Motor Unit Potential Recruitment . . . Made Simple!

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Learning Objectives
After this session, you should be able to:

• Understand concepts of normal and abnormal MUP recruitment

• Apply auditory recognition skills to learn accurate MUP recruitment
Assessing the Motor Unit Potential
Recognition of MUP changes

**Recruitment**
Number of motor units

**Stability**
NMJ function

**Phases/Turns**
Fiber synchrony

**Size of motor unit**
(duration, area, etc.)
Fiber size, density, distribution

[Diagram showing amplitude, duration, and phases]
Recruitment = the process by which different motor units are activated to produce a given level of muscle contraction.
Primary mechanism for increasing force output is recruitment of more MUs
Loss of MUs =

1) Reduced force generation
2) Preserved MUs fire **FASTER** to generate tetanic force
Low threshold MUs fire first during minimal contraction
• Fire slow (<25 Hz)
• Firing rate stabilizes (but increases some) as force increases

Recruitment of additional MUs takes precedence over increase firing rate at low force
MUP Recruitment

Number of motor units active
Two sites - solid & dashed line

Firing rate of multiple MUP at the two sites

Transient firing rate decrease with recruitment

From McGill Jour NS Methods 2005
Firing Rates at 2 Contraction Levels

Low

Strong

Reduced Recruitment
MUP Firing Rate is TOO FAST

Single MUs firing >20 Hz is abnormal

“The ability to hear and verify, by visual inspection, that one or more MUs are firing > 20 Hz during increasing muscle contraction is indicative of a decreased number of MUs.” *

Normal Recruitment

Orderly addition of potentials from different motor units with increase in discharge rate
Reduced Recruitment

Too few MUP for rate of firing
Disorders With Reduced Recruitment

**Neurogenic**
- Loss of axons (e.g. mononeuropathies, radiculopathies, axonal neuropathies)
- Anterior horn cell diseases (e.g. ALS)
- Conduction block (e.g. Saturday night palsy)

**Correlates with weakness !**

**Myopathies**
- Severe myopathy with loss of all muscle fibers in some motor units (e.g. end-stage muscular dystrophy)

**NMJ Disorders**
- Severe blocking of all fibers in a motor unit (e.g. severe LEMS)
Rapid (Early) Recruitment Assessment is Effort-Dependent!

Recruitment frequency and ratio are normal

Multiple MUP with minimal effort ("all or none pattern")

"... activation of >3 MUs with minimal effort or barely perceptible muscle contraction has been called early recruitment."

“Poor Activation”

![Graph showing MUP firing rate vs. force with labels for MUP1 and MUP2, and a box indicating pain, effort, central disorder, and myelopathy.]

- Effort
- Pain
- Central Disorder
- Stroke
- Myelopathy
How do you assess MUP recruitment in the EMG Laboratory?
Recruitment is determined by defining the relationship between:

# MUP activated
Firing rates of the MUP
Force of contraction
2 Methods of Recruitment Assessment

Recruitment Frequency or Rate

Maximum firing rate of the 1st MUP when the 2nd MUP is recruited

Recruitment Ratio

Ratio of rate of fastest firing MUP ÷ # of nearby MUP

Firing Rate Analysis

RF: 11.2 / 3 = 3.7

RR: 11.2 / 3 = 3.7

11.2
9.9
9.3
<table>
<thead>
<tr>
<th>Muscle**</th>
<th>Mean and standard deviation* of onset intervals (msec)</th>
<th>Mean and standard deviation of recruitment intervals (msec)</th>
<th>Number of units analyzed</th>
<th>Number of onset intervals</th>
<th>Number of recruitment intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontalis</td>
<td>9.8 102 ± 29</td>
<td>21.7 46 ± 16</td>
<td>72</td>
<td>316</td>
<td>78</td>
</tr>
<tr>
<td>Orbicularis oris</td>
<td>14.2 70 ± 19</td>
<td>14.2 34 ± 10</td>
<td>58</td>
<td>299</td>
<td>69</td>
</tr>
<tr>
<td>All facial muscles</td>
<td>11.7 86 ± 29</td>
<td>25 40 ± 16</td>
<td>130</td>
<td>615</td>
<td>147</td>
</tr>
<tr>
<td>Deltoid</td>
<td>8.6 116 ± 23</td>
<td>11.9 84 ± 16</td>
<td>53</td>
<td>353</td>
<td>94</td>
</tr>
<tr>
<td>Biceps</td>
<td>8.1 124 ± 21</td>
<td>11.6 86 ± 14</td>
<td>56</td>
<td>376</td>
<td>111</td>
</tr>
<tr>
<td>Triceps</td>
<td>7.7 132 ± 36</td>
<td>11.9 84 ± 17</td>
<td>49</td>
<td>332</td>
<td>80</td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>8.6 116 ± 22</td>
<td>12.8 78 ± 18</td>
<td>36</td>
<td>247</td>
<td>42</td>
</tr>
<tr>
<td>Pronator teres</td>
<td>7.7 132 ± 38</td>
<td>11.3 88 ± 19</td>
<td>35</td>
<td>132</td>
<td>46</td>
</tr>
<tr>
<td>First dorsal interosseous</td>
<td>7.0 142 ± 39</td>
<td>10.2 98 ± 21</td>
<td>51</td>
<td>318</td>
<td>122</td>
</tr>
<tr>
<td>Multifidus</td>
<td>6.6 152 ± 33</td>
<td>9.8 102 ± 20</td>
<td>39</td>
<td>240</td>
<td>41</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>7.9 126 ± 30</td>
<td>11.3 88 ± 18</td>
<td>80</td>
<td>520</td>
<td>143</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>7.8 128 ± 30</td>
<td>11.3 88 ± 16</td>
<td>48</td>
<td>323</td>
<td>56</td>
</tr>
<tr>
<td>Tibialis anterior</td>
<td>8.1 124 ± 26</td>
<td>11.1 90 ± 13</td>
<td>85</td>
<td>594</td>
<td>149</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>7.7 132 ± 29</td>
<td>10.9 92 ± 16</td>
<td>64</td>
<td>411</td>
<td>61</td>
</tr>
<tr>
<td>Medial gastrocnemius</td>
<td>6.4 156 ± 29</td>
<td>9.1 110 ± 23</td>
<td>54</td>
<td>326</td>
<td>76</td>
</tr>
<tr>
<td>Extensor digitorum brevis</td>
<td>7.2 138 ± 29</td>
<td>10.2 98 ± 13</td>
<td>43</td>
<td>260</td>
<td>77</td>
</tr>
<tr>
<td>All muscles</td>
<td>7.7 132 ± 32</td>
<td>11.1 90 ± 19</td>
<td>693</td>
<td>4,608</td>
<td>1,137</td>
</tr>
</tbody>
</table>

* Standard deviations are calculated from the numbers of onset and recruitment intervals recorded.
** Muscles are listed in descending order on the neuraxis.
Recruitment Ratio

Normal Ratio $\leq 5$ \textit{(most limb muscles)}

(15 Hz: 3 MUP; 20 Hz: 4 MUP)

Normal

Abnormal
Individual Steps to Recognizing Reduced Recruitment

**Step 1**
Determine the maximum firing rate of any individual MUP?
*(Temporal recruitment rate coding)*

**Step 2**
Determine how many different MUP are firing (sharp rise time)?
*(Spatial recruitment)*

**Step 3**
Calculate the recruitment ratio
(max firing rate ÷ number of nearby MUP)

*Normal Recruitment Ratio ≤ 5* *(most limb muscles)*
*(15 Hz: 3 MUP; 20 Hz: 4 MUP)*
Measurement Methods
MUP Quantitation
Methods to Confirm Firing Rate

1. Rate counter

2. 50 msec/div – 20 div sweep – count the number of MUP in 1 sec

3. 10 msec/div sweep – count the interspike interval and divide into 1000 msec

<table>
<thead>
<tr>
<th>INTERVAL (msec)</th>
<th>FREQUENCY, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>6.5</td>
</tr>
<tr>
<td>125</td>
<td>8.0</td>
</tr>
<tr>
<td>100</td>
<td>10.0</td>
</tr>
<tr>
<td>75</td>
<td>13.3</td>
</tr>
<tr>
<td>60</td>
<td>16.6</td>
</tr>
<tr>
<td>50</td>
<td>20.0</td>
</tr>
</tbody>
</table>
Firing Rate Visual Confirmation

50 msec / division x 20 divisions = 1 second = Hz
**Semi-quantitation**

Define a numerical value . . .

without measurement
Auditory Semi-quantitation

Training Ears (> eyes)
Making Errors
Correcting Errors
Repetition
Step 1
Identify the firing rate
Step 2
How many MUP are firing?
Step 3
Determine ratio of Rate: Number of MUP

8 Hz: 1 MUP*
Step 4: Grade Recruitment (1-mild, 2- moderate, or 3-severe)

Fastest Rate of firing of 1st MUP when 2nd MUP recruited and/or

Recruitment Ratio

<table>
<thead>
<tr>
<th>Grade</th>
<th>Rate of 1st MUP</th>
<th>Recruitment Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+ (Mild)</td>
<td>&gt; 10 Hz</td>
<td>&gt;5</td>
</tr>
<tr>
<td>2+ (Moderate)</td>
<td>&gt; 15 Hz</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>3+ (Severe)</td>
<td>&gt; 20 Hz</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>
### Case Examples

<table>
<thead>
<tr>
<th>Recruitment?</th>
<th>Type of disorder?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Normal</td>
<td>1. Normal</td>
</tr>
<tr>
<td>2. Reduced</td>
<td>2. Neurogenic</td>
</tr>
<tr>
<td>3. Rapid (Early)</td>
<td>3. Myopathy</td>
</tr>
<tr>
<td></td>
<td>4. NMJ</td>
</tr>
<tr>
<td></td>
<td>5. Central</td>
</tr>
</tbody>
</table>
Learning Points

- Practice recognizing firing rates by sound
- Rates > 20 Hz (at mild-moderate effort) in limb muscles indicates reduced recruitment
- Calculate recruitment ratios to detect mild-moderate reduced recruitment