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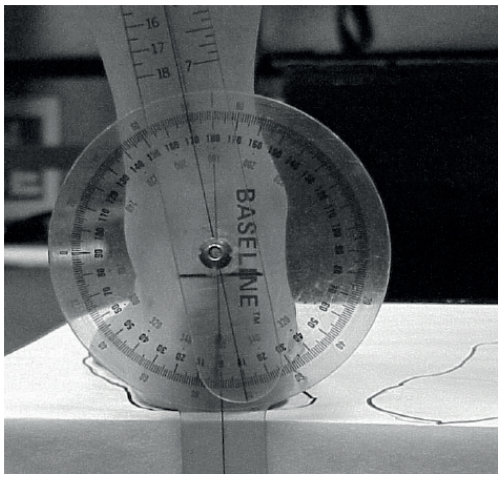
MODELS OF PODIATRIC BIOMECHANICS

PART II: TISSUE STRESS MODEL

As we continue exploring some of the more recent models of podiatric biomechanics, we will move on to look at the Tissue Stress Model (TSM). This model was initially introduced to the podiatric community in a publication by McPoil & Hunt (1995). The observation by these authors at that time was that there appeared to be some limitations in the Root model/paradigm of podiatric biomechanics.

McPoil & Hunt identified three limitations: 1) the reliability of the measurement procedures for identifying subtalar joint range of motion and for defining foot deformity; 2) the proposed criteria for normal foot alignment; and 3) the proposed position/motion of the subtalar joint during gait, specifically regarding whether the subtalar joint reached its neutral position between midstance and heel off during healthy gait.



Regarding the reliability of measurements, McPoil & Hunt (1995) reported that several research studies have revealed that the inter-rater (between clinicians) reliability for assessment measures such as: 1) subtalar joint neutral position; and 2) passive subtalar and calcaneal joint range of motion was poor.

That being said, intra-rater reliability was found to be acceptable. Meaning that if you, as a clinician, were to measure the same patient repeatedly, your findings would be likely similar across measurements for that patient. However, if you compare your patient's measures to a colleague's, you and your colleague would likely get different measurements for the same patient. These observations create a challenge and a potential limitation of the Root model/paradigm as pointed out by McPoil & Hunt (1995).

The second limitation that was discussed were the criteria recommended by Root and colleagues regarding normal foot alignment. This is generally a question of whether the Root criteria for normal foot alignment has external validity and would we expect to see a normal distribution of foot types across the general population.

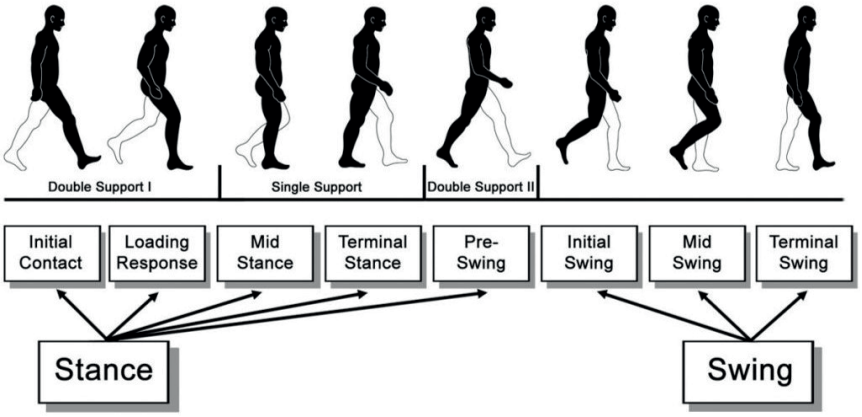


Figure 1: Gait/Walking Cycle

Unfortunately, the research has not supported this idea, and results indicate that a very small percentage of the general population actually fi ts into the defi nition of normal foot alignment.

The third limitation focused on whether the subtalar joint actually goes into the neutral position during dynamic gait. Root proposed that prior to heel strike, the subtalar joint is inverted. From heel strike to foot flat, the subtalar joint pronates and remains pronated, and from foot fl at to toe off, there is subtalar joint supination. Root also proposed that slightly before heel off, the subtalar joint would be in a neutral position at approximately 50-65% of the stance phase. The subtalar joint neutral position was defi ned as the position where the subtalar joint is not pronated or supinated.

Kinematic studies later revealed that this may not be the case. Root based his theory on the fi ndings of Wright et al. (1964), who reported that the subtalar joint reached its neutral position at 65-70% of the stance phase. However, Wright et al. (1964) only measured two individuals and defi ned the neutral position as essentially the resting calcaneal stance position (RCSP) rather than the neutral calcaneal stance postion (NCSP). Thus, there was a discrepancy between what Root was proposing as the neutral subtalar joint position and what Wright et al. (1964) reported as the neutral position i.e., RCSP.

A later kinematic study (McPoil & Cornwall, 1994) on 100 individuals revealed that the neutral position for the typical rearfoot movement pattern was RCSP and not NCSP. To this day, we cannot dynamically meaure what Root described as the neutral subtalar joint position so it is impossible to conclude whether Root's idea was correct or not.

McPoil & Hunt (1995) wanted to present an alternative approach given the limitations that have been observed with the Root model. The idea was based on the Load x Deformation curve and the concept of tissue (active and passive structures) irritation and stress that occur with activity (Figure 2). The Load x Deformation relationship as depicted in Figure 2. On the horizontal axis you will observe deformation. This is deformation of biological tissues and there are two regions the *elastic* and *plastic* regions, bordering these 2 regions is an area of micro-failure.

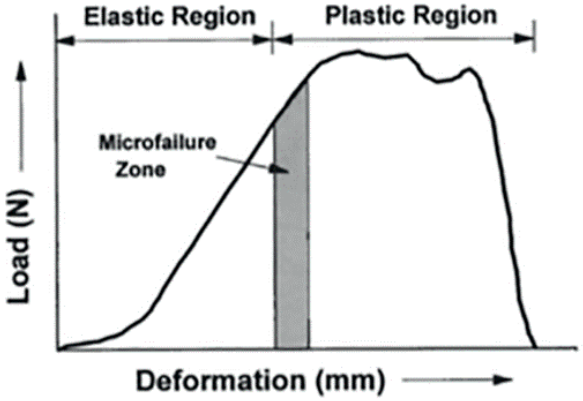


Figure 2: Load x Deformation Curve

The *elastic region* represents the healthy or normal quantities of load and deformation that any given tissue can tolerate. These are the loads applied and deformation of tissues that resist excessive joint movement such as when the foot is loaded and unloaded. Assum-

ing that an individual maintains a level of tissue stress within the elastic region, overuse injury would likely be avoided, and tissue irritation and inflammation maintained at a tolerable level. However, when the magnitude of loads is increased beyond the microfailure zone and into the *plastic region*, overuse injury will result. It is important to recognize that the level of tolerance will vary from individual to individual.

The TSM assessment and management approach entails four steps, including:

1. Identification of the injured tissue;

2. Functional assessments;

3. Determination of whether the etiology of the patient complaint is secondary to excessive loading; and

4. Design a management program.

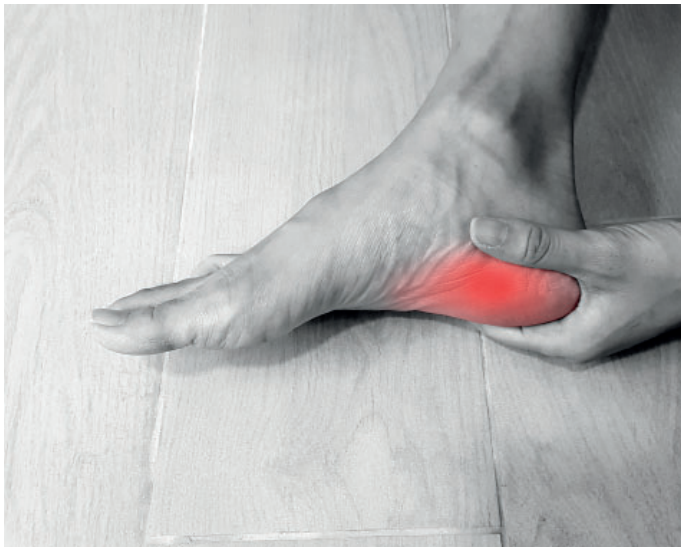
This approach provides the practitioner with much flexibility in how to assess and manage an injury. Footwear and foot orthotic therapy are useful tools in the toolbox to potentially unload overstressed tissues but are not the only interventions used. Comprehensive management would also involve additional modalities, strength and flexibility reconditioning.

Implementing TSM In Clinical Practice

Ross (2002) provided an excellent case study describing how the examination and treatment schemes for the TSM approach can be implemented in clinical practice. The author described this as a four-step process including:

Step 1: The clinician collects a detailed history to begin to ascertain what anatomical structure(s) are being stressed;

Step 2: A physical examination is performed to apply controlled stress to the tissue in question;



Step 3: The clinician determines if mechanical loading is the likely cause of the presenting tissue stress. If the clinician concludes that this is the case, they then move to Step 4; and

Step 4: This is the treatment program that categorizes management into 3 interventions:

a. Reducing pain and inflammation;
b. Reducing the deleterious tissue stress; and
c. Restoring muscle strength and flexibility.

In the presented case study, Ross (2002) described a female athlete who was returning to running and who experienced 8 weeks of unilateral plantar fasciitis on her right side. Her family physician diagnosed the injury, and she presented to Ross (a physical therapist) for ongoing treatment.

Initially, Ross conducted the first 2 steps of the TSM approach, including: 1) taking a comprehensive clinical history to develop a hypothesis regarding the tissue being stressed (Step 1) and 2) completing a thorough physical examination as a means of verifying the tissues identified in Step 1.

Through this process Ross concluded that the original family physician's diagnosis was correct. This conclusion was based on the athlete reporting that: 1) the right heel was most painful when first weight-bearing in the morning; 2) there was pain with palpation of the plantar fascia origin at the medial calcaneal tubercle and 3) there was pain with dorsiflexion of the 1st MTPJ.

The author then described advancing to Step 3, which involved trying to determine if the athlete's tissue stress was secondary to increased mechanical loading. Ross concluded that the right plantar fascial injury was likely caused by returning to running activity in a manner that was too progressive. A navicular drop test did not reveal any asymmetry between left and right sides. That being said, the athlete did, however, present with decreased right ankle dorsiflexion, which the author concluded was likely contributing to increased foot pronation that was observed during walking/running. This finding led to the author's hypothesis that the decreased right ankle plantar flexor tightness contributed to increased right foot pronation and ultimately increased plantar fascial stress on the affected side.

As a result, Ross advanced to Step 4 where interventions were planned and executed. First, to **reduce the pain and inflammation**, the athlete was encouraged to take Ibuprofen (NSAID) and perform ice massage 2-3 times, daily. Secondly, to **reduce the tissue stress** to the plantar fascia, the athlete was dispensed semi-rigid, foot orthoses and advised to remain active with low impact exercise such as cycling to maintain her aerobic fitness. Lastly, the athlete underwent a stretching program of the ankle plantar flexors to improve the **strength and flexibility** of the right ankle. The goal of this stretching intervention was to ultimately reduce the stress to the plantar fascia. Clinical documentation convincingly illustrated a progressive improvement in pain scores with improved plantar flexor flexibility on the affected side.

At initial evaluation, the athlete reported a pain scale of 7/10 and a 6° deficiency of ankle dorsiflexion on the affected side.
Following two weeks, this resolved to a pain scale of 1/10 and a 3° deficiency. Both were completely resolved at a 7-week follow up. At 11 weeks, the athlete had returned to run at 20-30 minutes per run, three times per week. Calf stretching also became an integral part of her run-ning/training regimen.

Although this type of clinical presentation is not uncommon to the foot care specialist, this is a good example of how to systematically approach any case using the TSM clinical approach.

Thank you for reading this edition of the Industry Bulletin.

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