Electrical Stimulation for Motor Responses
...from twitch to tetany...
“The stimulation seemed so scary when you suggested it but I can see the muscle working!”
Potential Goals:

Electrical Stimulation is often described in terms of the goals it is being used to accomplish.

- Edema reduction
- Pain reduction
- Muscle strengthening
- Muscle re-education
- Reduction in muscle guarding
Potential Goals that require a motor response:

- Edema reduction
- Pain reduction
- Muscle strengthening
- Muscle re-education
- Reduction in muscle guarding
What’s in a name?

Since different goals can be accomplished with the “same” modality......they are referred to by what they are being used for.

- **FES-Functional Electrical Stimulation**
  - aka-EMS
    - Electrical Muscle Stimulation

- **NMES-Neuromuscular Electrical Stimulation**
  - aka-EMS
    - Electrical Muscle Stimulation
Physiology Review

• **Neuron**
  - Cell body
  - Axon
  - Dendrite

• **Types of Neurons**
  - A fibers
  - Motor fibers
  - Nociceptors

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**Primary Afferent Axons**

<table>
<thead>
<tr>
<th>Axon Type</th>
<th>Aα</th>
<th>Aβ</th>
<th>Aδ</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (μm)</td>
<td>13-20</td>
<td>6-12</td>
<td>1-5</td>
<td>.2-1.5</td>
</tr>
<tr>
<td>Speed (m/s)</td>
<td>80-120</td>
<td>35-75</td>
<td>5-35</td>
<td>.5-2.0</td>
</tr>
</tbody>
</table>
Types of Nerve Fibers

- **A fibers (A Beta)**
  - Sensory, motor, fast pain, heat, cold, proprioception, pressure, touch and vibration
  - (mechanoreceptive)
Types of Nerve Fibers

• Nociceptors
  ○ Slow and fast pain, temperature excesses, tissue damage
Characteristics of Neurons

- Myelinization
  - Insulation covering the axon, enables more rapid conduction for impulses along the axon
Characteristics of Neurons

Diameter

- The greater the diameter of the nerve fiber, the more easily the nerve is stimulated and the lower the threshold of excitability to electrical stimulus.
- Shorter duration of an excitatory response
- The greater the diameter, the shorter the refractory period

“We’re coming through!”
Physiology

Neuron Characteristics
- Excitability
- Threshold for Action potential
- Stimulation Sites
  - Motor Point
    - Muscle belly
      - neuromuscular junction
  - Distal on the muscle belly
    - Longitudinal conduction through the muscle fiber

Figure 1 - General Shape of an Action Potential propagating down a loligo axon. Source picture take from Wikipedia.
Nerve Fiber Excitability

- Propagation of an impulse
  - The transmission of the electrical information along a nerve fiber
  - Diameter and myelinization of the nerve fiber
  - The stimulus must be of an adequate intensity and duration to meet or exceed the threshold of the nerve fiber

![Diagram](image-url)
Nerve Fiber Excitability

- Thresholds for nerve are lower than thresholds for muscle that is de-nervated
  - The conduction is poorer
  - Muscle fibers must be stimulated directly
  - instead of the motor nerve which is unavailable

Figure 3.19. Stimulus strength-duration curves for the three classes of peripheral nerve fibers and denervated muscle.
Physiology

- Refractory Period
  - The amount of time that it takes the nerve fiber to return to its pre-stimulus state
  - To re-polarize following de-polarization
    - To be able to carry another impulse
    - To continue the sensation or response of the fiber
    - Information may only be transmitted when the nerve fiber re-polarizes
Characteristics of Neurons:

- **Excitability**
  - **Action Potential**
    - The “message unit” of the nervous system to transmit information along a nerve fiber.

Figure 1 - General Shape of an Action Potential propagating down a loligo axon. Source picture take from Wikipedia.
Waveform Considerations

- General Considerations when applying Electrical Stimulation for a motor response
  - Think first...
What purpose does the skin serve?
Skin Stratum Corneum

- Stratum corneum
- Melanocyte (pigment mother cell)
- Elastin (elastic fiber)
- Collagen (collagen fiber)
- Fibroblast
- Capillary vessel
- Hyaluronic acid
- Hair pore
- Sebaceous gland
- Sweat pore
- Sweat gland
- Sulcus cutis
- Hill

- Appearance (looks)
- Balance between sebum and moisture
- Condition of the corneal layer and turnover
- Skin tone, complexion, and cleanness
- Elasticity, firmness, and fibroblast
If you want to accomplish your goal....

- You have to be able to cross over the skin!
Neuromuscular Electrical Stimulation

- NMES
  - Stimulation of the neuromuscular junction for the purpose of eliciting a motor response of the muscle
  - In accomplished whenever there is an electrically induced muscle contraction
    - Requiring that motor points be utilized
Indications for NMES

- Pain relief
- To enhance blood flow
- To fatigue muscles that are guarding
- To “re-educate” muscle
- To enhance muscle contraction strength and endurance
Types of Motor Responses

- Twitch \textit{link}
  - Response to one long duration pulse of electrical stimulus
  - Single motor unit response to stimulus
  - Non-physiological
  - Occurs in response to low frequency stimulus delivery

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{Chart showing different responses to stimuli.}
\end{figure}
Types of Motor Responses

- Tetany
  - The final fusion of muscle twitches
  - Tension is much greater than for individual twitches
  - It is a function of the applied frequency of the electrical stimulus at an amplitude sufficient to elicit a motor response
    - 35-50pps = optimal to limit fatigue
Selective Stimulation Parameters

SD Implications

- Pulse duration
  - For motor responses of innervated muscle
    - At least 200 usec

- Intensity
  - For motor responses of innervated muscle,
    - It must be more than just sensory

Figure 3.19. Stimulus strength-duration curves for the three classes of peripheral nerve fibers and denervated muscle.
Selective Stimulation Parameters

- Frequency
  - Less than 15 pps will produce a twitch response
  - More than 15 pps will produce more of a tetanic contraction
    - 35-50 pps for smooth tetanic responses
    - 50+ pps will produce a smooth tetanic contraction that will quickly fatigue
NMES for muscle strengthening

- What about ON times?
  - Are they important
    - Actually the recovery time for the muscle is more important!
      - It can take up to 50 seconds for a muscle to recover after a 10 second maximal contraction
  - Here’s an overview
Electrically Induced Muscle Contraction

• Following an electrically induced muscle contraction,
  ○ Marked increase in the blood flow in the treated extremity
    ‣ Hmmm... I wonder what effects that might have?
Electrically Induced Muscle Contraction

- Muscle contractions have been studied in response to different frequencies of ES
  - 8-32 pps significant increase in blood flow (Wakim 1953)
  - Above 32 pps smaller increases in blood flow than 8-32 pps (Wakim, Randall, Imig & Hines 1953)
Electrically Induced Muscle Contraction

- Direct stimulation of the afferent neurons causes peripheral vasodilation
- Recruitment of muscle fibers will occur in the opposite pattern to voluntary recruitment
  - With ES deeper, slower fatiguing muscles respond first
    - Also fatiguing more quickly
    - In other words, you will not get this, from this...
Electrically Induced Muscle Contraction

- Physiologic Response
  - Lymphatic return
  - Blood flow increase
  - Strength increase
    - ONLY IF
      - Against resistance
      - Exercised to the point of fatigue, etc.
Electrically Induced Muscle Contraction

What about electrical stimulation as an aide to ambulation? After a CVA it has been helpful in alleviating foot drop.

Bioness has several products and interesting case histories.
Contraindications to NMES

- Over a pregnant uterus
- In the presence of a pacemaker
- In anesthetic areas
- Transcranially

Hmmm...

Why is it contraindicated transcranially?
Contraindications to NMES

- In the presence of a thrombus
  - A blood clot
- In the vicinity of a thrombus
- These could cause...
Contraindications to NMES

- Unstabilized fracture!!!!!!
So what do you think?
Are you ready to let someone else
get your muscles
working for you?

Remember that it’s a strange
but awesome sensation!