Orthotic Management to Promote Walking Recovery in Persons Post-Stroke

Jennifer Hale, PT, DPT, NCS
Geneviève Olivier, PT, DPT, NCS
Jill Seale, PT, PhD, NCS

Objectives
• Review common gait impairments and deviations post stroke and describe their impact on function
• Compare and contrast historical vs current trends in orthotic management for persons post stroke
• Summarize and appraise the evidence describing the impact of orthotics on motor recovery post stroke
• Discuss a clinic decision making framework to assist clinicians in determining the appropriate timing and prescription of orthotics
• Evaluate the effects of different types of orthotics on biomechanics and functional outcomes through a series of video case studies.

Common Gait Deviations and Impairments Post-Stroke
• Circumduction
• Knee hyperextension during stance
• Knee wobble during stance
• Excessive knee flexion during stance
• Hip thrust
• Trendelenberg
• Reverse Trendelenberg
• Decreased dorsiflexion during swing
• Decreased clearance during swing (tripping or dragging)
• Absent or diminished heel strike
• Decreased knee flexion during swing
• Diminished arm swing
• Short step-length
• Wide base of support

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### Common Gait Deviations Post-Stroke

#### Swing Phase Deviations
- Circumduction
- Decreased dorsiflexion during swing
- Decreased clearance during swing (tripping or dragging)
- Absent or diminished heel strike
- Decreased knee flexion during swing
- Diminished arm swing
- Short step length
- Scissoring
- Excessive lateral lean
- Excessive posterior lean
- Excessive hip and trunk flexion
- Vaulting
- Excessive hip external rotation
- Hip hiking
- Limited hip flexion during swing

#### Stance Phase Deviations
- Knee hyperextension during stance
- Knee wobble during stance
- Excessive knee flexion during stance
- Hip thrust
- Trendelenberg
- Reverse Trendelenberg
- Absent or diminished heel strike
- Wide base of support
- Diminished arm swing
- Excessive lateral lean
- Excessive posterior lean
- Excessive hip and trunk flexion
- Weightbearing on lateral border of the foot
- Weightbearing on medial border of the foot
- Excessive hip external rotation
- Decreased stance time on hemiparetic side

### Common Impairments

#### Swing Phase
- Weakness – flexors primarily; knee extensors at terminal swing
- 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
- Decreased sensation

### Common Deviations

#### Impairment/Phase Level

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Potential cause/consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of heel first contact</td>
<td></td>
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<tr>
<td>Knee extended at LR</td>
<td></td>
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<tr>
<td>Lack of dorsiflexion at MS and TSt</td>
<td></td>
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<tr>
<td>Lack of hip extension at TSt</td>
<td></td>
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<tr>
<td>Absent heel raise</td>
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<tr>
<td>Stiff knee swing</td>
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<tr>
<td>Excessive PF in swing</td>
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<tr>
<td>Hip flexor weakness</td>
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</tbody>
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### Common Deviations

<table>
<thead>
<tr>
<th>Deprivation</th>
<th>Impairment/Phase Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion in stance</td>
<td></td>
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<tr>
<td>Excessive dorsiflexion in stance</td>
<td></td>
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<tr>
<td>Contralateral hip drop</td>
<td></td>
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<tr>
<td>Lateral trunk lean toward weak side</td>
<td></td>
</tr>
<tr>
<td>Lateral trunk lean away from weak side</td>
<td></td>
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<tr>
<td>Excessive trunk flexion</td>
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</tbody>
</table>

#### Potential cause/consequence

- Swing phase
  - Poor swing limb clearance
  - Equinovarus posture
  - Poor prepositioning for initial contact
- Stance phase
  - Foot flat or forefoot contact
  - Medial/lateral instability
  - Varus ankle
  - Lack of pronation
  - Lack of dorsiflexion
  - Absent first rocker
  - Absent or impaired second, third, and fourth rocker

### Typical Foot/Ankle Abnormalities

- Swing phase
  - Poor swing limb clearance
  - Equinovarus posture
  - Poor prepositioning for initial contact
- Stance phase
  - Foot flat or forefoot contact
  - Medial/lateral instability
  - Varus ankle
  - Lack of pronation
  - Lack of dorsiflexion
  - Absent first rocker
  - Absent or impaired second, third, and fourth rocker

### Typical Knee Abnormalities

- Instability
  - Poor tibial control and/or quadriceps weakness
    - Knee buckling
- Compensations for knee instability
  - Forward trunk lean
  - Knee hyperextension
    - Hyperextension could be from weak quadriceps but in patients with CVA/TBI, more likely cause is weak plantarflexors

Can you understand why weak plantarflexors would lead to knee hyperextension?
The Role of the Plantarflexors in Walking\textsuperscript{1}

- What gait deviations associated with PF weakness?
- How to assess?
- Commonly overlooked?
- Distinguishing weak PF from weak quadriceps

Typical Hip and Pelvis Abnormalities\textsuperscript{2}

- Hip weakness
  - Forward trunk lean to help stabilize knee
    - Increases energy costs and shortens step length
- Pelvic retraction
  - Decreases momentum that can be generated
  - Makes hip flexion activation more difficult
  - Again causes decrease in step length

No direct orthotic intervention; intervene at ankle or maybe knee/ankle to manage this by stabilizing base of support

Head, Arm, Trunk Abnormalities\textsuperscript{2}

- Lateral trunk lean
  - Over-reliance on sound side
  - Lean away from weaker side to assist with swing
- Forward trunk lean
  - Often due to knee instability
- Decreased arm swing
  - Often due to decreased gait speed, but lack of trunk and pelvic rotation contribute to this

No direct orthotic intervention; intervene at ankle or maybe knee/ankle to manage this by stabilizing base of support
Common Deviations

Activity Level

• Decreased velocity
• Unequal step lengths
• Altered swing and stance time ratios
• Increased base of support
• Swing and stance asymmetries
• Inability to alter speed or pattern
• Altered double limb : single limb support ratio

Patterns of Recovery

• What do we as therapists see?
• What does the literature show?

Risks Resulting from Altered Gait

• Additional impairments
• Potential musculoskeletal sequelae
• Increased energy expenditure
• Falls
• Activity limitations and participation restriction
• Stigma
• Decreases in QOL
Orthotic Management to Promote Walking Recovery in Persons Post-Stroke

Historical Orthotic Management of Persons with Stroke

- 22% of patients receiving stroke rehabilitation were discharged with an ankle foot orthosis (AFO)\(^3,4\).
- Patients who were most impaired in motor, walking, and balance functions typically received an AFO.\(^3\)
- Controversial\(^5\)
- Orthotic use discouraged due to perception that their use prevents or delays recovery\(^6-8\)
- Pre-fabricated PLS often provided in acute care

Current Trends - Orthotists

- Retrospective study over a 3 month period of time; multiple orthotic providers nationwide\(^9\)
- 2363 subjects with stroke, 2416 devices; average age: 62
- Most common device provided – Custom Articulated (40.98%)
- Devices which provide best stance control/stability
  - Solid
  - GRAFO
  - Double upright

Current Trends – PTs\(^10\)

- Focus on swing limb dysfunction
- Often don’t identify weakness in plantarflexors as cause of stance instability
- Reluctance to provide solid ankle device
- Philosophy on orthotics: wait to prescribe, try to do without, inhibits recovery
Orthotic Impact on Gait

- Improve quality of gait, improve gait speed, and reduce energy expenditure during ambulation.\textsuperscript{11-16}
- Immediate improvements in functional ambulation categories\textsuperscript{5}
- Immediate improvements in gait speed, quality, and endurance\textsuperscript{17-18}
- Increased step or stride length\textsuperscript{5}

Orthotic Impact on Balance and Other Function

- Immediate improvements in balance\textsuperscript{17-18}
- Decreased fall risk\textsuperscript{16-19}
- Not detrimental to stair climbing and sit<>stand\textsuperscript{5}
- Less postural sway, improved weight distribution symmetry\textsuperscript{19}
- No data on impact on quality of life or participation

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\textsuperscript{20,21}:
  – 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 individuals 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

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\textsuperscript{31}
Orthotic Goals Post Stroke

• Think back to the goals of orthotic management
• Specific goals for these diagnoses:
  – Maintain ROM
  – Improve balance
  – Encourage weight bearing
  – Promote ambulation and other mobility ASAP

Impairment and Functional Considerations

• Diagnosis
• Prognosis
• Posture
• Sensation
• Observational gait analysis
• Objective gait measures

• Motor control
• ROM (esp. PROM)
• Skeletal alignment
• Strength
• Coordination

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
There is supportive evidence related to orthotic design and prescription; we have clinical expertise that would indicate that orthotics can improve function; BUT, the orthotic prescription has to match the patient’s values/goals... if not, your great orthosis based on fantastic evidence and clinical experience ends up in the closet!

Orthotic Management

- If swing limb clearance is ONLY problem and patient is stable in stance:
- Stance instability (either knee hyperextension or buckling in stance), medial lateral instability:
- Stance instability and poor swing limb clearance with ankle PF contracture:

Why a Solid Ankle AFO?

- Re-establish lever arm for foot and ankle
- If plantar flexors are weak, patient won’t allow tibial advancement (ie 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

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

Ground Reaction AFO

- Traditionally used for pts with increased ankle DF and knee flexion in stance (crouch gait)
  - Promote knee extension
- May also be beneficial for those pts with knee hyperextension in stance due to weak PF
  - Doesn’t make sense if GR AFO promotes knee extension??
  - If a patient has significant PF weakness, they are choosing hyperextension for stability, they are too unstable to allow tibial forward progression. A GR AFO is a very stable, stiff AFO. This may afford the pt the confidence of allowing their tibia to translate forward and be supported by the AFO.
KAFO

- Traditionally, KAFOs have not been prescribed for persons with hemiplegia
- Added weight difficult for weak patients
- Often considered “overbracing”
- Locked knee makes swing phase very difficult
- Donning/doffing is difficult, often can’t be independent
- Typically, most knee control needs in patients with hemiplegia can be met with AFO
- If patient has true genu recurvatum, KAFO might be best option
- Can combine with any type of AFO

Understanding the Concept of “Shank to Vertical Angle (SVA)”
Shank to Vertical Angle (SVA)\textsuperscript{32}

![Diagram of Shank to Vertical Angle](image)

Figure 1. Measurement of segments relative to the vertical.

Shank Inclination—

- 10-12 degrees of shank inclination ideal at midstance\textsuperscript{32}

![Diagrams of Shank Inclination](image)

Figure 2. Normal gait. Images taken from Video Vector Generator.

What if ankle kinematics do not allow for an ideal SVA?

- “Don’t cheat a contracture”
  - Assess gastroc length
  - Assess R1/R2
    - R1 = the angle where you meet the first resistance
    - R2 = maximal stretch/end range angle
- Plantarflexor weakness
  - Knee hyperextension = excessive recline
  - Excessive knee/ankle flexion = excessive incline
How to achieve an ideal SVA when PF weakness and/or ankle ROM restrictions exist?

PF Weakness/ROM Restrictions

“incline”

“recline”
Use of FES as an orthosis

• What do current systems do?
  – Stimulate pre-tibials to facilitate swing

• When does this work?
  – Swing limb clearance problem only

• When does this not work?
  – When there is stance limb instability, significant spasticity, significant loss of range of motion

Evidence for FES as Orthosis

• Insufficient evidence to conclude that FES is superior to AFO use

• Patient preferences often for FES, but many still also continue use of AFO

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 and improve standing symmetry

What are the other factors?

- Intensity of training
- Task specificity
- Periodization
- Cardiovascular fitness (or lack thereof)

2. Fish


