Developing an Optimized EMS User Guide to Enhance Muscle Architecture

Natalie Ledezma
Carli Stewart
Project Aims

1. Evaluate prior studies involving electromyostimulation (EMS) to determine its effect on muscle cross-sectional area, torque, and pennation angle

2. Compile the results of the previous investigations to determine an effective plan-of-use for EMS

3. Test this plan-of-use in different population groups in order to ensure adequate applicability
EMS:
The use of electrical impulses to elicit muscle contractions

- Leads to significant changes in:
  - Muscle cross-sectional area
  - Pennation angle
  - Muscle torque

https://www.shocktherapyfitness.com/
Importance of Affected Muscle Architecture Properties

Cross Sectional Area: property of muscle architecture that is directly proportional to the force that a muscle can generate

\[ F_o^m \propto \text{PCSA} \]

Pennation Angle: The orientation between a muscle fascicle and tendon.

\[ f_t = \sum_i f_m^i \cos(PA^i). \]

Muscle Torque: The ability of force to cause a rotation about a lever. The greater the torque, the greater the movement produced on the body’s “levers.”
Potential Impact

Users

In the US alone:
- 16 million adults have COPD
- 68.7 people are over the age of 60 years old
- ~5,000 professional athletes
- ~45 million adults have a gym membership

Estimated Cost

- Electrodes: ~$15/40 pads
- Portable Stimulator: ~$250-500

https://www.compex.com
Variables in EMS

- Total Weeks
- Sessions/week
- Impulse Interval
- Impulse Waveform
- Impulse Frequency
- Impulse on-time

https://whatis.techtarget.com/definition/waveform
## Aim 1: Cross Sectional Area

<table>
<thead>
<tr>
<th>Authors</th>
<th>n</th>
<th>Sex</th>
<th>Age</th>
<th>Sessions/week</th>
<th>Total Weeks</th>
<th>Impulse Interval</th>
<th>Impulse Form</th>
<th>Impulse Frequency</th>
<th>Impulse On-Time</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gondin et al.</td>
<td>22</td>
<td>male</td>
<td>23.5±5</td>
<td>4</td>
<td>8</td>
<td>18 min sessions</td>
<td>Rectangular wave, pulse</td>
<td>75 Hz</td>
<td>400 μs</td>
<td>3-10% increase</td>
</tr>
<tr>
<td>Vivodtzev et al.</td>
<td>22</td>
<td>8 male, 4 female</td>
<td>70±1</td>
<td>5</td>
<td>6</td>
<td>35 min quadriceps; 25 min calf</td>
<td>Not mentioned</td>
<td>50 Hz</td>
<td>400 μs</td>
<td>6%±2% increase in both</td>
</tr>
<tr>
<td>Oliveira et al.</td>
<td>33</td>
<td>male</td>
<td>22.1±2.6</td>
<td>3</td>
<td>6</td>
<td>15 min sessions</td>
<td>Medium is biphasic (rectangular/sinusoidal)</td>
<td>Low: 1-100 Hz</td>
<td>500 μs</td>
<td>Thicker muscles</td>
</tr>
<tr>
<td>De Abreu et al.</td>
<td>15</td>
<td>Male (quadriplegia)</td>
<td>32.2±3.5</td>
<td>2</td>
<td>24</td>
<td>20 min sessions</td>
<td>NMES</td>
<td>25 Hz</td>
<td>300 ms</td>
<td>15% increase</td>
</tr>
<tr>
<td>Lotri-Koffi et al.</td>
<td>23</td>
<td>C57BL6 male mice</td>
<td>16-week old</td>
<td>5</td>
<td>2.5</td>
<td>20 min sessions</td>
<td>symmetrical, biphasic, square-pulsed</td>
<td>50 Hz</td>
<td>150 μs</td>
<td>~6% increase</td>
</tr>
</tbody>
</table>
## Aim 1: Pennation Angle

<table>
<thead>
<tr>
<th>Authors</th>
<th>n</th>
<th>Sex</th>
<th>Age</th>
<th>Sessions/week</th>
<th>Total Weeks</th>
<th>Impulse Interval</th>
<th>Impulse Form</th>
<th>Impulse Frequency</th>
<th>Impulse On-Time</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gondin et al.</td>
<td>22</td>
<td>Male</td>
<td>23.5±5</td>
<td>4</td>
<td>8</td>
<td>18 min sessions</td>
<td>Rectangular wave, pulse</td>
<td>75 Hz</td>
<td>400 μs</td>
<td>14±7% increase</td>
</tr>
<tr>
<td>Oliveira et al.</td>
<td>33</td>
<td>male</td>
<td>22.1±2.6</td>
<td>3</td>
<td>6</td>
<td>20 min sessions</td>
<td>Medium is biphasic (rectangular/sinusoidal)</td>
<td>Low: 1-100 Hz</td>
<td>500 μs</td>
<td>No difference</td>
</tr>
</tbody>
</table>
## Aim 1: Torque

<table>
<thead>
<tr>
<th>Authors</th>
<th>n</th>
<th>Sex</th>
<th>Age</th>
<th>Sessions/week</th>
<th>Total Weeks</th>
<th>Impulse Interval</th>
<th>Impulse Form</th>
<th>Impulse Frequency</th>
<th>Impulse On-Time</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maffiulett i et al.</td>
<td>8</td>
<td>male</td>
<td>20.4±2.1</td>
<td>4</td>
<td>4</td>
<td>18 min sessions</td>
<td>Rectangular wave, pulse</td>
<td>75 Hz</td>
<td>400 μs</td>
<td>8.1-10.8% increase</td>
</tr>
<tr>
<td>Oliveira et al.</td>
<td>33</td>
<td>male</td>
<td>22.1±2.6</td>
<td>3</td>
<td>6</td>
<td>15 min sessions</td>
<td>Medium is biphasic (rectangular/sinusoidal)</td>
<td>Low: 1-100 Hz</td>
<td>Medium: 1-10 kHz</td>
<td>Alternating: 19.6% Pulsed: 17.8%</td>
</tr>
<tr>
<td>Colson et al.</td>
<td>25</td>
<td>male</td>
<td>24±2.5</td>
<td>3</td>
<td>7</td>
<td>5 sets of 6 contractions every 3 minutes</td>
<td>Rectangular wave, pulse</td>
<td>80 Hz</td>
<td>240 μs</td>
<td>At 120°: +15.9±4% At 60°: +18.2±5% At 30°: +15.8±4%</td>
</tr>
</tbody>
</table>
Aim 2: EMS Plan-of-Use

• Frequency of EMS training sessions:
  • 3 times per week
  • 20 min sessions
  • 8 weeks or more
• Intensity: gradually increase until the maximum tolerated
• Waveform: Biphasic
• Frequency: 75 Hz
• Impulse on-time: 400 μs
Aim 3: Testing

Conduct three 8-week studies that use the previously outlined plan to test changes in quadricep muscle architecture properties in the following groups:

1. COPD patients - 30 total participants (Experimental (15) & Control (15))
   a. Age: 45-55 years old
2. Athlete Group - 30 total participants (Experimental (15) & Control (15))
   a. These participants will be from the same sports team
3. Young Adults - 30 total participants (Experimental (15) & Control (15))
   a. 20-25 years of age
Testing Conditions

Equipment:
- Cross Sectional Area Measurements:
  - B-mode ultrasonography
- Pennation Angle Measurements:
  - B-mode ultrasonography
- Torque Measurements:
  - Biodex-type Isokinetic Ergometer: measure muscle contractions

Constant variables:
- Time EMS sessions are held
- 60° knee flexion
- Frequency

https://m.biodex.com/physical-medicine/blog/what-isokinetic-testing
Expected Results

We expect to see:

• Significant increases in muscle architecture properties for each experiment

• Comparable changes between experiments

If the changes are not significant in one group, then we will reevaluate our EMS plan for the specific population group and test again.

Table 1. Quadriceps cross-sectional area of each individual in the gait group

<table>
<thead>
<tr>
<th>Gait group</th>
<th>Level of injury</th>
<th>Cross-sectional area (cm²)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C5</td>
<td>60.2</td>
<td>73.3</td>
</tr>
<tr>
<td>2</td>
<td>C4</td>
<td>59.1</td>
<td>69.3</td>
</tr>
<tr>
<td>3</td>
<td>C5</td>
<td>57.2</td>
<td>60.7</td>
</tr>
<tr>
<td>4</td>
<td>C4</td>
<td>38.9</td>
<td>53.0</td>
</tr>
<tr>
<td>5</td>
<td>C4</td>
<td>47.5</td>
<td>51.4</td>
</tr>
<tr>
<td>6</td>
<td>C5</td>
<td>48.5</td>
<td>52.8</td>
</tr>
<tr>
<td>7</td>
<td>C7</td>
<td>34.5</td>
<td>41.1</td>
</tr>
<tr>
<td>8</td>
<td>C6</td>
<td>52.5</td>
<td>56.9</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>49.8</td>
<td>57.3</td>
</tr>
<tr>
<td>Standard deviation</td>
<td></td>
<td>9.4</td>
<td>10.3</td>
</tr>
</tbody>
</table>

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Thank You!
References: