Physiology Lessons
for use with the
Biopac Student Lab

PC running Windows®
98SE, Me, 2000 Pro, XP Pro/Home/Media

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Lesson 1
ELECTROMYOGRAPHY I
Standard and Integrated EMG

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I. INTRODUCTION

In this lesson, you will investigate some properties of skeletal muscle. Physiological phenomena associated with other kinds of muscle, such as electrophysiology of the heart, will be studied in subsequent lessons.

The human body contains three kinds of muscle tissue and each performs specific tasks to maintain homeostasis: Cardiac muscle, Smooth muscle, and Skeletal muscle.

- **Cardiac muscle** is found only in the heart. When it contracts, blood circulates, delivering nutrients to cells and removing cell waste.

- **Smooth muscle** is located in the walls of hollow organs, such as the intestines, blood vessels or lungs. Contraction of smooth muscle changes the internal diameter of hollow organs, and is thereby used to regulate the passage of material through the digestive tract, control blood pressure and flow, or regulate airflow during the respiratory cycle.

- **Skeletal muscle** derives its name from the fact that it is usually attached to the skeleton. Contraction of skeletal muscle moves one part of the body with respect to another part, as in flexing the forearm. Contraction of several skeletal muscles in a coordinated manner moves the entire body in its environment, as in walking or swimming.

The primary function of muscle, regardless of the kind, is to convert chemical energy to mechanical work, and in so doing, the muscle shortens or contracts.

Human skeletal muscle consists of hundreds of individual cylindrically shaped cells (called fibers) bound together by connective tissue. In the body, skeletal muscles are stimulated to contract by somatic motor nerves that carry signals in the form of nerve impulses from the brain or spinal cord to the skeletal muscles (Fig. 1.1). Axons (or nerve fibers) are long cylindrical extensions of the neurons. Axons leave the spinal cord via spinal nerves and the brain via cranial nerves, and are distributed to appropriate skeletal muscles in the form of a peripheral nerve, which is a cable-like collection of individual nerve fibers. Upon reaching the muscle, each nerve fiber branches and innervates several individual muscle fibers.

![Fig. 1.1 Example of Motor Units](image)

Although a single motor neuron can innervate several muscle fibers, each muscle fiber is innervated by only one motor neuron. The combination of a single motor neuron and all of the muscle fibers it controls is called a motor unit (Fig. 1.1).
When a somatic motor neuron is activated, all of the muscle fibers it innervates respond to the neuron’s impulses by generating their own electrical signals that lead to contraction of the activated muscle fibers.

The size of the motor unit arrangement of a skeletal muscle (e.g., 1:10, 1:50, or 1:3000) is determined by its function (flexion, extension, etc.) and location in the body. The smaller the size of a muscle’s motor units, the greater the number of neurons needed for control of the muscle, and the greater the degree of control the brain has over the extent of shortening. For example, muscles which move the fingers have very small motor units to allow for precise control, as when operating a computer keyboard. Muscles that maintain posture of the spine have very large motor units, since precise control over the extent of shortening is not necessary.

Physiologically, the degree of skeletal muscle contraction is controlled by:

1. Activating a desired number of motor units within the muscle, and
2. Controlling the frequency of motor neuron impulses in each motor unit.

When an increase in the strength of a muscle’s contraction is necessary to perform a task, the brain increases the number of simultaneously active motor units within the muscle. This process is known as motor unit recruitment.

Resting skeletal muscles in vivo exhibit a phenomenon known as tonus, a constant state of slight tension that serves to maintain the muscle in a state of readiness. Tonus is due to alternate periodic activation of a small number of motor units within the muscle by motor centers in the brain and spinal cord. Smooth controlled movements of the body (such as walking, swimming or jogging) are produced by graded contractions of skeletal muscle. Grading means changing the strength of muscle contraction or the extent of shortening in proportion to the load placed on the muscle. Skeletal muscles are thus able to react to different loads accordingly. For example, the effort of muscles used in walking on level ground is less than the effort those same muscles expend in climbing stairs.

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 observe and record skeletal muscle tonus as reflected by a basal level of electrical activity associated with the muscle in a resting state.

2) To record maximum clench strength for right and left hands.

3) To observe, record, and correlate motor unit recruitment with increased power of skeletal muscle contraction.

4) To listen to EMG “sounds” and correlate sound intensity with motor unit recruitment.
III. MATERIALS

- BIOPAC electrode lead set (SS2L)
- BIOPAC disposable vinyl electrodes (EL503), 6 electrodes per subject
- BIOPAC Headphones (OUT1)
- BIOPAC electrode gel (GEL1) and abrasive pad (ELPAD) or Skin cleanser or alcohol prep
- Computer system
- Biopac Student Lab 3.7 for PC running Windows
- BIOPAC acquisition unit (MP35/30)
- BIOPAC wall transformer (AC100A)
- BIOPAC serial cable (CBLRSA) or USB cable (USB1W) if using a USB port
IV. EXPERIMENTAL METHODS

For further explanation, use the online support options under the Help Menu.

A. SET UP

FAST TRACK Set Up

1. Turn your computer ON.

2. Make sure the BIOPAC MP35/30 unit is OFF.

3. Plug the equipment in as follows:
   - Electrode lead (SS2L) — CH 3
   - Headphones (OUT1) — back of unit

4. Turn ON the BIOPAC MP35/30 unit.

5. Attach three electrodes to the forearm (Fig. 1.3).

Set Up continues…

DETAILED EXPLANATION OF SET UP STEPS

The desktop should appear on the monitor. If it does not appear, ask the laboratory instructor for assistance.

Headphones (BIOPAC OUT1)
Plugs into back of MP35/30

BIOPAC SS2l
Plugs into Channel 3

Fig. 1.2

Attach three electrodes to the forearm as shown in Fig. 1.3.

For the first recording segment, select the Subject’s dominant forearm (generally the right forearm if the Subject is right-handed, or the left forearm if the Subject is left-handed) and attach the electrodes onto the forearm as shown; this will be Forearm 1.

Use the Subject’s other arm for the second recording segment; this will be Forearm 2.

Note: For optimal electrode adhesion, the electrodes should be placed on the skin at least 5 minutes before the start of the Calibration procedure.
6. Attach the electrode lead set (SS2L) to the electrodes, following the color code (Fig. 1.3).

**IMPORTANT**
Make sure the electrode lead colors match Fig. 1.3.

7. **Start** the Biopac Student Lab Program.

8. Choose lesson “L01-EMG-1” and click **OK**.

9. Type in a unique **filename**.

10. Click **OK**.

**END OF SET UP**

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Each of the pinch connectors on the end of the electrode cable needs to be attached to a specific electrode. The electrode cables are each a different color. Follow Fig. 1.3 to ensure that you connect each cable to the proper electrode.

The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector.

No two people can have the same filename, so use a unique identifier, such as the Subject’s nickname or student ID#.

This ends the Set Up procedure.
B. CALIBRATION

The Calibration procedure establishes the hardware’s internal parameters (such as gain, offset, and scaling) and is critical for optimum performance. Pay close attention to the Calibration procedure.

FAST TRACK Calibration

1. Click on Calibrate.
2. Read the dialog box and click OK when ready.
3. Wait about two seconds, clench your fist as hard as possible, then release.

DETAILLED EXPLANATION OF CALIBRATION STEPS

This will start the Calibration recording.

A dialog box pops-up when you click Calibrate, telling you how to prepare for the calibration. The calibration will not begin until you click OK.

The program needs a reading of your maximum clench to perform an auto-calibration.

1. Click on Calibrate.
2. Read the dialog box and click OK when ready.
3. Wait about two seconds, clench your fist as hard as possible, then release.

4. Wait for Calibration to stop.
5. Check the Calibration data.

- If similar, proceed to the data Recording Section.
- If different, Redo Calibration.

END OF CALIBRATION

Clench Fist

Fig. 1.4

The Calibration procedure will last eight seconds and stop automatically, so let it run its course.

At the end of the eight-second Calibration recording, the screen should resemble Fig. 1.5.

Fig. 1.5

If your calibration recording did not begin with a zero baseline (Subject clenched before waiting two seconds), you need to repeat calibration to obtain a reading similar to Fig. 1.5.
C. DATA RECORDING

FAST TRACK Recording
1. Prepare for the recording.

DETAILED EXPLANATION OF RECORDING STEPS
You will record two segments:
   a. Segment one records Forearm 1 (Dominant).
   b. Segment two records Forearm 2.

In order to work efficiently, read this entire section so you will know what to do before recording.

Check the last line of the journal and note the amount of time available for the recording. Stop each recording segment as soon as possible to not waste recording time (time is memory).

SEGMENT 1 — Forearm 1 (Dominant)
2. Click Record.
3. Clench-Release-Wait and repeat with increasing force to reach your maximum force on the fourth clench.
4. Click Suspend.
5. Review the data on the screen.
   ➢ If similar and more recording segments are required, go to Step 7.
   ➢ If different, go to Step 6.
6. Click Redo if your data did not match Fig. 1.6, and repeat Steps 2-5.
7. Remove the electrodes from your forearm.

Recording continues…

Fig. 1.6 Clench, Release, Wait, Repeat

The data would be different if the:
   a. The Suspend button was pressed prematurely.
   b. Instructions were not followed.

Click Redo and repeat Steps 2-5 if necessary. Note that once you press Redo, the data you have just recorded will be erased.

Remove the electrode cable pinch connectors, and peel off the electrodes. Throw out the electrodes (BIOPAC electrodes are not reusable). Wash the electrode gel residue from your skin using soap and water. The electrodes may leave a slight ring on the skin for a few hours, which is quite normal.
SEGMENT 2 — Forearm 2

8. For **Forearm 2**, attach electrodes and leads to **Subject’s** opposite arm.

9. Click **Resume**.

10. Clench-Release-Wait and repeat with increasing force to reach your maximum force on the fourth clench.

11. Click on **Suspend**.

12. Review the data on the screen.
   - If similar, go to **Step 14**.
   - If different, go to **Step 13**.

13. If your data did not match Fig. 1.6, click **Redo** and repeat **Steps 9-12**.

14. Click **Stop**.

15. If you want to listen to the EMG signal, go to **Step 16**.
   - or
   - If you want to end the recording, go to **Step 21**.

16. **Subject** puts on the headphones.

17. Click **Listen**.

18. Experiment by changing the clench force as you watch the screen and listen.

| Refer to the Set Up Steps 5 and 6 and Fig 1.3 for proper electrode placement and lead attachment. |
| When you click **Resume**, the recording will continue and an append marker labeled “Forearm 2” will be automatically inserted. |
| Repeat a cycle of Clench-Release-Wait, holding for 2 seconds and waiting for two seconds after releasing before beginning the next cycle. Try to increase the strength in equal increments such that the fourth clench is the maximum force. |
| The recording should halt, giving you time to review the data for segment two. |
| If all went well, your data should look similar to Fig. 1.6. |
| The data would be incorrect if the: |
| a. The **Suspend** button was pressed prematurely. |
| b. Instructions were not followed. |
| Click **Redo** and repeat **Steps 9-12** if necessary. Note that once you press **Redo**, the data you have just recorded will be erased. |
| When you click **Stop**, a dialog box comes up, asking if you are sure you want to stop the recording. Clicking “yes” will end the data recording segment, and automatically save the data. |
| Clicking “no” will bring you back to the **Resume** or **Stop** options. This is simply one last chance to confirm you don’t need to redo the last recording segment. |
| Listening to the EMG can be a valuable tool in detecting muscle abnormalities, and is performed here for general interest. |
| **Listening to the EMG is optional. The data from this part of the Lesson will not be saved.** EMG data is sent to the headphones and simultaneously plotted so you can listen to the signal and see it at the same time. Note the increase in sound intensity as you increase the strength of your clench. |
| **Note:** When the **Listen** button is clicked in the next step, it’s possible that 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: CH 3 EMG and CH 40 Integrated EMG. The data on the screen will not be saved. |
The signal will run until you press **Stop**.

If others in your lab group would like to listen to the EMG signal, pass the headphones around before clicking **Stop**.

This will end listening to the EMG.

If another person wants to listen to the EMG, switch the headphones from the **Subject** to the new person and click **Redo**.

A pop-up window with options will appear. Make your choice, and continue as directed.

If choosing the “Record from another Subject” option:

a) Attach electrodes per Set Up Step 5 and continue the entire lesson from Set Up Step 8.

b) Each person will need to use a unique file name.
V. DATA ANALYSIS

FAST TRACK Data Analysis

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>CH 3</td>
<td>EMG</td>
</tr>
<tr>
<td>CH 40</td>
<td>Integrated EMG</td>
</tr>
</tbody>
</table>

2. Setup your display window for optimal viewing of the first data segment.

3. Set up the measurement boxes as follows:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 3</td>
<td>min</td>
</tr>
<tr>
<td>CH 3</td>
<td>max</td>
</tr>
<tr>
<td>CH 3</td>
<td>p-p</td>
</tr>
<tr>
<td>CH 40</td>
<td>mean</td>
</tr>
</tbody>
</table>

Data Analysis continues...

DETAILED EXPLANATION OF DATA ANALYSIS STEPS

Enter the Review Saved Data mode.

Fig. 1.7

Fig. 1.8 below shows a sample display of the first data segment recorded using the arm of the Subject’s dominant hand.

The following tools help you adjust the data window:
- Autoscale horizontal (Time) Scroll Bar
- Autoscale waveforms (Amplitude) Scroll Bar
- Zoom Tool
- Overlap button
- Zoom Previous
- Split button

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 on them. The following is a brief description of these specific measurements.

- **min**: displays the minimum value in the selected area.
- **max**: displays the maximum value in the selected area.
- **p-p**: finds the maximum value in the selected area and subtracts the minimum value found in the selected area.
- **mean**: displays the average value in the selected area.

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 measurements** to paste the data to your journal for future reference.
4. Using the **I-Beam** cursor, select an area enclosing the first EMG cluster (Fig. 1.8).

![Fig. 1.8](image)

Note: "Clusters" are the EMG bursts associated with each clench. A sample cluster is selected in the figure above.

5. Repeat Step 4 on each successive EMG cluster.

6. Scroll to the second recording segment.

7. Repeat Steps 4 and 5 for the Forearm 2 data.

8. Scroll to the first recording segment and select for measurement areas of tonus (between clenches) for Forearm 1, the dominant arm.

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

10. Save or print the data file.

11. Exit the program.

**END OF DATA ANALYSIS**

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**END OF LESSON 1**

Complete the Lesson 1 Data Report that follows.
ELECTROMYOGRAPHY I

Standard and Integrated EMG

DATA REPORT

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

I. Data and Calculations

Subject Profile

<table>
<thead>
<tr>
<th>Name</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gender: Male / Female

A. EMG Measurements

<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.

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: ____________ %


C. Tonus Measurements

<table>
<thead>
<tr>
<th>Cluster #</th>
<th>Forearm 1 (Dominant)</th>
<th>Forearm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-P [3 p-p]</td>
<td>Mean [40 mean]</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>
</tbody>
</table>

II. 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 sex 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 subject’s sex influence your expectations? Explain.

   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

G. Explain the source of signals detected by the EMG electrodes.
H. What does the term “motor unit recruitment” mean?

I. Define skeletal muscle tonus.

J. Define electromyography.

End of Lesson 1 Data Report