Objectives

1. To understand the basics of FES—Choosing appropriate clients, goals & parameters
2. To review the literature on FES & stroke
3. To become familiar with FES systems for stroke

Outline

First Hour
1. Review of FES basics ~15 min
2. FES for Upper Extremity ~15 min
3. FES for Lower Extremity ~15 min
***Break*** ~5-10 min

Second Hour
FES stations
Bioness, WalkAide, Odstock
Review of FES Basics

Functional electrical stimulation is the use of ES as...?

A. An orthotic substitute for a muscle function
B. A means to prevent learned non-use
C. A tool for motor relearning
D. A, B & C

Review of FES Basics

Which of the following is false regarding ES muscle contractions?

A. Recruit a small number of motor units
B. Motor units fire synchronously
C. Large, fast fatigable units fire first
D. More resistant to fatigue than physiologic contractions

Review of FES Basics

Increasing which parameter(s) will increase the strength of an ES contraction?

A. Pulse duration
B. Frequency
C. Intensity/amplitude
D. A & C
Review of FES Basics

If stimulating a small muscle, the best response is obtained by..?

A. Placing cathode on motor point, using asymmetric waveform
B. Placing cathode on motor point, using symmetric waveform
C. Placing anode on motor point, using asymmetric waveform
D. Placing anode on motor point, using symmetric waveform

Review of FES Basics

Research supports which parameter as the most important for achieving success with ES?

A. Duration of treatment
B. Waveform
C. Intensity/amplitude
D. Active participation of client

Review of FES Basics

Which stroke client is a good candidate for FES of the UE?

A. Peripheral nerve damage in UE
B. No AROM in UE
C. Pacemaker implanted
D. Impaired sensation in UE, some AROM
**FES**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse/cycle duration</td>
<td>150-200 µs small muscles, 200-350 µs large muscles</td>
</tr>
<tr>
<td>Current amplitude</td>
<td>Sufficient for functional activity</td>
</tr>
<tr>
<td>Ramp-up/Ramp-down</td>
<td>Activity specific</td>
</tr>
<tr>
<td>Frequency</td>
<td>35-50 pps</td>
</tr>
<tr>
<td>On time</td>
<td>Activity specific</td>
</tr>
<tr>
<td>Off time</td>
<td>Activity specific</td>
</tr>
<tr>
<td>Treatment time</td>
<td>Activity specific</td>
</tr>
<tr>
<td>Electrode configuration</td>
<td>Parallel to muscle fibers; 1 channel small muscles, 2 channels large muscles</td>
</tr>
</tbody>
</table>

From: Cameron, Michelle H. Physical Agents in Rehabilitation: From Research to Practice. 3rd ed. 2009.

**Increasing Intensity of Rehab**

FES leads to strength gains via **Overload** principle

- Greater strength gains occur when training at higher contraction intensities

(Delitto & Snyder-Mackler 1990)

**Box & Block Test**

Cauraugh et al. 2000
Chronic stroke
Experimental = EMG-triggered ES
Control = AROM
12 30-minute sessions

**Evidence-based Review of Stroke Rehabilitation**

Teasell et al. 2010 (ebrsr.com)

There is strong evidence that **FES:**

- improves upper extremity function in stroke
- reduces shoulder subluxation
- improves gait performance, when combined with gait retraining
- improves gait and standing post-stroke, when combined with biofeedback training
Hemiplegic Shoulder

Snels et al. 2002
- Methodological quality of reviewed studies moderate to poor
- Concluded that FES was 1 of the 2 most promising methods for treatment of hemiplegic shoulder pain

Van Peppen et al. 2004
- Strong evidence found for increasing PROM & reducing caudal subluxation with FES
- Insufficient evidence found for reducing pain with FES

Van Peppen et al. 2004
- Strong evidence found for increasing PROM & reducing caudal subluxation with FES
- Insufficient evidence found for reducing pain with FES

Hemiplegic Shoulder

- Early post-stroke: FES is efficacious for preventing subluxation & increasing UE function
- Chronic stroke: FES is efficacious for reducing pain
  (Chantraine et al. 1999; Linn et al. 1999; Ada & Foongchomcheay 2002)
- FES for hemiplegic shoulder does not improve UE function
  (Church et al. 2006, Price & Pandyan 2001)

Hemiplegic Shoulder

Goal – joint protection (early) pain reduction (late)

Parameters – endurance
- Posterior deltoid and supraspinatus (Baker and Parker 1986, Kobayashi et al. 1999)
- Use minimum amplitude needed to raise humeral head into glenoid fossa
Hemiplegic Shoulder

**FES Prescription** (Linn et al. 1999)

- 4X/day with >2 hrs between sessions
- Session length = 30 min wk 1, 45 min wk 2&3, 60 min wk 4
- Asymmetrical biphasic waveform
- Pulse width = 300μs
- Frequency = 30Hz
- On time 15 sec (including ramp up/down of 3/3)
- Off time 15 sec

FES in UE

*Popović et al. 2002*
FES in UE

- Combined sensory & motor ES for a home program
- Practice of functional activities
- Hand switch to trigger ES

The Bionic Glove

- Electronically senses voluntary wrist movements & provides ES to finger & thumb muscles to produce grasp & release (Prochazka et al. 1997, Popović et al. 1999)

The ReJoyce: In-Home Tele-Rehabilitation + FES
Kowalczewski et al. (under review NeuroRehab Neural Repair)
The ReJoyce: What is the evidence?

Kowalczewski et al.
Greater gains in functional tasks with ReJoyce compared with exercise therapy

![Graph A](image)

![Graph B](image)

The ReJoyce: What is the evidence?

Kowalczewski et al.
Improvements in pinch and grasp forces

![Graph C](image)

![Graph D](image)

NESS H200

Muscles targeted:
1. extensor digitorum communis
2. extensor pollicis brevis
3. flexor digitorum superficialis
4. flexor pollicis longus
5. thenar muscles

3 exercise modes
3 functional modes
1. Key grip & release
2. Palmar grip & release
3. Static open hand posture

NESS H200

Alon et al. 2002

chronic stroke
3 weeks of daily training (twice daily, 10 → 45 min)

Orthotic effect

NESS H200

Ring & Rosenthal 2005

FES & Pre-gait Activities

Maležić et al. 1994

- NMES to gluteus maximus, quads and hamstrings of hemiplegic leg
  - Subjects stood with 11.4% more weight on hemiplegic leg during FES
  - Subjects shifted their weight onto hemiplegic leg 50.8% faster with FES
FES for Gait

- Appropriate for clients with some walking ability
- Treatment tailored to client & his/her deficits

**Wieler et al. 1999**
- For foot drop:
  - ES to peroneal nerve to elicit ankle dorsiflexion
  - If dorsiflexion not sufficient, stim increased to elicit flexor reflex
- For knee or ankle instability during stance:
  - Add ES to quads or tibial nerve
- For instability of hip/pelvis:
  - Add ES of gluteus medius

FES for Gait – What is the evidence?

- **FES ↑ walking speed** (Laufer et al. 2009, Wieler et al. 1999)
  - **Kottink et al. 2004** – Systematic review
    - 5/6 studies showed positive effect of FES on walking speed
  - **Robbins et al. 2006** – Meta-analysis
    - FES has therapeutic effect on speed in subjects post-stroke

- **FES ↑ muscle strength**
  - **Glanz et al. 1996** – Meta-analysis
    - FES promotes recovery of muscle strength after stroke

FES for Foot Drop

- 1st functional application in neuro condition
  (Liberson et al. 1961)
- Target tibialis anterior
- External trigger

#1: Cathode over TA
FES for Foot Drop

- 1st functional application in neuro condition [Liberson et al. 1961]
- Target tibialis anterior
- External trigger

#1: Cathode over CPN

Odstock Dropped Foot Stimulator

- Single channel
- Synchronised to gait with foot switch
- Odstock sounder – useful for therapist

ODFS – What is the evidence?

**Clinical**
- Successfully treated >6000 pts in UK
- Compliance after 1 yr: 92% in MS. 86% in CVA
  (FES: Applications in Rehabilitation 2007)

**Research**
ODFS ↓ effort of walking [Taylor et al. 1999]
- 151 subjects with upper motor neuron lesions who had used ODFS for 4.5 months
- Saw 31% reduction in Physiological Cost Index (PCI) of walking
- PCI = change in HR from resting to steady speed of walking
  walking speed
NESS L300

- Stim to CPN & TA
- Triggered by force sensor under foot
- Wireless

NESS L300 – What is the evidence?

↑ gait symmetry

Hausdorff & Ring 2008
Chronic hemiparesis
n=24
↑ daily use from 1 hr/day to full day in 4 wks

Orthotic effect

NESS L300 – What is the evidence?

↑ gait speed (Hausdorff & Ring 2008)
- Over-ground & negotiating obstacle course
NESS L300 – What is the evidence?

Laufer et al. 2009
16 chronic stroke users followed for 1 year

<table>
<thead>
<tr>
<th></th>
<th>2 mos</th>
<th>1 yr</th>
</tr>
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<tbody>
<tr>
<td>Participation domain (Stroke Impact Scale)</td>
<td>25.2%↑</td>
<td>36.7%↑</td>
</tr>
<tr>
<td>Gait speed (10mWT)</td>
<td>29.2%↑</td>
<td>58.2%↑</td>
</tr>
</tbody>
</table>

WalkAide

- Single channel (CPN)
- Leadless
- Single-handed application
- Built-in accelerometer (tilt sensor)
  - ES on in late stance when lower leg is behind body (tilted back) & off at beginning of next stance when lower leg is in front of body (tilted forward)

WalkAide – What is the evidence?

Stein et al. 2006
↑ walking speed
↓ effort of walking
What causes a ‘therapeutic’ effect?

- Increased strength, coordination & conditioning (Wieler et al. 1999)

- Improved motor unit recruitment (Newsam & Baker 2004)

- Corticospinal connections strengthened with 3-12 months of WalkAide use (Everaert et al. 2010)

- Increased cortical activation after 8 wk FES program for hemiparetic wrist & hand (Page et al. 2010)

Increasing Intensity

- ↑ in speed correlated with amount of WalkAide use (Stein et al. 2006)


Cameron, Michelle H. *Physical Agents in Rehabilitation: From Research to Practice*. 3rd ed. St. Louis, Missouri. 2009


