I. INTRODUCTION

Mechanical work, in the physical sense, refers to the application of a force resulting in the movement of an object. Skeletal muscle performs mechanical work when the muscle contracts and an object is moved, as in lifting a weight. To lift a weight, your muscles must exert a force great enough to overcome the weight. If you exert less force, then the weight does not move (Fig. 2.1).

Physiologically, skeletal muscle is stimulated to contract when the brain or spinal cord activates motor units of the muscle.

Motor units are defined as a motoneuron and all of the muscle fibers that the motoneuron innervates. An action potential (AP) in a human motoneuron always causes an action potential in all of the muscle fibers of the motor unit. As a matter of fact, humans generally do not send just one AP at a time down a motoneuron. Instead, a train of APs is sent — enough to induce tetany (the sustained fusion of individual muscle twitches) in the muscle fibers of the motor unit.

(A discussion of motor units and their control was presented in Lesson 1.)

Most human skeletal muscles are composed of hundreds of motor units (Fig. 2.2). When a skeletal muscle is called on to perform mechanical work, the number of motor units in the muscle activated by the brain is proportional to the amount of work to be done by the muscle; the greater the amount of work to be done, the greater the number of motor units activated. Thus, more motor units are simultaneously active when a skeletal muscle lifts 20 kilograms than when the same muscle lifts 5 kilograms.

Fig. 2.2 Example of Motor Units
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.

Power is defined as the amount of work done per unit of time. Dynamometry means the measurement of power (dyne = power, meter = measure,) and the graphic record derived from the use of a dynamometer is called a dynagram.

In this lesson, the power of contraction of clench muscles will be determined by a hand dynamometer equipped with an electronic transducer. Model SS25LA/L measures force in "kg" units; model SS56L measures proportionality of bulb pressure to clench force in "kgf/m^2" units (a pressure unit). Both measures are accurate for the relative measures recorded in this lesson.

The BIOPAC system will simultaneously record three bands of information:

1) The force you exert on the transducer,
2) The electrical signal produced by the muscle during contraction, and
3) The integrated waveform, which is an indication of the activity levels of the muscle.
4. Clean and abrade skin.
5. **Attach three electrodes** to each forearm (Fig. 2.6).
6. **Clip** the Electrode Lead Set (SS2L) to the **Subject's** dominant forearm, following the color code (Fig. 2.6).
7. Hold hand dynamometer with dominant hand.

If the skin is oily, clean electrode sites with soap and water or alcohol before abrading.

If the electrode is dry, apply a drop of gel.

For optimal electrode contact, place electrodes on the skin at least five minutes before the start of Calibration.

Clip the Lead Set (SS2L) to the **Subject's** dominant forearm (Fig. 2.6) for recordings 1 and 2.

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

**Fig. 2.6 Electrode Placement & Lead Attachment**

- If **Subject** is right-handed, the right forearm is generally dominant; if the subject is left-handed, the left forearm is generally dominant.
- The pinch connectors work like a small clothespin and will only latch onto the nipple of the electrode from one side of the connector.

**Fig. 2.7 Proper Seating Position**

- Arm holding the hand dynamometer should rest on thigh to relax the muscles in the shoulder and upper arm.

Setup continues...
B. CALIBRATION

The Calibration procedure 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. Set the hand dynamometer down and click OK.

3. Hold the BIOPAC hand dynamometer with dominant hand when prompted and click OK.

SS25LA: Place the short grip bar against the palm, toward the thumb, and wrap your fingers to center the force.

SS25L: Grasp as close to the dynagrip crossbar as possible without actually touching the crossbar.

SS56L: WRAP your hand around the bulb with relaxed fingers—do NOT curl fingers into bulb.

IMPORTANT
Hold the dynamometer in the same position for all measurements from each arm. Note your hand position for the first recording and try to repeat it for the subsequent recordings.

4. When Calibration recording begins, clench the hand dynamometer as hard as possible for 2 sec. and then release.

5. Wait for Calibration to stop.

6. Verify recording resembles the example data.
   - If similar, click Continue and proceed to Data Recording.
   - If necessary, click Redo Calibration.

Detailed Explanation of Calibration Steps

You will be prompted to remove any grip force from the hand dynamometer.

This will remove any clench force which is important for establishing a zero force baseline.

Clench with the hand of your dominant forearm.

SS25LA grip position

SS25L grip position

SS56L grip position

Fig. 2.9

The program needs a reading of your maximum clench to establish proper force increments (grid settings) used during the recordings.

Calibration lasts eight seconds.

Both channels should begin with a zero baseline and then there should be a clear EMG “burst” and simultaneous increase in Clench Force when the Subject clenched.

- If using SS25LA/L, units are kg; If using SS56L, units are kgf/m².

Fig. 2.10 Example Calibration data

If recording does not resemble the Example Data
- If the data is noisy or flatline, check all connections to the MP unit.
- If the hand dynamometer signal is not zero when relaxed, make sure all grip force is removed until prompted.
- Verify electrodes are making good contact and that leads are clipped to the correct color position with minimal cable strain.
4. After maximum grip force is reached, click **Suspend**.
5. Verify recording resembles the example data above.
   - If similar, click **Continue** and proceed to Step 6.
   - If necessary, click **Redo**.
   - If all required recordings have been completed, click **Stop**.

**Dominant arm: Continued clench at maximum force**

- Review recording steps.
6. Click **Record**.
7. Clench the hand dynamometer as hard as possible and try to maintain maximum force.
8. Continue clenching until force has decreased by 50%.

9. Click **Suspend**.
10. Verify recording resembles the example data.
    - If similar to Fig. 2.12, click **Continue** and proceed to the next recording.
    - If necessary, click **Redo**.
    - If all required recordings have been completed, click **Stop**.

- The data must show multiple peaks of increasing clench force.
- The data shown above (Fig. 2.11) is from a **Subject** who was able to maintain an even force throughout the clench. Your data may be correct even if your peaks are not “flat.”

If recording does not resemble the **Example Data**

- If the data is noisy or flatline, check all connections to the MP unit. Click **Redo** and repeat Steps 2 – 5 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Note the maximum clench force so you can determine when the force has decreased by 50%. (The maximum force may scroll out of view.) Try to maintain the maximum clench force. (The forearm will fatigue and the force will decrease.) The time to fatigue to 50% of maximal clench force will vary greatly among individuals.

**Fig. 2.12 Example Fatigue data**

Note that the peak found immediately following the start of the recording represents the maximal clench force. This example shows the point of fatigue to 50% maximal clench force captured on the same screen, but maximum force may scroll out of view. Use the horizontal (time) scroll bar to see the beginning of the recording.

If recording does not resemble the **Example Data**

- If the data is noisy or flatline, check all connections to the MP unit. Click **Redo** and have the **Subject** rest arm for a few minutes. When ready, repeat Steps 6 – 10. Note that once **Redo** is clicked, the most recent recording will be erased.

Recording continues...
20. Verify recording resembles the example data.
   • If similar to Fig. 2.15, click Continue to proceed to the optional recording section, or click Stop to end the recording.
   • If necessary, click Redo.

**OPTIONAL ACTIVE LEARNING PORTION**

If recording does not resemble the Example Data
   • If the data is noisy or flatline, check all connections to the MP unit. Click Redo and have the Subject rest arm for a few minutes. When ready, repeat Steps 16 – 20. Note that once Redo is clicked, the most recent recording will be erased.

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.

*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. Data on screen is not saved.
Analysis of Increasing Clench Force

2. Setup your display for optimal viewing of "Dominant arm: Increasing clench force" data.

3. Read the journal and note your force increment in the Data Report.

4. Use the I-Beam cursor to select an area on the plateau phase of the first clench (Fig. 2.17).

5. Repeat Step 4 on the plateau of each successive clench.

6. Scroll to marker labeled "Nondominant arm: Increasing clench force" and set up your display for optimal viewing.

7. Repeat Steps 3 – 4 for this recording.

Analysis of Continued Clench

8. Scroll to "Dominant arm: Continued clench at maximum force" and set up your display for optimal viewing.

9. Use the I-Beam cursor to select a point of maximal clench force immediately following the start of the recording (Fig. 2.18).

10. Calculate 50% of the maximum clench force from Step 9.

Note: The append event markers ♦ mark the beginning of each recording. Click (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.

The Journal summary shows the force increment used in your recordings. The grid divisions should use the same increment. Note this increment in Table 2.1 in the second column, Force (kg) Increments for Peak #1. For subsequent peaks, add the increment (i.e., 5, 10, 15 kg or 10, 20, 30 kg).

Fig. 2.17 Plateau of first clench selected

This recording begins at the append event marker labeled "Dominant arm: Continued clench at maximum force."

Fig. 2.18

The point selected should represent the maximal clench force at the start of continuous maximal clench recording, as shown in Fig. 2.18.

This number is necessary in order to complete Step 11.

Data Analysis continues....
ELECTROMYOGRAPHY II

* Motor unit recruitment and Fatigue

DATA REPORT

Student’s Name: ___________________________________________
Lab Section: _______________________________________________  
Date: _______________________________________________________

Subject Profile

Name: ______________________________________________________  
Height: _______ Gender: Male / Female
Age: ________________________________________________________  
Weight: _______ Dominant arm: Right / Left

I. Data and Calculations

Motor Unit Recruitment

A. Complete Table 2.1 using Dominant arm and Nondominant arm data. In the "Force (kg) Increments" column, note the force increment assigned for your recording under Peak #1; the increment was pasted to the Journal and should be noted below from Data Analysis—Step 2. For subsequent peaks, add the increment (i.e., 500, 1000, 1500). You may not need eight peaks to reach max.

<table>
<thead>
<tr>
<th>Peak #</th>
<th>Assigned Force Increment</th>
<th>(Dominant arm)</th>
<th>(Nondominant arm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS25L/LA = Kg</td>
<td>Force at Peak</td>
<td>Integrated EMG (mV)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>41 Mean</td>
<td>41 Mean</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fatigue

B. Complete Table 2.2 using Dominant arm and Nondominant arm data.

<table>
<thead>
<tr>
<th></th>
<th>(Dominant arm)</th>
<th>(Nondominant arm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Clench Force</td>
<td>41 Value</td>
<td>41 Value</td>
</tr>
<tr>
<td>50% of Max Clench Force</td>
<td>calculate</td>
<td>calculate</td>
</tr>
<tr>
<td>Time to Fatigue</td>
<td>40 Delta T</td>
<td>40 Delta T</td>
</tr>
<tr>
<td>Maximum Clench Force</td>
<td>41 Value</td>
<td>41 Value</td>
</tr>
<tr>
<td>50% of Max Clench Force</td>
<td>calculate</td>
<td>calculate</td>
</tr>
<tr>
<td>Time to Fatigue</td>
<td>40 Delta T</td>
<td>40 Delta T</td>
</tr>
</tbody>
</table>
III. OPTIONAL Active Learning Portion

A. Hypothesis

B. Materials

C. Method

D. Set Up

E. Experimental Results

End of Lesson 2 Data Report
II. Questions

C. Is the strength of your right arm different than your left arm? _____Yes _____No

D. Is there a difference in the absolute values of force generated by males and females in your class? _____Yes _____No
   What might explain any difference?

E. When holding an object, does the number of motor units remain the same? Are the same motor units used for the duration of holding the object?

F. As you fatigue, the force exerted by your muscles decreases. What physiological processes explain the decline in strength?

G. Define Motor unit

H. Define Motor unit recruitment

I. Define Fatigue

J. Define EMG

K. Define Dynamometry
11. Find the point of 50% maximum clench force by using the I-beam cursor and leave the cursor at this point.

12. Select the area from the point of 50% clench force back to the point of maximal clench force by using the I-beam cursor and dragging (Fig. 2.19). Note the time to fatigue measurement (CH 40 Delta T).

Scroll to marker labeled “Non dominant arm: Continued clench at maximum force” and set up your display for optimal viewing.

13. Repeat Steps 8–12 for this recording.

Make an eyeball approximation of the point that is 50% down from the maximal clench point. Then, use the I-beam cursor to click points near this region, noting the value displayed in the measurement box, until you are on a point within 5% of the maximal clench force. Leave the cursor at this point.

One way to select the area is as follows: The cursor should be flashing on the point of 50% maximal clench force. Hold down the mouse button and drag to the left of this point until you reach the point of maximal clench force, then release the mouse button.

Note: You do not need to indicate the Delta T polarity as it only reflects the direction the “I-beam” cursor was dragged to select the data. Data selected left to right will have a positive (+) polarity, while data selected right to left will have a negative (−) polarity.

15. Save or Print the data file.
16. Quit the program.

END OF DATA ANALYSIS

Fig. 2.19 showing area max-50%

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

END OF LESSON 2
Complete the Lesson 2 Data Report that follows.
21. Click **Listen** to record EMG data and hear it through the headphones.

22. Increase clench force and notice how the volume increases.

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

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

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

26. Remove the electrodes.

**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 (hidden*)
     CH 40 Integrated EMG
     CH 41 Clench Force

   - Note measurement settings:
     
     **Channel**  **Measurement**
     CH 41  Mean
     CH 40  Mean
     CH 41  Value
     CH 40  Delta T

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 41 Clench Force.

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

This will end listening to the EMG.

If choosing the **Record from another Subject** option:
   - Repeat Setup Steps 4 – 7 and proceed to Calibration.

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.

**Detailed Explanation of Data Analysis Steps**

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

The data window should resemble Fig. 2.16.

![Example data](image)

**Fig. 2.16 Example data**

The measurement boxes are above the event 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 clicked.

**Brief definition of measurements:**

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

**Value:** Displays the amplitude value at the point selected by the I-beam cursor. If an area is selected, displays the value of the endpoint based on the direction the cursor was dragged.

**Delta T:** Measures the difference in time between the end and beginning of the selected area.

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

Data Analysis continues....
**Nondominant arm: Increasing clench force**

11. Prepare for the Nondominant arm recording.
   - Clip electrode leads to Subject’s nondominant arm.
   - Subject’s hand must be relaxed.
   - Grip hand dynamometer with nondominant hand.
   - Review recording steps.

   These recordings apply to the nondominant forearm, following the same procedure used for the dominant forearm.

   Disconnect the lead set (SS2L) from the electrodes on the “dominant” forearm and connect to electrodes on “nondominant” forearm per Fig. 2.13.

12. Click **Record**.


14. After maximum grip force is reached, click **Suspend**.

15. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to the next recording.
   - If necessary, click **Redo**.
   - If all required recordings have been completed, click **Stop**.

   Repeat a cycle of Clench-Release-Wait, holding for two seconds and waiting for two seconds after releasing before beginning the next cycle. Begin with your Assigned Increment of force (first grid) and increase by the Assigned Increment for each cycle until maximum clench force is obtained.

   ![Fig. 2.14 Example Increasing Clench Force data](image)

   If recording does not resemble the Example Data
   - If the data is noisy or flatline, check all connections to the MP unit. Click **Redo** and repeat Steps 12 – 15 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

**Nondominant arm: Continued clench at maximum force**

- Review recording steps.

16. Click **Record**.

17. Clench the hand dynamometer as hard as possible and try to maintain maximum force.

18. Continue clenching until force has decreased by more than 50%.

19. Click **Suspend**.

   Recording continues...

Note the maximum clench force so you can determine when the force has decreased by 50%. (The maximum force may scroll out of view.) Try to maintain the maximum clench force. (The forearm will fatigue and the force will decrease.)

The time to fatigue to 50% of maximal clench force will vary greatly among individuals.
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.
   - Grip the hand dynamometer with dominant hand.
   - Review recording steps.

**Dominant arm: Increasing clench force**

- Calibrated grip force

2. Click **Record**.

   - Hold clench for two seconds, release for two seconds.
   - Use sufficient grip force on each cycle to increase the force by one grid line per clench.

Detailed Explanation of Recording Steps

Four data recordings* will be acquired, two on each arm:

a. Recordings 1 and 3 record Motor unit recruitment.
b. Recordings 2 and 4 record Fatigue

In order to work efficiently, read this entire section, 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.

When **Continue** is clicked following Calibration, the display will change to show only the Clench Force channel, with grids displayed.

Based on maximum grip force during calibration, the software sets the grid as follows:

<table>
<thead>
<tr>
<th>SS25L/LA Force calibration (kg)</th>
<th>Assigned Increment (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 25</td>
<td>5</td>
</tr>
<tr>
<td>25 – 50</td>
<td>10</td>
</tr>
<tr>
<td>50 – 75</td>
<td>15</td>
</tr>
<tr>
<td>&gt;75</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SS56L Max Clench (kgf/m²)</th>
<th>Assigned Increment (kgf/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5,000</td>
<td>1,000</td>
</tr>
<tr>
<td>5,000 – 7,500</td>
<td>1,500</td>
</tr>
<tr>
<td>7,500 – 10,000</td>
<td>2,000</td>
</tr>
<tr>
<td>10,000 – 12,500</td>
<td>2,500</td>
</tr>
<tr>
<td>&gt;12,500</td>
<td>3,000</td>
</tr>
</tbody>
</table>

**Fig. 2.11 Example Increasing Clench Force data**

- Completely relax grip force between clenchers.
- It is important to reach the first gridline on the first clench. Increase grip on subsequent clenches to advance the force signal one gridline per clench until maximum grip force is reached.
- A total of five clenches are used in the Example Data, but certain **Subjects** may require a lesser or greater number of clenches to attain maximum grip force.

Recording continues...
8. Start the BIOPAC Student Lab Program.
9. Choose lesson "L02 – Electromyography (EMG) II" and click OK.
10. Type in a unique filename and click OK.
11. Make sure the picture in the journal (Hardware tab) matches your setup. If it does not, you may need to change preference settings.

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

If your lab is using multiple MP hardware types, choose the appropriate BSL program (shortcut icon contains MP number).

![BIOPAC BSL 4.0 MP36 BIOPAC BSL 4.0 MP25 BIOPAC BSL 4.0 MP45]

No two people can share the same filename, so use a unique identifier, such as the 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.

The SS25LA picture represents both the SS25LA and SS25L.

To change the preference, see next step.

This ends the Set Up procedure.

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor’s guidelines, you may set:

**Clench Force Transducer**: Choose model SS25LA/L or SS56L (Bulb)

**Lesson Recordings**: Specific recordings may be omitted based on instructor preferences.

END OF SETUP
II. EXPERIMENTAL OBJECTIVES

1) To determine the maximum clench strength for right and left hands and compare differences between male and female.

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

3) To record the force produced by clench muscles, EMG, and integrated EMG when inducing fatigue.

III. MATERIALS

- BIOPAC Hand Dynamometer (SS25LA or SS25L)
  - Optional: BIOPAC Hand Clench Force Pump Bulb (SS56L) may be used—pressure in bulb is proportional to clench force. For SS56L units, set the Clench Force Transducer Preference BEFORE starting calibration.

- BIOPAC Electrode Lead Set (SS2L)

- BIOPAC Disposable Electrodes (EL03.1) 6 electrodes per Subject

- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD) or Skin cleanser or alcohol prep

- Optional: BIOPAC Headphones (OUT1/OUT1A for MP3X or 40HP for MP45)

- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP45 hardware

- Computer system (Windows 8, 7, Vista, XP, Mac OS X 10.5 - 10.8)

IV. EXPERIMENTAL METHODS

A. SETUP

**FAST TRACK Setup**

1. Turn your computer ON.
   - If using an MP36/35 unit, turn it OFF.
   - If using an MP45, make sure USB cable is connected and “Ready” light is ON.

2. Plug the equipment in as follows:
   - Electrode Lead Set (SS2L) — CH 1
   - Hand Dynamometer (SS25LA or SS25L) or Clench Force Pump Bulb (SS56L) — CH 2
   - Headphones (OUT1 or OUT1A*) — back of unit
   - *OUT1A is compatible with MP36 only.

3. Turn ON the MP36/35 unit.

4. Detailed Explanation of Setup Steps

   - Fig. 2.5 MP3X (top) and MP45 (bottom) equipment connections

Setup continues...
The brain determines the number of active motor units required for a muscle to perform a given task by utilizing sensory information from stretch receptors in the muscle and associated tendons and joint capsules. For example, when lifting a bucket of water from the ground, the brain first activates several motor units in the requisite skeletal muscles. If sensory information returning from the muscles indicates the muscles are contracting but not developing adequate power to lift the bucket, the brain activates additional motor units until the sensory information indicates the bucket is being lifted. The sequential activation of motor units to perform a designated task is called motor unit recruitment.

Once you have lifted a light object, the brain recruits approximately the same number of motor units to keep the object up, but cycles between different motor units. The muscle fibers consume stored energy available in the muscle, and generate a force by contracting. As the muscle fibers deplete this fuel source, more energy must be created in order to continue contracting. By recruiting different motor units, motor units can relax and replenish their fuel sources.

Skeletal muscles performing acute maximum work or chronic submaximum work of a repetitive nature will eventually fatigue. Fatigue is defined as a decrease in the muscle’s ability to generate force. Fatigue is caused by a reversible depletion of the muscle’s fuel supply. If the muscle uses its energy sources faster than they can be generated by cellular metabolism, fatigue occurs. During contraction, skeletal muscle cells convert chemical energy into thermal and mechanical energy, and, in the process, produce chemical waste products.

Normally the waste products are removed from the muscle by the circulatory system as the blood brings nutrients to the muscle for energy transformation. If certain waste products (metabolites) are not removed at an adequate rate, they will accumulate and chemically interfere with the contractile process, thereby hastening the onset of fatigue. Some accumulated waste products also stimulate pain receptors in surrounding connective tissue and induce cramping of skeletal muscle, a general sign of inadequate blood flow to the muscle.

In this lesson, you will examine motor unit recruitment and skeletal muscle fatigue by combining electromyography with dynamometry.

When a motor unit is activated, the component muscle fibers generate and conduct their own electrical impulses, which cause the fibers to contract. Although the electrical impulse generated and conducted by each fiber is very weak (less than 100 μvolts), many fibers conducting simultaneously induce voltage differences in the overlying skin which 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, and 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.