Lesson 1 EMG 1
Electromyography: Motor Unit Recruitment
Lesson 1 ELECTROMYOGRAPHY 1 Motor Unit Recruitment

I. SCIENTIFIC PRINCIPLES

Skeletal muscles are attached to the skeleton and produce movements such as in walking, jogging, or lifting weights. The strength of a skeletal muscle’s contraction, or the amount of force the muscle develops when it shortens, is graded and depends on the workload placed on the muscle. For example, the force of muscle contraction required to lift a 5 kg weight is less than the force required to lift a 25 kg weight, and the effort of muscles used in walking on level ground is less than the effort those same muscles expend in climbing stairs. Physiologically, the strength of a skeletal muscle’s contraction is subconsciously adjusted by the brain, which controls the number of actively shortening muscle fibers and their degree of shortening.

A skeletal muscle is made up of thousands of individual long cylindrically-shaped cells called fibers. Each muscle fiber is supplied by a single motor nerve fiber that initiates and controls the contraction of the muscle fiber. One motor nerve fiber controls several muscle fibers simultaneously. The motor nerve fiber and all of the muscle fibers it controls is called a motor unit (Fig. 1.1).

One method the brain uses to increase the strength of skeletal muscle contraction when required is to increase the number of simultaneously active motor units. This process is known as motor unit recruitment.

Another way the brain can increase the strength of a skeletal muscle’s contraction is to increase the frequency of nerve impulses traveling in each motor nerve fiber. An increase in motor nerve fiber frequency increases the degree of shortening in each active motor unit, enabling the muscle to perform an increased amount of work.

When skeletal muscles are resting and appear to be not actively shortening, they nonetheless maintain a slight state of contraction and internal tension known as tonus. Tonus is due to alternate periodic activation of a small number of motor units within the muscle by control centers in the brain and spinal cord, and serves to maintain the muscle in a state of readiness.

When a motor unit is activated, the component muscle fibers generate and conduct their own electrical impulses that ultimately result in contraction of the fibers. Although the electrical impulse generated and conducted by each fiber is very weak (less than 100 microvolts), many fibers conducting simultaneously induce voltage differences in the overlying skin that are large enough to be detected by a pair of surface electrodes. The detection, amplification, and recording of changes in skin voltage produced by underlying skeletal muscle contraction is called electromyography. The recording thus obtained is called an electromyogram (EMG).

II. EXPERIMENTAL OBJECTIVES

1) To record maximum clench strength for right and left hands.
2) To observe, record, and correlate motor unit recruitment with increased power of skeletal muscle contraction
3) Optional: To listen to EMG “sounds” and correlate sound intensity with motor unit recruitment.

III. MATERIALS

- Biopac Science Lab system (MP40 and software) on computer running Windows XP or Mac OS X
- Electrode lead set (40EL lead set)
- Disposable vinyl electrodes (EL503), six electrodes per subject
- Optional: Headphones (40HP) to listen to the EMG signal
IV. EXPERIMENTAL METHODS

A. Set Up

**Equipment**

![Fig. 1.2 MP40 with 40EL connected](image)

**Subject**

![Fig. 1.3 Electrode connections for each arm](image)

**FAST TRACK**

1. Turn the computer **ON**.
2. Set the MP40 dial to **OFF**.
3. **Plug the equipment in** as follows:
   - Electrode leads (40EL) → MP40
   - **Optional**: Headphones (40HP) → computer
4. **Attach three electrodes** to each arm as shown in Fig. 1.3.
5. Connect the electrode **leads** (40EL) to the electrodes on the **Subject**’s dominant arm, matching lead color to electrode position as shown in Fig. 1.3.

**DETAILS**

- **Connect stereo headphones (40HP) to the computer to prepare for the optional “Listening to EMG” segment.**

- To detect grip muscle EMGs, attach electrodes to each anterior forearm and wrist as shown in Fig. 1.3.
  - For optimal electrode response, place electrodes on the skin at least five minutes before starting the lesson.
  - For the first recording segment, connect the leads to the Subject’s dominant arm (generally the right arm if the Subject is right-handed, or the left arm if the Subject is left-handed); this will be **Forearm 1**.
    - Use the Subject’s non-dominant arm for the second recording segment, labeled **Forearm 2**.
    - Each pinch connector on the end of the electrode cable needs to be attached to a specific electrode. Follow the color code above to ensure that each cable is connected to the proper electrode.

6. **Start** the Biopac Science Lab software.
7. Choose lesson **L01-EMG-1** and click **OK**.
8. Type in a unique **file name**.
9. Click **OK**.

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B. Check

**FAST TRACK**

**MP40 Check**
1. Set the MP40 dial to  "EMG (high)."
2. Press and hold the "Check" pad on the MP40.
3. Click when the light is flashing.
4. Wait for the MP40 check to stop.
5. Let go of the "Check" pad.
6. Click Continue.

**Signal Check**
7. Click Check Signal.
8. Click OK.
9. After two seconds, clench and release.
10. Wait for the Signal Check to stop.
11. Review the data.
   - If correct, go to the Record section.
   - If incorrect, click Redo Signal Check.

Continue to hold the pad down until prompted to let go.
The MP40 check procedure will last five seconds.
The light should stop flashing when you let go of the Check pad.
When the light stops flashing, click Continue.

After two seconds, clench your hand as hard as possible (Fig. 1.4) and then relax your hand.

The eight-second Signal Check recording should resemble Fig. 1.5.

*Fig. 1.4*

*Fig. 1.5*

If the recording check does not show a burst of activity for the hand clench, click Redo Signal Check.
C. **Record**

<table>
<thead>
<tr>
<th><strong>FAST TRACK</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
</table>
| 1. Prepare for the recording. | Watch the Help menu videos to prepare for the recording. You will record one segment on each arm.  
  - Segment 1: dominant  
  - Segment 2: non-dominant |

In order to work efficiently, read this entire section so you will know what to do before recording. Stop each recording segment as soon as possible so you don’t waste recording time (time is memory).

<table>
<thead>
<tr>
<th><strong>SEGMENT 1</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. <strong>Click <strong>[Record]</strong>.</strong></td>
<td>When you click <strong>Record</strong>, the recording will begin and an append marker labeled <strong>Forearm 1</strong> will automatically be inserted. During recording, you can visually review the EMG and Integrated EMG signals.</td>
</tr>
<tr>
<td>3. Complete four cycles of clench-hold-release with increasing clench force.</td>
<td>Clench fist and hold for two seconds, release the clench and wait for two seconds. Repeat for three more cycles with increased clench force until the maximum clench is achieved. Try to increase the strength in equal increments such that the fourth clench is the maximum force.</td>
</tr>
<tr>
<td>4. <strong>Click <strong>[Suspend]</strong>.</strong></td>
<td>When you click <strong>Suspend</strong>, the recording will halt, giving you time to review the data and prepare for the next recording segment. The data should resemble Fig. 1.6. The data should show multiple peaks for each clench, each with greater amplitude than the preceding clench.</td>
</tr>
</tbody>
</table>
| 5. Review the data.  
  - If correct, go to Step 6.  
  - If incorrect, click **Redo**. | ![Fig. 1.6 Motor unit recruitment—clenching with increased force](image-url) |

If the data does not match, click **Redo** and repeat Steps 2-5; the last data segment you recorded will be erased.

<table>
<thead>
<tr>
<th><strong>SEGMENT 2</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6. To record <strong>Forearm 2</strong>, switch the leads to the electrodes on the <strong>Subject’s</strong> other forearm (per <strong>Set Up Steps 4 and 5</strong>).</td>
<td>A marker labeled <strong>Forearm 2</strong> will automatically be inserted when you click <strong>Resume</strong>, and the recording will continue from the point it left off.</td>
</tr>
<tr>
<td>7. <strong>Click <strong>[Resume]</strong>.</strong></td>
<td>Clench fist and hold for two seconds, release the clench and wait for two seconds. Repeat for three more cycles with increased clench force until the maximum clench is achieved. Try to increase the strength in equal increments such that the fourth clench is the maximum force.</td>
</tr>
<tr>
<td>8. Complete four cycles of clench-hold-release with increasing clench force.</td>
<td></td>
</tr>
</tbody>
</table>
9. **Click Suspend.**

   When you click Suspend, the recording will halt, giving you time to review the data.

10. Review the data.
    - If correct, go to Step 11.
    - If incorrect, click Redo.

11. **Optional:** Click Resume to record additional segments.

12. Click **Stop.**

13. Click **Yes.**

   **SEGMENT 3 — Optional: Listening to EMG**

14. If you want to listen to the EMG signal:
    - Put on the headphones
    - Click Listen;
    or
    To end the recording, go to Step 17.

15. **Subject** must clench hard and release to optimize the signal for the listening segment.

16. As anyone listens, **Subject** should change the clench force.
    - Watch how the data changes.
    - Listen to the sound variation.

17. Click **Stop** to end the listening segment.

18. Click **Done** to end the lesson.

19. Choose an option and click **OK.**

20. Remove the electrodes.

   **END OF RECORDING**

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**Listening to the EMG is optional.**

Listening to the EMG can be a valuable tool in detecting muscle abnormalities and is performed here for general interest.

*Note* When the Listen button is clicked, the volume through the headphones may be very loud due to system feedback. The volume cannot be adjusted, so you may have to position the headphones slightly off the ear to reduce the sound.

You will hear the EMG signal through the headphones as it is being displayed on the screen. The screen will display two channels: CH1 EMG, and CH40 Integrated EMG. The data on the screen will not be saved. The signal will run until you click Stop. If others in your lab group would like to hear the EMG signal, pass the headphones around and click Redo.

When you click **Done**, a dialog with options will be generated. Make your choice, and click OK.

- If you choose Analyze current data file, go to the Analyze section for directions.

Unclip the electrode lead connectors and peel off the electrodes. Throw out the electrodes.
V. ANALYZE

FAST TRACK

1. Enter the Review Saved Data mode and choose the correct file.

Note Channel Number (CH) designations:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>EMG (raw signal)</td>
</tr>
<tr>
<td>CH40</td>
<td>Integrated EMG</td>
</tr>
</tbody>
</table>

2. Set up the measurement boxes as follows:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>Min</td>
</tr>
<tr>
<td>CH1</td>
<td>Max</td>
</tr>
<tr>
<td>CH1</td>
<td>P-P</td>
</tr>
<tr>
<td>CH40</td>
<td>Mean</td>
</tr>
</tbody>
</table>

Fig. 1.7

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click them. The following is a brief description of specific measurements.

- **Min**: displays the minimum value in the selected area.
- **Max**: displays the maximum amplitude value within the selected area (including the endpoints).
- **P-P**: Peak-to-Peak shows the difference between the maximum amplitude value in the selected range and the minimum amplitude value in the selected range.
- **Mean**: displays the average value in the selected area.

**Note** The “selected area” is the area selected by the I-Beam tool (including the endpoints).

You can record measurement data individually by hand or choose Edit > Journal > Paste measurement to paste the data to your journal for future reference.

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3. Set up the display window for optimal viewing of the first data segment.

4. Using the I-Beam tool, select an area enclosing the first EMG cluster.
   - A

5. Repeat Step 4 on each successive EMG cluster.
   - A

6. Scroll to the second recording segment.
7. Repeat Steps 4-5 for the Forearm 2 data.
8. Scroll to the first recording segment and select areas of tonus (between clenches) for Forearm 1, the dominant arm.
   - C

9. Scroll to the second recording segment and select areas of tonus (between clenches) for Forearm 2, the non-dominant arm.
   - C

10. Save or print the data file.
11. Exit the program.

12. Set the MP40 dial to Off.

End of Lesson 1
Complete the Lesson 1 Data Report that follows.
These are sample questions. You should amend, add, or delete questions to support your curriculum objectives.

Lesson 1  EMG 1
Motor Unit Recruitment

DATA REPORT

Student’s Name: _________________________________
Lab Section: _________________________________
Date: _________________________________

I. Data and Calculations

Subject Profile
Name________________________ Age________
Gender: Male / Female Height________
Dominant forearm: Right / Left Weight________

EMG Measurement
A. Complete the table with data from your recordings.

<table>
<thead>
<tr>
<th>Cluster #</th>
<th>Forearm 1 (Dominant)</th>
<th>Forearm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note “Clusters” are the EMG bursts associated with each clench.

Mean Measurements
B. Use the mean measurement from the table above to compute the percentage increase in EMG activity recorded between the weakest clench and the strongest clench of Forearm 1.

Calculation:

Answer: ________________%

Tonus Measurements
C. Complete the following table with data from your recordings.

<table>
<thead>
<tr>
<th>Cluster #</th>
<th>Forearm 1 (Dominant)</th>
<th>Forearm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-P [CH1]</td>
<td>Mean [CH40]</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
II. Data Summary and Questions

D. Compare the mean measurement for the right and left maximum-clench EMG cluster. Are they the same or different?

_______ Same ________ Different

Which one suggests the greater clench strength?

_______ Right ________ Left ________ Neither

Explain.

________________________________________________________

________________________________________________________

E. What factors in addition to gender greatly contribute to observed differences in clench strength?

________________________________________________________

________________________________________________________

F. Does there appear to be any difference in tonus between the two forearm clench muscles?

____ Yes  ____ No

Would you expect to see a difference? Does the Subject’s gender influence your expectations? Explain.

________________________________________________________

________________________________________________________

G. Explain the source of signals detected by the EMG electrodes.

________________________________________________________

________________________________________________________

H. Define motor unit recruitment.

________________________________________________________

________________________________________________________

I. Define skeletal muscle tonus.

________________________________________________________

________________________________________________________

J. Define electromyography.

________________________________________________________

________________________________________________________
VI. ACTIVE LEARNING LAB

Design a new experiment to test or verify the scientific principle(s) you learned in the Biopac Science Lab recording and analysis segments.

**For this lesson**, you might examine how different positions or muscle groups influence max force.

**Design Your Experiment**

Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. **Hypothesis**
   
   Describe the scientific principle to be tested or verified.

B. **Materials**
   
   List the materials you will use to complete your investigation.

C. **Method**
   
   Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

   - See the **Set Up** section or Help > About Electrodes for electrode placement guidelines.

**Run Your Experiment**

D. **Set Up**
   
   Set up the equipment and prepare the subject for your experiment.

E. **Record**
   
   Use the **Record**, **Resume**, and **Suspend** buttons in the Biopac Science Lab program to record as many segments as necessary for your experiment.

   Click **Done** when you have completed all of the segments required for your experiment.

**Analyze Your Experiment**

F. **Set measurements relevant to your experiment and record the results in a Data Report.**