Functional Electrical Stimulation & Ankle Foot Orthosis to Improve Lower Extremity Movement Post Stroke

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Introduction to Stroke

- Also known as a “brain attack”
- Occurs when part of the brain loses blood supply and stops working
- 2 Types:
  - Ischemic stroke
    - Part of the brain loses blood flow due to narrow or blocked arteries
  - Hemorrhagic stroke
    - Bleeding occurs within the brain due to a leaking or ruptured blood vessel
- Loss of blood supply in the brain deprives the brain of oxygen and nutrients, resulting in dead brain cells
- As a result, abilities controlled by the damaged area of the brain are lost

http://www.firstaidforfree.com/what-is-a-stroke-and-who-is-at-risk/
The Impact of this Condition

- Stroke is the most common acquired neurological disease in adult populations
  - Each year stroke affects nearly 800,000 people
- One-third of stroke survivors achieve only a poor functional outcome 5 years after the onset of stroke
- Many common effects are physical:
  - Foot drop - weakness of ankle/toe dorsiflexion; leads to high steppage gait
  - Hemiparesis - loss of control on one side of body
  - Paralysis - general loss of function; neurological and muscular causes
  - Spasticity - extreme tendon excitation
- Current noninvasive treatment options include physical therapy, functional electric stimulation, and orthotics
Functional Electrical Stimulation (FES)

- FES works by sending low level electrical impulses to nerves in the muscles
  - Stimulating the nerves causes the muscles to contract which induces limb movement
  - The use of FES can increase range of motion during gait
- FES mimics the electrical signals that should be coming from the central nervous system
  - This means that FES therapy can be used for a number of conditions
    - Spinal Injury
    - Stroke
    - Multiple Sclerosis
    - Cerebral Palsy
- FES also has been shown to have a therapeutic effect and promotes neuroplasticity
Stance
No stimulation

Foot switch detects heel rise

Causes stimulation to the electrodes

Produces dorsiflexion and eversion through swing

Produces dorsiflexion and eversion through swing

Foot switch detects heel strike

Stimulation ends after lowering the foot to the ground

FES Study (Gervasoni, et al.)

- Participants: 24 participants (10 with stroke and 14 with Multiple Sclerosis)
  - Study occurred over 8 weeks
  - 3 Tests: Baseline, 4 week mark, 8 week mark
  - Training Regiment:
    - Week 1: Wear device 15min to 1 hour
    - Week 2: Wear device 30 min to 4 hours
    - Weeks 3-8: Wear device for as long as possible (Up to 8 hours)

- Results:

Table 2
Instrumented gait analysis: foot clearance, lower limbs kinematic, and energy recovery factor

<table>
<thead>
<tr>
<th></th>
<th>Baseline Without FES</th>
<th>4-Week Without FES</th>
<th>4-Week With FES</th>
<th>Overall P Value</th>
<th>Post-Hoc Total Effect (Baseline Without FES vs 4-Week With FES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance, mm</td>
<td>17.06 (6.93)</td>
<td>19.97 (8.34)</td>
<td>22.06 (8.91)</td>
<td>.04</td>
<td>5.26 (7.16) P = .03</td>
</tr>
<tr>
<td>Ankle dorsiflexion at the initial contact, **</td>
<td>-42.08 (8.53)</td>
<td>-43.78 (9.61)</td>
<td>-37.89 (6.82)</td>
<td>.05</td>
<td>5.08 (7.18) P = .08</td>
</tr>
<tr>
<td>Ankle dorsiflexion at clearance, **</td>
<td>-39.76 (8.02)</td>
<td>-41.83 (10.11)</td>
<td>-35.97 (8.08)</td>
<td>.08</td>
<td>3.79 (7.79) P = .14</td>
</tr>
<tr>
<td>Energy recovery factor, %</td>
<td>43 (1)</td>
<td>43 (2)</td>
<td>45 (1)</td>
<td>.53</td>
<td>-2</td>
</tr>
</tbody>
</table>

Means (standard deviations) are reported.
Overall P value: analysis of variance P values across means.
* Greater values indicate increase of ankle dorsiflexion.
FES Study

Conclusions that can be made:

- FES does have an impact on gait
- Prevents falls
- Increases foot clearance

FES Drawbacks:

- Does not reduce energy costs of walking (fatigue happens often)
  - Inefficient gait pattern
- Hard to place electrodes on correct areas on subject
- Can be expensive
Orthoses

- **Two types:**
  - Passive - devices powered by the patient’s muscles
  - Active - consists of a powered exoskeleton to improve ambulation

- **Goal of orthoses:**
  - Provide support for weak muscles
  - Improve joint position and stability
  - Maximize functional movement
  - Prevent/compensate for limb deformities
Ankle-Foot Orthosis (AFO) Study (de Wit, et al.)

- **Aim:**
  - Investigate the effect of an AFO on walking ability in chronic stroke patients
- **Method:**
  - 20 chronic stroke patients were analyzed with and without an AFO for 6 months
- **Results:**
  - Made walking much easier for the patients; improved QoL
  - Lowered energy needed to walk
  - Statistically significant increase in walking ability
  - Low clinical improvement to walking ability (gait, stride length)
    - Did not meet threshold

https://www.anatomicalconcepts.com/store/prafo-550sk
Robot-Driven Gait Orthosis Study (Husemann, et al.)

- Lokomat (active)
- Method:
  - Treatment group received 30 minutes of robotic training daily
  - Control group received 30 minutes of conventional physiotherapy daily
  - Each group received an additional 30 minutes of conventional physiotherapy
- Results:
  - No difference between groups in gain of functional scores
  - Lokomat group showed an advantage in improvement of gait abnormality

http://exoskeletonreport.com/2016/06/medical-exoskeletons/
Potential for Study: Combination of FES and AFO

- Dropped foot concerns:
  - High steppage gait
  - Spastic equinus
- FES and AFO are comparable in terms of their net effects on walking, but act in differing ways
- Combination of the two disciplines allows for synergy
  - Promote normal muscle activation
  - Quick access to normal gait patterns
  - Reduce energy cost of walking
  - Minimize muscle fatigue
- Fairly inexpensive
- Allows patient freedom to work anywhere

Configuration of Potential Study

- Experiment over a three month period to test the efficacy of this approach:
  - Criteria:
    - 50 individual with chronic dropped-foot - hybrid orthotic system
      - At least semi-ambulatory
    - 50 control individuals with dropped-foot - standard PT practices
  - Daily therapeutic exercises
  - 3x meetings for PT weekly
    - Week 1: 30 minutes - 1 hour
    - Week 2: 1 hour - 4 hours
    - Onwards: As long as possible, use during daily activities
  - Weekly checks with researchers to determine progress for first month, then monthly evaluations
Analysis

- **Comparison:**
  - 10-Meter Walk Test
  - 6-Minute Walk Test
  - Physiological Cost Index (PCI)
  - Berg Balance Scale

- Analyze with and without device to see how much can be carried over
- Stroke presents uniquely for each individual
  - Expect variance in results
References


