

BIOPAC ELECTROMYGRAPHY LAB

Introduction

Contractions of the skeletal muscles occur when signals from the central nervous system travel via the motor neurons to stimulate the muscle fibers at the neuromuscular junction. When stimulated, the neuromuscular junction triggers the formation of an action potential which travels across the sarcolemma (the plasma membrane of the muscle fiber). **Action potentials** are formed by the rapid movement of ions across a membrane, resulting in a change in the distribution of ions on the inside relative to the outside of the membrane. As the action potential travels along the muscle fiber, portions of the muscle fiber will have different concentrations of ions, creating a charge difference, or electric potential, along the length of the muscle. If a conductor is placed between these points, the potential due to the relative concentrations of ions will induce a slight electrical current that can be measured. The measurement of the electric potentials generated by muscles is called **electromyography**, and recordings of these potentials is called an **electromyogram**, or **EMG**. We will use sensitive electrodes connected to Biopac machines to detect the slight potentials produced by the action potentials along the sarcolemma of the muscle fibers. At any instance in time the electrical potential between different parts of the muscle can be either positive or negative, depending on which end of the muscle fiber is experiencing the action potential. Thus, the voltage recorded can be either positive or negative, and changes rapidly.

The function of the action potentials of the sarcolemma is to initiate a complex chemical process that causes the muscle fibers to contract. As muscle fibers contract, they produce force or tension. The measurement of this force is known as **dynamometry** and will be measured with a **dynamometer**.

A single action potential generated at the neuromuscular junction produces a single muscle contraction known as a **muscle twitch**. Since action potentials are an all-or-none event, muscle twitches are also all-or-none. Nonetheless, our muscles are capable of producing **graded contractions** that vary in strength. This graded response is produced in large part by activating varying numbers of muscle fibers. Each muscle fiber is not independently controlled, however. Instead, a single motor neuron innervates several muscle fibers. A group of such muscle fibers that are innervated by a single motor neuron is known as a **motor unit**. An action potential along the motor neuron will produce a simultaneous muscle twitch in all of the fibers belonging to that motor unit. The muscle fibers of a single motor unit are not clustered together, but instead are distributed throughout the muscle. This allows for a uniform contraction of the muscle even if only one or a few motor units are activated.

Muscles can produce contractions of varying strength by varying the number of motor units that are activated (as well the frequency of stimulation). For weak contractions, only a few motor units need to be activated, while for stronger contractions, additional motor units can be activated. The maximum contraction strength occurs when all motor units are activated simultaneously (and repeatedly). The activation of increasing numbers of motor units to produce increasingly stronger contractions is known as **motor unit recruitment**. As each motor unit is activated, its action potentials are recorded by the EMG. Thus, we can measure the relative amount of motor unit recruitment by the overall strength of the measured EMG. In our first experiment, we will examine the relationship between the strength of muscle contractions with motor unit recruitment. Assuming most fibers are of approximately equal strength, we would expect that an increase in muscle force would be reflected in a corresponding increase in the EMG.

The above discussion might imply that a muscle that is fully relaxed would not have any motor units active, and thus produce an EMG reading of zero. That is not the case, however, because even a resting muscle produces a slight amount of tension. This tension, known as **tonus** or **muscle tone**, results from the periodic activation of small numbers of motor units. This process cycles through all of the motor units, a few at a time, and functions to maintain the muscles in a state of readiness. Even at rest we expect a small number of motor units to be active and their activity detectable by the EMG. We will measure this activity to estimate proportion of motor units needed to maintain tonus.

Skeletal muscles are unable to maintain high rates of sustained or repetitive contraction indefinitely; they will eventually **fatigue**, a reduced ability to perform work. There are two kinds of fatigue. **Psychological fatigue** results from reduced input from the central nervous system and usually occurs before the physical capabilities of the muscle are fully depleted. Psychological fatigue functions to protect the muscle from possible damage and contracture (where the muscles are unable to contract or relax due to a lack of ATP). Psychological fatigue can be overcome by high rates of motivation and the hormone epinephrine (adrenaline), which is why people seem to exhibit superhuman strength in life-threatening situations. **Physiological fatigue** results from the depletion of ATP at a rate faster than it can be replenished through respiration as well as a build up of lactic acid (from anaerobic respiration). The effects of physiological fatigue can only be reversed by resting the muscles.

Muscles also fatigue when contracting at less than their maximum strength, but will do so more slowly. When at less than maximum strength, only a proportion of the motor units are active at any one time. These motor units are cycled so that while the same *number* of motor units are being used, some of those motor units are allowed to rest while others are activated to replace them.

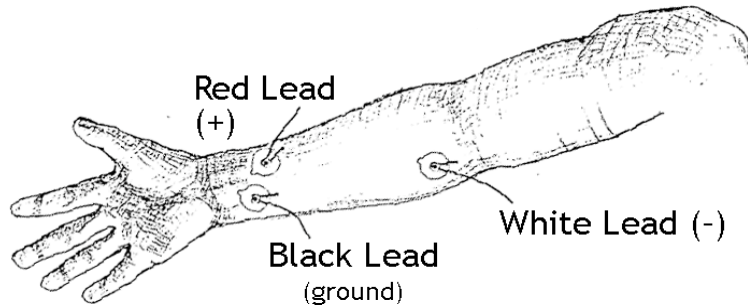
We can use our EMG study to distinguish between physiological and psychological fatigue. In psychological fatigue, the decline in muscle tension is due to reduced stimulation of the muscles, and thus the generation of fewer action potentials. Thus, we would expect that the EMG and muscle tension should both decline at equal rates if fatigue is mostly psychological. In contrast, in physiological fatigue, the muscles are continuously being stimulated by the motor neurons but are less able to produce tension due to the decline in ATP. In such a situation, we would expect the EMG to remain high even as the tension declines.

Biopac Electromyography Exercises — Procedures

GENERAL SET UP PROCEDURES

1. These BIOPAC lessons are to be performed by teams consisting of approximately 4 students. Suggested roles available for these groups members are:
 - Subject (pick the person likely to have the strongest grip; your instructor may provide other criteria)
 - Computer jockey (they will operate the computer)
 - Data recorder (these folks will record the group's data)
 - Coordinator (this person is in overall charge of the group and is responsible for ensuring the group completes their tasks)
2. In the event that the computer and MP30 device are not already on, turn these on (the switch for the MP30 is on the left rear).

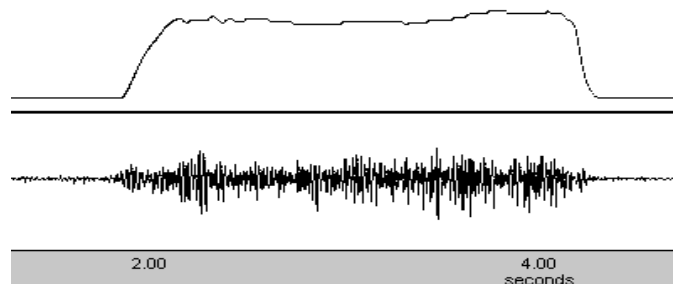
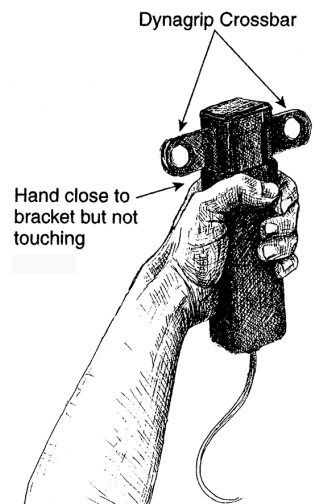
3. If the computers have not been logged into by your instructor, you will need to log in to an account created specifically for use with the machines (it will not work if you log in to your personal account). If necessary, your instructor will provide the login name and password.
4. Place electrodes on the skin of the subject's *dominant* arm as shown in the diagram below, and hook those electrodes up to the MP30 by clipping on the appropriately colored electrical lead wires.



5. Click on the **Biopac Student Lab v.3.6.7** icon on the computer screen.

CALIBRATION

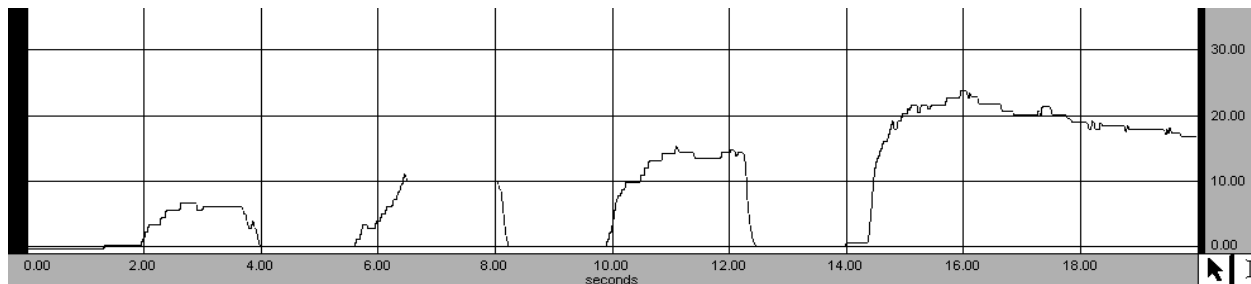
1. From the menu presented on the screen, click on **LO2-EMG-2**.
2. Enter the name of your subject or random letters as the filename.
3. After entering the filename, a calibration screen will pop up.
 - a. Spend a few minutes familiarizing yourself with the procedures listed below before proceeding. If you have questions, ask your lab instructor.
 - b. *Ideally, you should allow 5-minutes to elapse from the time of electrode placement on the skin before you do your calibration or testing.*
4. Once you are ready, click on **CALIBRATE** and follow the instructions on the screen of the computer and as follows:
 - a. Hold the hand dynamometer near the top, but do not touch the upper horizontal bars.
 - b. First, remove pressure from the dynamometer by holding it flat on your open palm.
 - c. As the recording begins (note the blue line moving across the screen), the subject should hold the dynamometer flat in their hand without any pressure on it for 2 sec
 - d. After two seconds, the subject should squeeze the dynamometer as shown above for *as hard as he/she can* for two seconds. The blue (top) and red (bottom) lines should appear similar to the figure below.



- e. Before dismissing the calibration screen, note how high the blue line (force) went, especially if it exceeded about 40 kg. You may wish to have your instructor examine the calibration curve before you dismiss the screen.
- f. If your maximum strength exceeds 40- or 50-kg, you may choose to use 10-kg increments of force rather than 5-kg increments in the following experiments.

EXPERIMENTAL PROCEDURE

1. After successfully completing the calibration, read the directions at the bottom of the computer screen to prepare for the next step.
2. *Read and be familiar with the following directions before proceeding:*
 - a. Begin by holding the dynamometer on your flat palm for 2 sec (note the time indicator at the bottom of the graph on the screen).
 - b. The subject will go through multiple cycles of squeezing the dynamometer and relaxing. As you do so, monitor your clench strength by reading the force (in kg) from the axis at the right of the graph.
 - c. Try to begin your first clench with a force of 5-kg, and hold for 2-seconds and then relax with no pressure on the dynamometer for 2-seconds. (If your strength during the calibration phase was high enough, you may wish to go in 10 kg increments instead of 5; consult your instructor.)
 - d. Next, go up to 10-kg, hold for 2 second and relax for 2-seconds. Then do the same for 15-kg, 20-kg, 25-kg, and so forth until you reach your maximum clench strength.
 - e. When applying your maximum force, **do not release after 2 seconds**, but continue to clench the dynamometer. Note the maximum force you applied, and **continue** clenching the dynamometer until the force you are able to apply drops well below half of your maximum. Your goal is to continue clenching for as long as your strength holds out.
3. Click on **RECORD**, and carry out the instructions above. Recording will begin immediately after you hit **RECORD**, so be ready!
 - a. Remember that *when you reach your maximum strength clench, do not relax after 2 seconds, but instead continue squeezing as long as you can.*
 - b. Your results should look similar to those shown below:



4. When you have finished the above procedures, click on the **SUSPEND** button.
5. We will not be doing both forearms, so click on **STOP**, and then select **YES** when you are asked if you are finished with both forearm recordings.

DATA ANALYSIS

1. Click on **DONE**, and select **ANALYZE CURRENT DATA FILE** from the menu that appears in the window.
2. When the data analysis screen appears, you will see a series of boxes (pairs of one short and one long box) with text along the top of the window, as shown below:



3. Clicking on these boxes will present you with a pop-up menu. You will use these to set the data you want to collect. The actual data will appear to the right of each pair of boxes.

The smaller box on the left of each pair is used to set the channel from which the data come:

Ch 1 represents the raw data from the dynamometer, which measures force. This is represented by the blue line on the graphs.

Ch 3 represents the raw data from the EMG electrodes. This is represented by red line. Note that this line extends above and below zero, depending on the direction of the potential.

Ch 40 represents the integrated EMG, data that have been processed and integrated by the software. This is necessary since a simple average of the raw EMG would produce a value near zero since it extends equally above and below the zero line.

The longer, right box is used to set the specific kind of data you will collect. Although the menu presents a number of options, you will need only the following:

p-p = Peak-to-peak; the distance between the lowest and highest points.


mean = the average value within the selected range of data.

value = the exact value of the datum at the specific cursor location.

delta T = the time span covered by the selected range of data.

4. For the first analysis, these menus should be set as follows, from left to right:

Ch 1 **mean** **Ch 3** **p-p** **Ch 40** **mean** **Ch 1** **value** **Ch 40** **delta-T**

5. Click on the **I-BEAM** icon () in the lower right corner of the screen. Your mouse will now move this I-beam anywhere on the screen.
 - a. Note that for the first analysis of strength, you will only be using the first three sets of data (**Ch 1-mean**, **Ch 3-p-p** and **Ch 40-mean**). The other two data boxes will be used for the analysis of fatigue, below.
 - b. To select a data segment for analysis, place the I-beam at the left edge of the portion of the data you wish to analyze, hold down the left mouse button, and drag the I-beam across to the end of the portion you wish to analyze.
 - c. The selected area will be indicated in black (as shown on the next page). You can drag in either the force (blue), raw EMG (red) or integrated EMG (green) graphs.
 - d. As you drag the I-beam, the data appear in the small windows above the graph (as in the example on the next page).
6. Select a 1-second wide area while you were relaxed, such as to the left of your first contraction. *Do not include any rising or falling portion of the clenches.*
 - a. This measurement will be used to determine the electrical activity produced during **tonus**.
 - b. Record your data on the worksheet (Row 0 of Question 1).

7. Select the first clench by dragging the I-beam from the left portion of the “plateau” to the right end (see example at right); *do not include the rising and falling portions of the clench.*
 - a. Record the data from the first three measurement boxes in the appropriate table on your worksheet.
 - b. Repeat the procedure for the remaining clenches and record those data (Question 1).
 - c. For the last, sustained clench, use only the first 2 seconds.
8. To determine the time to fatigue, scroll over to the part of the graph that contains that data and use the data from the right two measurement boxes (**Ch 1-value** and **Ch 40-delta-T**).
 - a. Move your I-beam to the start of the sustained clench. Drag it to the right while reading the number in the **Ch 1-value** (force) box. Note that **value** gives the magnitude of the data at the exact location of the I-beam cursor.
 - b. Make note of the highest recorded value that appears in that box. Record this value in the first row of Question 2 of the worksheet.
 - c. Divide the above number by 2 to calculate 50% of max clench force (2nd row of Question 2).
 - d. Next, continue dragging the cursor to the right (make sure the selected area is still at the start of the clench). As you drag the cursor, continue to watch the **Ch 1-value** box. When this number drops below the 50% max clench force that you just calculated, stop dragging the cursor.
 - e. Record the data for time to fatigue (from the **delta-T** box) on your worksheet (Question 2).
9. From the fatigue point that you just reached (50% of maximum force), click and scroll to the left to select the last two seconds of the sustained clench. Record the values from the first three measurement boxes in the bottom row (labeled “fatigue”) of Question 1.
10. If you want a print-out of the graph you produced, pull down the **FILE** menu and select **PRINT...** From the submenu, select **PRINT GRAPH.**
 - a. In the dialog box, make sure both custom print options are set to **1**
 - b. Click on the **SETUP** button and select **Landscape.**
 - c. Enter the number of copies to print for the members of your group.
 - d. Click on **OK.**
11. We will put data from the different groups on the blackboard to compare the clench strength, EMGs and time to fatigue of their subjects. Record the data in Question 3 of your worksheet.
12. When finished with the data analysis, pull down the **FILE** menu and select **QUIT.** It is not necessary to save any data.
13. You may now remove the electrodes from your subject. Be sure to throw the electrodes and their coverings in the trash.

