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LEARNING OBJECTIVES

- The participant will be able to accurately define functional electrical stimulation (FES) and describe the difference between FES and NMES.
- The participant will be able to identify at least three possible mechanisms for therapeutic benefit from FES and understand the indications/contraindications of treatment.
- The participant will be able to identify the common uses for FES in neurological rehabilitation including FES for shoulder subluxation, FES for upper extremity function, FES for ambulation and FES for exercise.
- The participant will be able to independently describe the current best evidence for the use of FES in persons with neurological diagnosis.
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

<table>
<thead>
<tr>
<th>NMES</th>
<th>FES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitute for or augment voluntary contractions</td>
<td>Substitute for or augment voluntary contractions</td>
</tr>
<tr>
<td>Used for strengthening or hypertrophy</td>
<td>Used for strengthening or hypertrophy</td>
</tr>
<tr>
<td>Part of a training program with goal of increasing strength</td>
<td>Use of NMES to promote functional activities</td>
</tr>
</tbody>
</table>
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

FES
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
WHERE DO WE START?

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 known 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*

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EXAMINATION AND RATIONALE FOR USE

<table>
<thead>
<tr>
<th>Exam</th>
<th>Question</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle</td>
<td>Capable of stimulation?</td>
<td>Typically require innervation</td>
</tr>
<tr>
<td>innervation</td>
<td></td>
<td></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*
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:
  - Shoulder subluxations
  - Upper extremity function
  - Ambulation
  - Exercise

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 JN, Archambault PS
FES FOR UPPER EXTREMITY 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
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

Traditional foot switch

Ness L300

WalkAide

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
- 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?

Peroneal nerve stimulation versus an ankle foot orthosis for correction of footdrop in stroke: impact on functional ambulation.

Schatzke, L.S.*; Hanneson, M.T.; Huston, G.; Chade, J.

© Author information

Abstract

OBJECTIVE: To compare the efficacy of the Odstock Dropped-Foot Stimulator (ODFS), a transcutaneous peroneal nerve stimulation device, versus an ankle foot orthosis (AFO) in improving functional ambulation of chronic stroke survivors.

INTERVENTION: Fourteen chronic stroke survivors with footdrop participated in the study. Participants received ambulation training under 3 test conditions: 1) ODFS, 2) custom AFO, and 3) no device. Each participant was evaluated using the modified Emory Functional Ambulation Profile under the 3 test conditions. All participants were evaluated with a post-evaluation survey to solicit device feedback and preferences.

RESULTS: Functional ambulation with the AFO was significantly improved, relative to no device, on the floor (P = 0.003), carpet (P = 0.013), and “up and go” test (P = 0.042). There was a trend toward significance on the obstacle (P = 0.052) and stair (P = 0.067) tests. Functional ambulation with the ODFS was significantly improved, relative to no device, on the carpet (P = 0.003). A trend toward significance on floor (P = 0.087), obstacle (P = 0.052), and stair (P = 0.075) trials was observed. The difference in functional ambulation between the AFO and ODFS showed a trend toward statistical significance on floor (P = 0.055) and up and go (P = 0.082) trials only. Given a choice between the ODFS and AFO for long-term correction of footdrop, participants indicated a preference for the ODFS.

CONCLUSION: The ODFS and the AFOs may be comparable in their effect on improving functional ambulation as compared to no device. Specific characteristics of the ODFS may make it a preferred intervention by stroke survivors. More rigorously controlled trials are needed to confirm these findings.
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…
AND 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

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 CYCLING
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?

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?

LET’S GO BACK
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?
WHAT ABOUT THIS ONE?

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
JISEALE@UTMB.EDU