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The Talus Control Ankle Foot Orthosis

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INTRODUCTION

Ankle/foot management in orthotics has had a variety of health care professionals concerned for many years. The development and use of polypropylene altered the direction of orthotics. Further realization of the capabilities of thermoplastics is leading to more advanced systems in orthotics. The orthosis presented in this article is an example of cooperation between practitioners in related medical fields, adaptation of available materials to the management of ankle/foot disorders, and the development of a system of design and fabrication to accommodate the diagnostic and treatment methods used under the direction of Franziska Racker, M.D., Physiatrist and Medical Director for The Special Children's Center, Ithaca, New York.

Review of the anatomy and physiology of the foot, evaluation, short leg cast boots and orthotic treatment of the unstable ankle/foot will be discussed. X-ray and gait studies of this new type of orthosis will document its feasibility.

ANKLE/FOOT EVALUATION

Physical evaluation of a vast number of so called flat feet, toe walkers, and other anomalies have revealed a stable medial longitudinal arch component, in most cases, when the talus and calcaneus are secured in neutral alignment. Furthermore, when the talus and calcaneus are in the neutral position, the arch is maintained without displacing the muscular and ligamentous structures of the foot and without additional plantar surface support.[5] Neutral foot position is determined by grasping the talus, at the talocrural joint, between the thumb and the index finger. The prominences should feel equal on either side of the dorsum of the foot. If hand pressure or weight bearing do not result in collapse of the arch until the talus is allowed to deviate from neutral, it is our contention that some support other than plantar surface pressure should maintain neutral foot position.

USE OF POSTERIOR AND PLANTAR SURFACE CONTROL

The posterior solid ankle foot orthosis (PSA) has been typically used for various ankle and foot deformities which require additional stabilization of the lower leg (i.e., the equinus or calcaneal foot). When this stabilization is not necessary (i.e., excessive pronation, supination, metatarsus adductus), foot appliances such as the supramalleolar orthosis (SMO),[7] low profile orthosis or UCBL orthosis have traditionally been used (Figure 1). These orthoses rely primarily on plantar surface pressure to realign the structures of the foot and ankle. Clinically it has been noted that the patient often complains of pressure on the medial border with a pronated foot or on the lateral border with a supinated foot. Subjective evaluation can often detect little correction of the deformity as the patient actually continues to malalign his foot inside the orthosis. Another measure of poor foot position is the "dirty heel syndrome" in which the inside heel area of the orthosis is dirty and dusty suggesting that the calcaneus is not maintained inside the appliance and indicates that the inferior aspect is not a weight bearing surface. Additions of ankle straps or tightly laced high topped shoes do not seem to alleviate this problem although they make the problem less obvious by obscuring the view. Extra padding and supports often increase pressure or merely disperse it over a greater area. X-ray studies of the calcaneus inside a PSA show that it easily slips into varus or valgus and thus does not maintain that very important structural component of the ankle.[5] Also, due to the bulk of the PSA, the patient often must wear a shoe at least one size larger than his actual foot. If then, the foot has not

Figure 1.

been well corrected in the orthosis, the musculature surrounding the joints continues to have poor biomechanical advantages. They must follow the laws of physics and their intended action over a part is often changed to a different action, which reinforces the cycle of abnormal joint position and motion.[6] An example would be the extensor hallucis longus slipping laterally (toward the midline of the foot) over the great toe when the foot is in excessive medial weight bearing causing this muscle to become a toe adductor rather than extensor. Hallux adductus is a common side effect of pronated feet in both young and old patients. The earlier these symptoms are addressed, the better the chances of preventing more serious foot disorders.

USE OF SHORT LEG CAST BOOTS AND DEVELOPMENT OF THE T.C.-A.F.O.

The use of short leg cast boots has been an adjunct to the management of poor foot position in children demonstrating varying degrees of abnormal tone.[1,2] These casts attempt to provide control of the talus and calcaneus, maintenance of neutral ankle/foot alignment, and approximately normal sensory feedback during stance. Securing the ankle/foot in neutral alignment places the muscles in their best biomechanical advantage, essentially reprogramming the child's kinesthetic awareness.[3] Unfortunately cast boots are bulky, heavy, and unattractive.

The orthotist, although sought out for advice and evaluation, is essentially excluded from the fabrication of cast boots. This provided an opportunity for the orthotist author to observe the effects of cast boots on foot control and ambulation. These observations led to research and the development of an orthosis which augments the positive features of cast boots while incorporating the light weight and cosmetic features more commonly associated with thermoplastic ankle foot orthoses.

When evaluating the foot to determine the possibility of fabricating short leg cast boots, the clinician (therapist, orthotist, etc.) should note muscle tone, range of motion, tendency toward varus or valgus at the subtalar joint, what happens to the forefoot when the hindfoot is corrected and associated reactions of the foot and body as a whole. In both weight bearing and non-weight bearing conditions, the foot is positioned as closely to neutral as possible. A neutral talus is achieved as previously described and the calcaneus is aligned under the tibia. The cast boots maintain this position by total foot contact.[7] Frequently, the next step in lower extremity management is the use of polypropylene ankle foot orthoses. As has been previously noted, the use of plantar surface correction does not appear to maintain subtalar control. At the Special Children's Center, the talus control ankle foot orthosis (TCAFO) or talus control foot orthosis (TCFO) has been a promising adjunct to the total therapeutic management.

The TCAFO was designed to augment the results of cast boot management. It is a posterior donning orthosis (Figure 2) which does not require the wearer to have the ankle/foot in a neutral position before the shoe is applied. However it is desirable to mobilize the ankle/foot prior to donning the orthosis. The anterior design allows the orthosis to serve as a dynamic device gradually pulling the foot into the desired ankle/foot alignment (neutral dorsiflexion). The talus is secured in neutral alignment and deviation of the calcaneus is resisted by an extension of plastic in that specific area. The support mechanisms within the shoe are essential to provide resistance against deviation of this plastic extension. Pads may be applied to increase the control of the calcaneus medially or laterally as needed. This extension is wedged between the counter of the shoe and the soft tissue of the foot. The orthosis should not be worn without a shoe for ambulating. However as a night time treatment, to augment the effects of day time wear, the orthosis may be effective. A laced shoe or good low cut sneaker or tennis shoe is adequate for weight bearing conditions.

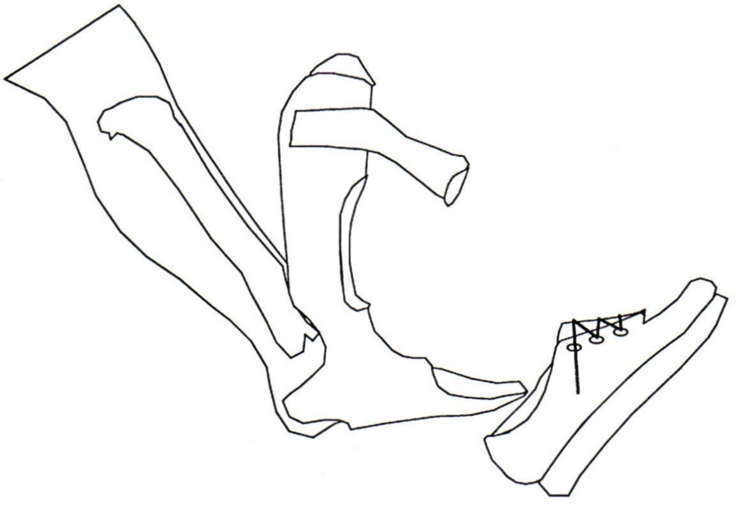


Figure 2.
1. Apply orthosis to foot only.
2. Apply shoe tied securely.
3. Slowly draw the tibial section of the orthosis to the leg and attach strap.

Follow-up visits are minimal after the first month. During the first month, if the patient is wearing the orthosis regularly, the medial malleolus or navicular area may show signs of excessive pressure. This is resolved by applying a firm pelite pad to the distal lateral calcaneus. The objective of this pad is to re-establish control of the calcaneus following dissipation or repositioning of fatty tissue in that area.

The talus control AFO has thus far proven effective in stabilizing the talus, the talocrural joint and the calcaneus. It is, however, not the only method of management used by our clinic team. To determine whether a patient is a candidate for the TCAFO or not he/she should:

- exhibit a stable arch when the talus and calcaneus are secured in neutral normal alignment.
- have an active, supportive family.
- be monitored by a team of persons knowledgeable in the fitting and followup of the TCAFO.

Many patients have been fitted successfully with the talus control ankle foot orthosis. Several have been fitted and refitted to achieve the desired results. Initially it was thought that the original trim lines would be adequate, to provide floor reaction, but we soon found it necessary to encapsulate the malleoli, and add channels or composite in order to meet this requirement. In all cases the achievement and maintenance of neutral leg, ankle, and foot alignment is the goal. Our team realized that we were trying a new approach in foot management and that failures were inevitable. It was necessary to develop a system of measuring and modifying to minimize the chances for technical or mechanical failure.

THE CASTING AND MODIFICATION PROCEDURES

The casting procedure for the TCAFO is preceeded by hands on mobilization of the foot to achieve the desired alignment. Neutral alignment is essential as plantar flexion will result in exaggerated knee extension. Similarly dorsiflexion will result in a crouch gait. Neutral position, in this procedure, is achieved with the patient seated and supported so that minimal weight is on the foot. The desired alignment of the foot should not deviate because of the weight of the foot/leg.

Meticulous care is taken to conform to all measurements taken during the measuring and casting session. The "rule of thumb" had been to follow the negative impression when in doubt but that method simply will not work when fabricating the TCAFO. When care is taken in the measurement session, these measurements should be and have been used to correct a poor positive model with excellent results. It is not always possible to get an ideal impression, but, in our experience, it is almost always possible to obtain good measurements.

GAIT ANALYSIS

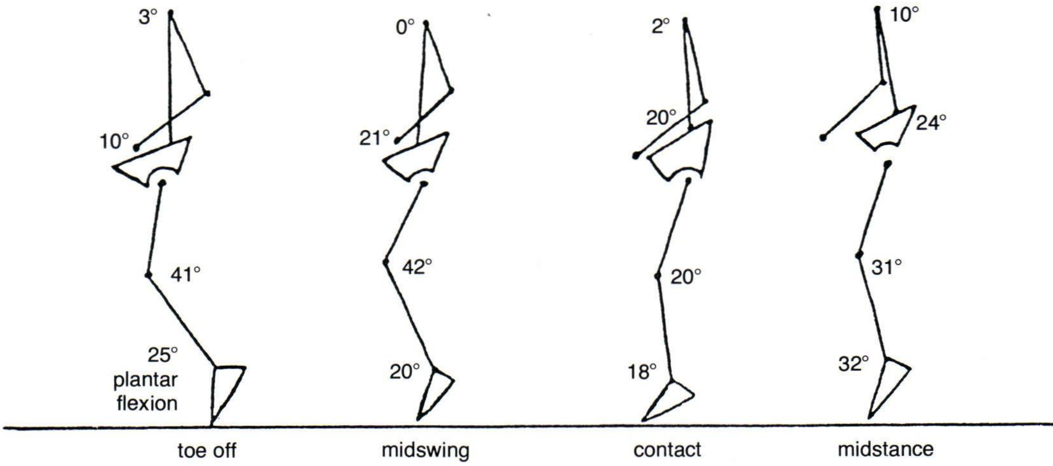
In order to fully evaluate the effects of the TCAFO in quantitative terms, an analysis of gait cycle is indicated. Studies have shown that the parameters of ambulation can be more fully appreciated by recording and analyzing data obtained through high speed photography, electromyography, dynamic peizoelectric force plate, and foot switches.[8, 9]

The authors, in conjunction with the Ithaca College School of Physical Therapy, developed a pilot study to research the complex pattern of movement that occurs during ambulation. This was done by comparing gait cycles and using two different types of lower extremity orthoses. Two children were fitted with both PSA's and TCAFO's. The positive models used to fabricate the PSA's were also used to fabricate the TCAFO's. This was done to preserve identical alignment characteristics. The patients' ages are three and four years and both have a diagnosis of cerebral palsy. One ambulates with a walker and has spastic quadraplegia. The other child ambulates independently and has spastic diplegia. Neither of the children has had any orthopedic surgery.

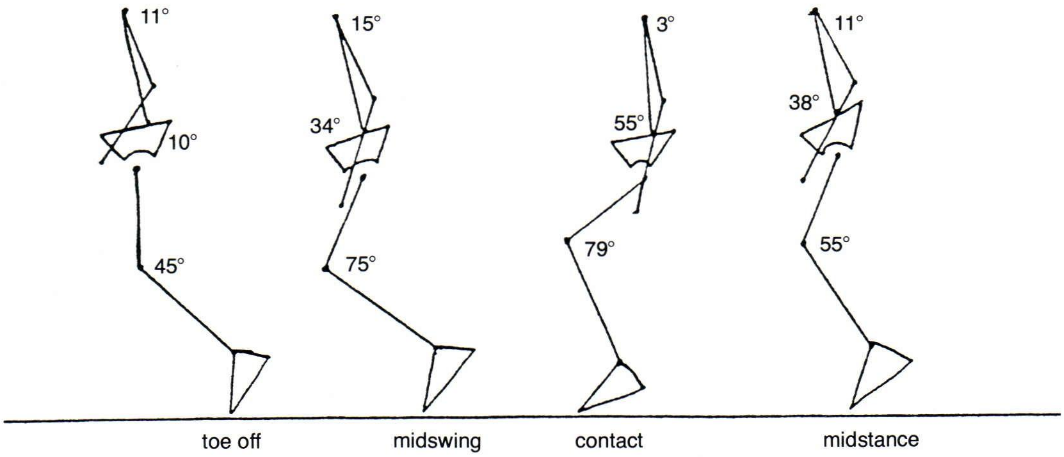
The patients were filmed, using high speed photography (60 frames per second), during barefoot, PSA and TCAFO ambulation. This information was then viewed on a Vanguard Motion Analyzer and from this, data was collected on upper body positioning, foot strike, joint angles, and changes occurring in these different phases of the gait cycle. The first subject, S., (the independent ambulator) showed remarkable improvement in general when using the TCAFO's. S. was usually a toe walker when walking barefoot (Figure 3-A). He held his arms in "high guard" with his elbows flexed and behind his trunk during most of his gait cycle. His trunk was relatively upright, but he took many small, quick steps and his gait and body appeared stiff.

With the PSA's, there was more forward trunk lean, and the elbows stayed behind the trunk. Hip and knee flexion angles increased in all phases, and the heel almost never contacted the floor during any stance phase (Figure 3-B). With TCAFO's, S. was able to stand more upright, his arms were more relaxed and down. He was able to swing his arms forward of the trunk during same leg mid-swing phase in a nice reciprocal arm motion (Figure 3-C). There was, most surprisingly, hip extension during toe off and heel-to-toe strike during the foot contact phases. Dorsiflexion of the ankle was also observed as the leg moved over the weighted foot because the TCAFO allows some movement in the ankle area. Subjectively, viewing the film, it could be noted that S.'s gait appeared more relaxed and "normal." Differences in knee, hip, and trunk angles were interesting in that the gait cycles using an orthosis followed a specific curve while the barefoot cycles were much different (Figure 4-B). Generally, there was a 15° to 40° increase towards extension in the hip and knee angles when using the TCAFO's as opposed to the PSA's. Although hip and knee flexion were more extended during the initial contact phase of the barefoot cycle, it must be remembered that S. was also walking on his toes and his arms were in back of his trunk, and therefore functionally useless in maintaining an upright position. In addition to high speed photography, a pressure sensitive electrode was placed on the heel of subject S. while walking with the PSA's and the TCAFO's. It was attached to a buzzer which was activated by heel contact. Out of ten steps, S. was unable to activate the buzzer with the PSA on. He was, however, able to do so 80 percent of the time with the TCAFO.

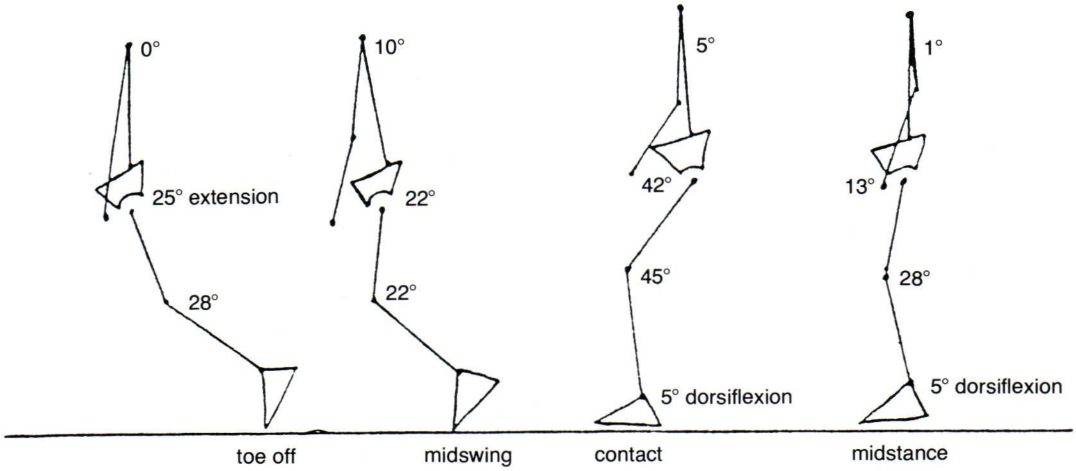
Although the changes in S.'s gait were dramatic, P.'s changes were less so, and most possibly due to overuse of his upper extremities on the walker; thus perhaps masking more pronounced gait differences with less actual lower extremity weight bearing. Again, there is a difference between curves developed with and without an orthosis (Figure 4-A). Generally, there is



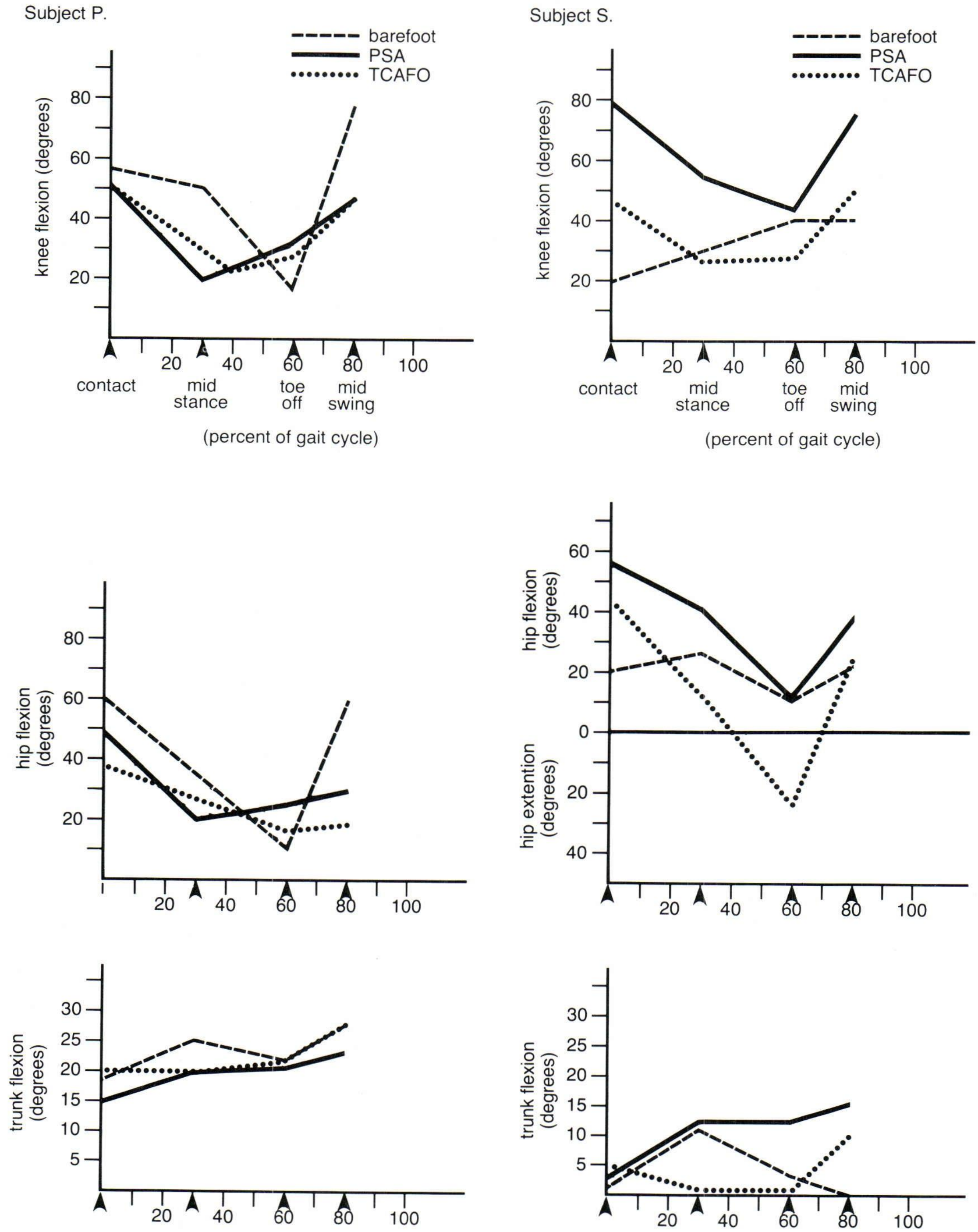
3-A. Subject S barefoot.



3-B. Subject S with PSA.



3-C. Subject S with TKAFO.



Figures 4-A and 4-B. Gait curves developed for patients P. and S.

more hip and knee extension with orthotic treatment during the gait cycle as the subject is in less of a crouched position with exception of toe off, in which the barefoot subject is seen on film to literally lurch forward to push himself through. Trunk angles change very little as P. is very dependent on the support of his walker and this does not change with or without the orthosis.

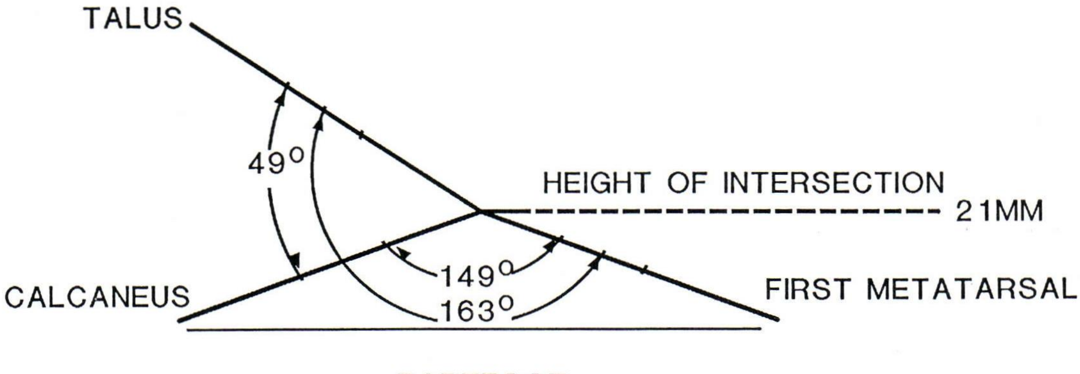
X-RAY STUDIES

In an attempt to verify that support other than plantar surface pressure should maintain neutral foot position, one patient was fitted with TCFO's and her feet were x-rayed:

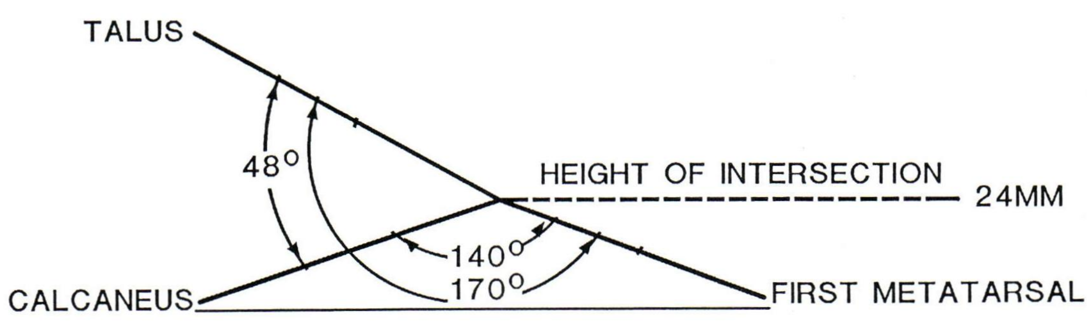
- barefoot,
- in sneakers without the use of any additional supports,
- with plantar surface (arch) supports,
- and finally with TCFO's.

The height of the arch is measured from a point where a line representing the angular relationship of the talus to the shaft of the first metatarsal (angle T) intersects with a line denoting the comparative angle of the calcaneus and the shaft of the first metatarsal (angle C). The ideal data for a patient of this size and weight is: height approximately 30mm, angle T approximately 180°, and angle C approximately 140°.[11]

The barefoot view is represented in graph form showing a height of 21mm with an angle T of 163° and angle C of 147° (Figure 5-A). Each of the following comparatives provided change, some positive (closer to the desired heights and angles) and some negative (farther from

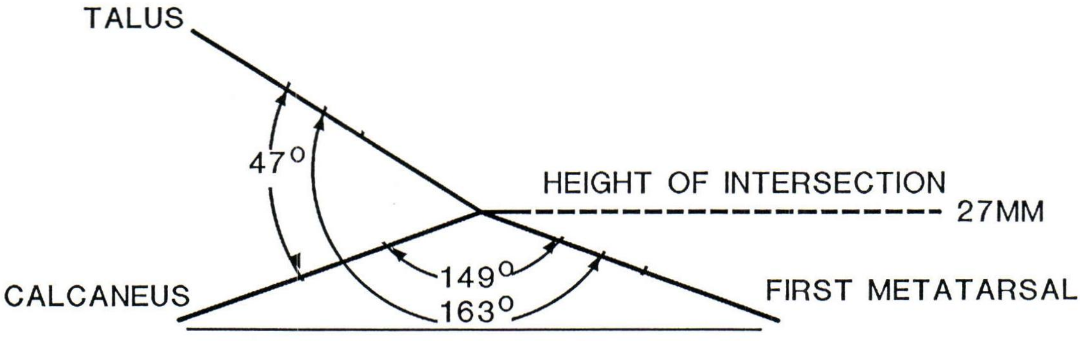


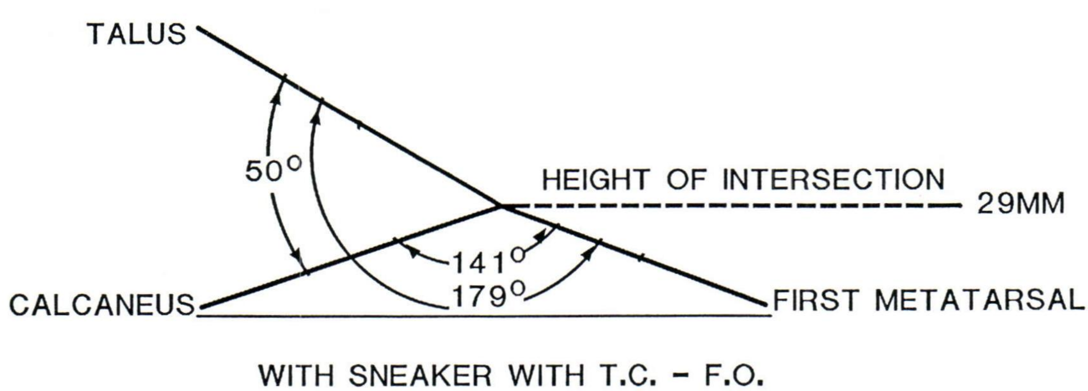
BAREFOOT



WITH SNEAKER - NO ADDITIONAL SUPPORT

Figures 5-A and 5-B.





Figures 5-C (top) and 5-D (bottom).

the approximate normal height and angular measurements).

The same patient wearing a running type sneaker without additional support produced a height of 24mm, an improvement of 6mm, with no measurable change in angle T and a negative value of 3° to 150° at angle C (Figure 5-B).

The next graph highlights data taken with sneakers and plantar surface arch supports featuring a height of 27mm, an improvement of 6mm, an improvement in angle T of 5° to 168° and an improvement in angle C of 2° to 145° (Figure 5-C).

Finally, and most dramatically, the information collected from the x-ray of this patient wearing the same sneaker with the talus control foot orthosis (TCFO) revealed a height of 29mm, a positive result of 8mm, an improvement of 16° in angle T to 179°, and an improvement of 6° in angle C to 141° (Figure 5-D).

CONCLUSION

Through open and frank discussion by the entire therapeutic and orthotic management team, meetings on a regular basis, and a respect for each discipline, continued growth can be assured. Research is time consuming and costly, but the benefits can be enormous. The implications of these pilot and comparative studies are that traditional plantar surface control may often be contraindicated, or may not provide the intended support and alignment. Further research is indicated, possibly including EMG and forceplate studies, on a larger patient population. By using the myriad of modern technical advances available to us, better methods of orthotic management may be realized. Indications or contraindications for surgery may be more thoroughly explored and developed, and treatment applications may be more representative of the growing knowledge of kinesiological and biomechanical movement parameters.

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