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Biopac Student Lab® Lesson 1
**ELECTROMYOGRAPHY (EMG) I**
**Introduction**
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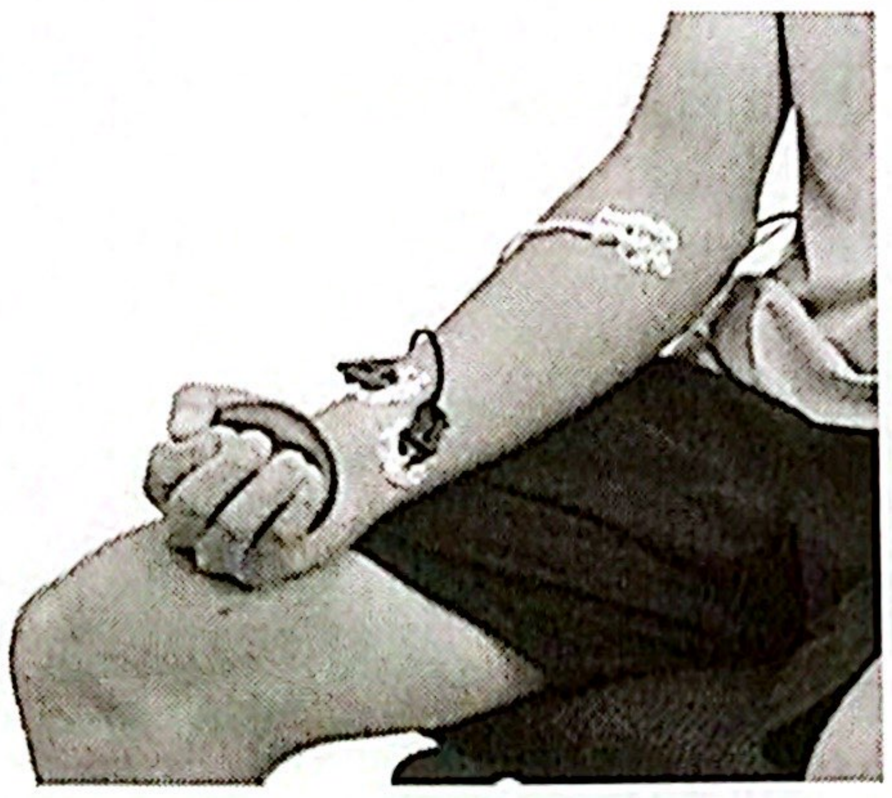

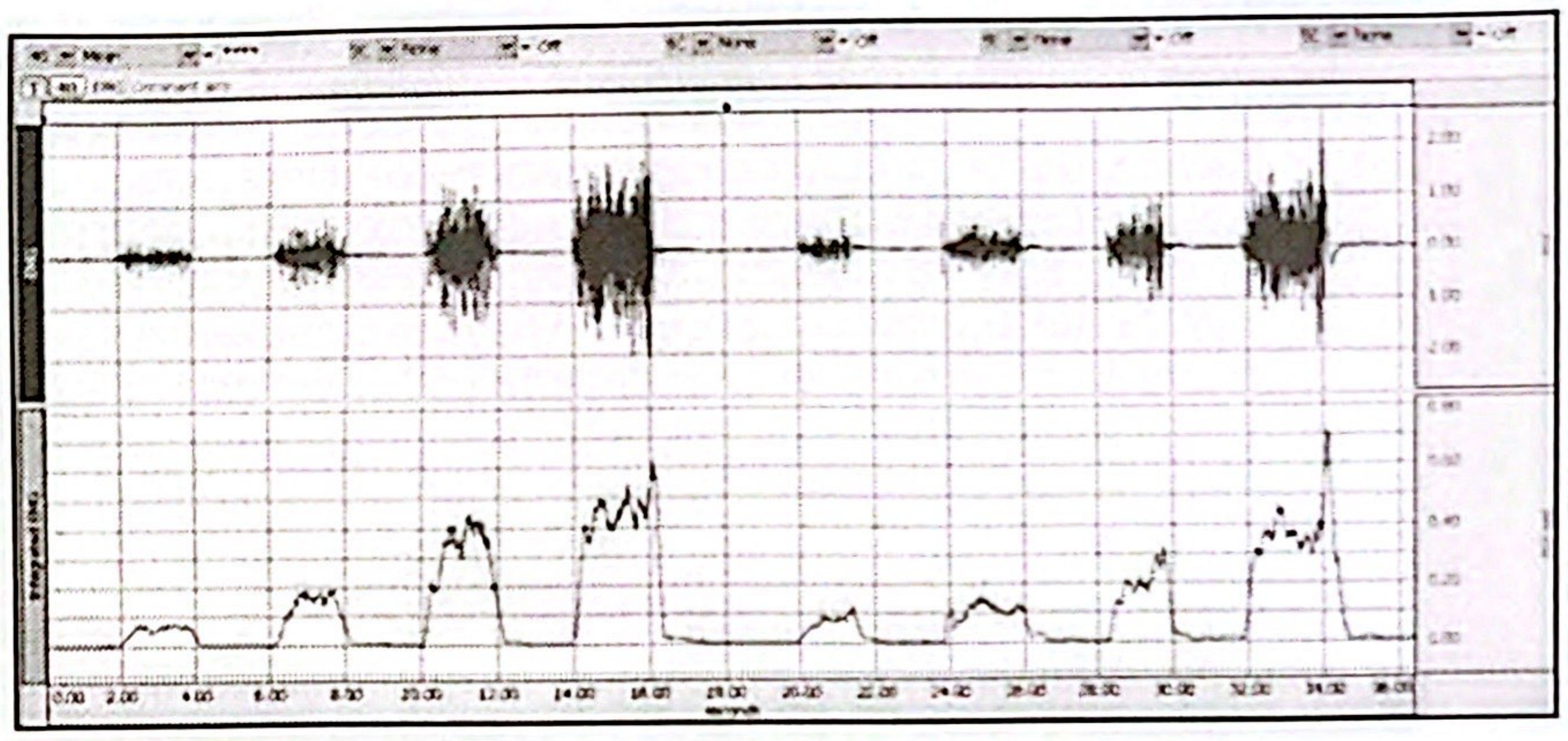

# I. INTRODUCTION

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.

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.

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.

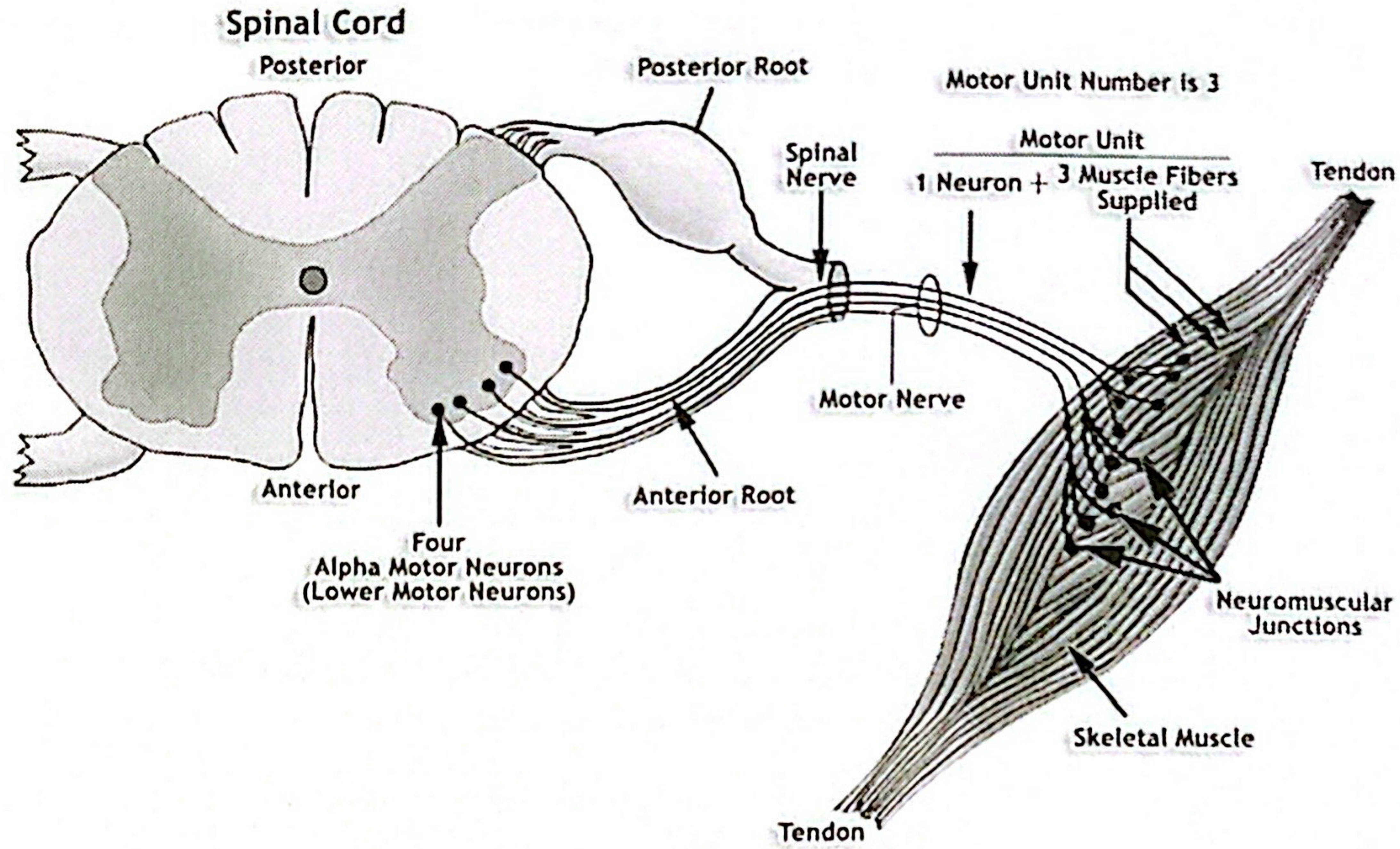


**Fig. 1.1 Example of Motor Units**

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).**

The **EMG signal** is the recorded consequence of two principal bioelectric activities: 1) propagation of motor nerve impulses and their transmission at the neuromuscular junctions of a motor unit, and 2) propagation of muscle impulses by the sarcolemma and the T-tubular systems resulting in excitation-contraction coupling. The magnitudes of the action potentials of active motor units are not all the same nor are they in phase with one another. Furthermore, the timing sequence of motor unit activation is variable. The net result of these and other factors is a complex EMG signal. Remember we are recording all of this activity as it is detected by surface electrodes, and propagation of muscle and nerve impulses involves both depolarization and repolarization phenomena. The "spikes" therefore, will have a negative and a positive component and the amplitudes will be influenced by the location of the recording electrodes with respect to the number of active underlying skeletal muscle and motor nerve fibers.

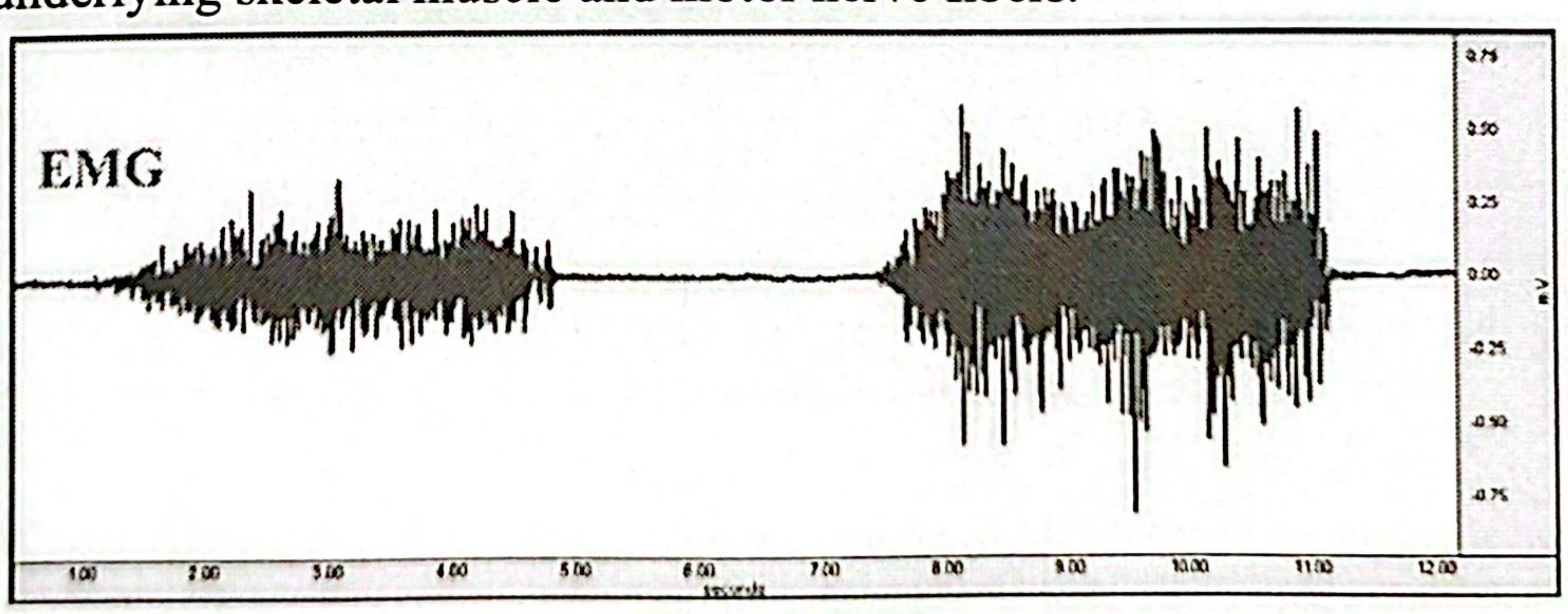


**Fig. 1.2 EMG**

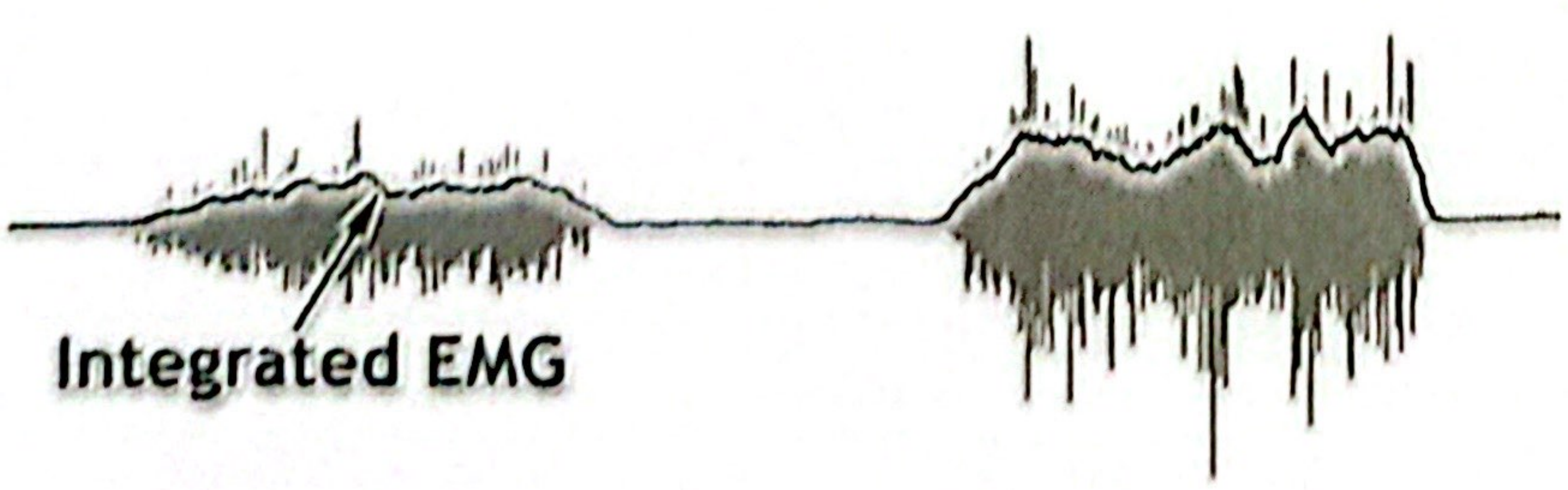


**Fig. 1.3 Integrated EMG**

Integrated EMG is an alternative view of the EMG signal that clearly shows the pattern of muscle activity. Integrated EMG "averages out" noise spikes in the raw EMG data to provide a more accurate indication of the EMG output level. Integrated EMG calculates a moving average (mean) of the EMG data by first rectifying each point in the sample range (inverting all negative values) and then computing the mean. In this lesson, each data point of Integrated EMG is calculated using 100 samples of data from the EMG source, so the first 100 sample points should be ignored since they reflect the number of zero values being averaged in with the first few samples of data.

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## 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 Electrodes (EL503,) 6 electrodes per Subject
- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD)
- *Optional:* BIOPAC Skin Prep Gel (ELPREP) or alcohol prep
- *Optional*: BIOPAC Headphones (OUT1/OUT1A for MP3X or 40HP for MP46/45)
- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP46/45 hardware
- Computer system (Windows or Mac)

## IV. EXPERIMENTAL METHODS

### A. SETUP

**FAST TRACK Setup**

1. Turn the computer **ON**.
   - If using an MP36/35 unit, turn it **OFF**.
   - If using an MP46/45, make sure USB cable is connected and "Ready" light is **ON**.
2. **Plug the equipment in** as follows:
   Electrode Lead Set (SS2L) — CH 1
   Headphones (OUT1 or OUT1A*) — back of unit
   **OUT1A is compatible with MP36 only.*
3. Turn **ON** the MP36/35 unit.

**Setup continues…**

**Detailed Explanation of Setup Steps**

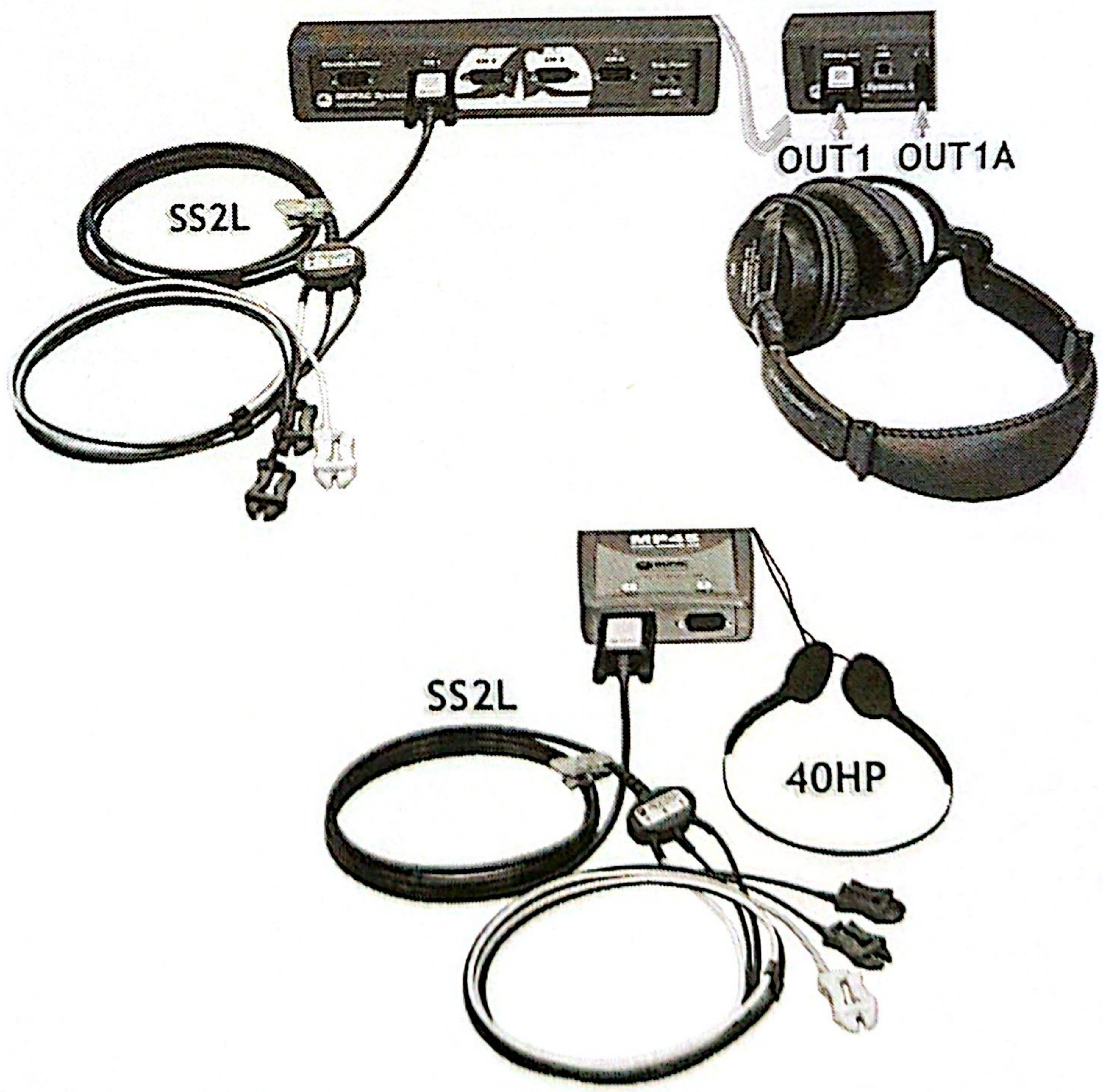


**Fig. 1.4 MP3X (top) and MP46/45 (bottom) equipment connections**

- Windows: If using MP46/45, the Sound Playback device must be set to MP46/45 via Start > Control Panel.

4. Clean and abrade skin.
5. Attach three electrodes to each forearm (Fig. 1.5).
6. Clip the Electrode Lead Set (SS2L) to **Subject's** dominant arm, following the color code (Fig. 1.5).

Clean electrode sites with ELPREP Skin Prep Gel or alcohol before abrading.

Always apply a drop of gel (GEL1) to the sponge portion of electrodes before attaching.

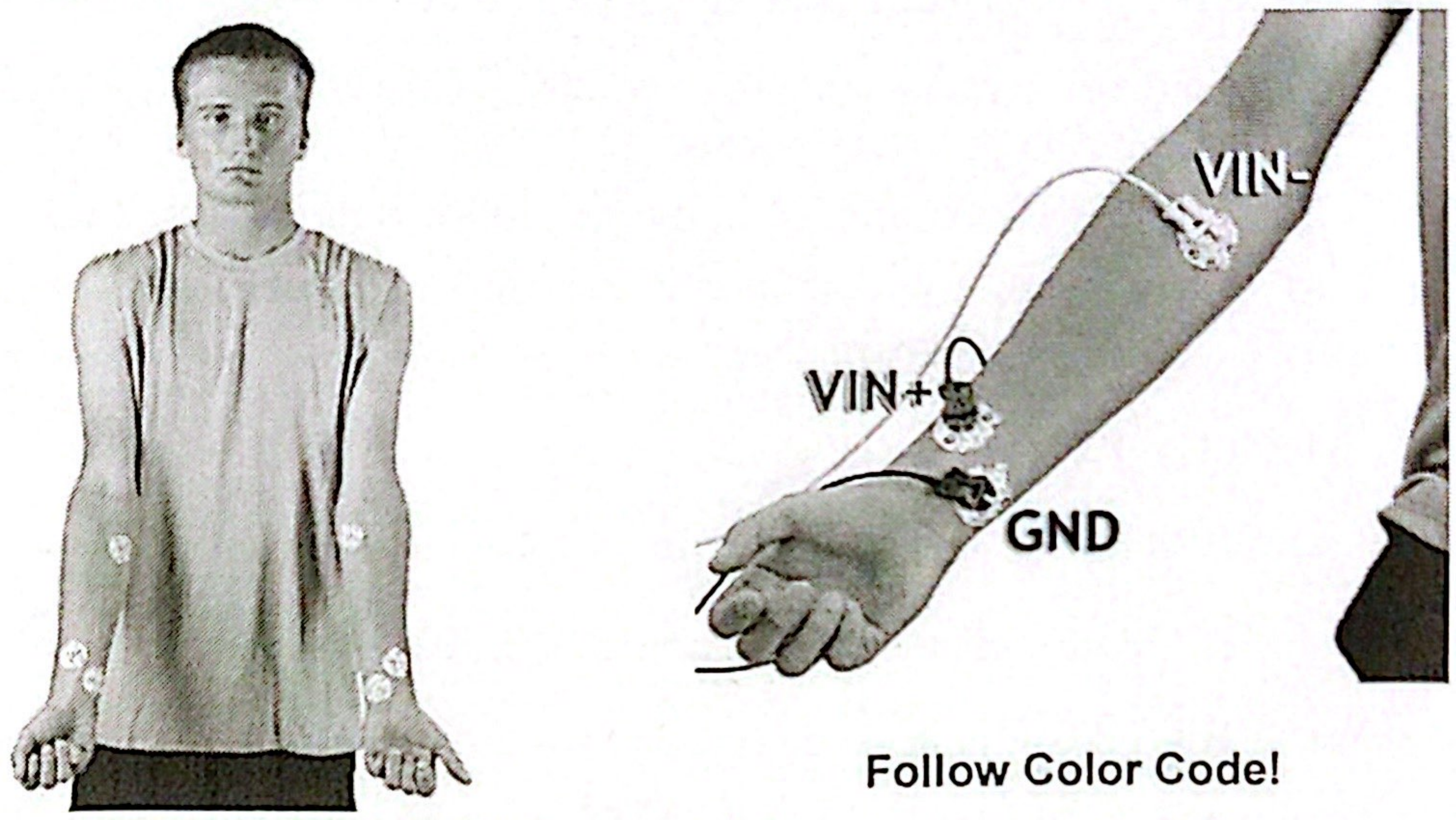


**Fig. 1.5 Electrode placement and lead attachment**

- If **Subject** is right-handed, the right forearm is generally dominant; if **Subject** is left-handed, the left forearm is generally dominant.
- For optimal electrode adhesion, place electrodes on the skin at least 5 minutes before the start of Calibration.
- The pinch connectors work like a small clothespin and will only latch onto the nipple of the electrode from one side of the connector.

7. **Subject** gets in a seated position, facing the monitor.

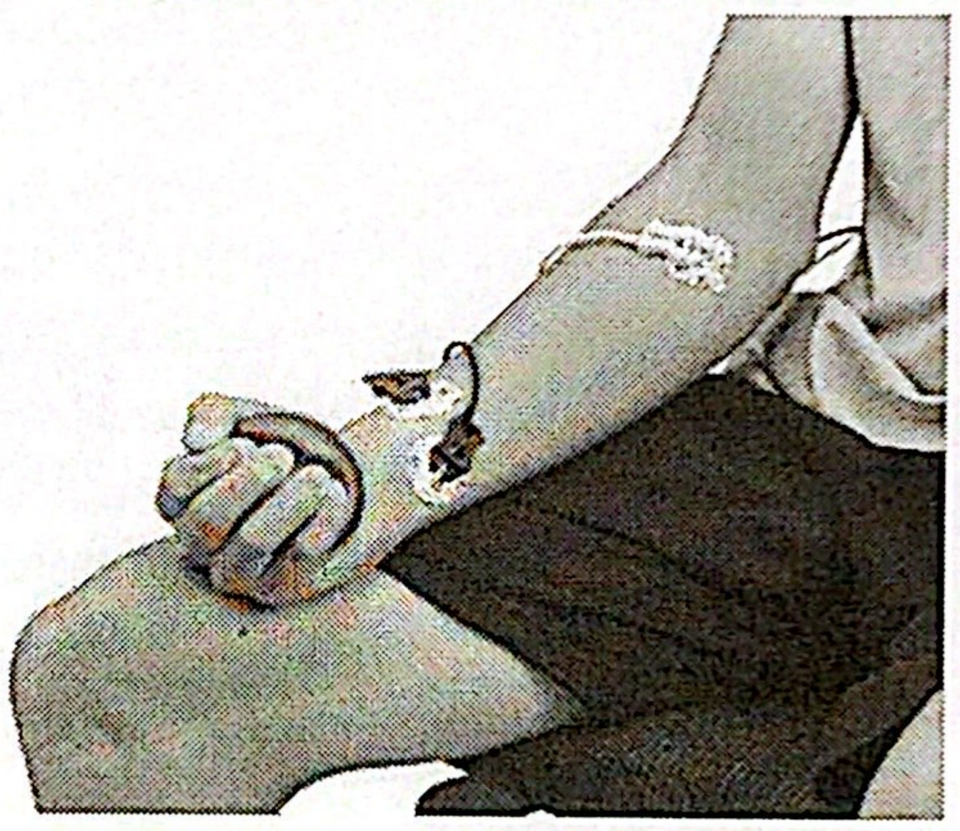

**Fig. 1.6 Proper Seating Position**

- The dominant arm should rest on thigh to relax the muscles in the shoulder and upper arm.
- Optional: Subject may hold a small object, such as a rubber ball, while performing this procedure.

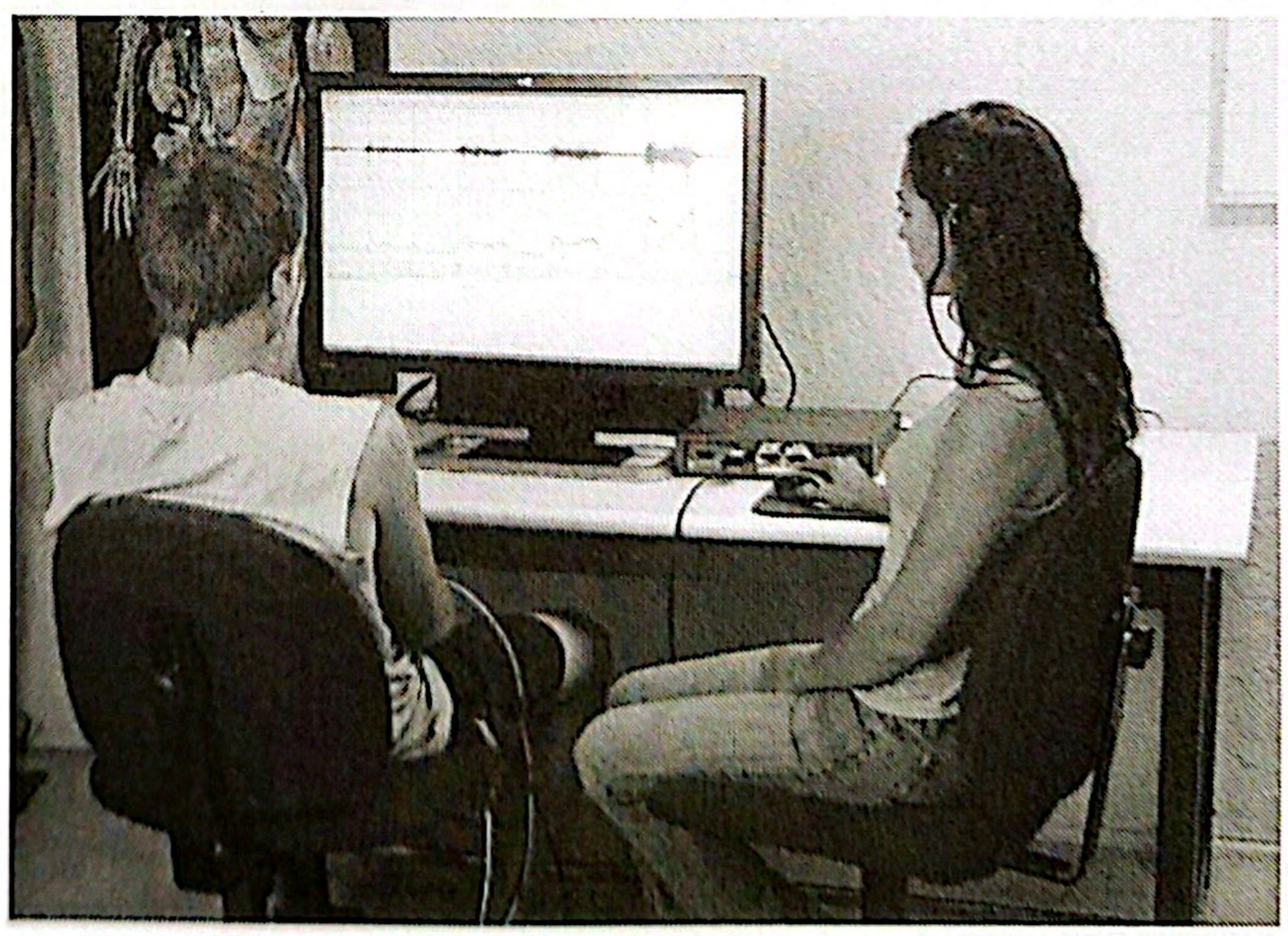

**Fig. 1.7 Positioning**

**Setup continues...**

8. **Start** the Biopac Student Lab Program.
9. Choose lesson "**L01 – Electromyography (EMG) I**" and click **OK.**
10. Type in a unique **filename** and click **OK.**

Start Biopac Student Lab by double-clicking the Desktop shortcut.


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

A folder will be created using the filename. This same filename can be used in other lessons to place the **Subject's** data in a common folder.

To change the preference, see next step.

11. *Optional*: Set Preferences.
    - Choose File > **Lesson Preferences.**
    - Select an option.
    - Select the desired setting and click **OK.**

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor's guidelines, you may set:
Grids: Show or hide gridlines
Lesson Recordings: Specific recordings may be omitted based on instructor preferences.

**END OF SETUP**

## B. CALIBRATION

Calibration establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimal performance. **Pay close attention to Calibration.** *For a video example of proper Calibration procedure*, click the **Calibration** tab in the Lesson Set Up Journal.

**FAST TRACK Calibration**

1. Click **Calibrate.**
2. Two seconds after Calibration begins, **clench** fist as hard as possible for two to three seconds, then **release.**

**Detailed Explanation of Calibration Steps**

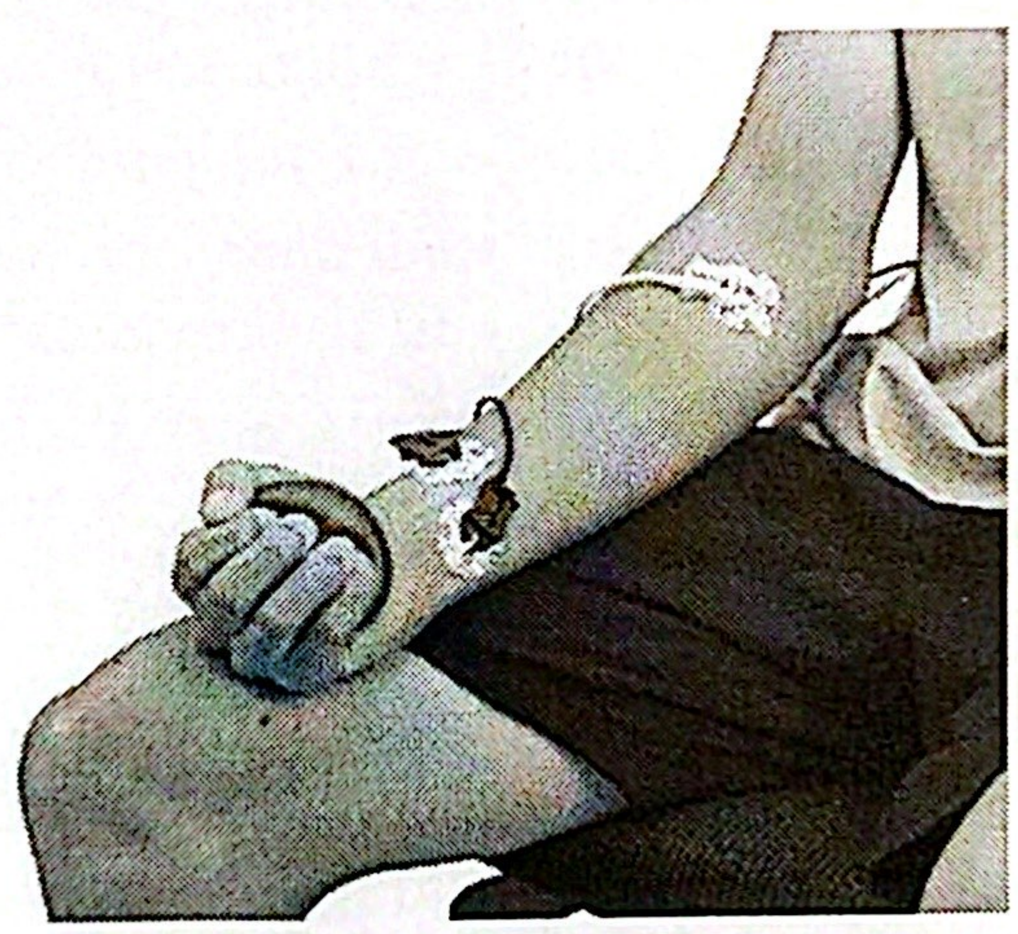

**Fig. 1.8 Clench Fist for Calibration**

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

3. **Wait** for Calibration to stop.
4. Verify recording resembles the example data
    - If similar, click **Continue** and proceed to Data Recording.
    - If necessary, click **Redo Calibration.**

Calibration lasts eight seconds.

Data should show a zero baseline and a clear burst when **Subject** clenched.

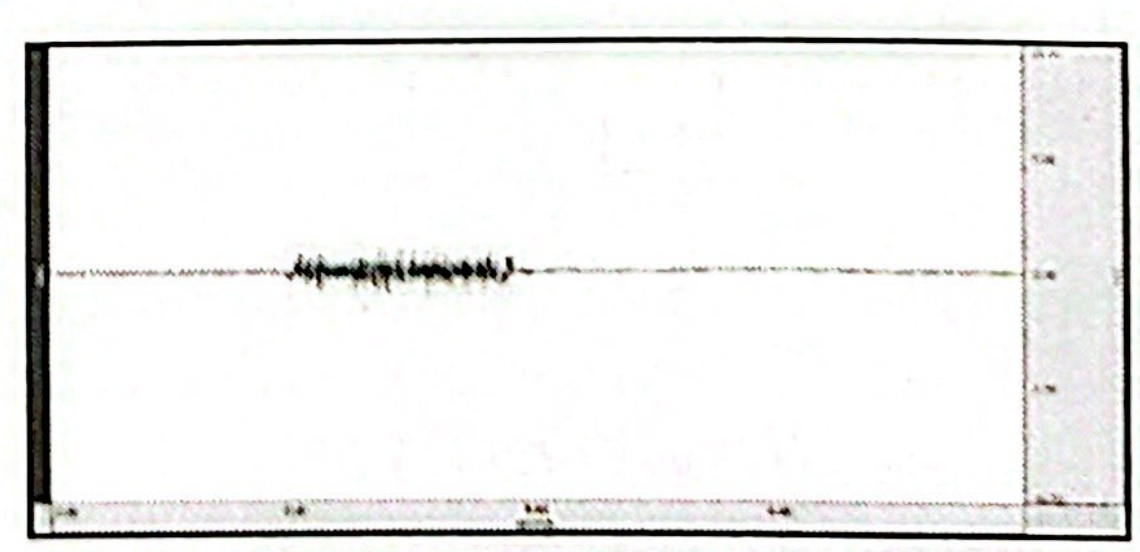

**Fig. 1.9 Example Calibration data**

<u>If recording does not resemble the Example Data</u>
- If the data is noisy or flatline, check all connections to the MP unit.
- Verify electrodes are making good contact and that leads are clipped to the correct color position with minimal cable strain.

**END OF CALIBRATION**

## C. DATA RECORDING

### FAST TRACK Recording

1. Prepare for the **Dominant arm** recording.
   - Electrodes must be attached to **Subject's** dominant arm.
   - **Subject's** hand must be relaxed.
   - **Review** recording steps.

### Detailed Explanation of Recording Steps

Two data recordings* will be acquired in this lesson:

a. Recording 1 records **Dominant arm.**

b. Recording 2 records **Nondominant arm.**

To work efficiently, read this entire section before recording, or review onscreen **Tasks** to preview recording steps in advance.

***IMPORTANT**

This procedure assumes that all lesson recordings are enabled in Lesson Preferences, which may not be the case for your lab. Always match the recording title to the recording reference in the journal and disregard any references to excluded recordings.

***Dominant arm***

2. Click **Record.**
3. Perform a series of four Clench -Release-Wait cycles.
   - Hold clench for two seconds, release for two seconds.
   - Begin with a weak clench, then increase grip so the fourth clench is at maximum.

- Completely relax the grip between clenches.
- Allow at least two seconds between clenches.
- Two channels will be presented during the recording, CH 1 = Raw EMG, and CH 2 = Integrated EMG (a moving average of the raw signal).

4. Click **Suspend.**
5. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to next recording.
   - If necessary, click **Redo.**
   - If all required recordings have been completed, click **Stop** and proceed to Step 11.

Data should show four EMG "bursts" of increasing amplitude.

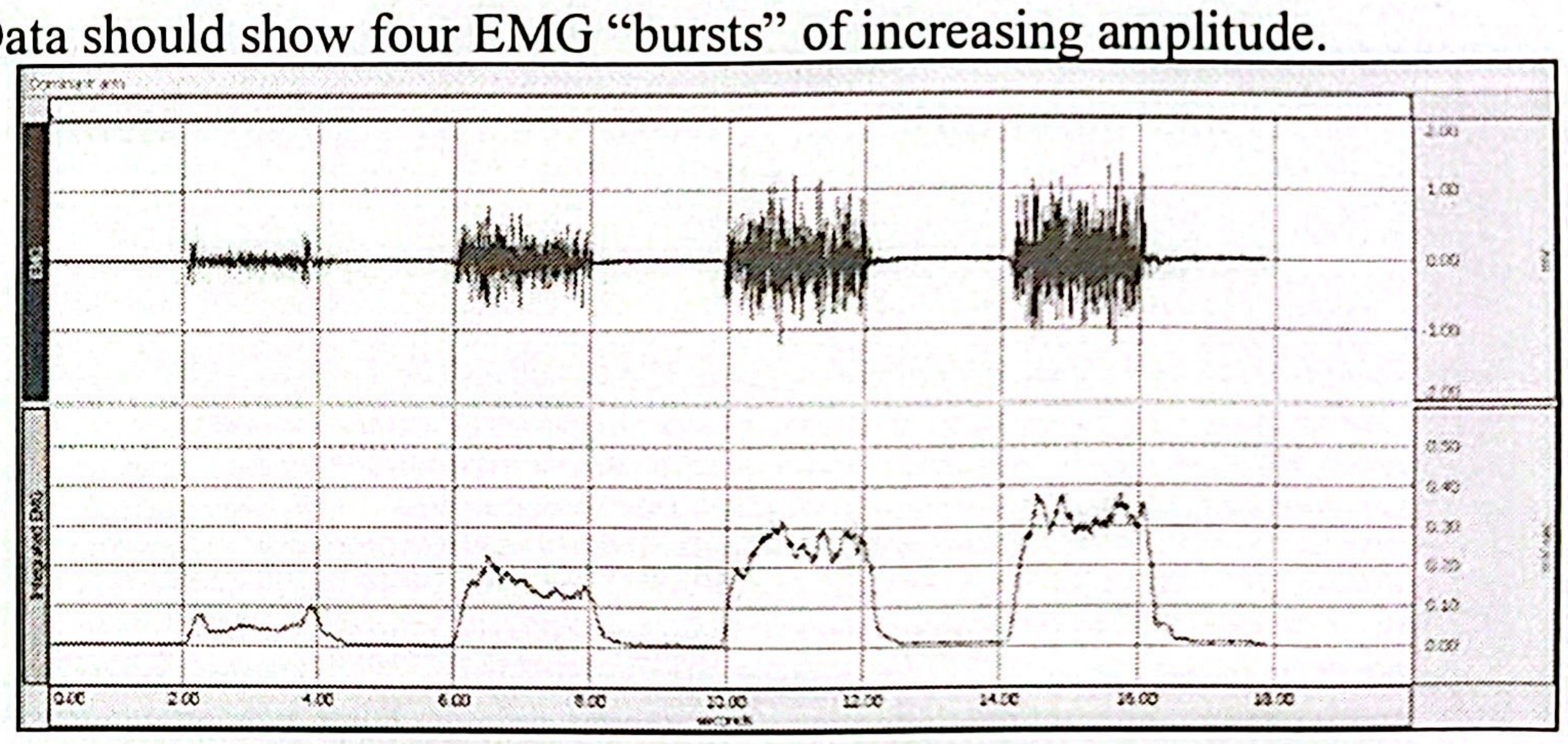

**Fig. 1.10 Example data – Dominant arm**

If recording does not resemble the Example Data

- If there is not enough variation between the clenches, repeat recording and start with a weaker clench.
- If the data is noisy or flatline, check all connections to the MP unit.
- Verify electrodes are making good contact and that leads are clipped to the correct color position with minimal cable strain.

Click **Redo** and repeat Steps 2 – 5 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

***Nondominant arm***

6. Prepare for the **Nondominant arm** recording.
   - Clip electrode leads to **Subject's** nondominant arm.
   - **Subject's** hand must be relaxed.
   - **Review** recording steps.

Disconnect the lead set (SS2L) from the electrodes on the "dominant" forearm and connect to electrodes on "nondominant" forearm. Refer to Fig. 1.5 for proper electrode lead attachment.

7. Click **Record.**

**Recording continues...**

8. Perform a series of four Clench-Release-Wait cycles.
   - Hold clench for two seconds, release for two seconds.
   - Begin with a weak clench, and then increase grip so the fourth clench is at maximum.

Perform four cycles of Clench-Release-Wait, holding for two seconds and waiting for two seconds after releasing before beginning the next cycle. Try to increase the strength in equal increments so that the fourth clench is at maximum force.

- Completely relax the grip between clenches.
- Allow at least two seconds between clenches.

9. Click **Suspend**.
10. Verify recording resembles the example data.
    - If <u>similar</u>, click **Continue** to proceed to the optional recording section, or click **Stop** to end the recording.
    - If necessary, click **Redo**.

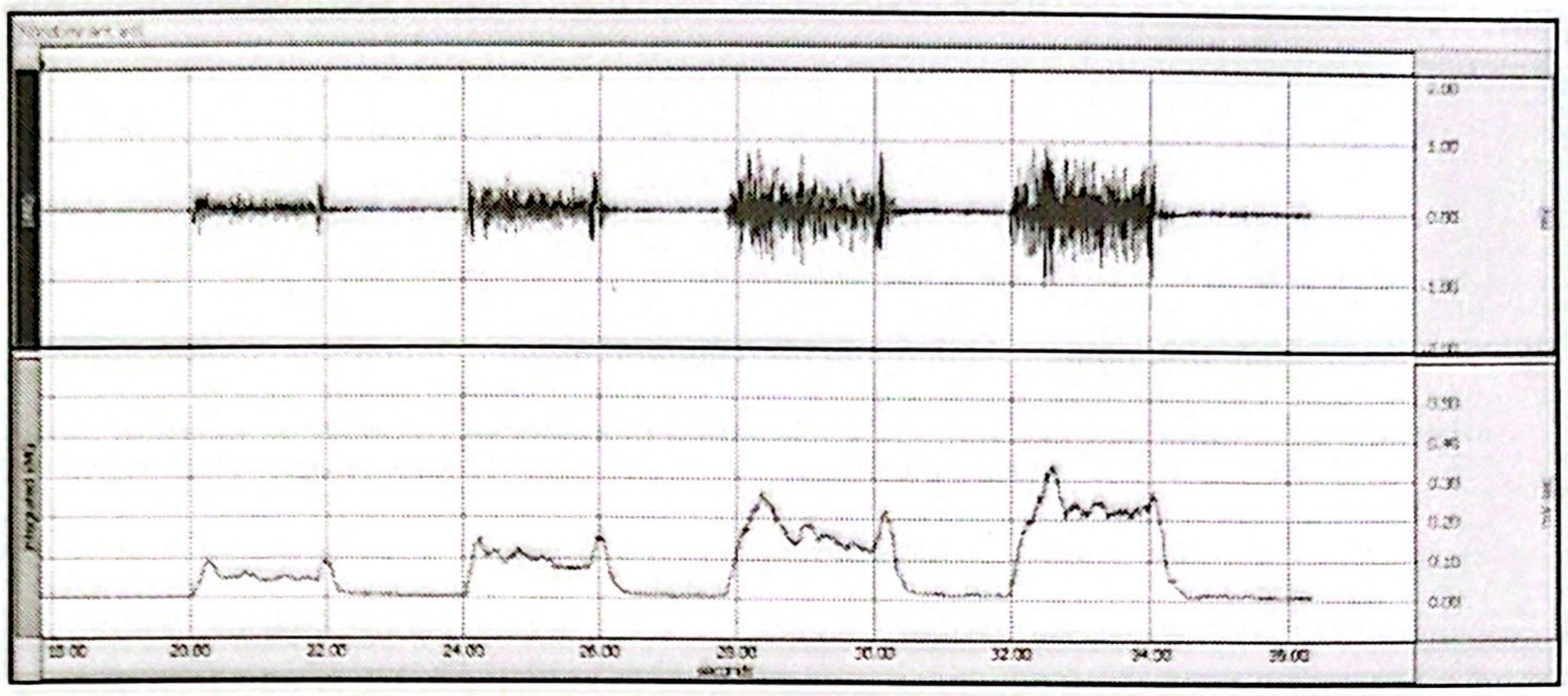

**Fig. 1.11 Example data– Nondominant arm**

The data description is the same as outlined in Step 4.

Click **Redo** and repeat Steps 7 – 10 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

**OPTIONAL ACTIVE LEARNING PORTION**

With this lesson you may record additional data by clicking **Continue** following the last recording. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. Although you are limited to this lesson's channel assignments, the electrodes may be moved to different locations on the **Subject**.

**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.

**Run Your Experiment**

**D. *Set Up***

Set up the equipment and prepare the subject for your experiment.

**E. *Record***

Use the **Continue**, **Record**, and **Suspend** buttons to record as much data as necessary for your experiment.

Click **Stop** when you have completed all of the recordings required for your experiment.

**Analyze Your Experiment**

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

**Recording continues…**

- To listen to the EMG signal, proceed to Step 11.
- To skip listening to the EMG signal and end the recording, proceed to Step 14.

*Listening to the EMG is optional.*

Listening to the EMG is optional and can be a valuable tool in detecting muscle abnormalities, and is performed here for general interest. Data on screen is not saved.

11. Click **Listen** to record EMG data and hear it through the headphones.
12. Increase grip force and notice how the volume increases.

The EMG signal will be audible through the headphones as it is being displayed on the screen. The screen will display two channels:

CH 1 EMG and CH 40 Integrated EMG

The signal will run until **Stop** is clicked. If others in lab group would like to listen to the EMG signal, pass the headphones around before clicking **Stop** or click **Redo** and then **Stop** when done.

13. Click **Stop** when finished.
    - Click **Redo** to hear EMG again.

This will end listening to the EMG.

14. Click **Done** to end the lesson.
15. Choose an option and click **OK**.

If choosing the **Record from another Subject** option:

- Repeat Setup Steps 4 – 7 and then proceed to Calibration.

16. Remove the electrodes.

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

**END OF RECORDING**

# V. DATA ANALYSIS

## FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode.
   - Note Channel Number (CH) designations:

| *Channel* | *Displays* |
|---|---|
| **CH 1** | **EMG** |
| **CH 40** | **Integrated EMG** |

   - Note measurement box settings:

| *Channel* | *Measurement* |
|---|---|
| **CH 40** | **Mean** |

2. Set up your display window for optimal viewing of "**Dominant arm**" recording.
3. Use the I-Beam cursor to select an area on the plateau of the first EMG clench data (Fig. 1.13).

   A

4. Repeat Step 3 on each successive EMG cluster.

   A

Data Analysis continues...

## Detailed Explanation of Data Analysis Steps

If entering **Review Saved Data** mode from the Startup dialog or Lessons menu, make sure to choose the correct file.

The data window should resemble Fig. 1.12.

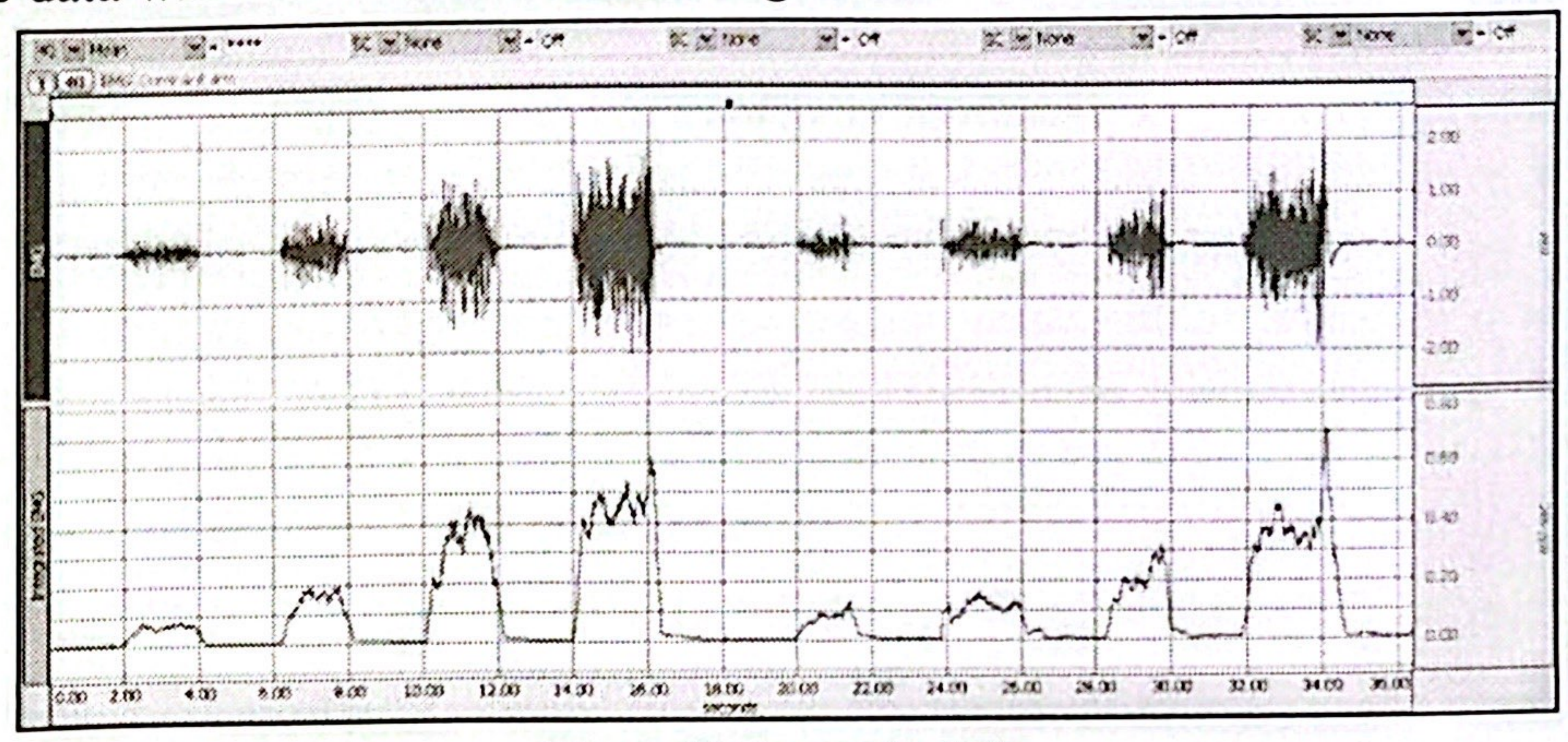

Fig. 1.12 Example data

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.

**Brief definition of measurements:**

**Mean:** Displays the average value in the selected area.

The "selected area" is the area selected by the **I-beam** tool (including endpoints).

Record measurement data individually by hand or choose **Edit > Journal > Paste measurements** to paste the data to your journal for future reference.

**Note:**

The append event markers ◆ mark the beginning of each recording. Click on (activate) the event marker to display its label.

**Useful tools for changing view:**

Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

Scroll Bars: Time (Horizontal); Amplitude (Vertical)

Cursor Tools: Zoom Tool

Buttons: Overlap, Split, Show Grid, Hide Grid, -, +

Hide/Show Channel: "Alt + click" (Windows) or "Option + click" (Mac) the channel number box to toggle channel display.

Fig. 1.13 below shows an EMG data selection in the first recording.

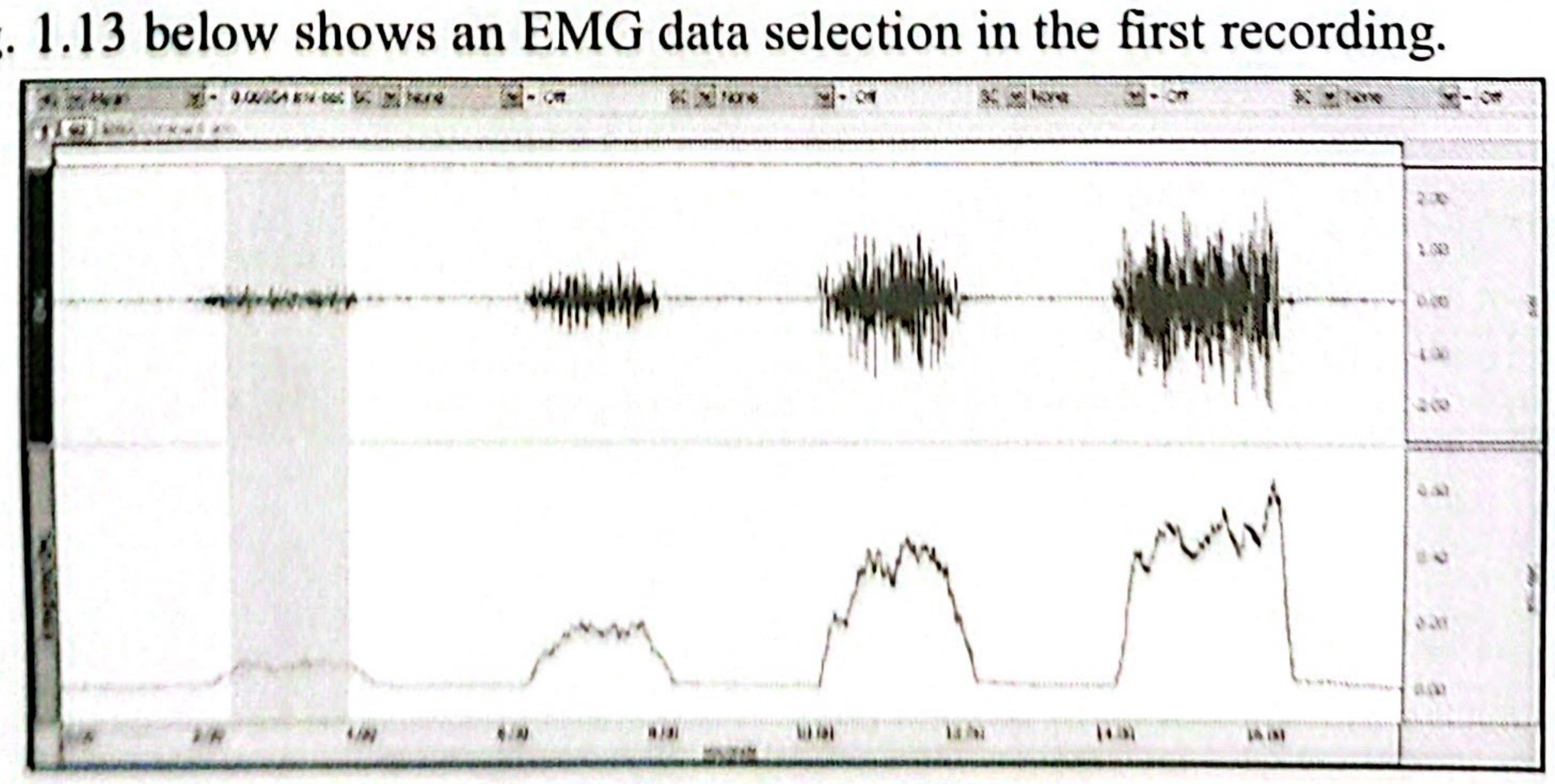

Fig. 1.13 EMG data selection

5. Scroll to the second recording.
6. Repeat Steps 3 and 4 for "**Nondominant arm**" data.
7. Scroll to the first recording.
8. Use the I-Beam cursor to select the area between the first and second clenches (Fig. 1.14).

   C
9. Repeat Step 7 between each successive clench.
10. Scroll to the second recording.
11. Repeat Steps 7 – 8 for "**Nondominant arm**" data.

   C
12. Answer the questions at the end of the Data Report.
13. **Save** or **Print** the Data Report.
14. **Quit** the program.

END OF DATA ANALYSIS

The second recording begins at the append event marker labeled "**Nondominant arm**" and includes four clenches from **Subject's** nondominant arm.

Tonus is the resting state, and is represented by the area between clenches (clusters). Fig. 1.14 below shows the selected area between clenches.

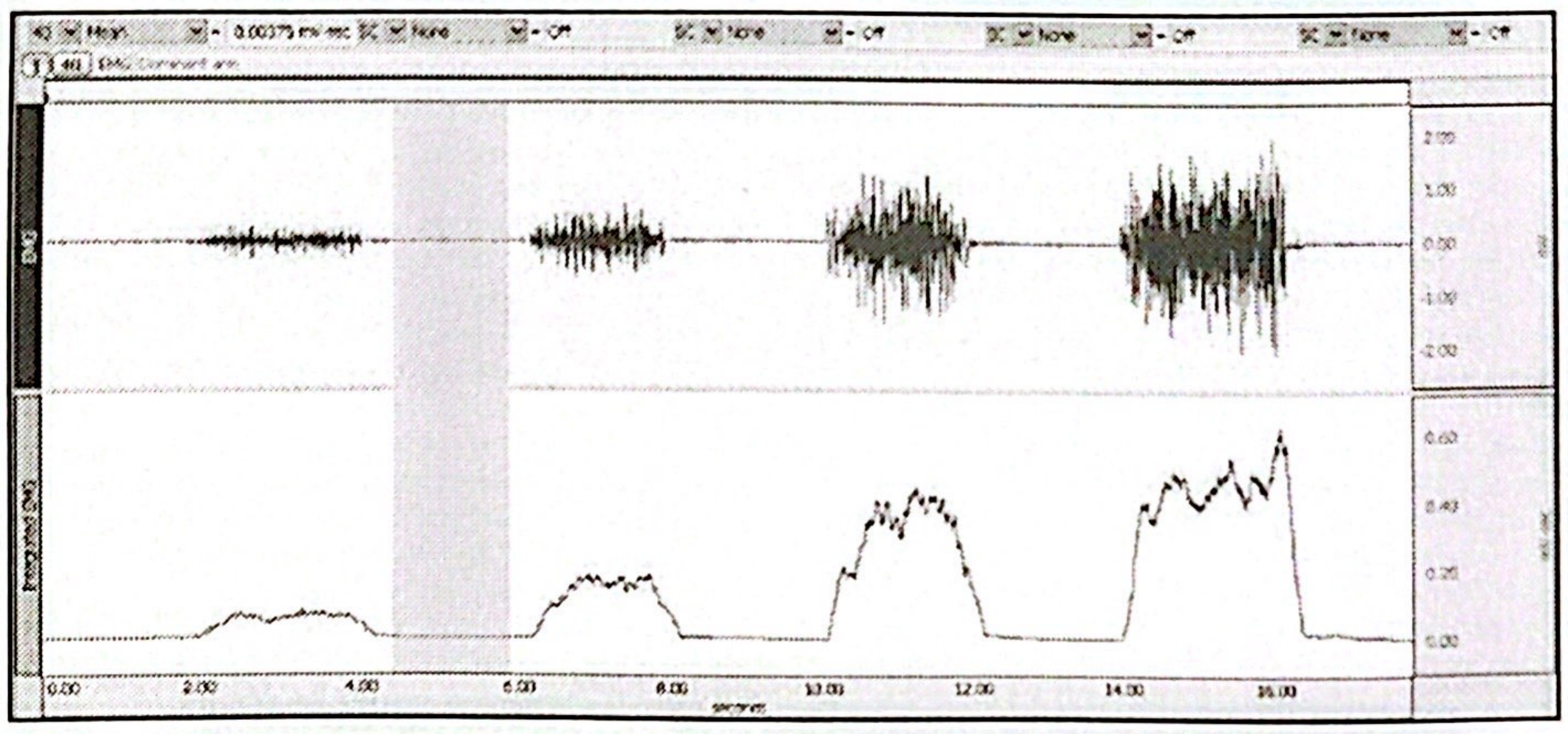

**Fig. 1.14 Selection between clenches to measure tonus**

An electronically editable **Data Report** can be found in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

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END OF LESSON 1

Complete the Lesson 1 Data Report that follows.

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# ELECTROMYOGRAPHY I

- *Standard and Integrated EMG*

DATA REPORT

Student's Name: ________________________

Lab Section: ________________________

Date: ________________________

## I. Data and Calculations

Subject Profile

Name:________________________ Height:__________ Gender: Male / Female

Age:________________________ Weight:__________ Dominant arm: Right / Left

A. **EMG Measurements**

**Table 1.1**

| Clench # | Dominant arm<br>40 Mean | Nondominant arm<br>40 Mean |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |

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 Dominant arm.

Calculation:________________________ Answer: __________%

C. **Tonus Measurements**

**Table 1.2**

| Between Clenches # | Dominant arm<br>40 Mean | Nondominant arm<br>40 Mean |
|---|---|---|
| 1-2 | | |
| 2-3 | | |
| 3-4 | | |

## II. Questions

D. Compare the mean measurement for the right and left maximum clench EMG data.

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 gender 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.