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Functional Electrical Stimulation for OTs: Principles and Application

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For occupationaltherapy.com. March 26, 2020

Learning Outcomes

After this course, participants will be able to:

- Recognize the therapeutic applications for using electrical stimulation.
- Identify contraindications and precautions for electrical stimulation.
- Describe the physiological mechanisms for muscle contraction when using electrical stimulation.
- Select alterable parameters to adjust for specific patient care.

NMES Assisted Grasp Training and Restoration of Function in the Tetraplegic Hand: A Case Study Series

Martin, Johnston, Sadowsky

Am J of Occupational Therapy, 66, 471–477.

Objective

- To determine the influence of repetitive NMES assisted grasp and release activities on the paretic tetraplegic hand.

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Participant #1

- 21 y.o., female
- C5 ASIA A
- 21 mos. post injury

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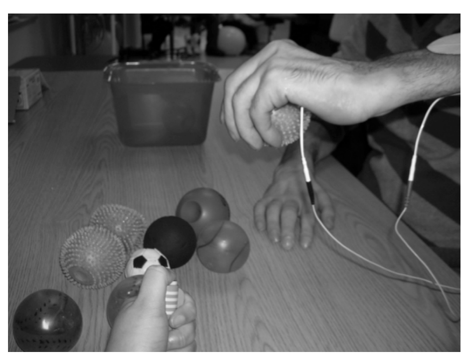
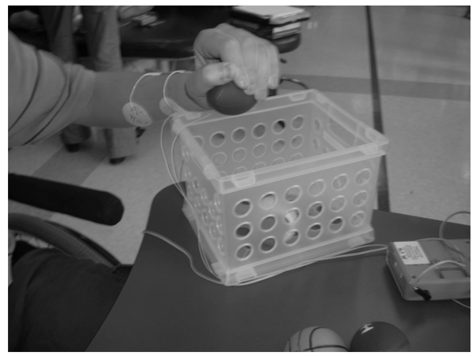
Participant #2

- 17 y.o., male
- C5 ASIA C
- 6 mos. post injury



Participant #3

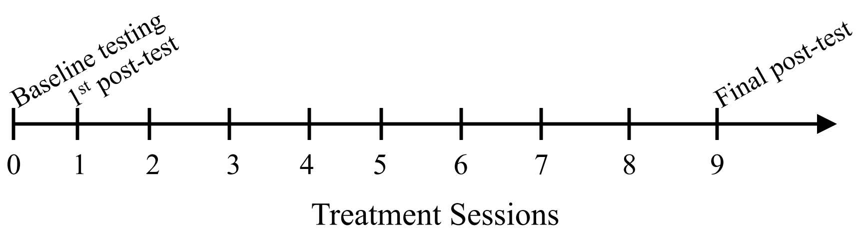
- 18 y.o., male
- C4 ASIA A
- 12 mos. post injury



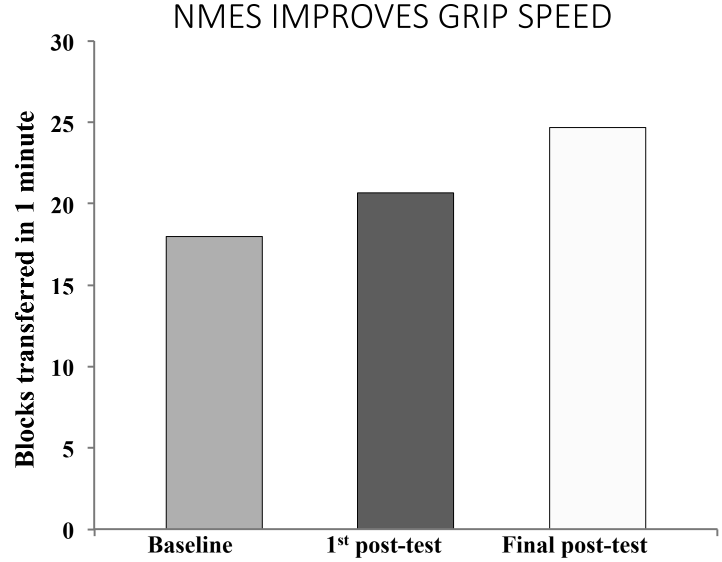
Intervention

Outcomes

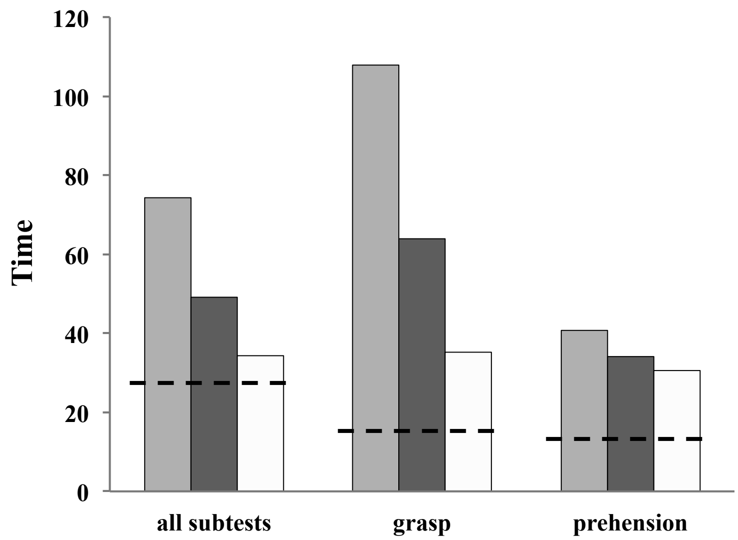
- Jebsen Taylor Hand Function Test
- Box and Blocks Test
- Semi-structured Interview



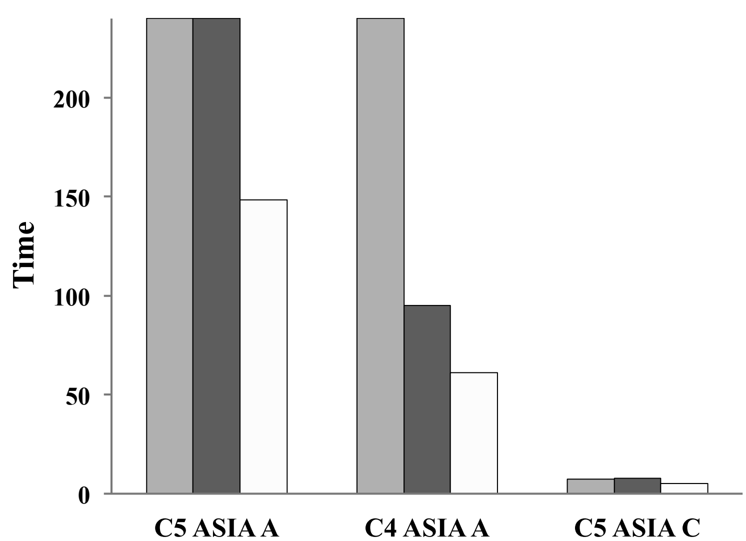
NMES IMPROVES GRIP SPEED



NMES IMPROVES GRIP AND PREHENSION PATTERNS



NMES SIGNIFICANTLY IMPROVES GRIP STRENGTH



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Subjective Patient Report

- "The treatment reminded me I have fingers."
- "My fingers feel much looser, like I can use them now."
- "This weekend I picked up a full soda can, and did not spill it!"

continued

Conclusions

- Improvements were observed in all main outcome measures.
- Most significant improvements were seen in grasp functions.
- Participants reported reduction of spasticity, more effective hand grasp, and greater endurance in functional tasks of the trained hand.

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Indications and Precautions

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Types of Electrical Stimulation

TES	NMES	FES	TENS
Therapeutic Electrical Stimulation	Neuromuscular Electrical Stimulation	Functional Electrical Stimulation	Transcutaneous Electrical Nerve Stimulation
Use of electricity to drive a desired nerve response for therapy.	Electricity applied across the surface of the skin over intact peripheral nerve evokes an action potential in the nerve fiber which causes an exchange of ions to drive the muscle to contract.	Application of electrical stimulus to a paralyzed nerve or muscle to restore or achieve function. Also refers to orthotic substitution (Bioness L300).	Pain modulation by exciting peripheral nerves. Common Types: • Sensory • Motor • Noxious

Q1

Therapeutic Indications

- Increase circulation
- Reduce muscle spasm
- Promote healing of fracture or tissue
- Reduce edema
- Strengthening
- Improve and maintain muscle mass during or following periods of inactivity

Q2

Therapeutic Indications

- Maintain/gain ROM
- Re-educate/facilitate voluntary contraction
- Reduce effects of spasticity
- Prevent/reverse disuse atrophy
- Orthotic substitution

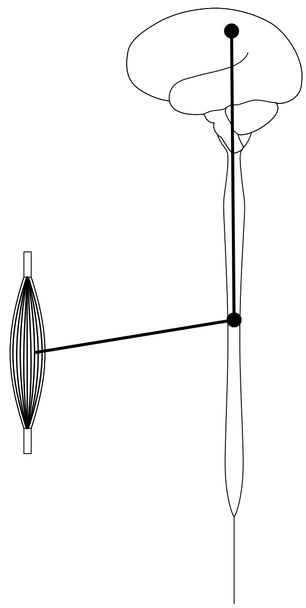
Contraindications/Precautions

(at the discretion of the treating team)

- Implanted electrical device
- Active metastases
- Evidence of osteomyelitis
- Decreased sensation
- Thrombosis/hemorrhage
- Pregnancy
- Epilepsy
- Cognitive status

Q3

Neuroanatomy: A quick review



Upper Motor Neuron (UMN)

- Nerve entirely in central nervous system
  - Cell body in brain
  - Axon in spinal cord
- Damage results in
  - Loss of movement and sensation
  - Hyperreflexia
  - Increased muscle tone
  - Disuse atrophy
  - Contracture secondary to increased tone
- Recovery is attributed to plasticity/redundancy, but is probably a combination of factors (remyelination, endogenous stem cells, sprouting to other intact tracts)

Q4

Lower Motor Neuron (LMN)

- Nerve which originates in the central nervous system, ends in the peripheral nervous system
  - Cell body in spinal cord
  - Axon outside the spinal cord (runs to a muscle)
- Damage results in
  - Loss of movement and sensation
  - Hyporeflexia
  - Low to no muscle tone
  - Dennervation atrophy
  - Contracture secondary to soft tissue shortening
- Damage to the axon only (in the extremity) regrows at the rate of 1cm/ month
- Damage to the cell body (in the cord) does not regrow, may impact response to ES

Basic Electrophysiology

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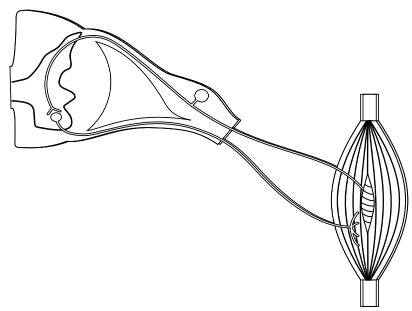
Mechanism for Contraction

Electricity applied across the surface of the skin over an intact peripheral nerve evokes an action potential in the nerve fiber (like physiologically generated potentials) causing muscle to contract.



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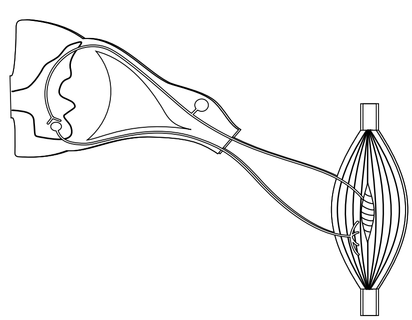
AP travels in both directions

- To contraction of muscle at synapse
- To motor neuron in ventral horn



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All or nothing contractions

- *Electrically* elicited contractions lack smooth, gradual onset of voluntary contraction, reflecting biased and synchronous motor unit recruitment.
- *Voluntary* contractions allow for asynchronous activation of varied motor units which allows for smooth switching between active and inactive motor units to maintain muscle activity, while allowing recovery time for individual motor units.

Q

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Recruitment of motor units

- Axons of the largest diameter are the easiest to activate and are recruited before axons of smaller diameter.
- Recruitment of motor units by electrical stimulation progresses from large to small, the reverse order of voluntary contractions.
- Recruitment is also a function of electrode proximity

Fatigue occurs more rapidly

- A greater proportion of fatigable motor units is necessary for a given contraction.
- Combining voluntary contractions with ES produces the best and strongest contraction, as the ES recruits different motor units not activated at a given moment by a voluntary contraction.

Stimulation Current & Parameters

continuED

Electrodes and Placement

- Use as small electrode as possible
  - One that will recruit entire muscle
  - Minimizes fatigue and bleed
- Larger electrode will be more comfortable
- Electrodes should encompass motor point of targeted muscle
  - Largest cross sectional area
- Consider skin health, factors of impedance

continuED

Alterable Parameters

- *Waveform*: biphasic (symmetrical or asymmetrical), monophasic
- *Frequency*: hertz (pulses per second)
- *Amplitude*: milliamperes
- *Ramp* (surging): time to maximum amplitude
- *Duration*: total treatment time and individual pulse (microseconds)

Q6

continued

Waveforms

Monophasic

- One phase each pulse
- Also known as pulsating DC
- Unidirectional flow
- One electrode is positive and the other is negative

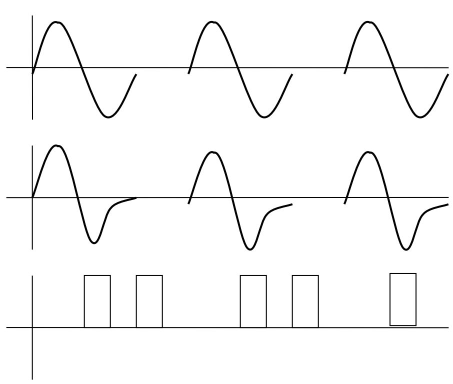
Biphasic

- 2 opposing phases are contained in a single pulse
- Asymmetric and Symmetric
- Symmetric is preferred to asymmetric if motor neurons are the target

33

continued

Waveforms



Biphasic symmetrical

Biphasic Asymmetrical

Monophasic

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Amplitude

- Magnitude of a current (or voltage)
- Peak amplitude: maximum current during a phase
- Measured in milliamps (mA)

Q7

Frequency

- The number of pulses (wave forms) repeated at regular intervals
- Referred to as pulses per second (pps) or Hertz (Hz)
- Inverse relationship between pulse frequency and tissue resistance

Pulse Duration

- The total time elapsed from the beginning to the end of one pulse
- Includes the phase duration of all phases and the interphase interval

Q8

Minimize Current

Primary goal is to get motor action or neurological benefit with as little external input as necessary, while minimizing fatigue.

continued

Parameters

Sensory (TENS)

- High frequency (80-100Hz)
- Low pulse duration (80-100μsec)
- Amplitude sub-motor

Motor (NMES, FES)

- Low frequency (20-60Hz)
- Longer pulse duration (100 μsec-1millisec)
- Amplitude to tolerance

continued

Starting Parameters

- Ex: 20Hz, 200μsec, timing based on condition/activity
- Pick a place to start. Adjust based on what you see.
  - Can the pt. tolerate it?
  - Can you reach tetany?
  - Are you getting capture of the whole muscle?
  - Are you getting the action you wanted?
  - Are you getting bleed into other muscles?

continuED

Altering Parameters

Goal	Frequency	Pulse Width	Intensity	Notes
Increase comfort	Increase (if reporting pins and needles)	Decrease	Decrease (only enough to get tetany)	Can also try using larger electrodes
Decrease electrical bleed	Increase or decrease	Decrease	Decrease	Can also try using smaller electrodes
Minimize fatigue	Decrease	Decrease	Decrease	Overall, aim to minimize current, consider variable waveform
To improve quality of tetany	Increase	Increase or decrease	Increase	Look for smooth fused contraction

continuED

Designing Treatment

continued

Goal

- Maximizing Efficiency
- To avoid fatigue and accommodation, use low frequency and gradual increases in intensity

continued

Assessment

- Evaluate muscle and nerve health to determine most appropriate intervention strategy.
- Must have intact peripheral nerve to stimulate.
- Stimulatable muscle must have some intact LMN
  - Look for PN injury with ortho conditions
  - Look at pattern of damage to CNS with neuro conditions

continued

Atrophy and Muscle Health

- Long-term atrophy may result in muscles which are too weak to move against gravity, even with electrical stimulation.
- Spindly motor units are sluggish to respond to electrical stimulation.
- Additional considerations:
  - Connective tissue and skin health
  - Hydration and nutrition

continued

UMN vs LMN: Complicating Factors

- Patterns of innervation:
  - More than one segment innervates each muscle; won't be clear myotome or peripheral nerve distribution.
- Long-term atrophy can appear as LMN injury secondary to weakness
  - Try extending pulse duration to reach slow twitch fibers
  - Not a one-time trial. Treat for 6-8 weeks with careful dosing before making a determination.
    - Patient will still receive secondary benefits: sensory stimulation, neural activity, peripheral, vascular, etc.

continued

Spasticity

- An increase in muscle tone due to hyperexcitability of the stretch reflex and is characterized by a velocity-dependent increase in tonic stretch reflexes
- UMN Syndrome: Lack of input from corticospinal tracts

continued

Impact of Spasticity on Therapy

- Unable to access normal movement patterns
- Masks underlying activation or strength
- Decreases ability to participate in mobility activities
- Safety impact

Spasticity Management

- E-stim also helps to strengthen muscles and has analgesic properties which both help to decrease spasticity.
- Successful clinical applications include long ramp times, to minimize stretch reflex, and variable pulse frequency and duration, to reduce summation and accommodation.

E-stim for spasticity management

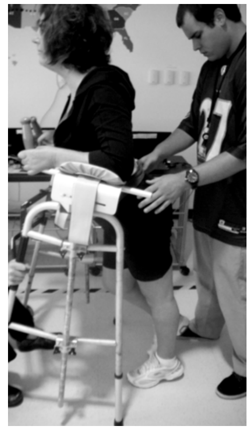
1. Sensory settings to spastic muscle
   - Applied prior to activity
   - Applied during to activity
   - Examples: Sensory e-stim to quadriceps either in the car on the way to therapy, or during gait, to increase knee flexion during swing
2. Motor settings to spastic muscle
   - Applied prior to activity (fatigue)
   - Example: Motor e-stim to quadriceps while standing in standing frame to fatigue quads, done prior to gait training, to increase knee flexion during swing
3. Motor settings to antagonist
   - Applied during activity
   - Example: Motor e-stim to hamstrings during gait training to increase knee flexion during swing

Q9

Case: E-stim

Before

After



Special Patient Populations

SCI

- Spinal stability
  - ES to LE while in traction/halo to provide input without motion
  - ES to LE to lower risk for DVT
- Medical fragility
  - ES to LE and trunk before getting out of bed or during upright to offset orthostasis
- Bedrest
  - ES to dorsiflexors or wrist extensors to offset ortho complications
- In ICU: ES early and often!

Needham, Truong, Fan, 2009

SCI

- Retrospective cohort to examine the effect of long-term lower extremity FES cycling on the physical integrity and functional recovery in people with chronic SCI.
- FES during cycling in chronic SCI may provide substantial physical integrity benefits, including enhanced neurological and functional performance, increased muscle size and force-generation potential, reduced spasticity, and improved quality of life.

Sadowsky et al., 2013

MS

Several studies involving ES for foot drop:

- ↓ effort in walking
- ↑ walking speed
  - Improved stair negotiation, increased ankle DF
- ↑ quality of life

Taylor et al., 1999; Sheffler et al., 2009

Q10

MS

Pilot study:

- 5 patients with primary or secondary progressive MS
- Cycled in the home for 6 months
- Results:
  - Improvements in 2 minute walk test, timed 25 foot walk, and TUG
  - Strength improved in muscles stimulated by FES cycle
  - Multiple Sclerosis Functional Composite (MSFC) and physical and mental health sub-scores and total SF-36 improved
- Conclusions: FES cycling was reasonably well tolerated by progressive MS patients

Ratchford et al. (2010). A pilot study of functional electrical stimulation cycling in progressive multiple sclerosis. *Neurorehabilitation,* 27(2), 121-8.

continuED

CVA

- Cognitive limitation
  - Ensure pt has a way to express discomfort
- ES improves uptake of Botox
- ES as compliment to splint program

Hesse, et al., 2001

continuED

Cardiac

- ES increases cardiovascular demand
- Pacemakers v. Defibrillator
  - Depends on type
  - Location of stimulation

Crevenna, et al., 2003

Ortho

- No ES close to external fixator
- OK around internal hardware
- Respect surgical precautions
- ES offset atrophy associated with immobilization
- TENS
- Sensitive skin electrodes for fragile or irritable skin

Pediatric

- Start slow
  - Decorate electrodes
  - Wear electrodes only
  - Demo on Mom/Dad
- Minimize current
- Can cut down electrode
- Distraction!

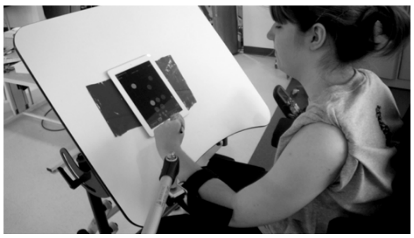
Functional Applications

To augment voluntary effort

To improve kinematics and endurance

Without

With



FES to paraspinals during seated play

FES to gluteals during half kneeling

FES to hip flexors using trigger switch during crawling

QUESTIONS:
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