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Utilization of Ankle Foot Orthoses (AFOs) in Patients with Neurological Dysfunction

Jill Seale, PT, PhD, NCS
PhysicalTherapy.com

Learner Outcomes

- Identify at least three important factors of the role of orthotics in gait rehabilitation post neurological injury/dysfunction.
- Identify at least four common gait deviations present following neurological injury/dysfunction that warrant orthotic management.
- Define three factors that cause common gait deviations that could be corrected with proper orthotic management.
- Describe at least two evidence-based interventions regarding the utilization of orthotics for persons following neurological injury/dysfunction.
- Review patient information to create an appropriate orthotic prescription, and examine effectiveness of the AFO, for persons with neurological injury/dysfunctions.
Current state of orthotic utilization

- 22% of patients receiving stroke rehabilitation were discharged with an ankle foot orthosis (AFO)
- Patients who were most impaired in motor, walking, and balance functions typically received an AFO
- Controversial
- Orthotic use discouraged due to perception that their use prevents or delays recovery
- Pre-fabricated PLS often provided in acute care

Physical Therapists’ Clinical Decision Making Regarding Orthotic Utilization In Persons With Hemiplegia Following Stroke

- Themes Identified:
  - Consistent use of observational gait analysis, but inconsistent processes for this analysis
  - Identification of common deficits in swing phase more often than deficits in stance phase
  - Variety of interventions to treat gait post stroke, including orthotics
  - Treatment should be focused on maximizing recovery and, therefore, not using orthotics
  - Seale J, Utsey C. Physiotherapy Theory and Practice, 2019
Participant Quotes

- “Control that footdrop…that’s always the first priority”
- “Hip is like the key…it’s then going to stabilize and get control of knee”
- “Stance phase doesn’t bother me… but in swing phase you have to clear the foot”
- “Do as little as possible because you know everything you limit in brace is actually taking away something that’s normal”

Seale J, Utsey C. Physiotherapy Theory and Practice, 2019

Participant Quotes

- “I try to stay away from them as much as possible to maximize recovery”
- “If I can get away without using an AFO, that is preference”
- “Wait until very, very close to discharge to get one, might temporarily use”
- “Can’t work on strengthening within it at all”

Seale J, Utsey C. Physiotherapy Theory and Practice, 2019
Barriers To Orthotic Utilization

- Lack of understanding of normal gait and effect of stroke on gait
- Unsubstantiated beliefs about impact of orthotics potential for recovery and motor activity
- Financial barriers, especially to early orthotic management
- Lack of definitive evidence about best orthotic design
- Great variability in orthotic prescription, as well as PT’s and Orthotist’s

Common Gait Deviations

- Phase by Phase
- Segment by Segment
Initial Contact

- Hip
  - 20° flexion
  - Hamstrings on to slow limb, other extensors turning on
- Knee
  - Neutral
  - Quadriceps
- Ankle
  - Neutral
  - Pretibials

Loading Response

- Hip
  - Still at 20°
  - Extensors and abductors
- Knee
  - 15° flexion
  - Quadriceps
- Ankle
  - 5° PF
  - Pretibials
  - Heel Rocker
Midstance

- **Hip**
  - Neutral
  - Abductors

- **Knee**
  - Neutral
  - Quads initially, then no muscle activity

- **Ankle**
  - 5° DF
  - Calf
  - Ankle Rocker

Terminal Stance

- **Hip**
  - 20° hyperextension
  - No muscle activity

- **Knee**
  - Neutral
  - No muscle activity

- **Ankle**
  - 10° DF
  - Calf

- **Forefoot Rocker**
  - Toes
  - 20-30° extension
Pre Swing

- Hip
  - 10° hyperextension
  - adductors
- Knee
  - 40° flexion
  - No muscle activity
- Ankle
  - 15° PF
  - No muscle activity
- Toes
  - 55-60° extension

Initial Swing

- Hip
  - 15° flexion
  - Flexors
- Knee
  - 60° flexion
  - flexors
- Ankle
  - 5° PF
  - pretibials
Mid Swing

- Hip
  - 25° flexion
  - Flexors initially, then hams
- Knee
  - 25° flexion
  - Flexors
- Ankle
  - Neutral
  - Pretibials

Terminal Swing

- Hip
  - 20° flexion
  - Hamstrings
- Knee
  - Neutral
  - Quads
- Ankle
  - Neutral
  - Pretibials
Stance versus Swing

- Most commonly identified, described, and addressed
- Greatly dependent on the stance phase
- Fairly easy to compensate for distal impairments of swing phase
- An orthotic solution often does not completely re-establish swing limb clearance
Swing depends on stance

- **Hip**: 20° hyperextension, No muscle activity
- **Knee**: Neutral, No muscle activity
- **Ankle**: 10° DF, Calf
- **Forefoot Rocker**: No muscle activity
- **Toes**: 20-30° extension

- **Hip**: 10° hyperextension, adductors
- **Knee**: 40° flexion, No muscle activity
- **Ankle**: 15° PF, No muscle activity
- **Toes**: 55-60° extension

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**Stance Phase**

- More than just decreased weight shift to affected side
- Acute and chronic phase: weakness of PFs is primary impairment
- Chronic phase: Weakness of PFs along with PF contracture and/or hypertonicity
- Often not identified, described, or addressed
Common Impairments

Swing Phase
- Weakness – flexors primarily; knee extensors at terminal swing; DFs for LATE clearance
- Spasticity – extensors primarily
- Decreased ROM – dorsiflexion
- Decreased sensation

Stance Phase
- Weakness – plantarflexors, hip abductors, adductors, and extensors, knee extensors, ankle everters
- Spasticity – extensors, primarily plantarflexors
- Decreased ROM – dorsiflexion, hip extension
- Decreased sensation

In summary….

- Persons with neurological dysfunction often recover some degree of ambulation
- Often, predictable patterns of gait deviations remain
- Walking is seldom normal or completely functional
  - Decreased speed
  - Significant asymmetry
  - Increased fall risk
  - Risk of musculoskeletal injury
  - Decreased walking endurance
  - Bottom line – limitations in participation
Deviation Impacted by AFOs

- Direct Impact
  - Foot
  - Ankle
- Indirect Impact
  - Knee
  - Hip
  - Head, arms, trunk

Indications for Orthosis

- Muscle weakness or paralysis
- Uncoordinated movement
- Alterations in muscle tone (hypo- or hypertonicity)
- Skeletal deformity or weakness
- Trauma
- Congenital defect
Goals of Orthotic Treatment

- Prevent deformity
  - Optimize skeletal alignment
- Provide stability
  - Block aberrant motion
  - Assist or resist joint motion
- Facilitate function**
  - Harness ground reaction forces to optimize phases of gait

  - Modified from Principles of Orthotic Treatment, 1976

Ideal Orthosis

- Control
  - What functional tasks need to be impacted
- Comfort
  - Also consider ease of application
- Cosmesis
  - If it is ugly, they likely won’t wear it!
- Cost
  - Not just $; also consider increased or decreased energy costs related to orthosis
Impairment and Functional Considerations

- Diagnosis
- Prognosis
- Posture
- Sensation
- Observational gait analysis
- Objective gait measures
- Motor control
- ROM (esp. PROM)*
- Skeletal alignment
- Strength
- Coordination
Details About ROM

- Need to assess ankle PROM with knee extended
  - Gastroc is 2 joint muscle
- Need to consider R1 and R2
  - R1 – first resistance
  - R2 – max stretch
- Brace at R1

AFO versus KAFO

- According to Rancho R.O.A.D.M.A.P
  - If patient has < 3+/5 quadriceps strength and/or absent proprioception, a Knee Ankle Foot Orthosis is warranted

- Ranchos Los Amigos National Rehabilitation Center
Physical Therapy Department, Rancho
Supramalleolar Orthosis
(SMO or SAFO)

- **Primary effect**: control rear and midfoot
- **Secondary effect**: mild control of inversion and eversion
- **Uses**: Severe pex plano valgus foot, intermittent toe walking, hypotonia or mild hypertonia
- **Not used with**: moderate to severe hypertonia, constant toe walking
- **DOES NOT CONTROL KNEE**

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**Posterior Leaf Spring AFO**

- A solid ankle AFO that has been trimmed back so that the plastic around the ankle is very narrow
- This make the brace essentially flexible in the stance phase

Because this posterior trim line is narrow, the brace will dorsiflex as weight is shifted over the foot
PLS AFO

- Primary effect: swing phase clearance, prepositions for initial contact
- Secondary effect: moderate inversion/eversion control
- Uses: open kinetic chain problems; most effective with hypotonia
- Not used with: stance instability of ankle or knee, hypertonia

Solid Ankle AFO
Solid Ankle AFO

- **Primary effect**: blocks movement of ankle in all planes
- **Secondary effect**: impacts movement and position of knee
- **Uses**: to control stance phase foot, ankle, knee position
- **Not used with**: open chain problems; when ankle movement in stance should be preserved

Articulated AFO

- **Primary effect**: controlled ankle motion, can block PF
- **Secondary effect**: less control of stance phase
- **Uses**: patients with swing limb clearance and medial/lateral instability of ankle/foot
- **Not used with**: patients with instability of knee in stance, absent quads
  - *** Just because you allow them the motion, does not mean they will actually use the motion in gait***
Articulated AFO

- A joint is built into the AFO
- Allows movement
- Movement can be free or limited

Dorsiflexion is restricted by strap; strap can be adjusted to allow more or less DF. Plantar flexion limitation is same as on brace to right.

Ground Reaction AFO

- Has rigid section over proximal tibia (can be larger)
- Transfers forces from toe of brace to shank (lower leg)
- Geometry of brace makes it very stiff
- Can be solid or articulated

Both of these are examples of ground reaction AFOs. To left, AFO as full anterior panel (open in back); on right, AFO has anterior band only.
Ground Reaction AFO

- **Primary effect:** applies external extension moment to knee; assist weak quad or PFs
- **Secondary effect:** good mid and rear foot control
- **Uses:** stance control; often used for patients who have excessive knee flexion/ankle DF in stance; may help with those who hyperextend; pt may be more inclined to allow tibia to come forward because of anterior support

Dynamic Ground Reaction AFO

- Carbon fiber strut substitute for lack of PF strength/activation
- Resists forward motion in stance
Double upright, Double action ankle AFO

- Metal AFO attached to shoe
- Also called duel chamber ankle joint
- Pins or springs in front and rear chambers allow for adjustable dorsiflexion and plantarflexion; can assist, resist, or stop motion
- Can provide nearly infinite amount of adjustment for DF and PF

Primary effect: assist or block dorsi and plantar flexion

Secondary effect: control mild inversion/eversion

Uses: For those patients at risk for skin breakdown (diabetic, etc.), or those with fluctuating volume (edematous)

Not used: when weight of orthosis is issue (severe weakness); when transverse plane control is needed
Review of current evidence for orthotic utilization following stroke

An AFO is better than NO AFO
AFOs Improve Multiple Domains

<table>
<thead>
<tr>
<th>Review</th>
<th>Focus</th>
<th>Number of Studies</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisholm et al. 2012</td>
<td>Gait and functional mobility</td>
<td>27</td>
<td>Most AFOs improve speed and ankle DF. Effect on knee unclear.</td>
</tr>
<tr>
<td>Ferreira et al. 2013</td>
<td>Walking speed and cadence</td>
<td>13</td>
<td>All types of AFOs improve speed. Codence results varied.</td>
</tr>
<tr>
<td>Guerra Podilla et al. 2014</td>
<td>Gait and postural control</td>
<td>10 RCTs only*</td>
<td>AFOs improve speed and cadence. Unclear effect on symmetry, postural sway and balance.</td>
</tr>
<tr>
<td>O'Connor et al. 2016</td>
<td>Knee instability</td>
<td>3 assessed AFOs</td>
<td>Inconclusive effect on knee stability.</td>
</tr>
</tbody>
</table>

Tyson SF, Kent RM, Arch Phys Med Rehabil, 2013

AFO Effect on Multiple Domains

- Walk more independently (3 studies)
- Decreased time to negotiate stairs (2 studies)
  - Faster with AFO, no statistical significance
- Faster performance of Timed Up and Go (TUG) (2 studies)
  - Faster, but no statistical significance
- Effect of walking speed (11 studies)
- Effects on step or stride length (7 studies)
- Effects on balance (2 studies)
- Effect on weight distribution (5 studies)
- Effect on postural sway (4 studies)
  - Less postural sway, but no statistical significance
AFO Effect on Kinematics

- **Ankle**
  - Increased DF at IC
  - Increased peak DF in stance and swing
  - Increased peak DF at toe-off
- **Knee**
  - Increase in peak knee flexion at IC
  - Increase in peak knee flexion at loading response
  - Improved peak knee extension in stance **BUT**
  - **no effect on peak knee flexion in swing**
- **Hip**
  - No effect on peak hip flexion at IC or peak hip extension during stance


AFO Effect on Kinetics and Energy Expenditure

- Increased COP excursion under affected foot (2 studies)
  - Positive effects on other aspects of kinetics – multiple factors not able to be pooled into review
- 3 studies found NO improvement in energy cost, **BUT no effect on energy consumption**
- 1 study with beneficial effect on Physiological Cost Index
Effect on Muscle Activity

- Perceptions/Myths Versus the Facts

Effect of AFOs on Muscle Activation

- Literature Review
  - 11 studies in individuals with neurological disorders
  - Diagnoses included: CVA, SCI, peripheral “foot drop,” & children with CP
  - Electromyography (EMG) of LE muscles while walking with & w/out AFOs
  - Multiple types of AFOs investigated (solid, hinged, oil-damper, PLS, etc)

- Weaknesses of the Literature
  - Variability in muscles tested
  - Variability in braces tested
  - Only 1 long-term outcome
  - Some used surface electrodes, some used intramuscular electrodes
  - Variability in data collected and analyzed
Effect of AFOs on Muscle Activation

Summary of the Evidence

- Of the 11 studies:
  - 6 showed equal or more normalized EMG in AFO
  - 4 showed less normalized EMG in AFO
  - 1 showed equal, more normalized, and less normalized EMG in AFO depending on the muscle tested
  - No notable trend toward the rigidity of the brace resulting in more or less normalized EMG

- No clear evidence that:
  - AFOs decrease muscle activation in pts with neurological disorders
  - More rigid braces exaggerate any possible negative side effects of bracing
  - There is a long-term detriment to muscle activation, function, or impairments

But is this indication followed?

Personalized Bending Stiffness AFO

- Completely novel
- \( N = 2 \)
- \( \geq 6 \) months post
- Needed 15° DF
- Decrease peak PF moment during stance
- Highly instrumented assessment using patented technology to personalize and manufacture device


Timing of Orthotic Intervention

- Small sample, average of 3.5 weeks post-stroke
- Fitted with solid AFO
- Only investigated immediate effects
- Significant increases in gait speed, overall average step length, cadence
- Step length symmetry improved, as well as trend for more normal joint kinematics but not significant
Timing of Orthotic Intervention

- All subjects within first 6 weeks of stroke
- Comparison of early (week 1) versus delayed (week 9) provision of AFO
- Positive effects both early and delayed
- Significant improvements in all outcome measures for early group, with improvements in Berg Balance Scale and Barthel Index being significantly larger than delayed group (non-significant improvements in speed and TUG)
- Called for future analysis of kinematic and muscle activation patterns
  - Nikamp et al, Clin Rehabil, 2016

Timing of Orthotic Intervention

- F/u study with methodology as reported previously
- Utilized kinematic analysis
- No significant effects of timing comparing early versus late
- Significant positive effects of AFO provision in ankle dorsiflexion at “initial contact, foot-off and during swing”
  - Nikamp et al, Gait Posture, 2017
Early, Intense Rehab that Includes AFO Utilization

- Early intervention combining use of AFO and intensive locomotor training
  - Initiated < 6 weeks post stroke, prior to overground walking
  - Program of body weight supported treadmill training
  - Use of double adjustable AFO to substitute for weak DF and PF
  - Standardized progression of program based on subjects walking ability and speed.


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Early, Intense Rehab that Includes AFO Utilization

- Results:
  - Improved temporal and spatial symmetry
  - Decreased falls
  - Improved gait speed and endurance
  - Decreased assistive device and orthotic usage
  - More normal kinematics

Kinematic Data - McCain

- Gait analysis showed:
  - Increased knee flexion during swing
  - Absence of knee hyperextension in stance
  - More normal ankle kinematics at initial contact and terminal stance
  - Improved symmetry – single support time, hip flexion at initial contact, maximum knee flexion and maximum knee extension during stance


Clinical Decision Making

Step 1

- SINGLE LIMB INSTABILITY IN STANCE
- IMPAIRED LIMB CLEARANCE IN SWING
Impaired Limb Clearance in Swing

- If swing limb clearance is ONLY problem and patient is stable in stance:
  - Posterior Leaf Spring AFO (PLS-AFO) or similar type device
  - This rarely occurs except with peripheral neuropathies

Single Limb Instability in Stance

- Which deviation occurs? When does it occur?
  - Knee hyperextension vs. Increased knee flexion
  - Early or late stance phase?

- Identifying the cause:
  - Quad Weakness vs. PF Weakness?

- Sagittal plane versus medial/lateral instability (or both)
Orthotic Management

- Stance instability (either knee hyperextension or buckling in stance), medial lateral instability:
  - Solid Ankle AFO
- Stance instability and poor swing limb clearance with ankle PF contracture:
  - Solid Ankle AFO; wedge AFO to optimize mid stance alignment

Why a Solid Ankle AFO?

- Re-establish lever arm for foot and ankle
- If plantar flexors are weak, patient won’t allow tibial advancement (i.e. dorsiflexion) in stance for fear of collapsing.
- If patient lacks the dorsiflexion PROM, tibial advancement is not possible, so no need to articulate AFO
- Solid ankle AFO will allow for greatest stability of knee and ankle in stance
When to use Articulated AFO?

- Articulated AFO with free DF:
  - Pt who needs the medial/lateral stability of AFO, but has good control of DF (strong PFs) in stance

- Articulated AFO with DF restraint strap:
  - Pt who has some active PF, will allow tibial to progress forward, but needs assistance in stopping tibial progressing and producing heel rise

- Controlling PF in the articulated AFO:
  - PF is limited in articulated AFO to facilitate swing limb clearance; can increase or decrease amount of PF allowed to slightly manipulate knee angle

  Articulating the AFO decreases the intimacy of the fit.... 
  Just keep this in mind

Changing Amount of PF to Manipulate Knee Angle

- Allowing greater PF will move the knee toward extension
- Decreasing amount of PF will move the knee toward flexion

  Does this make sense???
Shank to Vertical Angle

Owen E, Prosthet Orthot Int, 2010
Plantarflexor Contracture and Use of Wedge

- Ankle MUST be casted in available ROM.
- Example: Pt has -10° of DF with knee extended. Casting/fabricating the AFO in neutral will mean that in stance (when knee should be extended), patient will either NOT extend knee or ankle will PF inside brace (leading to shearing and skin breakdown)
- Accommodating PF contracture in AFO means that a wedge must be used to normalize alignment

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Plantarflexor Contracture and Wedging

a. Example of ankle with PF contracture; AFO would be fabricated at this angle. Without wedge, this is how they would stand (pf at ankle would cause knee hyperextension; shank to floor angle is reclined

b. Adding wedge under ankle pictured in a will bring shank to vertical

c. Increasing wedge will now cause shank to be inclined forward, better simulating the 10° of DF needed in terminal stance

Owen E, Prosthet Orthot Int, 2010
Manipulating Leg Length

- Don’t forget to “level out”
  - Contralateral lift with ipsilateral wedge

- Consider the use of a contralateral lift to facilitate ipsilateral swing

What are the other factors?

- Intensity of training
- Task specificity
- Periodization
- Cardiovascular fitness (or lack there of)
Case 1

- Video 1 and 2

- Stance – lack of full hip extension in terminal stance
- Swing –
  - Excessive PF throughout swing
  - Excessive hip and knee flexion throughout swing
Case 1 Orthotic Intervention

- Video 3 and 4

Case 2

- Patient with a stroke, initially provided a solid ankle AFO
- AFO casted at neutral, however patient lacked significant ROM (at my initial encounter with patient)
- Patient began experiencing pain and skin breakdown; AFO adjusted to essentially be PLS
- Presented with complaints of knee pain
Case 2

- Video 5

Determine Effectiveness

- Step 1: Go back to the goal of the device
Determine Effectiveness

- Step 2: Use appropriate tests and measures to determine if orthosis adequately addresses goals

Measuring Effectiveness

- Was your orthotic intervention effective?
  - Objective assessment across all domains of the ICF
    - Body Structure & Function
      - MMT, ROM
    - Activity:
      - Gait speed, Balance, Endurance
    - Participation:
      - QOL

Probably what matters most, but is assessed LEAST!
Determine Effectiveness

- Video 6 and 7

Any Questions?

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