification based on Current Best Evidence

New research that enhances our knowledge of foot mechanics as well as the effect of bone alignment on foot mobility during activity has significantly influenced how clinicians utilize foot orthoses in the management of overuse or chronic disorders affecting the foot. For many years, the role of the subtalar joint on foot mechanics was over-emphasized because of the articulation's tri-plane axis which lead to the theory that the subtalar joint was the pivotal joint for explaining foot pronation and supination.(1) As a result, foot orthoses were often designed with rearfoot wedges or posts to help control the movement of the subtalar joint while discounting the other joints of the foot (i.e.; the concept of "arch fill" when ordering custom foot orthoses).(2) Recent research has demonstrated that the midfoot and forefoot articulations contribute as much, if not more, than the rearfoot (subtalar) joint during dynamic activity.(1) These findings would suggest that foot orthotics need to provide support across the entire rearfoot and midfoot providing as much support as possible to these articulations to produce a desired mechanical effect on the foot. Thus, when the clinician desires to control foot mobility and posture it is critical that they consider foot function in terms of the entire foot and not just the rearfoot.

The influence of bone alignment on foot mobility, which was a key element of the "*Podiatric Model*" advocated by Root, Orien and Weed in the late 1960's, has been discussed for years.(3) The *Podiatric Model* proposed that there was an ideal or normal foot alignment and variations from the normal alignment were called "intrinsic foot deformities." The most common intrinsic foot deformities were forefoot varus, forefoot valgus and rearfoot varus.(3) Intrinsic

foot deformities were considered an atypical variation of “normal” foot alignment that would cause abnormal foot motion or posture during weight bearing or activity. This thought process promoted the premise that “structure dictates function” and that a foot orthosis with wedges or posts positioned to counteract the intrinsic foot deformities would lead to a more normal pattern of foot motion or posture. However, previous research has shown that forefoot or rearfoot deformities do not influence foot motion refuting the concept that “structure dictates function.”(4,5) The most recent research on this topic by Jarvis et al concluded that none of the intrinsic foot deformities proposed by the podiatric model were associated with distinct differences in foot mobility (kinematics) during walking and even more importantly, static and dynamic parameters associated with these measurements were not correlated.(6)

With these issues associated with the podiatric model as well as with our increased understanding of the impact of the midfoot and forefoot articulations of foot kinematics, how does the clinician design and utilize foot orthoses for their patients/clients? A recent systematic review and meta-analysis by Mills et al assessed the potential mechanisms that can explain the effect of foot orthoses.(7) They concluded that to obtain maximum shock attenuation and motion control the foot orthosis should be molded and medially posted in the rearfoot. The concept of a molded foot orthoses reinforces the recent kinematic research demonstrating the need to provide support to the midfoot and forefoot articulations in addition to the rearfoot.

From a holistic perspective, it is well accepted that the etiology of numerous injuries affecting the foot are multi-factorial in nature affected by both external factors (i.e.; training schedule, surfaces used for training, previous injury, footwear) and internal factors (i.e.; lower extremity alignment, foot mobility & posture, muscle strength, power & endurance, age &

gender, postural stability, cardio-vascular fitness). With so many factors influencing the development of overuse injuries to the foot, how does the clinician rationalize the use of foot orthoses as one PART of the overall management program? In 1995, McPoil & Hunt proposed the use of a "Tissue Stress Model" based on a Load-Deformation Curve to elucidate both the etiology and management concepts required to understand and treat overuse or chronic injuries to the foot.(8) The load-deformation curve consists of two regions or zones: an elastic and plastic region. The elastic region represents the normal give-and-take of soft tissues (both non-contractile – *capsule, ligamentous*; and contractile – *muscle, tendon*) which act to control excessive joint movements as the foot is loaded and unloaded during activity. Once tissues leave the elastic region and enters the plastic region, permanent deformation of the soft tissues will occur. An example of permanent deformation would be a grade I, II, or III acute sprain affecting the lateral ligaments of the ankle. Between the elastic and plastic regions is the microfailure zone which can be *very narrow* when assessing one specific tissue (i.e.; the anterior cruciate ligament) or quite broad when representative of all the different types of soft tissues supporting the rearfoot, midfoot and forefoot regions. With activity, if an individual maintains the level of tissue stress within the elastic region, the degree of tissue irritation and inflammation associated with overuse will most likely be maintained at a tolerable level. If the individual's level of activity or the magnitude of the load applied to the soft tissues of the foot are amplified due to increased activity, the deformation of soft tissues can then enter the microfailure zone and without adequate rest lead to an overuse injury. Although foot mobility and posture are just two of numerous factors affecting the degree of stress placed on the soft tissues of the foot, foot orthoses can be effectively used to control or modify foot posture or mobility. In other words,

the foot orthosis in conjunction with the shoe can be used to maintain foot motion within the elastic range and prevent movement into the microfailure zone, thereby allowing the involved tissues to rest and heal. When prescribing a foot orthosis as part of the overall management program, a key question for the clinician is how much should foot posture or mobility be controlled especially since the best available evidence indicates a foot orthoses should be molded to provide as much support to the midfoot and forefoot as well as rearfoot. However, too much molding using an excessively dense material, especially in the midfoot region, can lead to medial longitudinal arch discomfort and pain. To permit as much "total contact" to support the articulations in the midfoot region while at the same time allowing some "give-and-take" in the midfoot region to prevent arch discomfort, the Vasyli-McPoil foot orthoses is fabricated using two different material densities. The "*Duo-Density*" design of the Vasyli-McPoil foot orthoses consists of a bottom or "control" layer of a dense EVA material and a polyurethane "top cover" to allow both cushioning and compressibility to prevent arch discomfort. Although the orthosis is designed with higher than normal contour in the arch region, sculpting of the EVA material beneath the arch region as well as the ability to heat mold the midfoot region of the orthosis allows the clinician to provide the patient or client with maximum "total contact" but comfortable support in the medial longitudinal arch. The provision of comfortable "total contact" that provides maximum support to the midfoot as well as forefoot and rearfoot regions along with the ability to add rearfoot posting, allows the clinician to provide their patients/clients with a foot orthoses that satisfies current best evidence-based practice requirements for optimal foot orthosis design.

References

1. Nestor CJ. Lessons from dynamic cadaver and invasive bone pin studies: do we know how the foot really moves during gait? J Foot Ankle Res 2009; 2:18.
2. Sgarlato TE. *A Compendium of Podiatric Biomechanics*. Published by the California College of Podiatric Biomechanics, San Francisco, CA, 1971.
3. Root ML, Orien WP, Weed JH. *Normal and Abnormal Function of the Foot*. Published by Clinical Biomechanics Corp, Los Angeles, CA, 1977.
4. Cornwall MW, McPoil TG, Fishco WD, Hunt L, Lane C, O'Donnell D. The relationship between forefoot alignment and rearfoot motion during walking. Australasian J Podiatr Med 2004; 38:35-40.
5. Cornwall MW, McPoil TG. Influence of rearfoot postural alignment on rearfoot motion during walking. FOOT (Edinb) 2004; 14:133-138.
6. Jarvis HL, Nester CJ, Bowden PD, Jones RK. Challenging the foundations of the clinical model of foot function: further evidence that the Root model assessments fail to appropriately classify foot function. J Foot Ankle Res 2017; 10:7.
7. Mills K, Blanch P, Chapman AR, McPoil TG, Vicenzino B. Foot orthoses and gait: a systematic review and meta-analysis of literature pertaining to potential mechanisms. Br J Sports Med 2010; 44:1035-1046.
8. McPoil TG, Hunt GC. Evaluation and management of foot and ankle disorders: Present problems and future directions. J Orthop Sports Phys Ther 1995; 21:381-388.