Objectives

- Define functional electrical stimulation (FES)
- Identify the possible mechanisms for therapeutic benefit from FES
- Identify the common uses and methods for delivery of FES in neurological rehabilitation based on current best evidence
  - FES for upper extremity function (focus on shoulder subluxation)
  - FES for ambulation
  - FES for exercise
- Develop plan of care using FES based on actual patient cases.

Functional Electrical Stimulation (FES)

- Using neuromuscular electrical stimulation to enhance control of movement
- Replacing or assisting a person's voluntary movement when motor function is impaired
- Goal is to improve performance of activity
- Common diagnoses: stroke, spinal cord injury, traumatic brain injury, MS, other neurological diagnoses
NMES v FES

**NMES**
- Substitute for or augment voluntary contractions
- Used for strengthening or hypertrophy
- Part of a training program with goal of increasing strength

**FES**
- Substitute for or augment voluntary contractions
- Used for strengthening or hypertrophy
- Use of NMES to promote functional activities

Benefits of NMES
- No clear evidence to support OR refute that NMES results in increased voluntary muscle strength in: Spina bifida, peripheral nerve injury, MS, SCI, or CP
- May increase strength after stroke (modest support)
  - Better than no intervention
  - Not clear if better than progressive resistive training
  - Not clear if NMES added to training = additional benefit
Possible Peripheral Mechanisms

• Improve fitness and strength of remaining motor units
• Improved flexibility and ROM, thereby making voluntary efforts more effective
• Reduce spasticity, and subsequently improve function

Possible Central Mechanisms

• Cortical reorganization
  – Central effects of FES
    • Activates motor and sensory fibers
  – Segmental reorganization – changes in reflex function occur at segmental level post injury; alterations in connectivity of anterior horn cell
    • Antidromic firing – capable of repeated activation of horn cell
    • Hebb synapses - modifiable synapses strengthened if pre-synaptic firing coincided with or was shortly following by postsynaptic discharge

What does all that mean for us?

• FES may provide artificial way to sync presynaptic and postsynaptic activity

• ONLY WORKS IF… electrical stimulation applied in combination with voluntary effort
Other (less scientific) Benefits

• Facilitate practice that could otherwise not occur
• Engage attention
• Provide repetition
• Provide challenge
• Provide sensory and visual feedback

Contraindications

• Demand type pacemakers or implantable cardioverter defibrillators
  – Don’t place electrodes on trunk or heart region
  – Consult with cardiologist
• Pregnancy
  – Don’t use over abdominal, pelvic, lumbar or hip region
• Over carotid bodies

Adapted from Modalities for Therapeutic Intervention, 5th Ed, 2012

Contraindications

• Other implanted electrical devices such as phrenic nerve or urinary bladder stimulators
• Areas of know peripheral vascular disease, areas of DVT or thrombophlebitis
• Over phrenic nerve, gonads, or eyes
• Areas of active osteomyelitis
• Areas of hemorrhage

Adapted from Modalities for Therapeutic Intervention, 5th Ed, 2012
### General Parameters for FES

- **Waveform**
  - Biphasic PC or burst modulated AC
- **Pulse Frequency**
  - 20-60 pps or burst per second
- **Pulse Duration**
  - 200-600 µsec
- **Amplitude**
  - To level appropriate for functional activity
- **Duration**
  - Task Specific

### Common uses of FES in Neurological Diagnoses

- Limited only by creativity
- Most common uses will be covered today:
  - Upper extremity function
  - Ambulation
  - Exercise

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**Examination and Rationale for Use**

<table>
<thead>
<tr>
<th>Exam</th>
<th>Question</th>
<th>Reason</th>
</tr>
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<tbody>
<tr>
<td>Muscle innervation</td>
<td>Capable of stimulation?</td>
<td>Typically require innervation</td>
</tr>
<tr>
<td>Strength</td>
<td>Current accurate MMT</td>
<td>Determine effectiveness</td>
</tr>
<tr>
<td>ROM</td>
<td>Limitations?</td>
<td>May affect function; may be rationale for ES</td>
</tr>
<tr>
<td>Sensation</td>
<td>Normal, impaired, absent</td>
<td>Caution and monitoring with sensory impairment</td>
</tr>
<tr>
<td>Pain</td>
<td>Present? When? Severity?</td>
<td>Determine effectiveness</td>
</tr>
<tr>
<td>Spasticity</td>
<td>Present? Severity?</td>
<td>Impact on parameters; may have + or – impact on spasticity</td>
</tr>
<tr>
<td>Cognition</td>
<td>Able to provide feedback?</td>
<td>Safety issue</td>
</tr>
</tbody>
</table>

Adapted from *Modalities for Therapeutic Intervention, 5th Ed, 2012*
FES for Shoulder Subluxation

How’s it done?

Parameters for Subluxation

- Waveform: Symmetrical or asymmetrical biphasic
- Pulse Frequency: 20-40 pps
- Pulse Duration: 200-350 µsec
- Amplitude: To achieve only desired effect
- Ramp up/down: 3 sec : 3 Sec
- Duty Cycle: 1:5 to 15:1 (goal to increase on time, decrease off time)
- Time and Duration: 30 minutes to 6 hrs (start low and increase); 5-7 days per week x 4-6 weeks

Adapted from Modalities for Therapeutic Intervention, 5th Ed, 2012
Evidence

• FES in addition to conventional superior to conventional alone
  – Prevention or treatment
  – Acute to subacute stroke (less than 6 months)

• Review is strongly supportive of short-term effects, but inconclusive for long term effects
  - Vafadar AK, Cote IN, Archambault PS

FES for Upper Extremity Function

FES for UE Function

• Most common in stroke and TBI
  – Also CP and SCI
• Trigger devices
  – More for training
• Forearm and hand-molded orthoses
  – Devices that stimulate wrist and finger flexors AND extensors
• Dfad;lkjd
Parameters for Hand Function

- Waveform: Symmetrical or asymmetrical biphasic
- Pulse Frequency: 12-40 pps
- Pulse Duration: 200-350 µsec
- Amplitude: To achieve only desired effect (keep as low as feasible)
- Ramp up/down: shortest to achieve function
- Duty Cycle: N/A (timed with demand)
- Time and Duration: 30 -40 minutes, once or twice daily, 3-6 times per week, 6-16 weeks

Adapted from Modalities for Therapeutic Intervention, 5th Ed, 2012

Evidence

- FES does not have significant effect on upper arm motor function early after stroke (impairments improved, not necessarily function)
- In chronic stroke, 2/3 studies found effect (EMG activity and abduction force, but no functional improvement)
- Lateralization of activity dependent on severity of impairment... patients with some finger extension shift towards focused activity in ipsilesional site; those without finger extension showed enhanced involvement of contralateral site
  - Quandt F, Hummel FC, Experimental & Translational Stroke Medicine, 2014

FES for Ambulation

Primary use is for providing dorsiflexion assist for patients who present with decreased foot clearance (AKA drop foot) during swing phase of gait
Trigger Mechanisms

• Heel switch or foot switch

• Tilt sensor that detects leg’s position
  — WalkAide

• Sensor on shoe and computer based algorithms to control timing of stimulation
  — NESS L300

FES for Ambulation

Parameters for Dorsiflexion Assist

• Waveform: Symmetrical or asymmetrical biphasic
• Pulse duration: 200-350µsec
• Frequency: 30-40 pps
• Amplitude: to achieve 3+/5 contraction
• Ramp up/down: 0-1 sec/ 0-1 sec
• Duty cycle: N/A
• Time and duration: determined by muscle fatigue

Adapted from Modalities for Therapeutic Intervention, 5th Ed, 2012
FES for Ambulation post Stroke

- Faster walking speeds than walking training alone or no intervention  

- Evidence inconclusive  
  — Roche et al, Physical Therapy Reviews, 2009

- Further walking distance compared with walking training alone or no intervention  
  — Pereira et al, Topics in Stroke Rehabilitation, 2012

- FES appears to moderately improve activity compared with no intervention and training alone  

FES for Ambulation in Persons with MS

- Significant increase in walking speed, initially and at 20 week f/u

- No significant training effect

- Functional walking category maintained or improved in 95% of responders  

FES for Ambulation after SCI

- Parastep®
- Stim to dorsiflexors
- Stim to glutes and quads
- Operated by controls on walker
But is it a “replacement” for an AFO?

More Recently

• Long term f/u comparing FES to AFO in persons with chronic stroke

• AFO provided “to adequately alleviate foot drop” only

• Results: FES proved “noninferior” to AFOs for all primary measures
  — Bethoux et al, *Neurorehabilitation and Neuro Repair*, 2015

The problem is this...
User experiences, preferences and choices

• Qualitative study in persons with stroke
• Preference for FES for “primary tool for managing foot drop”
• But…”different experiences of both tools led to frequent choices to supplement FES with different types of AFOs”

FES for Exercise

FES Cycling

• Mainly used with persons with SCI
• Bicycle with stim to quadriceps, gluteal, hamstring, anterior tibialis, gastroc-soleus
• Can be used at home
• 60 minutes daily, 5 times per week
• Can add volitional UE exercise
FES UE Cycling

• Used in persons with tetraplegia
• Unilateral or bilateral UE FES
• Gains in oxygen uptake and power output for single case with C6 tetraplegia, increased power output for additional case with C6 tetraplegia

Utilization of FES Cycling

• Usage frequency of home –based FES cycling below recommended levels
• Most users classified in low-frequency category
• Below standards for overall health maintenance

Questions thus far?
What about FES in peripheral nerve injury (PNI)?

Current Evidence on PNI and FES

- Controversial
- Critical level of intensity
  - Bohannon RW, Gajdosik RL. Phys Ther. 1987
- Acceleration of axon growth in PNI
  - Gordon T et al, Neurosurg. 2009
- Use of Bioness L300 resulted in improved gait, decreased fall risk, decreased fear of falling
  - Single case
  - Incomplete sacral nerve root lesion
  - Ambrose K, Wilmarth MA. The Foot and Ankle Online Journal. 2010

Patient Cases and Treatment Plan Development
Patient Mary

- 68 y/o female with R CVA 2 wks ago
- Complaints of pain in L UE
- Minimal UE movement: shrug, slight abduction
- X-ray shows 7mm inferior subluxation of humerus
- Ambulating with Min Assist with SPC

Decision Making Process

- Can condition be treated with FES?
- Is patient appropriate?
- What do we need to know to determine appropriateness?
- Parameters for stimulation?
- How do we progress?

Patient Bob

- SCI T12 incomplete AIS D, 1 year post
- Significant weakness in R LE:
  - 1/5 PF
  - 2/5 DF
- Stronger in L LE:
  - 4/5 PF
  - 2/5 DF
- Lacking ROM at L ankle: -5 degrees DF
Assessment

• Evidence of stance phase instability?
  – YES
  – Deviations?
  – Likely impairments?

• Evidence of swing phase dysfunction?
  – YES
  – Deviations?
  – Likely impairments?

• FES or AFO?

Thanks!
Feel free to contact me
jseale@endicott.edu