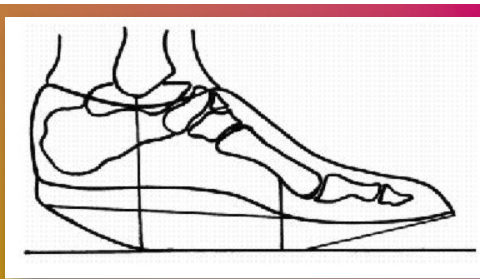

The Biomechanics of Ankle-Foot Orthoses

Properly designed devices can positively affect gait.

Goals and Objectives

1) To provide an overview of the various mechanisms of action of ankle-foot orthoses on the lower extremity.

2) To compare the effects of solid versus articulated ankle-foot orthoses on the knee and midfoot joints.

3) To review research relevant to ankle braces and ankle-foot orthoses and their effects on balance and proprioception.

4) To provide evaluation, prescription and casting guidelines to optimize treatment outcomes with ankle-foot orthoses.

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By Douglas H. Richie Jr. DPM

Introduction

Prior to 1995, the dispensing of ankle-foot orthoses (AFOs) by podiatric physicians was a rare occurrence. Despite the fact that podiatric medical education provided stellar training in lower extremity biomechanics and taught the pathomechanics of virtually every neuromuscular disease, treatment options utilized by podiatric physicians in the '70's thru '90's were limited to foot orthotic therapy and shoe modifications.

In 1995, a modified version of

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an ankle-foot orthosis, utilizing podiatric biomechanical principles (i.e., Richie Brace) was introduced to the profession. Since that time, the majority of podiatric physicians have expanded their treatment protocols to include AFO therapy into non-operative interventions for many lower extremity pathologies. These treatments have not been limited to podiatric devices, but now include almost every type of sophisticated brace, which were previously dispensed only by orthotists.

Bracing the lower extremity can be challenging and rewarding for the podiatric physician. However, evaluating patients with significant deformity and gait impairment requires the highest level of understanding of lower extremity biomechanics. This article is intended to provide an overview of the biomechanics of ankle-foot orthotic therapy relevant to podiatric practice. Guidelines for evaluation, casting, and prescription of these devices will be provided to optimize outcomes with this powerful treatment intervention.

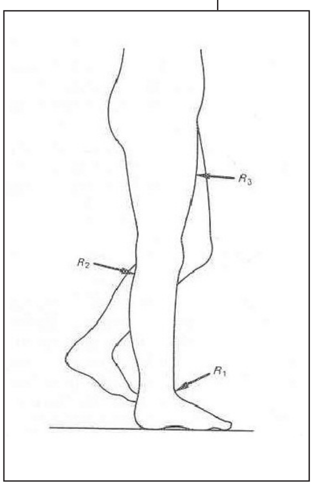

Figure 1: A three-point force system is applied by an ankle-foot orthosis. Control of joint moments by an orthosis requires a three-point fixation. This strategy applies three controlling forces to the limb: one placed over the joint center, with the other two forces applied proximal and distal to the joint and acting in opposite directions to each other.

Figure 2: Straps and pads applied to a podiatric ankle foot orthosis can control translational forces, i.e., internal/external rotation of the tibia

Definitions and Terminology

An orthosis is defined as: An externally applied device used to modify the structural or functional characteristics of the neuro-musculo-skeletal system.[1] An orthosis has also been defined as: An apparatus used to support, align, prevent, or correct deformities or to improve the function of movable parts of the body.[2] Orthoses is the plural of orthosis.

Internal moments are produced by active and passive structures within the body itself such as muscles, ligaments and joint capsules.

The term "orthotic" has been traditionally used as an adjective, i.e., "orthotic device." Today, most dictionaries list both an adjective and a noun usage of the term "orthotic" and consider it synonymous with the term "orthosis."

Lower extremity orthoses function by affecting joint moments. A moment is also known as a force couple, which acts at a distance from an axis of rotation of a specific joint in the body. This force is measured in Newton-meters.

Joint moments can be produced externally and internally. External moments are produced by inertia and ground reaction forces. Internal moments are produced by active and passive structures within the body itself, such as muscles, ligaments and joint capsules. In the scientific literature, the term "moment" refers to internal moment, produced by anatomic structures which are actually resisting external moments which are produced by physical forces. When internal structures fail, orthoses can modify external forces and moments to allow the body to function in a "normal" manner.

An external device used to support or improve function of the foot and ankle can take many physical forms. This orthotic can be as simple as a felt pad placed under the metatarsals or as sophisticated as a composite brace controlling foot and ankle motions.

Orthotics prescribed for lower extremity pathologies include foot orthoses (FOs), ankle-foot orthoses (AFOs), knee orthosis (KOs) and knee-ankle-foot orthoses (KAFOs). Podiatric physicians primarily prescribe or dispense FOs and AFOs.

Bowker has described four different ways in which an orthosis may modify the system of external forces and moment acting across a joint.[3] The first three patterns of action are peculiar to ankle-foot orthoses, while the last pattern would also include the action of foot orthoses.

Restriction of Rotational Motion at a Joint

Restriction of rotational motion through control of joint moments is the most common reason for prescribing ankle foot orthoses in podiatric medicine. An AFO may limit the range of motion about any particular axis, or may limit the number of axes about which motion may occur. For example, an ankle foot orthosis can limit inversion/eversion motion of the ankle joint, while preserving dorsiflexion/plantarflexion.

Control of joint moments by an orthosis requires a three-point fixation. This strategy applies three controlling forces to the limb: one placed over the joint center, with the other two forces applied proximal and distal to the joint and act-

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ing in opposite directions to each other (Figure 1). Applications of these forces proximal and distal to the subtalar and ankle joint are not possible with foot orthoses, but can be accomplished with ankle foot orthoses.

Ankle-foot orthoses can apply a moment to a joint not only to restrict motion, but also position a segment into a preferred alignment. For example, a fixed position solid AFO can maintain the foot at a pre-determined alignment at the ankle joint. For drop foot conditions, a solid AFO can hold the foot at a 90 degree angle to the leg. Clinicians must carefully evaluate available joint range of motion when prescribing AFO devices. If a patient has a fixed equinus deformity, fitting a neutral-positioned, 90 degree solid AFO will be impossible. Similarly, when there is a fixed varus alignment of the hindfoot, application of an AFO can only correct the foot position to the available range of eversion at the ankle and subtalar joint.

Restrict Translational Motion at a Joint

Since normal joint motion in the lower extremity is rotational, any translational motion could be considered abnormal. Translational motion occurs when there is loss of ligamentous integrity around the joint, which can occur after acute trauma or as a result of a chronic degenerative process.

Braces which limit translational motion require four points of fixation. This requires a rigid brace which incorporates straps and pads applied tightly to the skin surface. This feature is incorporated into podiatric ankle foot orthoses which are designed to control excessive transverse plane rotation of the ankle joint which occurs in chronic ankle instability and adult-acquired flatfoot (Figure 2).

Translational motion occurs when there is loss of ligamentous integrity around the joint, which can occur after acute trauma or as a result of a chronic degenerative process.

Control of Axial Forces Across a Joint

Axial loading of joints in the lower extremity can contribute to pain and disability when the articular cartilage is damaged, or the underlying bony structures become deformed. An ankle-foot orthosis can off-load a specific joint when it is properly designed to transfer load to other anatomic structures. An example of such a device is the patellar tendon-bearing orthosis.[3]

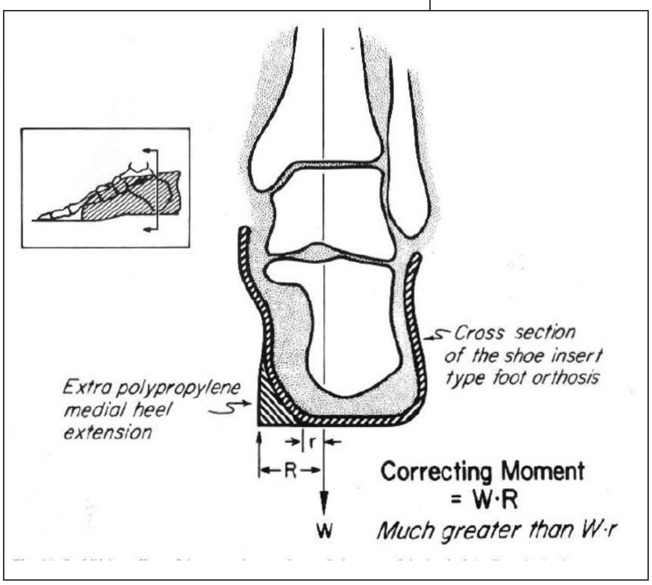

Figure 4: Foot orthoses can alter alignment of ground reaction forces to change moment to the subtalar joint

Control of Line of Action of Ground-Reaction Force

Ground-reaction forces pass through the foot from heel strike to toe off and create a line of action on every joint in the lower extremity. These ground-reaction forces will therefore create a moment about each of these joints. Orthoses can affect the alignment of ground reaction forces to change joint moments. This is the primary function of foot orthoses (Figure 4).

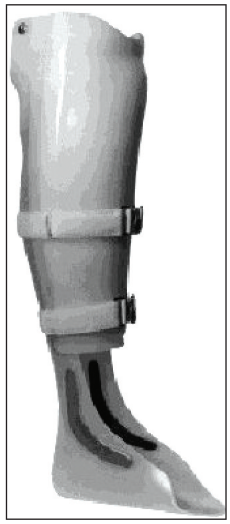

Figure 3: A patellar tendon weight-bearing brace

Foot orthoses cannot apply a three-point force system to the subtalar joint or the ankle joint, but can possibly do so at the midtarsal joint. Thus, kinematic studies of foot orthotic treatment effects have shown very minimal improvements of alignment of the rearfoot.[4]

Conversely, many studies have documented positive effects of foot orthoses to alter joint moments of the lower extremity.[5-10] Munderman has shown that the most important feature of foot orthoses to positively affect lower joint moments is contouring the device to the shape of the foot.[11] Thus, ankle foot orthoses which contour the footplate can be expected to offer the positive effects on joint moments that are found with foot orthoses alone.

Studies of Ankle Foot Orthoses: Kinetics and Kinematics

Kinetic and Kinematic effects of ankle-foot orthoses have been extensively studied.[12-16] However, most of this research has focused on the effects of ankle-foot orthoses on patients with neuromuscular conditions. Few studies have been published on the effects of ankle foot orthoses in healthy subjects, and

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virtually no studies have been conducted on sport applications of these types of devices.

Kitaoka, et al. studied the kinetic and kinematic effects of three types of ankle foot orthoses in twenty healthy subjects walking over ground.[17] In the frontal plane, all three orthoses (a solid AFO with footplate, solid AFO with heel portion only, and articulated AFO with footplate) significantly reduced maximal hindfoot inversion, but did not affect eversion. The solid ankle AFO design significantly reduced both plantarflexion and dorsiflexion of the ankle, while the articulated ankle AFO did not affect ankle sagittal plane motion compared to the unbraced condition. Midfoot motion was reduced with the articulated AFO, and increased with the solid AFO. Cadence was reduced with the solid AFO's. All three braces were associated with decreased aft and medial shear forces compared to the non-braced condition.

Radtka, et al. studied the kinetic and kinematic effects of solid and hinged (articulated) ankle foot orthoses on nineteen healthy subjects during stair locomotion.[18] A unilateral hinged (articulated) ankle-foot orthosis produced kinematic and kinetic effects which were similar to subjects wearing no orthosis. The unilateral solid ankle-foot orthosis produced more abnormal ankle joint angles, moments and powers and more proximal compensations at the knee, hip and pelvis than the hinged AFO during stair locomotion. Subjects wearing either orthosis walked slower during stair locomotion compared to the non-braced condition.

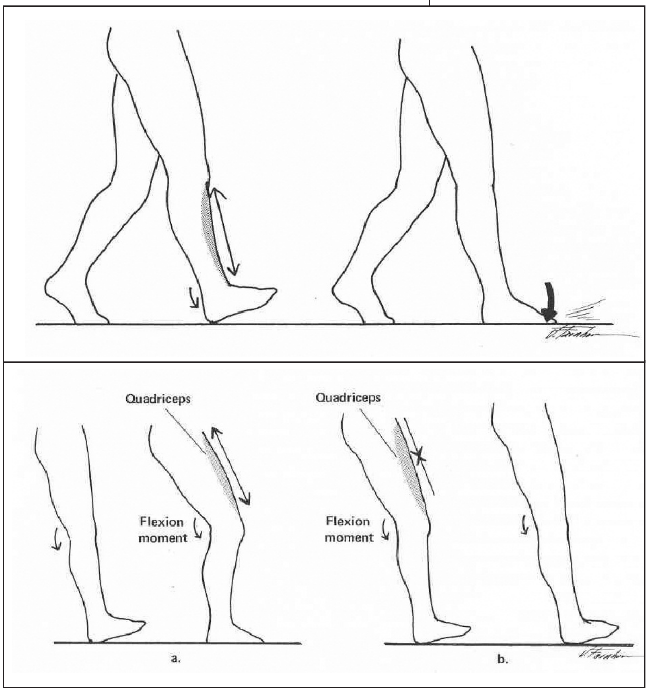

Figure 5: A solid AFO restricts ankle plantarflexion and causes knee flexion moment to bring the forefoot to the ground

Huang, et al. also compared solid and articulated ankle-foot orthoses in terms of restriction of motion at the ankle, hindfoot, and forefoot.[19] The subjects all had arthritis of the ankle either post-traumatic or osteoarthritis. A solid ankle-foot orthosis restricted ankle motion better than an articulated ankle foot orthosis, but also caused greater sagittal plane motion across the midfoot joints.

Hartsell and Spaulding measured passive resistive torque applied throughout inversion range of motion of the ankle in healthy subjects and those with chronically unstable ankles.[20] A hinged semi-rigid, non-custom ankle-foot orthosis demonstrated significant increased passive resistive inversion torque forces and restricted overall inversion motion better than a lace up ankle brace.

What remains obscure is an understanding of the optimal range and plane of motion controlled by an ankle orthosis to achieve a desired treatment effect. The studies just cited have conclusively shown that restriction of motion of any joint in the lower extremity will have negative effects in the neighboring joints, both proximal and distal.

> ***Excessive transverse plane rotation of the ankle joint occurs in chronic ankle instability and adult-acquired flatfoot.***

Solid Versus Articulated Ankle Foot Orthoses: Clinical Considerations

The kinematic studies comparing solid versus articulated ankle-foot orthoses suggest that changes occur during ambulation which can have significant clinical consequences. Not only are forces or moments transmitted to neighboring joints, but also alterations of neurosensory feedback can adversely affect balance and proprioception.

When an orthosis eliminates motion at the ankle joint, significant adaptation must occur by the patient to continue ambulation. The primary effects of a fixed or "locked" ankle position during gait, achieved by wearing a solid AFO brace, are at the knee joint.

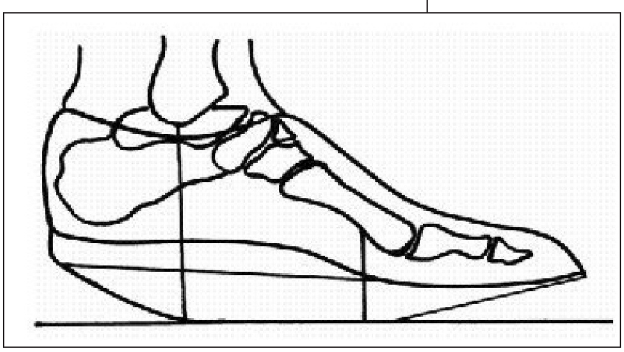

Figure 6: A heel rocker can slow or reduce knee flexion moment when wearing a solid AFO

When the ankle is fixed at 90 degrees by an AFO,

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the contact phase of gait will be prolonged, as the ankle cannot plantarflex to bring the forefoot to the ground. This places a significant external knee flexion moment to force the tibia forward and bring the forefoot to the ground (Figure 5). The knee can be protected from this damaging force if the patient's shoe can be beveled in the heel (i.e., heel rocker) or if a pad is placed in the heel section of the shoe (Figure 6).[21]

A fixed-ankle AFO will also cause abnormal knee joint moment during mid-stance. As the leg passes forward over the foot, a lack of ankle joint dorsiflexion will prevent forward migration of the tibia which will then cause an external knee extension moment. This may cause pain or even hyperextension of the knee during late mid-stance. Hullin has shown that a rocker sole modification of the shoe will decrease the knee extension moment caused by a fixed ankle AFO.[22]

> ***The most important feature of foot orthoses to positively affect lower joint moments is contouring the device to the shape of the foot.***

This same effect of a solid AFO on knee moments can be used in a positive way to improve gait in patients with muscle weakness. In patients with weak quadriceps muscles, there is a tendency for delayed knee extension at the end of mid-stance. A solid AFO will extend the knee in patients with weak quadriceps and prevent the "drop-down" normally seen at the knee of these patients during gait. A solid AFO can also provide knee flexion moment to prevent recurvatum deformity at the knee. By re-directing ground-reaction forces posterior to the center of rotation of the knee joint, a flexion moment, rather than extension moment, will occur. This is made possible by orienting the footplate alignment of the AFO in slight dorsiflexion (Figure 7).

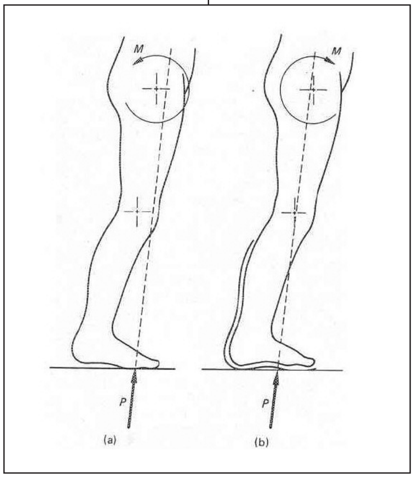

Figure 7: A solid AFO can direct ground reaction forces posterior to the knee axis of rotation to reduce a recurvatum deformity.

Balance and Proprioception

The effects of ankle braces on postural control have been extensively studied. Baier and Hopf studied 22 athletes with functional instability of the ankle joint compared to 22 healthy athletes.[23] A significant improvement of postural control, as evidenced by reduced mediolateral sway velocity, was found in the instability group when wearing both a rigid and semi-rigid stirrup ankle brace. However, other studies performed on both healthy subjects and on subjects with functional ankle instability have failed to show any improvements of postural control with the use of ankle braces.[24-27]

Similarly, studies of effects of ankle-foot orthoses on balance and proprioception do not provide consistent findings.[28] Yet, studies of treatment effects of these devices commonly attribute any positive findings to improvements in proprioception.[29,30] Interestingly, studies of foot orthoses, compared to ankle foot orthoses, show much more consistent improvements of balance and postural control.[31]

The reason that foot orthoses, rather than ankle foot orthoses, can improve postural control may relate to two mechanisms. First, the contoured shape of a foot orthosis has been speculated to improve the receptor field for sensory feedback in the proprioceptive loop between the foot and the spinal cord.[31] Many traditional ankle braces and ankle foot orthoses do not have contoured footplates. Second, the limitation of ankle motion in restrictive AFO's and certain ankle braces can adversely affect other sensory pathways for proprioception.

When the ankle joint is locked, mechanoreceptors within the liga-

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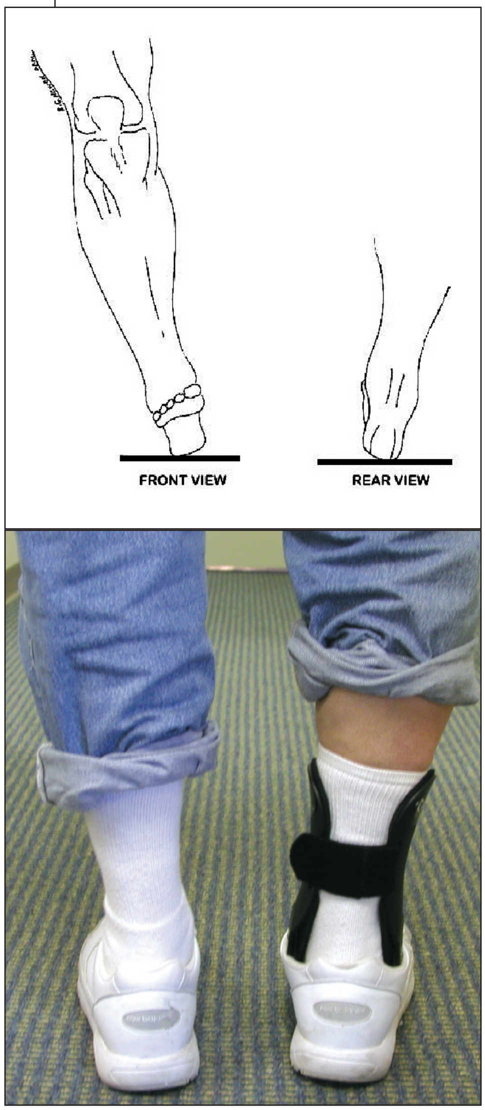

Figure 8: An AFO attached to a leg with tibial varum will invert the foot the same degree of varus deformity in the leg.

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ments cannot be stimulated to provide proprioceptive input.[28] Secondly, restriction of ankle motion can inhibit the stretch reflex of the leg muscles and tendons, which are considered the most important component of the somatosensory system for balance and postural control.[28,31]

These factors become important when considering bracing an individual with compromised balance and postural control. Ironically, these patients may otherwise be the most likely candidates for AFO therapy in podiatric practice: elderly, diabetic, and neurologically impaired individuals.

In elderly patients, falls are the leading cause of accidental death.[32,33] Studies have shown that patients with diabetes are fifteen times more likely to suffer catastrophic falls than their age-matched counterparts.[34] Whether due to sensory neuropathy of diabetes, or due to motor neuropathy from stroke, patients with neurologic impairment are at risk for falling.[35-38]

Lavery, et al. previously suggested that the efforts to off-load the neuropathic foot may have deleterious effects on postural control.[39] Studies of ankle-foot orthoses have shown that AFOs which restrict ankle motion will inhibit postural control and decrease velocity during gait.[40,41] Cattaneo, et al. showed that AFOs would improve static balance in patients with multiple sclerosis, but would compromise dynamic balance during gait.[42]

The unilateral solid ankle-foot orthosis produces more abnormal ankle joint angles, moments and powers, and more proximal compensations at the knee, hip and pelvis than the hinged AFO during stair locomotion.

Evaluation and Prescription Guidelines

Patients should be carefully observed in gait before any joint range of motion and muscle testing are performed. Knee flexion stability should be evaluated. In cases of recurvatum or excessive knee flexion during stance, a solid AFO should be prescribed.

A plantarflexed foot position at touchdown may be due to: fixed equinus of the ankle, spasticity of ankle plantarflexors or weakness of ankle dorsiflexors. A hinged AFO with dynamic assist ankle joints can be prescribed for only one of these conditions: weak ankle dorsiflexors with a flaccid drop foot deformity. In cases of spasticity, a hinged AFO with a plantarflexion stop is recommended.

When the ankle is fixed at 90 degrees by an AFO, the contact phase of gait will be prolonged, as the ankle cannot plantarflex to bring the forefoot to the ground.

During gait, and in static stance, balance and postural control should be evaluated. A modified Romberg test with eyes open will detect loss of postural control. This will commonly be found in patients with diabetes and with adult-acquired flatfoot deformity. Careful consideration should be made about using solid AFO devices and gauntlet style braces which limit ankle joint motion in these patients. It is recommended that all patients with balance problems be prescribed a cane to use when wearing solid AFO devices. A cane has been demonstrated to normalize postural control in neuropathic patients.[37]

Off-weight-bearing range of motion of the ankle and subtalar joints should be carefully evaluated before casting and prescribing an AFO. If the ankle joint is not capable of dorsiflexing to neutral (90 degree alignment of foot to leg) with the knee extended, then a neutral solid AFO should not be prescribed. The footplate of the solid AFO should be oriented to the maximum available dorsiflexion position when there is restricted ankle dorsiflexion. A heel lift should then be applied to the shoe or to the AFO to assure proper alignment of the leg and knee.

Restricted subtalar joint motion, particularly in the direction of eversion, may mandate modification of the AFO prescription. In cases of severe uncompensated rearfoot varus, commonly seen in Charcot Marie Tooth disease, traditional AFO's may not be able to prevent lateral instability. Lateral wedging of the forefoot and rearfoot of the AFO footplate should be considered in these cases. Also, pedorthic modifications including a lateral shoe flare and/or lateral wedging of the midsole can improve stability in cases of reduced rearfoot eversion.

In terms of posting AFO braces, the practitioner should be aware that these additions will not only tilt the footplate, but will tilt the entire leg portion of the brace. Therefore, adding a 3 degree forefoot varus post to the footplate of the AFO will tilt the leg portion of the device 3 degrees inverted to the floor. If the patient does not have an existing tibial varum alignment of 3 degrees or more, posting the brace will cause an ill-fitting brace and potential rocking between the heel and forefoot.

At the same time, a patient with significant genu varum or tibial varum, exceeding 6 degrees, will require a modification of the AFO prescription. Unlike wearing foot orthoses where leg alignment will not change orthotic alignment, ankle-foot orthoses create a new situation not always familiar to the podiatric physician. The frontal plane alignment of the leg to the

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floor in midstance will determine the alignment of the entire AFO, including the footplate. In other words, the AFO, when attached to the leg, will align the footplate to the floor in the same alignment that the leg is oriented to the floor. Thus, when the tibia is aligned in 10 degrees of varum, attaching an AFO to this leg will orient the footplate 10 degrees inverted (Figure 8).

Significant tibial varum or genu varum will require that the footplate of the AFO be posted to the same degrees of limb varus to provide a stable interface between the AFO and the supportive surface. Alternatively, depending on the pathology, the footplate of the AFO can be hinged and re-oriented to rest flat on the supportive surface while the leg upright portion of the brace remains aligned in varus. This is recommended only when there is available range of motion in the ankle and subtalar joints to evert the foot away from the inverted tibia in order to bring the foot flat on the floor.

A partial weight-bearing cast, placing the foot flat on the floor, will capture any varus/valgus limb alignment which can be preserved in the fabrication of the AFO. However, in most cases, this technique will eliminate the ability of the practitioner to position the foot into subtalar neutral while the midtarsal joint is locked and stable.

A solid AFO will extend the knee in patients with weak quadriceps and prevent the "drop-down" normally seen at the knee of these patients during gait.

The neutral suspension casting technique continues to be the preferred method of capturing an optimal model of the foot for functional foot orthoses fabrication by podiatric physicians. Munderman has shown that the most important feature of foot orthotic devices to improve kinetics and kinematics of lower limb function is the contouring of the device to the shape of the foot.[11] Such contouring is lost when the impression casting technique is performed on a weight-bearing foot. In a previous article published in *Podiatry Management* (Sept. 2007), the benefits of neutral suspension casting for AFO braces was demonstrated in comparison to partial and full weight-bearing casting techniques.

When neutral suspension casting techniques are utilized, leg alignment to the floor in static stance should be taken into consideration when balancing and fabricating the AFO brace.

A padded heel, a heel rocker, and a forefoot rocker are all shoe modification which can neutralize most of these abnormal knee moment forces.

Footwear should be considered and prescribed to match the AFO and patient needs. Solid AFO braces will translate significant abnormal moments to the knee both during contact phase and late mid-stance. A padded heel, a heel rocker, and a forefoot rocker are all shoe modification which can neutralize most of these abnormal knee moment forces. Solid AFOs and gauntlet AFOs will not fit into the posterior margin of the heel counter-insole junction. This is because the solid plastic posterior heel of the brace will contact the top-line of the heel counter, which is always tilted slightly forward. This will push the brace forward in the shoe, and keep the foot plate from conforming to the posterior margin of the heel counter. Thus, solid AFOs and gauntlet braces will mandate an increase of at least one full shoe size.

Finally, the shoe upper is an essential component of the three point force system which AFOs utilize to correct foot and leg alignment. The midfoot and forefoot shoe upper sections (vamp and toebox) should fit snugly and conform to the foot to prevent frontal, sagittal and transverse plane movement.

Summary

Ankle foot orthoses have significant advantages over foot orthoses to improve alignment and change joint moments in the lower extremity. However, application of AFOs can also have deleterious effects on a patient, which must be considered when prescribing these devices. Ankle-foot orthoses, depending on design, can have damaging effects on the knee and midfoot. These negative effects can be neutralized by appropriate shoe modifications.

The effects of bracing the lower extremity can also be positive or negative in terms of balance and proprioception. Many patients who require AFO therapy are already at risk for catastrophic falls. Practitioners should consider whether solid vs. articulated AFO's should be prescribed, taking into consideration the desired treatment effects versus the potential negative aspects of limiting motion around the ankle joint. ■

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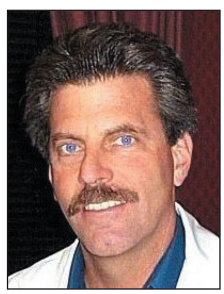

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EXAMINATION

See answer sheet on page 183.

1) An orthotic is:
A) A metatarsal pad
B) A custom foot support
C) A pre-fabricated foot support
D) All of the above

2) Internal joint moments are produced by:
A) Ground-reaction forces
B) Inertia
C) Cartilage
D) Tendons and ligaments

3) AFOs can limit motion better than foot orthoses because they:
A) Have stronger plastic
B) Have special hinges
C) Apply three-point force systems
D) Have special straps

4) AFOs can decrease the pain of osteoarthritis of the knee by
A) Off-loading compressive forces
B) Cushioning the bottom of the foot
C) Locking the ankle
D) Assisting ankle joint motion

5) Abnormal translational joint motion occurs when:
A) Muscles become weak
B) Ligaments are disrupted around the joint
C) Proprioception is lost
D) Internal joint moments increase

6) Abnormal transverse joint motion is seen in:
A) Cerebral palsy
B) Muscular Dystrophy
C) Charcot Marie Tooth Disease
D) Adult-Acquired Flatfoot

7) Foot orthoses and AFOs can both:
A) Alter the line of ground-reaction forces
B) Improve skeletal alignment
C) Reposition the ankle
D) Lock the knee

8) The most important feature of foot orthoses to affect joint moments is:
A) Posting
B) Molding or contouring the footplate
C) Topcover
D) Heel cup

9) Studies have shown that midfoot motion increases with:
A) Dynamic assist AFOs
B) Hinged AFOs
C) Solid AFOs
D) Patellar tendon bearing AFOs

10) Proximal compensation at the knee, hip and pelvis is seen with:
A) Solid AFOs
B) Dynamic assist AFOs
C) Hinged AFOs
D) Articulated AFOs

11) Which phase of gait is prolonged when wearing a solid AFO?
A) Midstance
B) Heel rise
C) Terminal stance
D) Contact phase

12) Solid AFOs cause a significant external moment causing:
A) Knee extension at contact
B) Knee flexion at contact
C) Toe grasping
D) Calf spasm

13) During midstance, solid AFOs can cause:
A) Pelvic tilt
B) Knee flexion
C) Knee hyperextension
D) Ankle plantarflexion

14) The negative effects of solid AFOs at the knee can be prevented by:
A) Rocker shoe soles
B) Special straps
C) Padded topcovers
D) Stronger plastic

15) Patients with weak quadriceps muscles should be prescribed a:
A) Hinged AFO
B) Solid AFO
C) Dynamic Assist AFO
D) Custom foot orthotic

Continued on page 182

Continuing Medical Education

EXAMINATION

(cont'd)

16) If the footplate of a solid AFO is positioned in dorsiflexion, the effect on the knee in static stance is:

A) Flexion
B) Extension
C) Varus
D) Valgus

17) Drop foot can be controlled by a:

A) Foot orthosis
B) Rearfoot post
C) Standard hinged AFO
D) Solid AFO

18) A patient with midfoot arthritis can have more motion and pain when wearing a:

A) Hinged AFO
B) Solid AFO
C) Dynamic Assist AFO
D) Foot Orthosis

19) Balance and Proprioception can be compromised by AFOs due to:

A) Restriction of joint range of motion
B) Restrict input of muscle spindles
C) Restrict input of joint proprioceptors
D) All of the above

20) Tibial varum deformity of 10 degrees will orient the footplate of a neutral AFO:

A) Flat on the floor
B) 5 degrees inverted to the floor
C) 10 degrees inverted to the floor
D) 20 degrees inverted to the floor

See answer sheet on page 183.

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ENROLLMENT FORM & ANSWER SHEET (cont'd)

EXAM #7/09
The Biomechanics of Ankle-Foot Orthoses (Richie)

Circle:

1.	A	B	C	D	11.	A	B	C	D
2.	A	B	C	D	12.	A	B	C	D
3.	A	B	C	D	13.	A	B	C	D
4.	A	B	C	D	14.	A	B	C	D
5.	A	B	C	D	15.	A	B	C	D
6.	A	B	C	D	16.	A	B	C	D
7.	A	B	C	D	17.	A	B	C	D
8.	A	B	C	D	18.	A	B	C	D
9.	A	B	C	D	19.	A	B	C	D
10.	A	B	C	D	20.	A	B	C	D

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Please indicate the date you completed this exam

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_______Very well _________Well

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Additional comments and suggestions for future exams:

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