FLEX CEUs

AFO - Ankle Foot Orthoses: Analysis & Application of Various Types

Introduction to the course[1,7,10]

A thorough understanding of the fundamentals of orthotics is critical for physical therapists and physical therapy assistants. Clinicians who identify the need for orthoses and then choose to prescribe, fit, and train patients with them must possess knowledge regarding the purpose, construction, and function as well as how to apply such knowledge across various neuromuscular pathologies.

The primary goal of using orthotics is twofold: (1) to restore normal function and (2) prevent further progression of abnormal biomechanical processes. This can be accomplished by designing orthotics to offset areas of pressure, minimize shear forces, correct flexible deformities, and provide support. Other secondary goals of orthotics may be to restrict painful movement, gain compensation for lost motion, accommodate deformities, and improve gait quality and efficiency.

An ankle-foot orthosis (AFO) is a device that is worn on the distal part of the lower extremity to assist with alignment of the ankle and foot. AFOs may be prefabricated (also referred to as off-the-shelf) or custom-made for an individual and prescribed according to the patient's unique biomechanical impairment(s) and desired functional outcome.

Selecting an AFO for an individual must take several factors into account. Oftentimes, a "one size fits all" approach leads to ineffective outcomes and should not be viewed as a viable solution to the patient's needs. It is imperative that the clinician understand mitigating factors that can affect the prescription of an orthosis, including the patient's pathology. Because an AFO affects many aspects of the wearer's life, the most effective orthotic prescription is one that minimizes the individual's particular functional deficits while optimizing safety and comfort.

This course will introduce pertinent information and clinical concepts for the application of various types of AFOs for different neuromuscular pathologies.

Section 1: Background and Functionality of Ankle Foot Orthoses (AFO)[1,2,3,4,5,6,7,8,9,13]

Background of AFOs[2,5]

As stated in the introduction, the primary goal of using orthotics and footwear modifications is to attempt to restore normal function and subsequently prevent further progression of abnormal biomechanical processes. AFOs in particular can reduce the metabolic cost of walking for individuals with neuromuscular impairments that affect the foot and ankle joints.

- They do this by providing push-off assistance that propels the body forward during ambulation. Therefore, the metabolic cost (energy expenditure) of walking is lower than that of ambulation without an AFO for individuals with neuromuscular impairments that affect the foot and ankle joints.
- AFOs can assist weakened or paralyzed lower extremity muscles that are active during the gait cycle, most notably the muscles that are responsible for dorsiflexion. Muscles that control plantarflexion are less commonly affected than those that control dorsiflexion.
- When designed to optimize the individual's biomechanical function and foot-ankle alignment, AFOs can indirectly affect hip and knee control during the stance phase of the gait cycle. This occurs when AFOs take advantage of the ground reaction force vector between the ankle, knee, and hip joints.

It is important to note that AFOs are not primarily intended to permanently prevent or passively correct the development of structural abnormalities. However, other secondary goals of AFOs may include:

- Shock attenuation and absorption
- Cushioning to tender areas
- Relief of abnormal pressure on the plantar surface of the foot
- Minimization of shear forces
- Support of flexible deformities
- Accommodation of rigid deformities
- Restriction of painful joints

Custom versus Prefabricated (Off-the-shelf) AFOs[1,4]

Ankle-foot orthoses are prescribed in two forms: prefabricated (off-the-shelf) or custom-made.

- Advantages of prefabricated AFOs

- Immediate availability
- Lower cost
- Decreased time commitment for therapists

- Advantages of custom-made AFOs
    - Individually designed to provide an optimal fit and meet the patient's biomechanical needs
    - Can be adjusted to optimize alignment and fit for the patient
    - May be better suited for patients with severe deformities or those who are at heightened risk for skin breakdown, loss of protective sensation, and joint collapse

Unfortunately, the cost differential plays a large factor in the prescription of a custom versus prefabricated AFO.

- Custom AFOs are estimated to be 3-5x more costly than prefabricated AFOs, and that figure does not include additional resources that may be needed for adjustments and training.
- With prefabricated AFOs, the lower out-of-pocket cost may be advantageous to patients who require immediate assistance to reduce the risk for falls. A recent study in 2018 comparing the provision of custom and prefabricated AFOs in patients after stroke suggested that prefabricated AFOs may be preferred for patients with high fall risks due to two serious adverse events that occurred when study subjects were awaiting fitting for custom-made orthoses. Additionally, the study also encouraged the use of lightweight and flexible prefabricated AFOs for stroke survivors with dorsiflexion weakness as they await the manufacturing of their custom orthoses.[4]

Lastly, custom-made AFOs should be strongly considered if the patient fails to improve with a prefabricated orthosis. Some common problems that may arise from use of either type of AFO include:

- Falls
- Skin breakdown
- Increased areas of friction between the skin and the device

- Discomfort and/or pain

Manufacturing and materials[1,2,6,9]

AFOs can be manufactured from several types of materials in order to address specific types of dysfunction. It is important to note that AFOs that are designed to accomplish the same function between two patients may differ in design, material, geometry, joint mechanisms, and surface area that can result in changes to the patients' comfort, total cost of the device, and energy consumption. Additionally, technological advances have enabled experts to utilize additive manufacturing, three dimensional scanning, and computer aided design-computer aided manufacturing methods for unparalleled designs and robotic capabilities.

AFOs can be constructed from the following materials:

- Metal
- Carbon fibers
- Composite
- Leather
- Metals
- Plastic
- Plastic polymers
- Polypropylene
- Rubber

Each material is unique in its aesthetic, function, and energy cost and should be taken into consideration when placing an order for a patient.

- AFOs that are intended for daily wear should have a simple design that is lightweight and compact. The use of plastic as a primary material is usually preferred over metal due to its weight and appearance.
- Keep in mind that AFOs with joints, which are typically made from metal, will add to the overall weight of the device. Consequently, this will add to the weight of the overall orthotic and contribute to heightened energy expenditure.

- In a study comparing the effectiveness between different AFO materials, researchers found that both metal and plastic AFOs resulted in improvements in walking speed, cadence, and step length. However, researchers concluded that AFOs made from metal may outperform their plastic counterparts in some patient populations that require increased levels of stability.[6]

- There may be a slight advantage of selecting carbon fiber over plastic materials, especially in consideration of the patient's abilities and optimal level of function. Studies have found improvements in static and dynamic balance, gait speed, and subjective performance as measured by the Berg Balance Scale, Timed Up and Go, and Functional Ambulatory Category in patients with both types of AFOs. However, when the performance of those with carbon fiber AFOs was compared to those with plastic AFOs, it was concluded that carbon fiber AFOs resulted in faster improvements in gait speed and various gait kinematic parameters over the course of 90 days.[6]

Lastly, the stiffness of the AFO should be a consideration when selecting the appropriate type of material for a patient's AFO. This topic will be explored more in depth in Section 2.

Indications for use

Orthotic devices have the ability to align, protect, and assist limbs with movement and can be used for orthopedic, neurological, or congenital conditions. This course will focus on the prescription of AFOs to patients with neuromuscular dysfunction.

- **Multiple Sclerosis[3]**:

  Indications for use: People with Multiple Sclerosis (MS) are often characterized by varying levels of physical dysfunction. Within 10-15 years of onset, 80% of people who are diagnosed with MS will have impaired mobility with accompanying fatigue, muscle weakness, spasticity, impaired coordination, and balance dysfunction. Those who are ambulatory may experience foot drop which is characterized by weak dorsiflexion during the swing phase of the gait cycle. Consequently, individuals with foot drop may attempt to compensate for weakness through pelvic elevation, hip abduction, or contralateral vaulting. Associated with these gait abnormalities is increased energy expenditure, heightened risk of falls, and lower-than-normal levels of physical activity participation.

Purpose of AFOs for individuals with MS: The use of AFOs is standard practice to correct foot drop in individuals with MS. Common materials for orthotic devices include plastic and carbon fiber.

Research on AFO use for individuals with MS: A small study on 15 individuals with MS did not find statistically significant improvements in walking speed with or without custom AFOs. The authors of the study concluded that justification of custom AFOs as the most commonly prescribed device to improve functional ambulation in this population may be difficult.

- **Cerebral Palsy (CP)[13]:**

  Indications for use: AFOs are commonly prescribed for children with CP in order to control the alignment of the foot that affects the swing phase of the gait cycle. Many children with CP exhibit an equinovarus position that impedes their ability to achieve an effective heel strike. Additionally, those with spasticity secondary to CP may require specific components of the AFO to reduce tone and improve gait kinematics.

  Purpose of AFOs for individuals with CP: Children with CP may require various types of orthotic devices depending upon their Gross Motor Function Classification System (GMFCS) levels. Use of AFOs in children with lower levels should aim to improve function and gait quality, as well as prevent deformity. AFOs in children with higher GMFCS levels should prioritize the prevention of deformity.

  Research on AFO use for individuals with CP: Strong considerations should be given to the child's ankle function and tone when determining the most appropriate type of AFO. Also, the thickness of the material used to manufacture the AFO should be chosen according to the degree of desired rigidity and flexibility for children presenting with lower limb spasticity.

- **Incomplete Spinal Cord Injury (SCI)[16]:**

  Indications for use: Patients with spinal cord injury damage can experience weakness or paralysis of different muscle groups, as well as spasticity in the extremities. The ability to walk following a spinal cord injury depends upon many factors including level of injury, severity, age, time since injury, level of fitness, sensation, and presence of contractures and spasticity. For those with sufficient hip flexion to advance the legs and a 4/5 or greater quadriceps muscle grade, an

AFO can be prescribed to improve gait efficiency and decrease energy expenditure associated with walking in patients after a SCI.

Purpose of AFOs for individuals with SCI: AFOs can be used for patients who have retained a majority of lower extremity strength. Individuals may be categorized as a household or community ambulator in which the AFO is primarily prescribed to protect a weak joint, prevent knee hyperextension, and prevent abnormal joint movement around the foot and ankle during weight bearing. Use of an AFO in this patient population can also reduce the risk for falls as well as increase gait speed.

Research on AFO use for individuals with SCI: Research supports the use of AFOs in combination with Functional Electrical Stimulation (FES) in patients with SCI. Studies have shown both interventions to increase foot clearance, gait speed, and endurance when used together as opposed to individually. Additionally, experts recommend the use of custom-made orthoses when considering the primary long-term outcomes for AFO use in persons following SCI. Commonly utilized functional outcome measures to observe the effects of AFOs in this patient population include the Walking Index for SCI II, the 10-Minute Walk Test, the 6-Minute Walk Test, the Spinal Cord Functional Ambulation Profile, and the Spinal Cord Independence Measure.

- **Charcot Marie Tooth (CMT)[15,17]:**

Indications for use: Individuals with CMT frequently experience progressive distal weakness or paralysis of lower extremity muscles, especially in the calf. As a result, gait kinematics and quality are affected and characterized by excessive dorsiflexion, knee flexion, and impaired terminal stance. Such gait deviations can lead to foot and ankle instability, pain or discomfort, slow gait speed, and increased energy expenditure while walking. Additionally, distal lower extremity weakness in individuals with CMT can result in changes to their gait mechanics that may impact walking endurance.

Purpose of AFOs for individuals with CMT: The efficacy of AFO use for gait dysfunction secondary to CMT has been associated with improvements in gait quality, independence, confidence, and energy expenditure. AFOs are commonly prescribed to reduce the presence of foot drop, lessen compensation of proximal muscles, and restrict excessive ankle dorsiflexion that may be seen during late stance phase. With respect to AFO utilization, the degree of disease severity may determine whether or not individuals with CMT are compliant.

Research on AFO use for individuals with CMT: Researchers hypothesize that AFOs can significantly compensate for the lack of muscle strength and its resulting effect on gait performance in this population. However, studies on gait kinematics found heightened hip flexor activation as a compensation in people with CMT and state that AFO prescription should be done with the consideration of the wearers' fatigue levels, confidence, and self-efficacy.

- **Stroke[1,4,5,6,8]:**

  Indications for use: Stroke survivors can suffer from impaired mobility secondary to muscle weakness, spasticity, and balance dysfunction. One commonly seen characteristic is weak dorsiflexion contributing to foot drop, which increases one's risk for falls. Consequently, this limits functional mobility, community participation, and quality of life for many individuals following stroke.

  Purpose of AFOs for individuals after stroke: The main functions of an AFO for foot drop in patients following stroke are to provide resistance during loading response of the gait cycle, promote free dorsiflexion during stance phase, inhibit weakness of the dorsiflexors during swing phase, and assist push-off as needed. AFOs applied during stroke rehabilitation may have positive benefits on hemiplegic gait patterns which are characterized by poor interlimb coordination and high energy expenditure. It is widely accepted that the use of AFOs during rehabilitation for patients following stroke should be seen as an adjunct to therapeutic activities.

  Research on AFO use for individuals after stroke: The efficacy of AFOs in this patient population has been well established. Because a majority of spontaneous motor recovery occurs within six months of stroke, AFOs should be considered to combat the negative functional effects of spasticity, rigidity, and synergistic movement patterns. Based upon recent findings, most AFOs encourage significant improvement in stroke survivors' dorsiflexion during the gait cycle when compared to control groups without AFO interventions.

Research implications

Many research efforts have studied the efficacy of AFOs on several gait parameters, patient satisfaction and compliance, and meaningful functional outcomes. While the primary objectives of an AFO may slightly vary according to patient population and clinical presentation, many researchers view AFO interventions to be significant to progress in neurological rehabilitation.

As with other industries, the advancement of technology has inspired novel designs of robotic devices and their corresponding strategies to enhance rehabilitation techniques. Future research is warranted to examine physical therapists' interventions strategies and therapeutic effects on patient satisfaction and compliance with device wearing.

Section 1: Key Words

Ankle-foot orthosis (AFO) - a device that is worn on the distal part of the lower extremity to assist with alignment of the ankle and foot

Prefabricated AFO - also referred to as an off-the-shelf AFO, these are AFOs that are sized or modified for use by a patient but do not require substantial clinical judgment or alteration for appropriate use

Custom-made AFO - an orthosis device that is fabricated to original measurements or a model for use by only that individual to meet a specific prescription

Metabolic cost of walking - refers to the energy expended by the body to move a certain distance

Energy expenditure - total energy cost of maintaining constant conditions in the body, plus the energy cost of physical activities

Ground reaction force - an external force (gravity) that pulls the body toward the ground and the opposing reaction force from the body-ground interaction

Flexible deformity (of the foot/ankle) - refers to a foot deformity that may be corrected with active (muscular contraction) or passive (manual correction) interventions.

Rigid deformity (of the foot/ankle) - refers to a foot deformity that may be difficult or impossible to correct and may indicate a structural abnormality

Carbon fiber - a strong material that is also lightweight

Multiple Sclerosis - a disease of the central nervous system that disrupts the flow of information within the brain and and body

Cerebral Palsy - a term to describe a group of disorders that affect a person's ability to move and maintain balance and posture

Spasticity - a condition in which there is an abnormal increase in muscle tone or stiffness of muscle, which might interfere with movement and speech or be associated with discomfort or pain

Gross Motor Function Classification System (GMFCS) - a classification that differentiates children with CP based on their current gross motor abilities, limitations in gross motor function, and need for assistive technology and wheeled mobility

Spinal Cord Injury - damage to the spinal cord that results in a loss of function, such as mobility and/or feeling

Functional Electrical Stimulation (FES) - a treatment that applies small electrical charges to a muscle that has become weak or paralyzed due to damage in the brain or spinal cord

Charcot Marie Tooth (CMT) - a relatively common hereditary condition characterized by a slow decline in distal muscle strength and sensation due to degeneration of the longer peripheral nerves. Distal muscle wasting causes the classic inverted champagne bottle appearance of the lower portion of the leg.

Gait kinematics - describes the extent, speed, and direction of movement of joints or body segments during ambulation

Stroke - caused by a sudden interruption of blood flow in the brain and considered to be a life-threatening condition

Section 1: Summary

- The primary goal of an AFO is to attempt to restore normal function and subsequently prevent further progression of abnormal biomechanical processes.
- Other secondary goals of AFOs may include: shock attenuation and absorption, cushioning to tender areas, relief of abnormal pressure on the plantar surface of the foot, minimization of shear forces, support of flexible deformities, accommodation of rigid deformities, and restriction of painful joints.
- AFOs can be manufactured from several types of materials in order to address specific types of dysfunction. Each material is unique in its aesthetic, function, and energy cost and should be taken into consideration when placing an order for a patient.

- AFOs can be beneficial for a variety of patient conditions, however, specific indications exist for neurological conditions like Multiple Sclerosis, Cerebral Palsy, spinal cord injury, Charcot Marie Tooth, and stroke.

Section 1: Personal reflection question

When selecting a prefabricated or custom-made AFO for your patient, what are some factors that assist in your decision-making? If cost was not a factor, what are some reasons to select a prefabricated AFO as opposed to a custom-made AFO?

Section 2: Various types of AFOs and their applications[1,9,10,11]

This section will review different types of AFOs and two common classifications: material type and stiffness (refer to Tables 2.1 and 2.2, respectively). Various types of AFOs can be prescribed, both prefabricated and custom-made, with different designs that address a wide range of neuromuscular problems.

When selecting an orthosis based upon material, clinicians must consider the overall weight of the orthosis. Since heavier materials require more energy expenditure during functional activities, many clinicians and wearers prefer AFOs that are made from strong, durable, and lightweight materials.

Depending on the wearer's clinical diagnosis and presentation, the orthosis can be prescribed as fixed (molded) or articulated (jointed) which will affect the range of motion at the foot and ankle. Various adjustments of the AFO can be made to accomplish the wearer's functional goals and anatomical deformities.

It is important for the clinician to realize that AFOs can potentially affect proximal joints, like the hip and knee, in addition to the ankle. As with most orthoses, AFOs are viewed as biomechanical interventions that apply forces to facilitate or restrict joint movement. Each component of the AFO will play a role in the wearer's functional capabilities and influence gait parameters like gait velocity, step length, kinetics, and kinematics.

Table 2.1 Classification of AFOs according to materials[2,10]

	Conventional	Molded	Hybrid
Purpose	An articulated ankle joint in which the shoe is an integral part of the brace and contributes to stability of the calcaneus.	Restricts normal ankle movement since the joint is held in a relatively neutral position by the AFO.	An articulated ankle joint in which design is dictated by the condition and the desired treatment effect of the brace.
Constructed materials	Articulations (joints) are made from metal, leather, fabric	Plastic	Same materials as molded AFOs but with articulations that are made from metal, plastic, or composites
Defining characteristics	A thick leather calf cuff attaches to metal articulations that are directly connected to the outside of the shoe	Single piece of material without articulations that makes total contact with the limb	Calf component that articulates with the footplate; connected through articulations
Specific types	Conventional double upright AFO	Posterior calf shell/ Posterior leaf spring Spiral/Hemispiral Anterior ground/Floor reaction Anterior shell/Anti-talus Rigid/Solid Tone reducing	Hinged Tamarack Flexure Joint

See below for more detailed descriptions of molded and hybrid AFO designs.

Table 2.2 Classification of AFOs according to stiffness[1,7,9,10]

Significance: Stiffness of the AFO's material is an important parameter that should be considered since it can affect the wearer's functional outcomes, deformities, and energy expenditure. Overall stiffness of the orthotic should be determined based upon the individual's type of deformity, severity of structural abnormality, weight, and biomechanics.			
	Soft	**Semirigid**	**Rigid**
Purpose	Provide cushioning and protection, padding, shock attenuation, and reduction of friction shear forces.	Used to decrease and redistribute areas of abnormal pressure, especially in the plantar aspect of the heel and forefoot.	Provide support and control for flexible deformities, as well as control or decrease motion.
Materials	They are constructed from softer and less durable materials which makes them more prone to frequent follow-ups.	Manufactured with a soft and dense layer for cushioning and a firm base for support.	Various forms of plastic
Indications for use	Wearers with foot and fixed deformities with bony prominences or impaired sensation.	Wearers who require accommodative properties, like cushioning, shock absorption, and protection) and support for flexible deformities. These AFOs are easily modified but may require periodic follow-up and replacement.	Wearers who require maximum support or motion control with minimal need for cushioning or protection. These AFOs are not suitable for those with sensation loss or foot deformities.

More on Molded AFOs

Also known as non-articulating AFOs, some commonly prescribed molded AFO designs include:

- Anterior shell/Anti-talus
- Posterior calf shell/Posterior leaf spring
- Rigid/Solid
- Spiral/Hemispiral
- Tone reducing

Clinicians should understand that some features of molded AFOs may negatively affect the wearer's functional abilities. For example, rising from a chair, ascending ramps, squatting, and descending steps can be difficult with a solid AFO due to the ankle being fixed in dorsiflexion. Alternatively, blocking plantarflexion can affect one's ability to descend ramps or ascend a curb while wearing a solid AFO. Therefore, it is important for physical therapists to consider the positive and negative aspects of a particular AFO on the wearer's overall function.

Anterior Shell/Anti-talus AFO[9,10]

- Typically prescribed to provide support while allowing some range of motion and most effective at preventing excessive ankle dorsiflexion
- Made from composite, lightweight, and freely available materials
- Also known as dynamic response orthoses due to their ability to store and release energy
- Provide dorsiflexion resistance during mid to late stance along with plantarflexion assist at preswing and forward propulsion
- Provide adequate amounts of assistance which may help reduce energy expenditure during gait
- Not recommended for individuals with poor stabilization in the subtalar joint
- May not be suitable for individuals with hemiparesis due to their lack of posterior calf support and limited ability to stabilize the joint[8]

Posterior Calf Shell/Posterior Leaf Spring AFOs[8,10,11]

- Despite design similarity, posterior calf shell AFOs can significantly vary in design from one another, especially with respect to rigidity and degree of ankle motion allowed.
    - Rigidity of an AFO is associated with the type, thickness, and shape of the material used to construct the AFO.
    - Rigidity is also associated with the design of the trimlines around the ankle joint.
    - In general, increased contact of the orthosis with the wearer indicates higher amounts of rigidity and, therefore, resisted motion.
- During early stance phase, the posterior aspect of the AFO, known as the posterior calf shell, acts as a spring and bends backward slightly. When the individual transitions into swing phase, the upright recoils and "springs" forward to lift the foot. This is why the posterior calf shell AFO is commonly referred to as a posterior leaf spring AFO.

- The posterior calf shell AFO is not easily adjusted and should not be prescribed for individuals who need a high amount of ankle support.
- Ankle trimlines are located behind the malleoli to support the foot during swing phase. Consequently, posterior calf shell AFOs will not have a significant effect on the ankle during stance phase and are usually indicated for individuals with small amounts of ankle instability.
- It is important to note that AFO interventions may not have a large effect on the recruitment of muscle activity in individuals following stroke. Research studies have not found significant findings to show that non-articulated AFOs, specifically posterior leaf spring AFOs, activate the tibialis anterior during the swing phase of gait.[8] This emphasizes the importance of combining AFOs with therapeutic rehabilitation strategies and neuromuscular re-education to promote restorative function.

Rigid Solid Ankle AFOs[7,9,10,11]

- Rigid AFOs are characterized by a non-articulating joint with ankle trimlines that extend anteriorly beyond the malleoli. This results in an extremely strong orthotic that does not permit movement in either plane, especially inversion and eversion.

- These orthoses are the most stable AFO design and often prescribed for individuals with spasticity or hyperextension at the knee joint.
- Typically, rigid AFOs are fixed in a few degrees of ankle dorsiflexion to manipulate the ground reaction force vector during stance phase and control for knee hyperextension. As a result, individuals who wear rigid AFOs must have sufficient quadriceps strength to avoid knee buckling.
- Rigid AFOs can also prevent excessive plantarflexion to enhance stability during stance phase.
- Additionally, there is a possibility that rigid/solid ankle AFOs may be appropriate in individuals with CP who require motion control for forefoot adduction/abduction.
- Due to the strength and stability of these orthoses, there may be a transition phase for the wearer in which small modifications may be necessary to optimize comfort and wearability. Solid AFOs can be adjusted by adding small heel wedges to adjust the angle of dorsiflexion.

Spiral/Hemispiral AFOs[9,10]

- Provides mild to moderate control of the foot and ankle while allowing normal plantarflexion and dorsiflexion during the gait cycle.
- Preserves normal tibial translation during stance phase
- The hemispiral AFO is characterized by more rigidity than the full spiral AFO and can resist a flexible varus hindfoot deformity.
- The full spiral AFO is indicated when plantarflexion is desired during early stance phase while preventing drop foot during swing phase.

Tone-Reducing AFOs[9,10,11]

- Aptly named to describe AFOs with foot plates that extend the length of the wearer's foot and are indicated for patients with upper motor neuron conditions, hypertonicity, and spasticity.
- Provide a prolonged stretch for plantarflexion muscles and tone-inhibiting/ constant pressure to the tendons of the toe flexors

- Inhibit automatic reflexes that are provoked by tactile stimulation
- The research supporting the efficacy of tone-reducing AFOs is unclear.

More on Hybrid AFOs

Hybrid AFOs can be referred to as articulated and/or jointed AFOs because they all consist of a variety of hinges, stops, and varying degrees of stiffness to control or encourage motion at the ankle joint. Certain articulations, known as joint mechanisms, can be easily adjusted to accommodate a wide range of abilities, deformities, and muscle weakness.

The joint mechanisms function to control varying amounts of plantarflexion and dorsiflexion as well as functioning to provide assistance or restrict/stop movement altogether. The following information describes the type of control exerted by the AFO on the foot and ankle joints and is also summarized in Table 2.3.

- Free (motion) - No control is exerted, and the joint is free to move in a designated plane.
- Assist - Assists motion to increase the range, velocity, or force of a desired motion (e.g., dorsiflexion assist increases dorsiflexion and decreases foot drop)
- Resist - Resists undesired motion
- Stop - Stops or limits motion at a joint (e.g., an AFO with a plantarflexion stop at 0° allows plantarflexion 0°). Adjustable stops for both dorsiflexion and plantarflexion can be incorporated into the hinged AFO.
    - A posterior stop is designed to allow dorsiflexion and prevents or "stops" plantarflexion.
    - An anterior stop limits or "stops" dorsiflexion.
- Hold - Controls and eliminates all motion at a joint in all planes (e.g., to hold the ankle at 5° dorsiflexion and subtalar neutral).

Table 2.3 Commonly-prescribed joint mechanisms in articulated AFOs

Free motion	AFO allows free movement of the ankle joint
Assist	AFO assists movement
Resist	AFO resists movement
Stop	AFO stops a specific movement
Hold	AFO holds the ankle in a specific angle

Some commonly-prescribed hybrid/articulated AFO designs include:

- Tamarack Flexure Joint AFOs
- Hinged AFOs

Tamarack Flexure Joint AFOs[9,18]

- Named for a specific type of composite joint, the Tamarack Flexure Joint AFOs offer subtalar joint stabilization with many options for customization to accommodate the patient's clinical presentation.
- According to the manufacturer, the Tamarack Flexure Joint line offers three options for hybrid AFOs: free motion, dorsiflexion assist, and variable assist.
    - Free motion allows full dorsiflexion and plantarflexion and is indicated for patients with posterior tibialis weakness or subtalar instability.
    - Dorsiflexion assist provides a dorsiflexion moment with or without a plantarflexion stop. This is indicated for patients with CP, weakness, and subtalar instability.
    - Variable assist can assist with dorsiflexion during swing phase with easy adjustments. It is indicated for use in people with CP, weakness, mild SCI, MS, and subtalar instability.

Hinged AFOs[1,9,10,11]

- Hinged AFOs are commonly prescribed to restrict ankle mobility within the sagittal plane. They are characterized by a calf component that articulates with the footplate by metal, plastic, or composite joint mechanisms.

- Hinged AFOs are preferred over molded AFOs for patients in which a molded AFO provides too much rigidity that affects functional performance.

- Compared to molded (non-articulated) AFOs, hinged AFOs have the ability to store energy and, thereby, provide assistance during the swing phase of gait. They have been known to improve function by controlling subtalar joint instability, flexible ankle equinus, or knee hyperextension. However, it should be acknowledged that the total surface area pressure is less evenly distributed in hinged AFOs versus molded AFOs, which may affect longevity of the brace.

- Hinged AFOs are indicated for individuals with foot drop or hemiparetic gait in which dorsiflexion assist is desired. One approach to prevent foot drop is to use plantarflexion resistance provided by an AFO with a posterior stop. The posterior stop prevents toe drag and encourages a flexion force at the knee during early stance, thus, preventing the knee from hyperextending.

- Similar to the posterior calf shell AFOs, little evidence exists to support the efficacy of hinged AFOs on ankle muscle activation in individuals following stroke.[8] This suggests the importance of combining AFO interventions with therapeutic rehabilitation strategies and neuromuscular re-education when restoration of function is desired.

Other AFOs

Prefabricated (off-the-shelf) AFOs[1,7,10]

- Introduced in Section 1, prefabricated AFOs can be safely prescribed for patients without severe deformities, neuropathy, or sensation loss to provide cushioning and shock attenuation.

- Prefabricated AFOs are indicated to prevent foot drop (plantarflexion) during the swing phase of gait and potentially limit extensor thrust during stance phase. However, many prefabricated designs are not strong enough to resist the plantarflexion during stance phase.

- Typically ordered from medical suppliers but may require individual fitting by an orthotist. Clinicians may order prefabricated AFOs when minimal adjustments are required or when the orthotic device is being trialed.

- Wearers should be educated on proper ways to don/doff prefabricated AFOs and appropriate shoewear (which will be discussed in Section 4).

Ground reaction ankle foot orthosis[9,10]

- AFOs that affect proximal joints that are not contained within the orthosis are known as ground reaction or floor reaction AFOs. They can manipulate the forces on unbraced joints by changing the location of the ground reaction force vector with respect to the proximal joints.

- These devices are mainly indicated in individuals with excessive knee flexion (crouching gait) due to the tibial support that prevents the knee joint from moving anteriorly.

Assessment for orthotic prescription[5,7,9,10]

- Selecting an AFO should result from an interdisciplinary and comprehensive assessment of the patient's biomechanics, gait analysis, functional deficits, and anatomical deformities. Additionally, clinicians should recommend orthotic prescriptions based upon the ability of the brace to improve upon the patients' participation in activities of daily living.
    - Commonly used functional tests to assess deficits and participation barriers include the Functional Independence Measure, Gross Motor Function Measurement, Gait speed, Timed Up and Go, and the Functional Reach Test.
    - When available, gait laboratories that utilize high speed cameras, force plates, and electromyography sensors should be utilized to objectively quantify movement dysfunction.

- It is important to remember that the AFO should be able to successfully utilize ground reaction forces to positively influence hip and knee joint stabilization during movement patterns. Furthermore, the AFO should correct abnormal movement patterns that affect gait kinematics and lead to changes in energy expenditure, self-esteem, and gait quality.

- Additionally, there may be a need for adjunctive therapeutic, pharmacological, or surgical interventions to enhance or facilitate device interventions. This underlines the importance of an interdisciplinary approach to orthotic prescription in which the responsibility of design specification should be shared by the clinician and orthotist.

- In the presence of complex gait dysfunction and anatomical deformities, custom-made AFOs should be prioritized over the prescription of prefabricated AFOs.
- Patients should also be educated on the importance of footwear and other appropriate assistive devices that will affect overall outcomes related to AFO usage.

Common components of a pre-orthotic physical examination

- Musculoskeletal Examination
    - Joint mobility (passive and active range of motion)
    - Joint stability (ligaments, capsule, articular surfaces)
    - Deformities or alignment abnormalities
    - Limb length
    - Motor function
    - Selective muscle control
    - Muscle strength (active hip flexion, >4/5 quadriceps muscle strength)
- Neurological Examination
    - Sensation (touch, pain, proprioception, kinesthesia)
    - Deep tendon reflexes
    - Muscle tonicity
    - Balance
    - Coordination
- Integumentary Examination
    - Wounds and skin integrity
- Cardiovascular/Pulmonary Examination
    - Limb edema
    - Signs of peripheral vascular disease
    - Endurance and ability to tolerate energy demands of activity
    - Aerobic capacity

- Heart rate, blood pressure, respiratory rate at rest and with activity
- Psychological and Cognitive Screening
    - Ability to understand and follow directions
    - Ability to comprehend procedures that are necessary for safe orthotic use
    - Motivation

Goals of a pre-orthotic physical examination[10]

1. To determine patient-specific impairments
    a. Type of impairment
        i. Insufficient movement or force
        ii. Abnormal movement or force
        iii. Excessive movement or force
        iv. Fixed or flexible deformity
    b. Location of impairment
        I. Joint
        II. Limb
2. To create functional goals to improve the patient's quality of life and participation in activities of daily living

Orthotic prescription and fitting

Orthotic prescription[9,10]

Upon evaluation, if an AFO is indicated, then the next step would be to develop specific functional goals and generate the orthotic prescription. Objectives of orthotic prescription were thoroughly discussed in Section 1 and reviewed here:

SPAM acronym: Stabilize, Protect, Assist, or Manage

Additional goals:

- Minimize the skin and tissue injury
- Reduce energy expenditure during activities of daily living
- Low energy cost

- Affordable, easy to use

Factors to consider when generating an orthotic prescription include:

- Select an orthotic design that provides the least amount of control while being optimally effective. Consider these factors:
    - The number of joints in a limb that require orthotic control
    - Muscle strength and available range of motion at the involved and adjacent joints
    - The presence of abnormal muscle tone or involuntary muscle contractions
    - The size and weight of the patient
- Choose a design that minimizes interference of normal movement patterns at the ankle joint and adjacent joints along the kinematic chain.
- Choose a design that minimizes energy expenditure when performing activities of daily living with the orthosis donned.
- Choose a design that applies its force in close proximity to the joint that is causing the problem.
    - An AFO applies forces to three different points of the limb: proximal-posterior calf, sole of the foot, and the dorsal foot.
    - These areas will aid in managing deformities, like excessive pronation or valgus, and limit motion around each joint axis.
- Choose the design that maximizes participation in functional activities.

General orthotic fitting objectives[10,11,12]

- Safety considerations
    - The orthosis should never bring harm to the wearer.
    - The AFO should never result in irreversible secondary effects when worn for an extended period of time.
- Considerations for donning and doffing

    - Ideally, the wearer should be able to don/doff the orthotic independently or be able to direct a caregiver in how to do so.
    - The orthotic closing fasteners should be checked for safety and security.
    - Wearers should be educated on guidelines for appropriate footwear to wear with the AFO.

- Considerations for tolerance
    - Wearers should be able to tolerate the device for the allotted wear schedule without any skin or soft tissue irritation. After wearing the orthotic for 30 min, remove and check skin integrity for signs of irritation, excessive pressure, or poor fit.
    - Prescribe a schedule to progressively increase wearing time, also known as a wear schedule. Wear schedules will be introduced later in Section 4.
    - Patients may need to wear a stocking or thin sock to increase air flow and reduce shear forces between the skin and the AFO. This is done in order to decrease heat retention that is characteristic of orthoses that are made of certain types of plastic.

    - Patients should be educated on the importance of hygiene to reduce skin-related issues secondary to normal or excessive perspiration against the orthotic.
- Considerations for appearance
    - An orthotic should be aesthetically acceptable to the patient.
    - Its design should mimic the anatomical shape of the foot and ankle.
- Psychological considerations
    - Wearers should be encouraged and motivated to wear the orthotic.
    - Clinicians may need to educate patients and caregivers on the relationship between orthotic interventions and functional movement in order to improve compliance and to decrease fall risk.

Functional expectations with an AFO[12]

Sitting and standing

- A patient should be able to achieve a stable and balanced sitting and standing posture that is required for everyday tasks while wearing an AFO.
- The design of the AFO should not impede the patient's ability to independently stand or sit and should be considered when determining appropriate degrees of ankle dorsiflexion.
- The AFO should accommodate adequate foot and ankle position required to perform a sit-to-stand transition from a chair. To accomplish this, the hip, knee, and ankle should be positioned at or near 90 degrees.
- In static stance, the wearer should be able to achieve a normal skeletal alignment with the AFO.
- The AFO should allow for static stance without affecting normal standing posture for the wearer.
- An AFO should not require the concurrent use of an assistive device for safety and stability. While the patient may require an additional device to safely perform standing tasks, that decision should not be driven by the AFO alone.

Ambulation

- Wearing an AFO should optimize the individual's ability to safely ambulate.
- Any articulations and biomechanical controls (like an assist or stop) should contribute to improvements in the patient's walking capabilities.

AFO fabrication: clinician versus orthotist/prosthetist[10,12]

Recall that orthotic devices are made to encourage individual functional goals and to control anatomical deformities. This is achieved through a meticulous selection of orthotic design, materials, and components. Other factors that may affect the overall prescription of an orthotic device include:

- Duration of use (e.g., short versus long term)
- Patient's physical capabilities (e.g., does the patient have upper extremity motor function to be able to don/doff the device independently)
- Cost of the device

Indications for AFO fabrication by the clinician

- Unless the clinician has relevant experience in fabricating custom-made orthoses, AFOs should be ordered by the clinician when little-to-no adjustments are needed.
- Clinicians should also feel comfortable recommending a prefabricated AFO.
- The clinician may also consider ordering an AFO if the device is a trial or temporary.

Indications for AFO fabrication by the orthotist/prosthetist

- Custom-made orthoses are typically fabricated by orthotists because they require careful selection of the most appropriate materials and components to achieve the orthotic and functional goals for the patient.
- Coordinating the prescription of an AFO with an orthotist ensures that the brace is optimized for the wearer according to the most updated knowledge of components, materials, and articulations. When working alongside an orthotist to create or fabricate an orthotic prescription, the following measurements should be communicated:

- Functional objectives for the orthosis
- Hip, knee, ankle, and foot range of motion values (passive and active)
- Lower limb and ankle girth
- Patient's diagnosis and body weight
- Skin integrity
- Any sensation deficits
- Presence of abnormal tone or deformities

Section 2: Key Words

Non-articulating AFO (fixed) AFO - a specific type of AFO in which the design, material, and alignment are usually determined during the fabrication, fitting and adjustment process

Articulating (jointed) AFO - a specific type of AFO in which the calf and foot plates are connected by adjustable joints to allow for optimal ankle/foot alignment and function

Common gait parameters - includes frequently-measured walking components such as gait velocity, step length, kinetics, and kinematics

Dynamic response orthoses - a specific type of AFO that is usually recommended due to its ability to store and release energy as it provides support and normal range of motion

Joint mechanisms - can control various amounts of plantarflexion and dorsiflexion and other functions such as assisting, restricting, or stopping movement

Ankle trimlines - refers to the area in which the AFO is fitted around the ankle joint; can affect the rigidity about the joint

Varus hindfoot deformity - a deformity of the foot/ankle that causes abnormal (excessive) plantarflexion and inversion

Orthotist - a healthcare professional who works with devices designed to assist a limb or another part of the body

Prosthetist - a healthcare professional who works with devices designed to replace a limb or other parts of the body (e.g., due to an amputation)

Section 2: Summary

- Various types of AFOs can be prescribed, both prefabricated and custom, with different designs that address a wide range of neuromuscular problems.
- AFOs are considered to be biomechanical interventions that apply forces to facilitate or restrict joint movement. Therefore, each component of the AFO will play a role in the wearer's functional capabilities and influence gait parameters like gait velocity, step length, kinetics, and kinematics.
- When selecting an orthosis based upon material, clinicians must consider the overall weight of the orthosis. Since heavier materials require more energy expenditure during functional activities, many clinicians and wearers prefer AFOs that are made from strong, durable, and lightweight materials.
- Two common classifications systems for AFOs are material type and stiffness. When classified by material type AFOs can be divided into three categories: conventional, molded, and hybrid. AFOs that are classified by stiffness can be categorized into three groups: soft, semirigid, and rigid.
- Other AFOs, including those that are prefabricated or designed to manipulate ground reaction forces, can be beneficial for patients with specific needs.
- Designing an AFO should result from an interdisciplinary and comprehensive assessment of the patient's biomechanics, gait analysis, functional deficits, and anatomical deformities. Additionally, clinicians should recommend orthotic prescriptions based upon the ability of the device to improve upon the patients' participation in activities of daily living.
- Patients should also be educated on the importance of footwear and other appropriate assistive devices that will affect overall outcomes related to AFO usage.
- Common components of a pre-orthotic physical examination should include: Musculoskeletal Neurological, Integumentary, Cardiovascular/Pulmonary, Aerobic capacity, and Psychological and Cognitive Screening
- Once the design of the AFO has been agreed upon, clinicians should ensure that it is safe for the patient and will enable the patient to meet appropriate functional goals.

- When the patient may benefit from a custom brace or the clinician requires the assistance of a specialist, an orthotist may be consulted to ensure that the brace is optimized for the wearer according to the most updated knowledge of components, materials, and articulations.

Section 2: Personal reflection question

What is your biggest challenge when it comes to selecting an appropriate AFO for your patient(s)?

Section 2: Clinical scenario

Roberta is a 60-year-old woman who suffered a cerebral vascular accident with resulting left hemiparesis about 4 weeks ago. Although she has a history of type 2 diabetes and hypertension, both conditions are medically controlled and currently stable. Prior to the stroke, Roberta resided alone and was active in her community.

Pertinent exam findings are as follows:

- Intact sensation, cognition, and communication skills
- $4/8$ strength in the left quadriceps muscle, $2/5$ strength in the left tibialis anterior
- Mild difficulty dissociating volitional movements in the left lower extremity
- Gait quality: (+) varus positioning of her left ankle at initial contact, mild knee instability during stance phase.
- Gait assessment: Roberta can ambulate with modified independence using a single point cane, however, her gait speed is .7 m/s with evidence of mild foot drop during gait.
- Body mass index: 22
- (+) lower limb edema

Clinical scenario questions

1. Is Roberta appropriate for orthotic intervention? Why or why not?
2. State 2-4 functional goals for Roberta that could be achieved with the assistance of an orthotic device.

3. Describe the relevant components of a pre-orthotic physical exam that you would perform to develop an appropriate orthotic prescription for Roberta.
4. Using the SPAM acronym (Stabilize, Protect, Assist, or Manage), which primary objective(s) would be achieved through an orthotic prescription for Roberta?

Section 3 Gait Analysis and Implications for AFO use

Section 3 will review the characteristics of a normal gait cycle in order to prepare for the discussion on pathological gait and implications for orthotic use. Later in the section, therapeutic exercises that will enhance the patient's strength, neuromuscular control, and function while wearing an AFO will be shared.

Ideally, an interdisciplinary team that consists of a physician, physical therapist, and orthotist should conduct the gait analysis together. Many institutions currently conduct this type of program as a "Gait Lab" that also serves as a learning opportunity for young clinicians. Gait labs should be performed during several points throughout the patient's orthotic experience. Initially, it should be completed as part of the pre-orthotic examination in order to identify the patient's biomechanical and physical requirements. Then, once the orthosis has been prescribed, a second gait analysis should be conducted with the AFO to ensure proper fit, function, and training.

Normal gait characteristics[2,7,10]

Importance and purpose

Clinicians must have a thorough and fundamental understanding of the gait cycle in order to perform a functional gait analysis that is required to (1) identify the biomechanical need for an orthotic and (2) design an effective rehabilitation program once the AFO has been constructed. In the presence of impaired neuromuscular and musculoskeletal function that affects the gait cycle, a gait analysis is indicated. A gait analysis is performed through observation or instrument-assisted technology.

- In an observational gait analysis, clinicians rely upon the universally-accepted phases within a gait cycle to identify and evaluate individual kinematic, spatial, and temporal abnormalities.
- Instrumental gait analysis observes similar parameters as an observational gait analysis but provides quantitative data that also calculates distance and time. Because instrumental gait analysis often requires costly equipment, many

clinicians should be well-versed in performing observational gait analysis and its implications for pathological gait and orthotic devices.

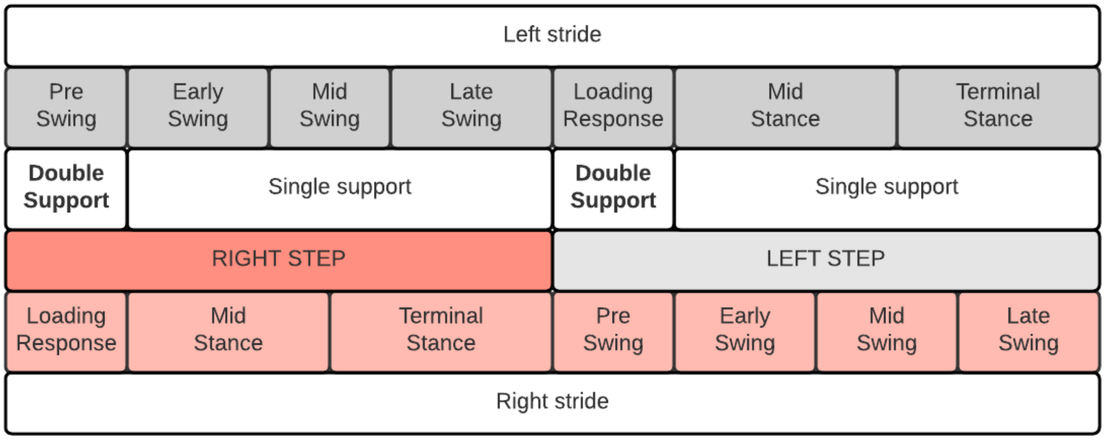
The purpose of the gait cycle is to propel the body forward, also known as forward locomotion. The following tasks must be accomplished in order to achieve forward locomotion:

1. Support of the body while not allowing the weight-bearing lower limb to collapse
2. Upright posture and balance
3. Proper clearance during swing phase
4. Effective initial contact with the ground
5. Energy and/or force to produce, maintain, or enable forward propulsion of the body
6. Shock absorption to slow forward progression of the body

Normal gait cycle

- Begins when one foot contacts the ground and ends when the same foot contacts the ground again. This is known as one cycle which also consists of alternating stance and swing phases.
- The gait cycle is broken down into two phases:
    - Stance phase: a period of time when each foot is in contact with the ground. Stance phase begins with heel contact at the loading response and ends with pre-swing.
    - Swing phase: a period of time when the foot is off of the ground as the limb advances. Swing phase starts with early swing and ends upon heel strike at the loading response.
- The stance and swing phases of gait are further divided into subphases. Figure 3.1 describes the subphases in relation to one another.
- During stance phase, the body is controlled and stabilized before it propels forward. In contrast, hip muscle activation and momentum propel the body forward during swing phase.

Figure 3.1 The gait cycle



Gait kinetics play an important role in forward propulsion of the body during a normal gait cycle.

- In a normal gait cycle, ground reaction forces (GRF) occur in close proximity to the leg and pass through both sides of the knee and ankle joints during stance phase. This implies that GRFs are minimized and do not significantly contribute to the destabilization of the leg during stance phase. As a result, the body does not need to expend large amounts of energy to fight against GRFs which correlates to low energy expenditure during a normal gait cycle.

- A key moment occurs during the end of stance phase when the GRF passes anteriorly to the knee joint but posterior to the hip. This allows for concurrent stabilization of the hip and knee joints without a significant amount of knee and hip extension muscle activation. However, it is critical that there is sufficient range of motion in the hip and knee to allow for this moment to accurately occur.

Significance of ankle motion during a normal gait cycle

- The ankle has a significant role throughout the gait cycle. It is responsible for:
    - Shock absorption during loading response
    - Energy storage
    - Forward propulsion of the body

- Recall that the ankle joint is a hinge-type joint with three degrees of freedom to allow for dorsiflexion/plantarflexion, inversion/eversion, and pronation/supination.
    - Ankle dorsiflexion/plantarflexion is responsible for forward progression during stance phase.
    - Ankle dorsiflexion is also important to ensure foot clearance during the swing phase.
- At midstance, the ankle is positioned in a small amount of dorsiflexion to allow the tibia to incline forward as the femur advances. This is known as tibial inclination.
- At terminal stance, the ankle is held in small dorsiflexion moment, commonly mistaken for plantarflexion, by isometric muscle activation of the plantarflexors. It is only during preswing when the ankle begins to plantarflex as the limb is unloaded.

Pathological gait[2,7,10,11,12]

- Individuals with ankle dysfunction typically have muscular weakness in the plantarflexion and/or dorsiflexion muscles. Weakness in the muscles that control the ankle has been correlated with decreased walking capacity, limited participation in activities of daily living, and poor quality of life.[2]
- Weakness of the plantarflexion muscles affects:
    - The gastrocnemius, soleus, and the peroneal and posterior tibial muscles
    - Weakness in these muscles decreases the forces that are essential for forward momentum during preswing.
- Weakness of dorsiflexor muscles affects:
    - The tibialis anterior, extensor digitorum longus, and extensor hallucius longus
    - Weakness in these muscles results in inadequate lifting of the toes during the swing phase, also commonly known as foot drop.
    - An individual with a foot drop may exhibit toe drag, poor gait speed, and shortened step length resulting in a high metabolic cost of walking and an increased risk for falls.

- After a stroke, the foot and ankle may be positioned in a fixed plantarflexion moment which will affect both swing and stance phases of the gait cycle.
    - This may be caused by upper motor neuron dysfunction resulting in plantarflexion tone, spasticity, or a contracture.
    - Regardless of the cause, a fixed plantarflexion position causes limitations in forward progression of the tibia during midstance and may lead to excessive knee extension.
- Other neuromuscular conditions cause a pathological gait known as foot drop gait.
    - Foot drop gait is characterized by foot-slap during initial contact and toe drag during the swing phase of a gait cycle. This is associated with dorsiflexion paresis or paralysis.
    - To compensate, individuals will drag their affected limb in a circle by activating their hip flexors during swing phase. This gait deviation is referred to as circumduction.
    - Individuals with foot drop gait will typically have a shorter stance phase and step length on the affected side which results in an asymmetric gait pattern.
    - Foot drop gait has been associated with decreased range of motion, poor gait speed, high energy expenditure, and an increased risk for falls.[2]
- Changes to the foot/ankle position will also significantly affect gait kinetics and GRFs throughout the entire lower limb.
    - Persistent plantarflexion interferes with weight bearing through the heel, which is necessary for heel strike during loading response.
    - Misplaced GRFs, combined with limited tibial advancement during midstance, creates an excessive knee extension moment that can lead to hyperextension, also commonly referred to as "extensor thrust." Consequently, the knee becomes incredibly stable in this position, which makes the necessary knee flexion during terminal stance difficult to initiate.
    - Furthermore, excessive plantarflexion at the ankle changes the GRF vector at the hip joint that can result in abnormal hip flexion and retraction, as opposed to hip extension, in terminal stance. In response, hip extensors

must activate at a time when they would normally be inactive (or, at the very least, minimally active), thus, placing high demands upon the neuromuscular and energy systems.

- Stability of the entire lower limb is affected and can result in changes to step length, gait speed, and efficiency.

Effects of an AFO on Pathological Gait[2,7,8,10,11,12,13]

For an AFO to be successful, it must apply forces to the involved limb in a way that takes the underlying anatomical impairments and pathological gait kinematics into consideration. The AFO should apply force(s) in a manner that maximizes lever arms and equally distributes pressure over a large area. Accuracy in prescription and design of the AFO is needed to ensure comfort for the wearer as well as to control for foot and ankle deformities.

- In the presence of dorsiflexion weakness, an AFO can (1) prevent toe drag and/or foot drop and (2) decrease the amount of compensatory hip flexion needed to clear the limb during swing phase.
    - AFOs can prevent foot drop during the swing phase and improve ground clearance, thus, reducing the risk of falls.
    - This is achieved by applying forces to the wearer's posterior calf, the plantar surface of the foot near the metatarsal heads, and to the dorsum of the foot near the ankle joint.
    - An ankle strap should be considered in the presence of increased tone. This helps to help maintain the proper foot position in the AFO within the shoe.
- In the presence of weak quadriceps, individuals may benefit from anterior shell or solid AFOs with 2-5 degrees of plantarflexion. This particular design is often referred to as a Floor Reaction AFO, which was previously discussed in Section 2.
    - Floor reaction AFOs are effective by manipulating the GRF during the midstance phase of gait.
    - As a result, the individual with weak quadriceps may be able to stabilize the knee during stance phase without needing a knee-ankle-foot-orthosis (KAFO).

- For individuals with rigid/solid AFOs to control tone, the AFO will assist the wearer in achieving heel strike but will subsequently affect push-off at terminal stance since plantarflexion is limited.
  - If an individual presents with extensor tone, then correction of ankle supination should be addressed. If left untreated, it may contribute to the formation of genu varus at the knee and eventually cause ligamentous laxity or structural deformities.
  - Traditionally, orthotic interventions for varus deformities (supination of the foot) consisted of a conventional double upright AFO with a lateral T-strap around the middle of the brace. Since recent literature has proven this solution to be ineffective, modern-day prescriptions to correct varus deformities usually consist of plastic.[7]
- In contrast, flexible solid AFOs allow for some degrees of plantarflexion and may enable dorsiflexion during pre-swing since the flexible material stores energy and acts like a spring during the swing phase. This type of brace would not be appropriate for those with moderate to severe amounts of spasticity as it would trigger clonus or a strong plantarflexion moment.
- For individuals with hemiplegia, AFOs can decrease deformities associated with plantarflexion and inversion contractures, improve balance, and affect gait parameters such as heel contact, shock absorption, stability during midstance, forward progression of the tibia, and foot clearance. Additionally, prescribing an AFO with a posterior stop may reduce genu recurvatum whereas anterior stops may assist in facilitating weight shifting on the affected side.
- For individuals with CP, AFOs have been found to improve stride length, gait velocity, and foot clearance during swing phase. Commonly prescribed AFOs for this special population include hinged and floor reaction AFOs.

Functional exercises to perform alongside AFO training[10,11,12]

Whenever possible, the physical therapist and physical therapy assistant should instruct the patient in methods to develop static and dynamic standing balance, pre-gait/gait retraining, and other functional activities with the AFO. Successful achievement of these tasks relies upon coordination of the musculoskeletal and neuromuscular systems with consideration of the patient’s muscle tone, cardiopulmonary endurance, body weight, age, and level of motivation.

Clinicians should prioritize the following interventions with patients while wearing new AFOs:

1. Functional training with the AFO donned is encouraged. This includes:
    - Transfer training
    - Stair/curb negotiation
    - Uneven (outdoor) surfaces
    - Ramps
    - Floor transfers
    - Vehicle transfers
    - Any other functional tasks that are meaningful for the patient
2. Functional activities with an assistive device (if appropriate)
3. Standing Balance
    - Weight shifting in stance
    - Dual task training in static stance with visual/cognitive distraction
4. Pre-gait/Gait training
    - Dissociation of lower leg movements
    - Retraining compensatory strategies
    - Limb advancement with and without Functional Electrical Stimulation (FES)
    - Eccentric control of foot/ankle movements
    - Forward and backwards gait, sidestepping, turn in place
    - Dual task training during gait with visual/cognitive distractions and upper limb carrying tasks/manipulation
    - Mental practice and/or motor imagery
5. Other exercises that maintain or improve joint range of motion, strength, and cardiovascular fitness
    - Range of motion
        - Talocrural joint mobilizations
        - Metatarsal abduction exercises

        - Mobilizations with movement
        - Soft tissue mobilization
        - Stretching
    - Strength
        - Weight bearing and non-weight bearing positions
        - FES to the weakened muscles
        - Strengthening exercises for plantarflexion and dorsiflexion
        - Lower extremity strengthening, specifically quadricep and glute strength
    - Cardiovascular
        - Treadmill walking
        - Outdoor gait training

A brief comment about FES[11]: Functional electrical stimulation (FES) is commonly applied to the peroneal nerve to improve foot drop secondary to weak eversion and dorsiflexion. It can be used as an alternative or supplement to AFO in individuals with hemiparesis or paralysis. Commonly used products consist of a small cuff that is worn proximally, near the fibular head, with a skin electrode that is placed directly over the fibular nerve. These systems enable dorsiflexion and eversion during the swing phase, thus, reducing foot drop and toe drag. Several research studies have compared the performance of those who ambulate with FES with individuals who only wear an AFO. Both groups exhibit improvements in gait speed, however, FES wearers express higher amounts of satisfaction which may be a factor in long-term compliance. Additionally, FES may benefit some children who present with spastic hemiplegia and are non-compliant with wearing their AFOs.

Section 3: Key Words

Gait cycle - refers to the interval of time between any of the repetitive events of walking

Gait analysis - a method for identifying biomechanical abnormalities in the gait cycle

Observational gait analysis - describes a specific type of gait analysis in which clinicians rely upon the universally-accepted phases within a gait cycle to identify and evaluate individual kinematic, spatial, and temporal abnormalities

Instrumental gait analysis - describes a specific type of gait analysis in which clinicians use technology to quantify kinematic, spatial, and temporal abnormalities in the gait cycle as well as overall distance and gait speed

Stance phase - refers to a specific period of time during the gait cycle when each foot is in contact with the ground. It begins with heel contact at the loading response and ends with pre-swing.

Swing phase - refers to a period of time when the foot is off of the ground as the limb advances

Plantarflexion muscles - name given to the group of muscles (gastrocnemius, soleus, and the peroneal and posterior tibial muscles) that produce plantarflexion

Dorsiflexion muscles - name given to the group of muscles (tibialis anterior, extensor digitorum longus, and extensor hallucius longus) that produce dorsiflexion

Foot drop - refers to a weakness in the dorsiflexion muscles that results in inadequate lifting of the toes during the swing phase

Foot drop gait - refers to a type of pathological gait that is associated with dorsiflexion paresis or paralysis and is characterized by foot-slap during initial contact and toe drag during the swing phase of a gait cycle

Circumduction - refers to a compensatory strategy in which individuals drag their affected (weak) limb in a circle during swing phase to clear the foot

Extensor thrust - refers to an excessive knee extension moment during midstance due to changes in the GRF vector

Section 3: Summary

- Understanding the gait cycle is necessary for clinicians to perform a functional gait analysis to identify the biomechanical need for an orthotic. Additionally, it will enable the clinicians to design an effective rehabilitation program once the AFO has been constructed.
- The purpose of the gait cycle is to propel the body forward, also known as forward locomotion. It is broken down into two phases: swing and stance. One gait cycle occurs when one foot contacts the ground and ends when the same foot contacts the ground again.

- During the gait cycle, the ankle is responsible for shock absorption during loading response, the storage of energy, and forward propulsion of the body.
- Individuals with ankle dysfunction typically have muscular weakness in the plantarflexion and/or dorsiflexion muscles. Weakness in the muscles that control the ankle has been correlated with decreased walking capacity, limited participation in activities of daily living, and poor quality of life.
- The AFO should apply force(s) in a manner that maximizes lever arms and equally distributes pressure over a large area. Accuracy in prescription and design of the AFO is needed to ensure comfort for the wearer as well as to control for foot and ankle deformities.
- Whenever possible, clinicians should instruct the patient in methods to develop static and dynamic standing balance, pre-gait/gait retraining, and other functional activities with the AFO.

Section 3: Personal reflection question

Are you comfortable with performing a functional gait analysis? How can you create opportunities to improve your observational gait skills with your patients with ankle-foot dysfunctions?

Section 3: Clinical scenario

Paula is a 50-year-old woman who was diagnosed with Relapsing-Remitting Multiple Sclerosis over 20 years ago. Until now, Paula's condition was fairly stable, and she was able to work as a librarian without difficulty. Following the recent death of her husband, she experienced a relapse that lasted several weeks and resulted in right hemiparesis with foot drop in swing phase and knee hyperextension throughout stance phase with occasional knee buckling.

During Paula's short inpatient rehabilitation stay, she was given an off-the-shelf solid AFO and has used it for the past few weeks. She continues to ambulate with a single point cane for level ambulation with an asymmetrical step length and slow gait speed. Paula was referred to outpatient physical therapy to improve her mobility and safety. Her goals are to be able to climb 5 stairs to enter her grandson's home and to attend the library's monthly Book Club meeting.

Results of her functional assessment are as follows:

- Gait: Asymmetric weight-bearing, decreased stance time on the right lower extremity, lack of right hip extension past neutral. Ambulates with cane in left hand.
- Gait speed: 0.6 m/s with a single point cane and right solid AFO (RLE SAFO)
- Transfers: Modified independence with excessive posterior lean and use of armrests
- Stair negotiation: Non-reciprocal, leads with left lower extremity

Clinical scenario questions

- What is the function of a solid AFO? How does it assist function, in Paula's case?
- Is a solid AFO appropriate for Paula's presentation? If not, name 1-2 additional options that may be more suitable for her.
- State 2-3 functional goals that would be achievable through therapeutic exercise and functional activities.
- Describe 2-3 therapeutic interventions that would be appropriate to improve Paula's ankle range of motion and strength.

Section 4: Other considerations to AFO prescriptions

Physical therapists can contribute to the orthotic process in several ways. Initially, the clinician may see the patient prior to the orthotic prescription and then again once the device has been delivered. Afterwards, the clinician may need to conduct functional training to facilitate proper use and care of the orthosis. In an ideal setting, the clinician plays an instrumental role within the interdisciplinary clinical team that oversees all orthotic management, including the orthotic prescription, examination, and pre/post functional training.

Without an interdisciplinary team approach to orthotic prescription, the clinician is expected to perform the following tasks when recommending an orthotic device: preorthotic examination, recommendations for the orthotic prescription, orthotic examination and evaluation, orthotic instruction and training, and the final examination and follow-up care. At minimum, clinicians should work closely with the orthotist and prescribing physician to ensure that the patient's needs are being met and that the device is appropriate for the patient's current functional status.

The importance of timing AFO interventions, especially after stroke[5,7]

- Clinicians should be aware of the importance of timing when prescribing an AFO to improve and enhance function and safety. If an AFO could have a significant effect on reducing a patient's risk for falls, then the prescription and fitting should be done as soon as possible. While AFOs are largely viewed as compensatory strategies that do not promote restoration of normal movement, they should be strongly considered for patients who expend high amounts of energy to complete basic, functional activities.

- There is evidence to imply that AFOs may be more beneficial when prescribed early in the recovery process for individuals after stroke. One study in particular recommends prescribing an AFO, when indicated, about one month following the initial injury.[7] This recommendation stems from the theory that AFOs may assist in preventing the development of abnormal movement patterns. Additionally, researchers recommend them to be highly effective when combined with other therapeutic strategies during early intervention post-stroke rehabilitation.

- For individuals whose recovery is further along, such as the subacute phase of stroke recovery, research studies have demonstrated that AFOs have positive effects on balance, walking ability, and activities of daily life.[7]

Shoe, sock & insert considerations[7,11]

Footwear, socks, and additional inserts are not considered to be part of the AFO design or fabrication, but they exert a considerable amount of influence on the overall fit, function, and wearability of the AFO. Because of this, they are considered to be an integral component of orthotic management.

Considerations for shoewear

- The thickness, stiffness, contour, and width of the patient's shoe are important, specifically in heel and sole.
    - Heel height is also important to consider as it can influence the ankle of tibial inclination. The heel height is measured as the distance between the heel and sole.
    - Stiffness of the heel may also affect the tibial, particularly tibial advancement during stance phase. Heels that are too soft can potentially increase the wearer's tendency to hyperextend the knee during midstance.
    - Heel width is correlated with ankle/foot stability. Patients who require extra stability should purchase a shoe with a wide heel, which can improve mediolateral stability.

- Recommend that patients select shoes with wide toe boxes to accommodate the width of the AFO and to ensure that there is no additional pressure on the lateral aspect of the foot.

- When learning how to don/doff the AFO along with the shoe, patients may initially require a long-handled shoe horn to aid in the process. Ideally, the AFO should be donned prior to putting on one's shoe in order to ensure that the foot is correctly placed in the AFO. The shoe's original manufacturer insert may need to be removed in order for the AFO to properly fit within the shoe.

- Patients may need to select a new pair of shoes with different closures, depending on the style and size of the AFO. Shoes with Velcro closures may be easier for the wearer and/or caregiver to manage. They are also easy to adjust and can accommodate a wider girth.

- Patients should be encouraged to bring new shoewear to their AFO fittings so that they can be further evaluated by the clinician(s) or orthotist. Additionally, patients should be aware that any future changes to their footwear may affect the way in which the AFO fits and functions during daily activities.

- There are special circumstances in which patients may require custom shoewear to accommodate their new AFO. However, not all patients will require custom shoewear for a new AFO. Before exploring that option, clinicians should attempt to remove the shoe's insole, stretch the shoe, or find a different size. In the event that these solutions are not effective, custom shoewear may be indicated, especially for individuals with severe deformities or sensory impairments.

Considerations for socks

- Thin socks, preferably white, should be worn underneath the AFO at all times. This is important to reduce skin friction and pressure from the device closure(s), articulations, pads, or material.

- Cotton socks are preferred since they absorb perspiration and can protect the skin from minor skin tears.

- Thick socks are not recommended as they can add to the limb girth and affect the fit of the AFO.

Considerations for inserts

- While additional footwear modifications are rarely necessary if the AFO has been appropriately designed, they may be indicated in certain situations when the wearer has a fixed deformity that requires extraneous support. Footwear modifications are categorized as internal or external inserts.
    - Internal modifications are typically used to provide cushioning, shock absorption, pressure relief, or to balance small leg length discrepancies on the contralateral limb. Because these internal modifications do not permanently alter the shoe and are relatively inexpensive, they can be easily trialed along with AFOs and shoewear.
    - External modifications are added to the outside of the shoe and are viewed as permanent changes. They are typically used to balance major leg length discrepancies, relieve pressure, or alter the center of pressure on the weight-bearing foot.
- Heel wedges are slanted blocks that are usually placed on the medial or lateral aspect of the wearer's shoe. They are used to address varus, valgus, or equinus deformities.
- A pressure relief pad is a type of shoewear modification that can primarily reduce pressure on sensitive areas by shifting the weight to another aspect of the foot within the AFO.
- A rocker sole may be indicated to improve the transition from heel strike to preswing when motion at the metatarsal heads is unavailable, blocked, or undesired. These modifications are beneficial for patients with increased areas of pressure on the metatarsal heads who still require assistance with ankle dorsiflexion during stance phase.

Adult and pediatric recommendations for AFO wear schedules

Wear schedules will drastically differ according to the wearer's diagnosis, functional status and goals, cognitive status, skin integrity, tolerance, age, and compliance. Further, wear schedules can vary between manufacturers, AFO design, and orthotist and clinician preference. When in doubt, clinicians should consult with an orthotist regarding the application of a newly-fabricated AFO to adults and children. Examples of wear schedules for adults and children can be found in Table 4.1.

Upon receiving the AFO for the first time, patients should wear the device for at least 30 minutes in the presence of a clinician or orthotist. Once the 30 minutes has expired, the patient should be taught to doff the AFO and perform a skin check. Some redness on areas of high pressure is to be expected, but any skin discoloration should abate within 20-30 minutes of removing the AFO.[19,20]

Table 4.1 AFO wear schedules for adults and children[19,20,21]

	Day 1	Day 2	Day 3	Day 4
Wear schedule for adults	Wear 1 hour on, 1 hour off, up to 3 times a day.	Wear 2 hours on, 1 hour off, up to 3 times a day.	Wear 3 hours on, 1 hour off, up to 2 times a day.	Wear 4 hours on, 1 hour off, up to 2 times a day.
Wear schedule for children	1 hour on, 3 times daily-total 3 hours	2 hours on, 3 times daily-total 6 hours	4 hours on, 2 times daily-total 8 hours	
	Week 1	**Week 2**	**Week 3**	

It is important that all patients follow some type of wear schedule. They should be thoroughly discussed with the patient, caregiver, and other members of the interdisciplinary team and include a gradual progression to build the patient's tolerance to the orthotic device in order to diminish the chances of skin or joint irritation. Over time, wearing the AFO will become second nature to the patient, like any other article of clothing.

Other considerations for wearing an AFO

- Unless prescribed otherwise, AFOs should not be worn while the patient is sleeping.
- Encourage patients to wear long, thin white cotton socks underneath their AFO. Patients should be discouraged from wearing thick socks as this may improperly distribute pressure within the orthotic.
- In children, it may take up to three weeks to complete the wear schedule. Afterwards, the orthotic should be worn for a majority of the time that the child is awake.

- When removing a child's AFO, redness that lasts 10-15 minutes is normal. However, if redness persists longer than 15 minutes, clinicians should reassess the brace for areas of increased pressure and inappropriate fit.

Checking for proper fit

All AFOs must be examined for proper fit prior to functional training with the new orthotic. By doing so, clinicians can check the safety of the device to ensure that it does not cause harm for the wearer. Any problems that are identified should be immediately addressed prior to the patient wearing the AFO for daily functional use.

How to examine an AFO for proper fit[7,10,11]

The following steps should be taken to examine the AFO for proper fit:

1. Examine the device to ensure that it has been made as prescribed without any faults in the manufacturing.
2. Remeasure the patient's weight, ankle and calf girth, and joint range of motion to identify any changes that may have developed since the AFO fitting.
3. Assess the fit of the device on the patient while sitting and standing.
4. Assess the fit of the device on the patient under dynamic conditions, like walking or negotiating stairs.

When assessing the fit of the AFO during static activities (like sitting or standing), the clinician should verify that the device does not cause excessive pressure on bony prominences. It is appropriate to teach the patient and/or caregiver(s) how to properly don and doff the AFO and perform daily skin checks. Table 4.2 includes a checklist of questions that should guide clinical decision-making when assessing the fit of the patient's new AFO.

Table 4.2 Considerations for static assessment while the patient is wearing a new AFO

Actions to perform	Questions to ask
Assist the patient in donning the AFO and examine its fit while the patient is seated. Next, ask the patient to stand. Observe the fit during static stance and any changes in the patient's performance during the transfer. Educate the patient and/or caregiver to don/doff the AFO appropriately. Be sure to add teaching strategies for inserts, shoewear, and AFO closures. Depending on the patient's upper extremity strength and dexterity, he/she may require assistance from a caregiver to safely don/doff the device.	Is the AFO comfortable? Are the joint articulations appropriately aligned with the patient's anatomical joints? Are there any areas of excessive pressure? When the patient is standing, does the AFO inhibit the ankle/foot alignment in either plane? Is the patient able to balance while standing still with the AFO donned?

When assessing the AFO's fit during dynamic activities, the clinician should verify that the device enhances the wearer's participation in functional activities. If the patient has never worn an AFO, then the clinician should provide training to instruct the patient on the usage of the device. Afterwards, the AFO should be reassessed to ensure that it did not cause excessive pressure or irritation on bony prominences, like the malleoli, metatarsal heads, heel, or plantar surface of the foot. Table 4.3 includes a checklist of questions that should guide clinical decision-making when assessing the fit of the patient's new AFO during dynamic tasks.

Table 4.3 Considerations for dynamic assessment while the patient is wearing a new AFO

Actions to perform	Questions to ask
Examine the fit of the AFO during functional movements like walking, climbing stairs, negotiating a curb, and transferring between different surfaces. Observe any changes in the patient's functional performance and make note of them to include in the treatment plan. Observe for signs of excessive pressure or skin irritation during and after movement. Assess for new gait abnormalities with the AFO donned. Educate the patient on the importance of performing skin checks immediately after donning the AFO and 30 minutes post.	Is the AFO stable during movement? Does the orthosis move on the body? Does the orthosis function as prescribed? Does the orthosis assist in helping the patient achieve functional goals? Are there any adjustments that should be made? Can any issues be addressed by the orthotist? Is the patient satisfied with the orthosis?

Common issues that may affect proper fit of the AFO[6,7,8]

Despite best efforts, some issues may arise during the orthotic fitting and training that may negatively affect the wearer and/or fit of the AFO. While these issues are highly individualized, there may be some commonalities that are described in detail below.

1. **Issues with AFO stiffness**

   If the AFO is deemed to be too stiff (e.g., resists too much motion), then the patient's ability to transfer, balance, and ambulate may be affected. Conversely, if the AFO allows too much motion (too flexible), then the AFO may not provide enough support to prevent abnormal movement patterns, like extensor tone. Any issues regarding the stiffness of the AFO should be remedied as they may affect the wearer's functional status and safety with mobility.

2. **Issues with articulated AFOs**

   Frequent adjustments to articulated AFOs may be necessary, especially in the first few days of the patient's wear schedule. Ultimately, any adjustments to the design should optimize biomechanical processes and overall function of the AFO. Other adjustments, like adding a heel wedge to the contralateral (unaffected) limb, may also be indicated, especially in the presence of a leg length discrepancy caused by the AFO.

   Much of the fine tuning done on articulated AFOs aims to manipulate the ground reaction force to promote ease of movement during the gait cycle. Many orthotists recommend a shank-to-vertical angle (SVA) of 10°–12° during mid-to-late stance phase which enables the ground reaction force vector to pass anteriorly to the knee joint and posterior to the hip joint.[6] As mentioned in previous sections, this closely mimics normal biomechanics during gait. Adding a heel wedge may affect tibial inclination. For reference, a 5 mm heel wedge will increase the angle of tibial inclination by about 2° which will move the hip forward approximately 30 mm.[7]

3. **Issues with non-articulated AFOs**

   Many adjustments that are needed for non-articulated AFOs usually involve adjusting the angle of tibial inclination with the device to optimize the position of the ground reaction force vector at the knee and hip. This can be accomplished by adding or removing heel wedges, changing the amount of dorsiflexion allowed in the brace, or adjusting the positioning of the patient's foot in the AFO on the affected side. If the tibia is placed directly perpendicular to the ground, the ground reaction force vector cannot align normally and, therefore, will result in knee hyperextension. Adding heel wedges may remedy this scenario and optimize the GRFs at the hip and knee joints.

   Clinicians should be aware that many special populations, like stroke survivors, are extremely sensitive to AFO adjustments or small changes to shoewear design. Because of this, any necessary adjustments may need to be conducted in gradual amounts to allow the wearer time to acclimate to the changes.

4. **Issues with skin integrity**

Fortunately, the presence of sensorineural deficits, neuropathy, or impaired skin integrity does not necessarily contraindicate the use of an AFO as long as the fit is optimal for the patient. Clinicians must be extra vigilant for signs of skin irritation and breakdown and teach patients/caregivers how to perform daily skin checks after donning the brace.

Best practice for follow-up visits[7,11]

Patients who have been prescribed an AFO should be routinely assessed at regular intervals. This practice guideline is based upon the fact that patients, especially those with progressing conditions, have the potential to change over time which will increase the risk of skin irritation and/or breakdown. These patients also may experience large fluctuations in functional status that may indicate a need for different AFO prescription.

Additional recommendations are as follows:

- Patients should be seen throughout the wear schedule to ensure proper fit.
- Articulations should be checked at least every six months for evidence of wear/tear.
- Patients should be able to easily contact their orthotist for questions, concerns, and follow-up.
- Shoewear should be assessed for functionality and checked regularly for signs of wear/tear that may adversely affect AFO function.
- For those who require a new AFO prescription due to a change in function status or disease progression, they should also receive concurrent access to physical therapy services.
- AFO use should not be discontinued without consultation of the interdisciplinary team.

In addition to the best practice recommendations, patients should be aware of how to care for their devices to minimize breakdown and repairs needed.

- Advise patients to use a damp cloth to frequently wipe plastic parts and bands. Do not encourage the use of hair dryers or heat may affect the integrity of the AFO's material.

- Teach the patient to observe for cracking in the plastic or deterioration of leather materials.
- All closure straps should be checked for lint and dirt that may interfere with the closing action.

Documentation[14]

Reimbursement for AFO devices can significantly vary depending upon the insurance provider and patient diagnosis. One of the ways in which clinicians can contribute to the reduction of out-of-pocket costs on behalf of the patient is by providing thorough documentation that explicitly describes the patient's functional benefit from an orthotic device. In some cases, clinicians may assist the orthotist in writing a letter of necessity to support the patient's case.

The following tips may be helpful when writing supporting evidence for an AFO prescription:

- Describe the AFO using patient-centered language. Include information that describes how the patient's impairments relate to loss of function, safety, and mobility. Include a synopsis of the patient's condition, progression, and any recent changes to his/her functional status. Clinicians may also choose to describe meaningful functional outcomes, like gait speed or fall risk, and how these findings pose a risk for further injury or decline. This will become especially important when writing a letter of necessity to justify a patient's need for a custom AFO.
- If the AFO has already been prescribed and fitted, describe how the patient must be frequently monitored to ensure that the AFO fits and functions properly. The patient will also require education and/or family training regarding wear schedule and care of the AFO. Should the patient require training to use the device, the clinician can also write supporting documentation to justify the additional necessary visits.
- When recommending a new AFO prescription, documentation should include objective measurements of the patient's posture, gait parameters, gait speed, anatomical alignment, type of device, and ways in which the AFO will enhance the wearer's ability to perform functional tasks. Additionally, the clinician should describe components of the post-prescription examination, including education regarding donning/doffing the AFO, training, and proper care of the device.

- Documentation should also address interventions that will enhance the patient's functional outcomes with/without the use of the AFO.
- Lastly, clinicians should document their plan to provide patient and caregiver/family education with respect to skin integrity, any ongoing maintenance of the AFO, and periodic follow-up visits with the clinician or orthotist.

Section 4: Key Words

Shoe horn - refers to an adaptive tool with a short handle that flares into a longer spoon-like head. The shoe horn is meant to be held against the inside back of a shoe so that a person can slide the heel easily along its basin to the inner sole.

Rocker sole - describes a shoe that has a thicker-than-normal sole with rounded heel

Wear schedules - a time frame that is designed to allow your body to gradually accommodate the new device

Static activities - refers to tasks that require a person to independently maintain a position without moving or falling

Dynamic activities - refers to a person's ability to maintain a position while moving, such as while walking, running, or standing up and throwing a ball

Bony prominences - a collective term that refers to anatomical structures that are not surrounded by large amounts of soft tissue

Heel wedge - slanted orthotic inserts that can be applied internally within the shoe or externally on the shoe to lift and control the position of the heel, correct pronation, supination, or ankle instability

Shank-to-vertical angle - described as the angle of the shank relative to the vertical and a common gait parameter with respect to AFOs.

Tibial inclination - refers to the angle in which the tibia is aligned and often discussed in relationship to abnormal joint angles

Section 4: Summary

- Without an interdisciplinary team approach to orthotic prescription, the clinician is expected to perform the following tasks when recommending an orthotic device: preorthotic examination, recommendations for the orthotic prescription, orthotic examination and evaluation, orthotic instruction and training, and the final examination and follow-up care. At minimum, clinicians should work closely with the orthotist and prescribing physician to ensure that the patient's needs are being met and that the device is appropriate for the patient's current functional status.

- Clinicians should be aware of the importance of timing when prescribing an AFO to improve and enhance function and safety, especially in patients following stroke. One study suggests providing an AFO as early as one month following stroke.
- Footwear, socks, and additional inserts are considered to be an integral component of orthotic management despite not being part of the AFO design or fabrication. They exert a considerable amount of influence on the overall fit, function, and wearability of the AFO.
- Wear schedules should be provided for every patient upon receiving a new AFO. They should be thoroughly discussed with the patient, caregiver, and other members of the interdisciplinary team and include a gradual progression to build the patient's tolerance to the orthotic device in order to diminish the chances of skin or joint irritation.
- Examining the AFO for proper fit includes checking to ensure that it has been made as prescribed, taking remeasurements of the patient's lower extremities, and assessing the device under static and dynamic conditions.
- Common issues that may affect the fit of the AFO include problems with the stiffness of the brace, articulations, ground force reaction vector, and contact with the patient's skin.
- All patients should be seen for frequent follow-up visits to ensure that the patient continues to benefit from current AFO design.

Section 4: Clinical scenario

Paula, who was previously introduced in Section 4, has been attending outpatient physical therapy for four visits. Upon meeting with the orthotist, the interdisciplinary team decided that Paula should be prescribed a new custom AFO. She was fitted for a hinged AFO with a dorsiflexion assist to assist with foot clearance during swing phase.

Following the preorthotic examination, Paula is ready to complete her orthotic examination and evaluation, orthotic instruction and training, and the final examination and follow-up care.

Prior to the AFO fitting, Paula's outcome measures were as follows:

- Gait: Asymmetric weight-bearing, decreased stance time on the right lower extremity, lack of right hip extension past neutral; ambulates with cane in left hand.
- Gait speed: 0.8 m/s with a single point cane and right solid AFO (RLE SAFO)
- Transfers: Modified independence with mild posterior lean and use of armrests
- Stair negotiation: Non-reciprocal, leads with left lower extremity

Additionally, Paula has recently started to see an occupational therapist for impaired fine motor coordination and loss of intrinsic muscle strength in the right hand.

Clinical scenario questions

1. How should the clinician check that Paula's hinged AFO fits properly?
2. What are some considerations that may affect an individual's wear schedule? What type of wear schedule would be appropriate for Paula?
3. Name 2 ways in which articulated AFOs can affect an optimal fit and consequently disrupt Paula's functional status.

Section 5: Clinical Scenarios revisited

Section 2: Clinical scenario

Roberta is a 60-year-old woman who suffered a cerebral vascular accident with resulting left hemiparesis about 4 weeks ago. Although she has a history of type 2 diabetes and hypertension, both conditions are currently medically controlled and stable. Prior to the stroke, Roberta resided alone and was active in her community.

Pertinent exam findings are as follows:

- Intact sensation, cognition, and communication functions
- 4/8 strength in the left quadriceps muscle, 2/5 strength in the left tibialis anterior

- Mild difficulty dissociating volitional movements in the left lower extremity
- Gait quality: (+) varus positioning of her left ankle at initial contact, mild knee instability during stance phase.
- Gait assessment: Roberta can ambulate with modified independence using a single point cane, however, her gait speed is .7 m/s with evidence of mild foot drop during gait.
- Body mass index: 22
- (+) lower limb edema

Clinical scenario questions/responses

1. *Is Roberta appropriate for orthotic intervention? Why or why not?*

   In order to answer this question, it is helpful to ask these three reflection questions regarding the patient's presentation. First, is it likely that an orthotic will be helpful and improve Roberta's function? Secondly, what type(s) of orthotic would be most effective? Lastly, would Roberta benefit from any other therapeutic interventions to achieve optimal outcomes?

   If the answer to these questions is "yes," then it is likely that Roberta would benefit from an orthotic.

   An AFO would most likely improve Roberta's ability to ambulate safely while lowering her risk for falls. She may benefit from an AFO that improves foot drop throughout the gait cycle and lowers energy expenditure to allow for better gait quality and speed.

2. *State 2-4 functional goals for Roberta that could be achieved with the assistance of an orthotic device.*

   Some examples of appropriate functional goals for Roberta could include:

   - Ambulate 50 feet (household distances) with a single point cane at 1.2 m/s
   - Ambulate at least 150 feet (community distances) with a single point cane at 1.0 m/s
   - Ambulate on uneven surfaces with a single point cane without loss of balance

- Safely perform sit-to-stand transfers, from various surface heights, with use of an AFO without loss of balance

3. *Describe the relevant components of a pre-orthotic physical exam that you would perform to develop an appropriate orthotic prescription for Roberta.*

   The goal of the pre-orthotic physical exam would be to identify limitations and functional impairments that may be improved with an AFO. Because Roberta exhibits structural abnormalities (varus positioning and lower limb edema), the clinician should prioritize the following measurements:

   - Joint mobility (passive and active range of motion)
   - Joint stability (ligaments, capsule, articular surfaces)
   - Deformities or alignment abnormalities
   - Motor function
   - Selective muscle control
   - Muscle strength
   - Limb and ankle girth

   Additionally, the clinician should include functional outcome measures to objectively record gait speed, static and dynamic balance, and transfer ability.

4. *Using the SPAM acronym (Stabilize, Protect, Assist, or Manage), which primary objective(s) would be achieved through an orthotic prescription for Roberta?*

   - ASSIST with dorsiflexion during swing phase of gait
   - STABILIZE the knee joint during stance phase of gait

Section 3: Clinical scenario

Paula is a 50-year-old woman who was diagnosed with Relapsing-Remitting Multiple Sclerosis over 20 years ago. Until now, Paula's condition was fairly stable, and she was able to work as a librarian without difficulty. Following the recent death of her husband, she experienced a relapse that lasted several weeks and resulted in right hemiparesis with foot drop in swing phase and knee hyperextension throughout stance phase with occasional knee buckling.

During Paula's short inpatient rehabilitation stay, she was given an off-the-shelf solid AFO and has used it for the past few weeks. She continues to ambulate with a single point cane for level ambulation with an asymmetrical step length and slow gait speed. Paula was referred to outpatient physical therapy to improve her mobility and safety. Her goals are to be able to climb 5 stairs to enter her grandson's home and to attend the library's monthly Book Club meeting.

Results of her functional assessment are as follows:

- Gait: Asymmetric weight-bearing, decreased stance time on the right lower extremity, lack of right hip extension past neutral; ambulates with cane in left hand.
- Gait speed: 0.6 m/s with a single point cane and right solid AFO (RLE SAFO)
- Transfers: Modified independence with excessive posterior lean and use of armrests
- Stair negotiation: Non-reciprocal, leads with left lower extremity

Clinical scenario questions/responses

1. *What is the function of a solid AFO? How does it assist function, in Paula's case?*

   Solid AFOs are the most stable form of AFOs and indicated for individuals with hyperextension at the knee joint. They control for knee hyperextension by manipulating the ground reaction force vector during stance phase. However, individuals who wear a solid AFO must have sufficient quadriceps strength to avoid knee buckling.

   In Paula's presentation, the solid AFO functions to improve foot clearance during swing phase and hyperextension during stance phase.

2. *Is a solid AFO appropriate for Paula's presentation? If not, name 1-2 additional options that may be more suitable for her.*

   The solid AFO may not be suitable for Paula due to the fact that her knee occasionally buckles during stance phase. Other options that may be appropriate for Paula include a Hinged/Hybrid AFO with a dorsiflexion assist or a Posterior Leaf Spring.

   The Hinged/Hybrid AFO with a dorsiflexion assist would enable foot clearance during swing phase while allowing for plantarflexion to enhance knee stability during stance phase.

The Posterior Leaf Spring also assists with foot clearance and knee stability, however, it does not provide any support for ankle instability or weakness.

3. *State 2-3 functional goals that would be achievable through therapeutic exercise and functional activities.*

   Paula will be able to negotiate 5 steps with a handrail and a single point cane using a reciprocal pattern in order to enter her grandson's home.

   Paula will be able to negotiate one curb with a single point cane in order to access the library.

   Paula will be able to ambulate community distances (about 150 feet) with a single point cane on level surfaces in order to attend her monthly Book Club meeting at the community library.

4. *Describe 2-3 therapeutic interventions that would be appropriate to improve Paula's ankle range of motion and strength.*

   Joint mobilizations (e.g., mobilization with movement or talocrural mobilization in prone)

   Soft tissue mobilization for plantarflexor muscles and hip flexors

   Hip and knee extension strengthening in weight bearing positions (e.g., squats, lunges, lunge and reach activities)

Section 4: Clinical scenario

Paula, who was previously introduced in Section 4, has been attending outpatient physical therapy for four visits. Upon meeting with the orthotist, the interdisciplinary team decided that Paula should be prescribed a new custom AFO. She was fitted for a hinged AFO with a dorsiflexion assist to assist with foot clearance during swing phase.

Following the preorthotic examination, Paula is ready to complete her orthotic examination and evaluation, orthotic instruction and training, and the final examination and follow-up care.

Prior to the AFO fitting, Paula's outcome measures were as follows:

- Gait: Asymmetric weight-bearing, decreased stance time on the right lower extremity, lack of right hip extension past neutral; ambulates with cane in left hand.

- Gait speed: 0.8 m/s with a single point cane and right solid AFO (RLE SAFO)
- Transfers: Modified independence with mild posterior lean and use of armrests
- Stair negotiation: Non-reciprocal, leads with left lower extremity

Additionally, Paula has recently started to see an occupational therapist for impaired fine motor coordination and loss of intrinsic muscle strength in the right hand.

Clinical scenario questions/responses

1. *How should the clinician check that Paula's hinged AFO fits properly?*

   Clinicians should perform a four-pronged assessment to check the fit of the new AFO. First, the AFO should be closely examined to ensure that it has been made as prescribed without any faults in the manufacturing. Secondly, the patient should be re-measured to identify any changes (e.g., weight, ankle girth, joint range of motion) that may have developed since the initial AFO fitting. Next, the device should be assessed for fit and functionality during static tasks, like standing or sitting. Lastly, the clinician should perform a dynamic assessment with the AFO donned in order to verify that the device does not cause excessive pressure on bony prominences and that the device enhances the wearer's participation in functional activities. The clinician should observe for skin irritation, breakdown, or areas of excessive pressure after the AFO is removed.

2. *What are some considerations that may affect an individual's wear schedule? What type of wear schedule would be appropriate for Paula?*

   Wear schedules can be affected by a number of variables including internal and external factors. Internal factors that may affect a patient's wear schedule include skin integrity, cognition, compliance, comfort, medical condition, and functionality of the brace. External factors might consist of caregiver availability or therapy schedule. Because Paula does not have any pre-existing sensory impairments that may affect her skin integrity, she is most likely appropriate for a gradual wear schedule that begins with one hour per day.

3. *Name 2 ways in which articulated AFOs can affect an optimal fit and consequently disrupt Paula's functional status.*

   Articulated AFOs may require fine tuning, especially right after the orthotic is received. Overall, all adjustments should optimize Paula's biomechanicals and overall function with the AFO donned. Depending on her leg length, she may require a heel wedge to the left limb in order to avoid a leg length discrepancy that is exacerbated by the orthotic. Leg length discrepancies can disrupt functional activities, like gait and stair negotiation, and increase one's risk for falls.

Many adjustments on articulated AFOs are done to manipulate the ground reaction force for ease of movement during the gait cycle. Usually, a 10°–12° shank-to-vertical angle during mid-to-late stance phase will allow the ground reaction force vector to pass anteriorly to the knee joint and posterior to the hip joint, which mimics normal biomechanics during gait. In Paula's case, manipulating the ground reaction force vector will discourage abnormal knee extension during mid stance as well as prevent knee buckling.

Conclusion

Physical therapists and physical therapy assistants must seek to gain a thorough understanding of ankle foot orthotic (AFO) prescription, examination, and evaluation. In addition to this, clinicians must be able to apply this knowledge across several neuromuscular conditions including Multiple Sclerosis, Cerebral Palsy, stroke, and spinal cord injury. It is highly recommended that therapists work in collaboration with an orthotist, physician, and the patient to create meaningful functional goals that can be accomplished with orthotic interventions and accompanying rehabilitation strategies.

The primary goal of using an AFO is to restore normal function as well as prevent further progression of abnormal biomechanical processes. By designing orthotics to offset areas of pressure, minimize shear forces, correct flexible deformities, and provide support, this goal can be accomplished. AFOs may also be recommended to accomplish secondary goals such as restricting painful movement, gaining compensation for lost motion, accommodating deformities, or improving gait quality and efficiency.

Careful selection and prescription of the right AFO for each patient can be challenging. A "one size fits all" approach to orthotic interventions often leads to ineffective outcomes and should not be viewed as a viable solution to the patient's needs. Clinicians have the responsibility to understand how the patient's condition may affect the orthotic prescription as well as how the patient's presentation may progress over time. Because an AFO affects many aspects of the patient's life, the most effective orthotic prescription is one that minimizes the individual's particular functional deficits while optimizing safety and comfort.

At the conclusion of this course, physical therapists and physical therapy assistants should be familiar with various types of AFOs, their application to patients with neuromuscular conditions, and methods to evaluate, prescribe, and assess the effects of AFOs on gait and function.

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