Muscle Physiology and Electromyogram (EMG) Activity

Background

A motor unit is composed of a motor neuron and all of the muscle fibres that are innervated by that motor neuron. In a persistent muscle contraction, like a clench, multiple motor units are firing repetitively throughout the contraction of the muscle. The strength of a muscle contraction is related to the number of motor units in the muscle that are activated during the same time period. The electrical activity in the muscle is caused by the changes in membrane potential that occur during synaptic transmission at the neuromuscular junction, and can be measured using the electromyogram (EMG). The EMG recorded during muscle contraction is seen as a burst of spike-like signals, and the duration of the burst is about equal to the duration of the muscle contraction. The amount of electrical activity in a muscle is best reflected by the integration of the absolute values of the amplitudes of the EMG spikes (i.e., the area under the curve). Normally, it is found that the area under the absolute integral of the EMG is linearly proportional to the strength of the muscle contraction.

In this experiment, students will use a hand dynamometer to measure a subject's grip strength as the EMG forearm muscle activity is recorded. EMG activity will be related to grip strength by plotting the maximum grip strength as a function of the area under the absolute integral of the EMG activity during the muscle contraction. Data recordings will be made from the subject's dominant and non-dominant forearms, and the relative strength and electrical activity of each forearm will be compared to its diameter. Recordings of prolonged grip strength and forearm EMG activity will also be made to determine the rate of fatigue in the dominant and non-dominant forearm.

Equipment Setup

1. The subject should remove all jewellery from their wrists.
2. Use an alcohol swab to clean and scrub three regions on the subject's dominant forearm (the arm used for writing) where the electrodes will be placed: near the wrist, in the middle of the forearm, and lastly about 2 inches from the elbow. Let dry before attaching the electrodes.
3. Attach three color-coded cables to the ground and Channel 1 inputs on the lead pedestal and snap the other ends onto the disposable electrodes, so that:

    a. The red "+1" lead is attached to the electrode near the elbow
    b. The black "-1" lead is attached to the electrode in the middle of the forearm
    c. The green "C" lead (the ground) is attached to the electrode on the wrist.

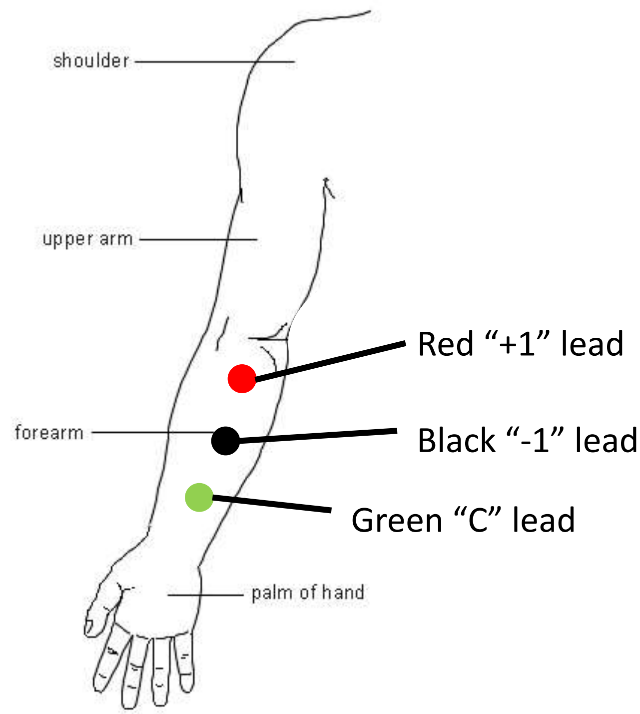

Figure 1: Electrode placement

Start the software

1. Click on the LabScribe2 icon on the Desktop.

Click on the **Settings** menu and select **Human Muscle** >**EMG-GripStrength**

Calibrating the Hand Dynamometer

1. Gather a stack of 5 or 6 textbooks.
2. Weigh yourself, holding the textbooks as well as without them and subtract to find the weight of the stack of textbooks.
3. Lay the hand dynamometer down on the bench top. Click **Record** and record for 10 seconds to obtain a baseline.
4. Continue to record as you place the stack of textbooks on the bulb of the hand dynamometer. You can hold the textbooks for balance, but try to exert as little pressure as possible to keep them upright and fully on the bulb. Once the recording is stable for 10 seconds, click the **Stop** button.
5. Use the **Display Time** (double and half display) icons to adjust the time displayed on the **Main** window. On one screen width, display the recording from the time before and the time after the stack of books was placed on the bulb.
6. Click the **2-cursor** icon on the toolbar. Place a cursor on a section of the baseline recording before the stack of textbooks was placed on the bulb. Place the other cursor on the stable plateau after the textbooks were placed on the bulb.

7. **Right-click** on the data display area of the **Force** (CH3) channel. Select **Units**>**Simple** from the **right-click** menu. Type zero (0) in the box next to the voltage value of the first cursor; enter the weight of the stack of textbooks (in kg) in the box next to the voltage value of the second cursor. Type the unit 'kg' in the **Name** box. Click **OK**.

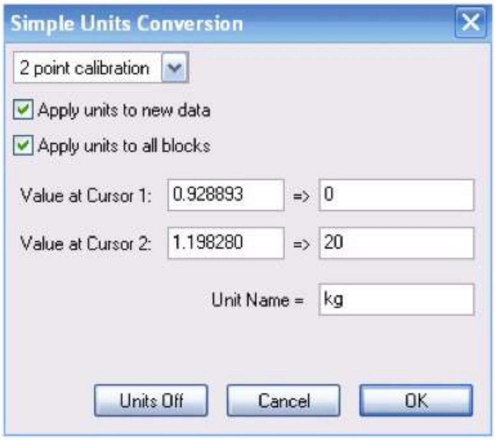

Figure 2: Units conversion box

Exercise 1: EMG Intensity and Force in Dominant Arm

Aim: To determine the relationship between intensity of EMG activity and force of a muscle contraction.

1. The subject should sit quietly with his or her dominant forearm resting on the table top. The subject will clench his or her fist around the hand dynamometer four times, each clench being two seconds long followed by two seconds of relaxation. **Each clench should be stronger than the previous one.**
2. Click the **Start** button to begin recording. Type "Increasing Clenches" in the comment line to the right of the **Marks** button. Press the **Enter** key on the keyboard. The subject should clench the hand dynamometer with progressively stronger force as directed in the previous step. After the final two second relaxation on the last clench cycle, click **Stop**.
3. Click the **AutoScale** buttons for the **EMG** (CH1) and **Force** (CH2) channels. The recording should be similar to Figure 3.

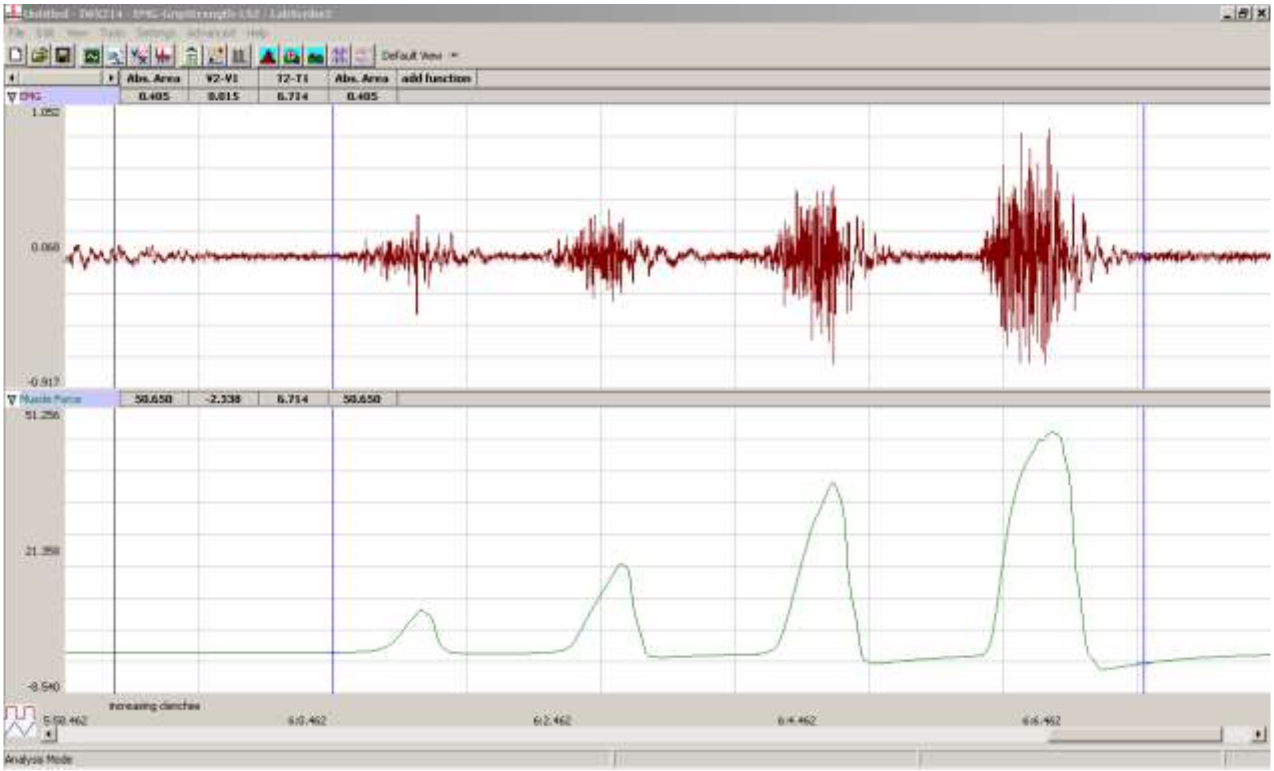

Figure 3: The EMG (upper) and the clenching force (lower) for four progressively stronger clenches.

Data Analysis

1. Adjust the time displayed on the **Main** window to display the subject's four clenches on the screen. Use the **Display Time** icons on the toolbar.
2. Click the **2-cursor** icon on the toolbar. Place the two cursors on either side of the four clenches cycles displayed in the **Main** window. Click the **Analysis** icon on the toolbar to view the data in the **Analysis** window.
3. Select Add function > Integral (area)> Abs.Area from the bar above the EMG trace (CH1). **You must be in the analysis window to perform this step.**
4. Place the two cursors on the **Analysis** window at either end of the maximum force plateau **for the first clench** on the **Force** channel (CH3). Record the value for the **Absolute Area** for both force (kg) as well as EMG (mv).
5. Move the cursors on the **Analysis** window to either end of the force plateau for the second, third and fourth fist clenches sequentially and repeat Step 4, recording all of your data.

Exercise 2: EMG Intensity and Fatigue in Dominant Arm

Aim: To observe the relationship between the length and strength of a muscle contraction and EMG activity in the dominant forearm.

1. The subject should sit quietly with his or her dominant forearm on the table top. The subject will clench the hand dynamometer as tight and as long as possible in an attempt to fatigue the muscles of the forearm. When the subject's clench force falls **below 50%** of the maximum clench force, the recording can be halted. **Pay attention at the beginning of the experiment to be sure that you determine the maximum grip strength.**
2. Click **Record**. Record a baseline for a few seconds, after which the subject should clench the hand dynamometer with maximum force. **AutoScale** both channels if required. Continue to record the fatigue of the subjects forearm until the force of the muscle contraction drops below 50% of the maximum; at that time, click the **Stop** button. The recording should be similar to Figure 4.
3. Use a tailor's tape measure to determine the circumference of the widest part of the subject's dominant forearm. Record your findings.

Data Analysis

1. Adjust the screen time of the **Main** window to display the complete record of this experiment on the same screen.
2. Click the **2-cursor** icon. Place the cursor on the relaxation period that directly precedes the beginning of the clench. Place the second cursor at the point when the subject's clench force had fallen to 50% of the maximum clench force. Record the duration (T2-T1) between these two points as an index of the time to fatigue in the dominant arm.
3. The difference in amplitude (**V2-V1**), between relaxation and the highest part of the clench trace is the maximum clench force of the subject, which should also be recorded. Manipulate the cursors to calculate this value.
4. Divide the maximum clench force by 2. Record this value as the half-maximum clench force.

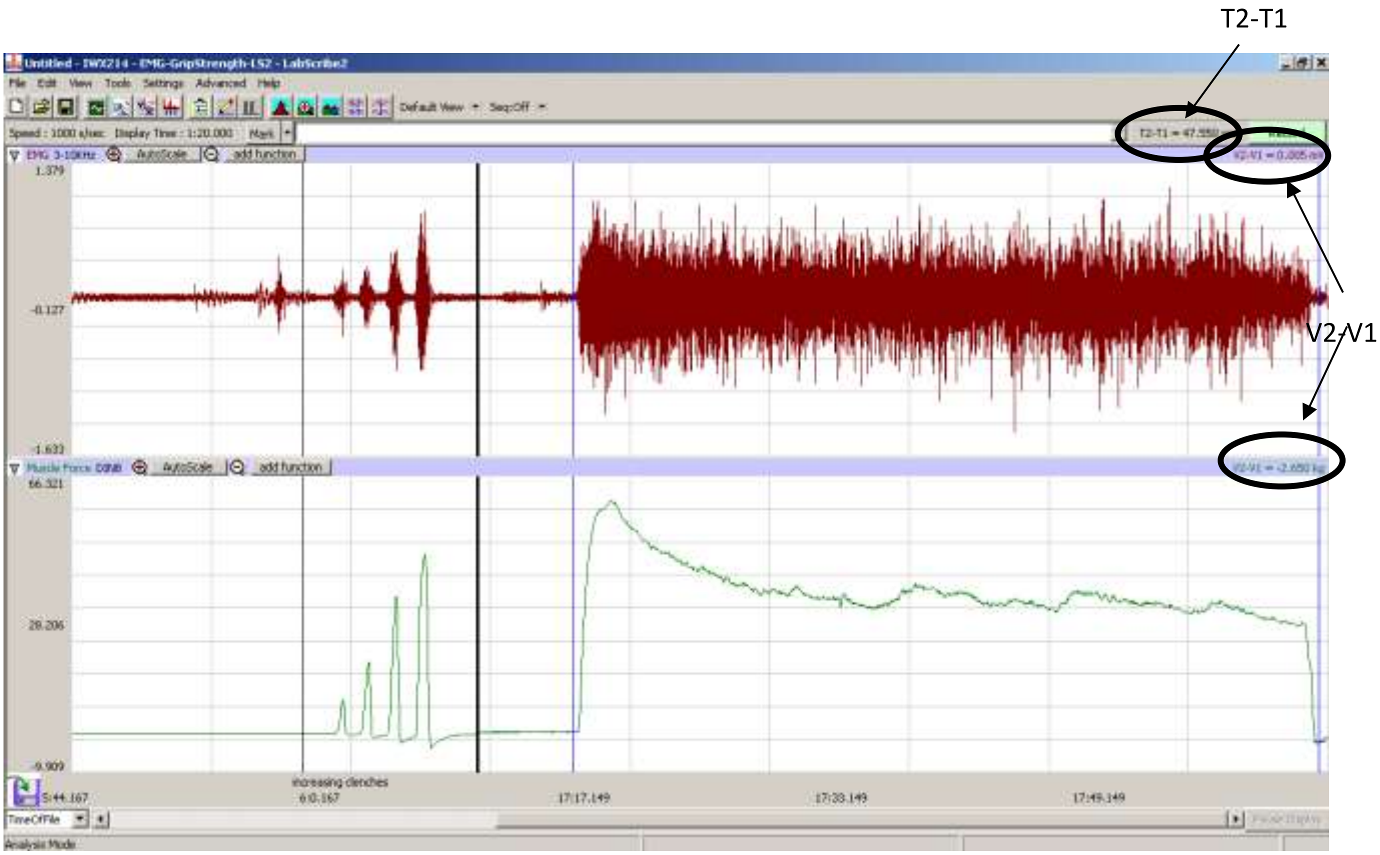

Figure 4: The EMG (upper) and clench force (lower) during a prolonged muscle contraction. The cursors are placed to measure the time needed to lose 50% of the maximum clench strength

Exercise 3: EMG Intensity and Force in the Non-Dominant Arm

Aim: To determine the relationship between the intensity of EMG activity and the force of a muscle contraction in the subject's non-dominant forearm.

Procedure

Follow the same directions used in Exercise 1 for the subject's non-dominant forearm.

Data Analysis

Analyze and record the data from the subject's non-dominant forearm as was done in Exercise 1.

Exercise 4: EMG Intensity and Fatigue in Non-Dominant Arm

Aim: To observe the relationship between the length and strength of a muscle contraction and EMG activity in the non-dominant forearm.

Procedure

Follow the same directions used in Exercise 2 to record fatigue data from the subject's non-dominant forearm.

Data Analysis

Analyze and record the fatigue data from the subject's non-dominant forearm as was done in Exercise 2.

Save your Exercise 4 data as an iWorx file on the desktop before you proceed on to Exercise 5. You will need this data when you complete your report.

Exercise 5: EMGs in Antagonistic Muscles

Integration of Motor Activity

Aim: To study EMG activity in antagonistic muscles during normal movement.

Procedure

1. Place recording electrodes on the left biceps and triceps muscles as shown in Figure 5.
2. Go to the Settings menu, select **EMG-Antagonistic-Muscles**. LabScribe2 will be configured to record EMGs from the biceps and the triceps on Channels 1 and 2.
3. Instruct the subject to sit on a chair and support his/her left elbow with his/her right hand.
4. Attach the lead wires to all five electrodes:
    - the red "+1" lead is attached to the electrode just below the shoulder
    - the black "-1" lead is attached to the electrode in the middle of the biceps
    - the green "C" lead is attached to the electrode just above the elbow
    - the white "+2" lead is placed on the upper portion of the triceps
    - the brown "-2" lead is placed in the middle of the triceps

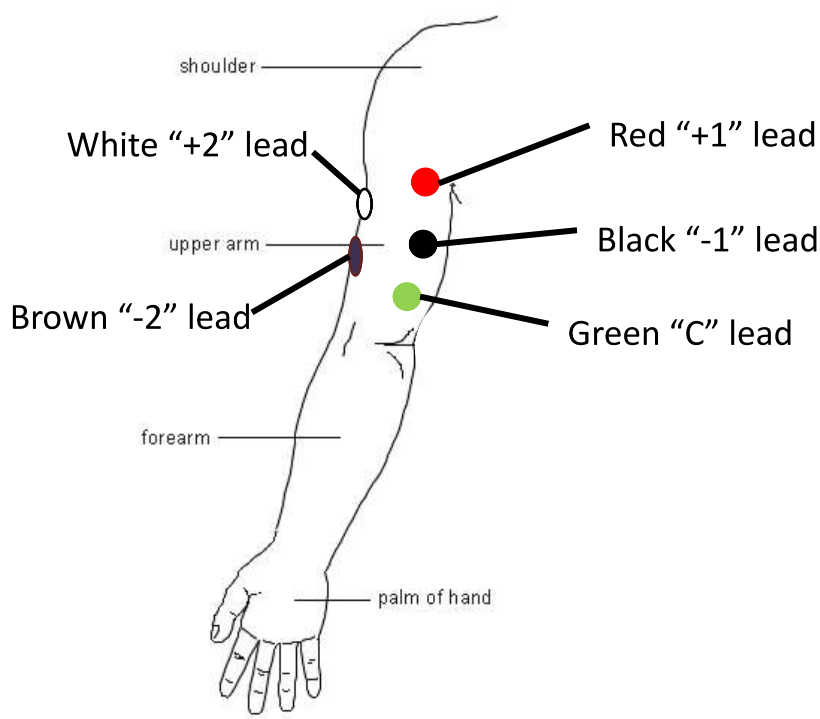

Figure 5: Electrode placement to measure EMGs in antagonistic muscles.

5. Click **Start** to begin recording. Type “No Weight” in the comment line to the right of the **Mark** button, and press **Enter**.
6. Instruct the subject to start with his/her arm at the side and bend the arm to his/her chest, pause for three seconds, then extend the arm slowly back to the starting position. The motion being performed is similar to a bicep curl, with a pause when the hand is closest to the shoulder. Type “Bend” and press **Enter** every time the arm is bent. The partner controlling the recording should prompt the subject to bend the arm. You should record 5-6 bend and extend “cycles”. See Figures 6 and 7 below.
7. Click **Stop** to halt recording.
8. Repeat the experiment, lifting a reasonable heavy weight like a book bag or a text book used earlier in the lab.
9. Click **Start**. Type “Weight” on the comment line and press **Enter** to annotate the record.
10. Repeat step #6.
11. Click **Stop** to halt recording.
12. Extend the arm to **eye** level and redo steps **5-7**.
13. Attempt steps 5-7 with either more or less weight.

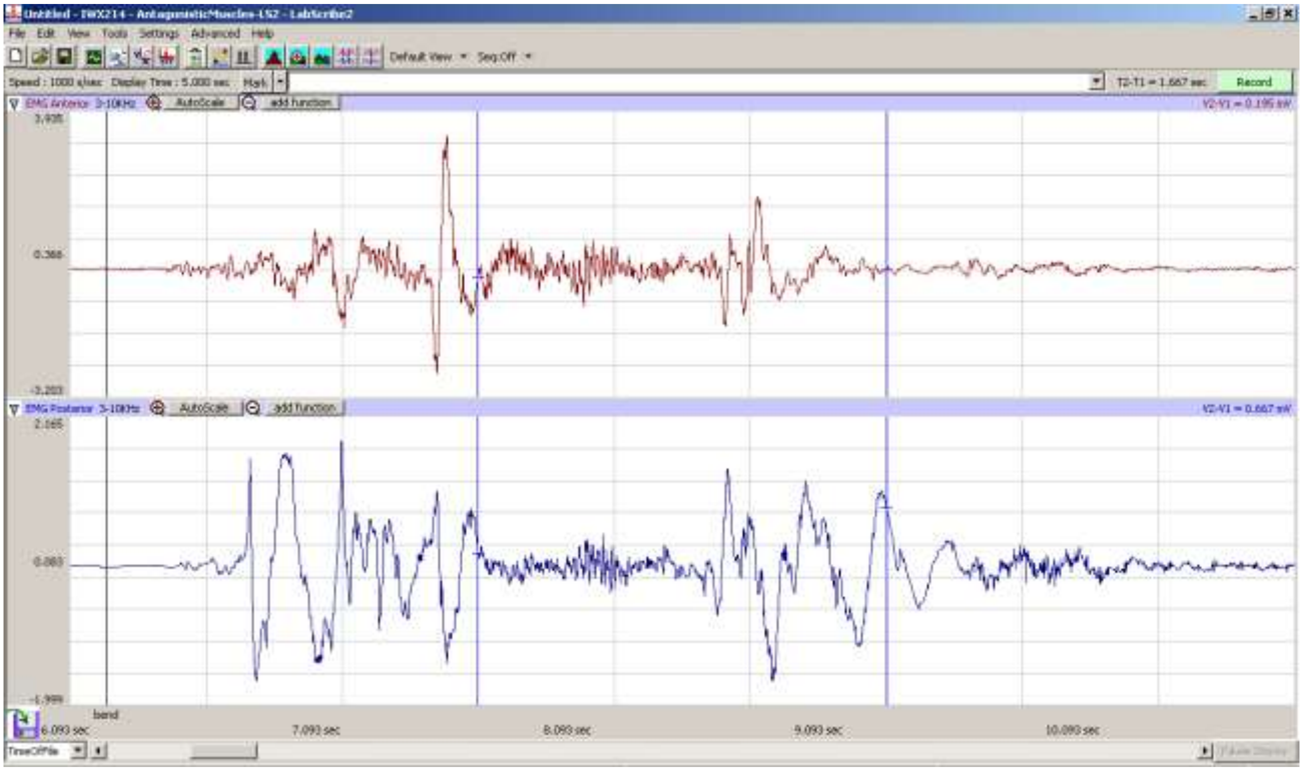

Figure 6: EMG during arm bending.

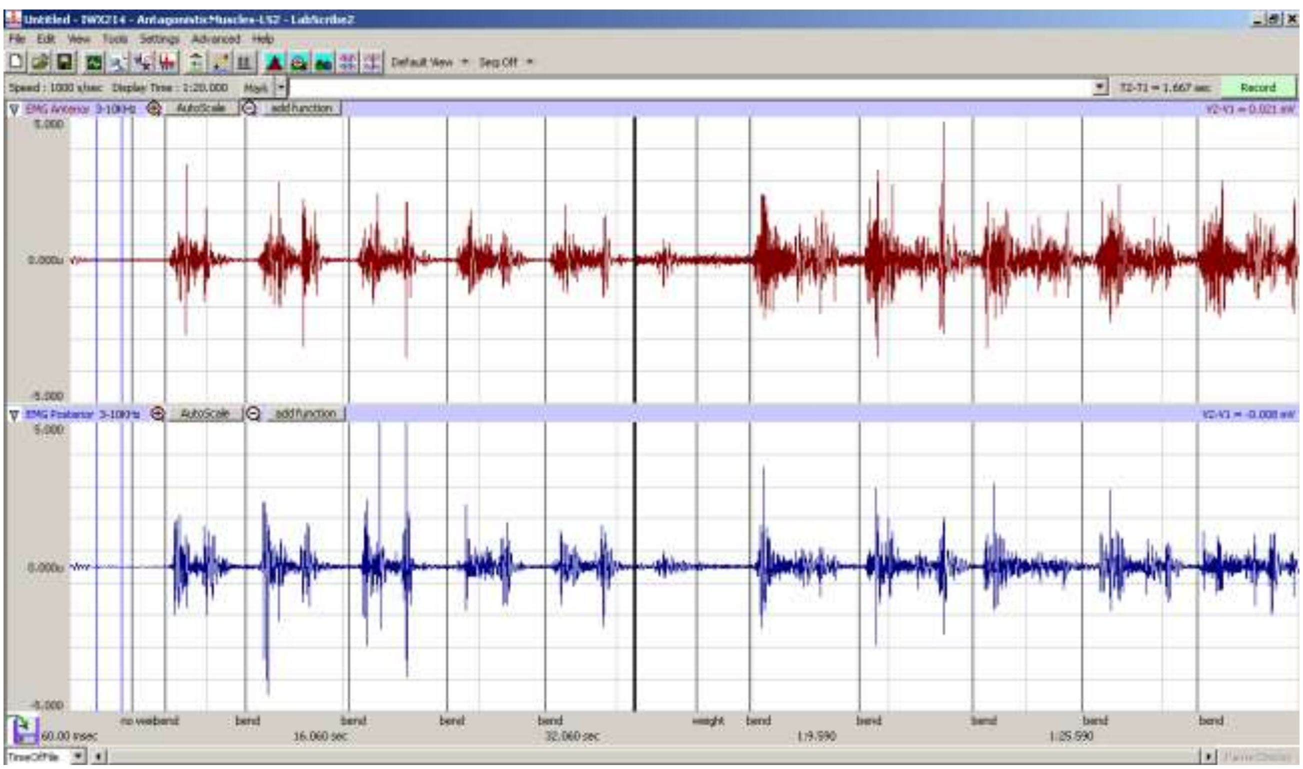

Figure 7: EMG during arm bending

Lab Report

The following questions/issues should be addressed in your lab report.

1. Plot the force of the muscle clenches as a function of the areas under the EMG trace for each muscle clench, and briefly describe your results (i.e., as in a Results section).

2. Discuss your findings, as in a Discussion section, by answering the questions below. Be sure to take into account the muscle physiology that underlies your observations.
   a) Is there a linear relationship between the area under the EMG trace for each clench and the force of the clench (indicated by total area under clench)?
   b) How does the amplitude and duration of the EMG signal and of muscle contraction relate to the number of motor units recruited, and to the number of times each unit is stimulated?
   c) Does the type of muscle fibre recruited change with contraction force?
   d) Does the stronger forearm have a different relationship than the weaker forearm between grip strength and EMG signal? Why or why not?
   e) How are forearm strength and/or endurance related to forearm circumference?
   f) When there is a difference in the circumference of the forearms, is it likely caused by a difference in the total number of muscle fibres in the forearm or in the diameter of each muscle fibre?
   g) Why are antagonistic muscles recruited during the bicep curl?
   h) How do the patterns of muscle shortening and lengthening during the bicep curl relate qualitatively to the EMG signals in each muscle?