Experiment 16: Grip Strength and EMG Activity in the Forearm

Background

A motor unit is composed of a motorneuron and all the muscle fibers that are innervated by that motorneuron. 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 electromyogram (EMG) recorded during the 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 strength of a striated muscle contraction is directly proportional to the amount of electrical activity in the muscle. However, it is difficult to quantify the amount of electrical activity in a muscle unless the raw EMG data is mathematically transformed. One of the most common transformations used is the integration of the absolute values of the amplitudes of the EMG spikes. Through this transformation, it has been found that the area under the graph of 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 activity of the forearm muscles used to generate the subject's grip are recorded. The EMG activity will be related to the grip strength by plotting the maximum grip strength as a function 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 forearms.

Equipment Required

PC Computer
iWorx unit, and USB or serial cable
AAMI cable and five EMG leads
Hand Dynamometer
Alcohol swabs
5 or 6 textbooks
Bathroom scale

Equipment Setup

1. Connect the iWorx unit to the computer (described in Chapter 1).
2. Attach the AAMI connector on one end of the cable to the isolated Channel 1 and 2 inputs on the iWorx unit.
3. Connect the hand dynamometer to the input of Channel 3 on the iWorx unit.
4. The subject should remove all jewelry from their wrists. For the first exercises in this lab, record EMG's and clench forces from the subject's dominant arm, the arm used most often.
5. Use an alcohol swab to clean and scrub three regions on the subject's dominant forearm where the electrodes will be placed (Figure 3-1 on page 2). One area is near the wrist, the second is in the middle of the forearm, and the third area is about 2 inches from the elbow. Let the areas dry before attaching the electrodes.
6. Remove the plastic disk from a disposable electrode and apply it to one of the scrubbed areas. Repeat for the other two areas.
7. Attach three color-coded electrode cables to the ground and Channel 1 inputs on the lead pedestal and snap the other ends onto the disposable electrodes, so that:

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

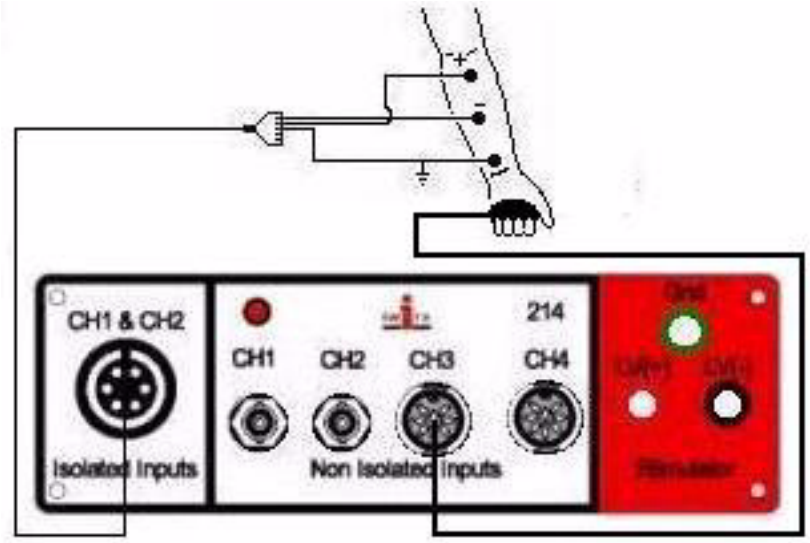

Figure 3-1: The equipment used to monitor EMGs from a volunteer.

Start the Software

1. Click the Windows **Start** menu, move the cursor to **Programs** and then to the **iWorx** folder and select **LabScribe**; or click on the LabScribe icon on the Desktop
2. When the program opens, select **Load Group** from the **Settings** menu.
3. When the dialog box appears, select **AddedLabs.iws**. Click **Load**.
4. Click on the **Settings** menu again and select the **EMGMuscleStrength** settings file.
5. After a short time, LabScribe will appear on the computer screen as configured by the **EMGMuscleStrength** settings.

Calibrating the Hand Dynamometer

1. Gather a stack of 5 or 6 textbooks.
2. Lay the hand dynamometer down on the bench top. Click the **Start** button on the LabScribe **Main** window and record for 10 seconds.
3. Continue to record as you place the stack of text books on the bulb of the hand dynamometer. Once the recording is stabile for 10 seconds, click the **Stop** button.
4. Weight the stack of books on a scale.
5. Use the **Display Time** icons to adjust the time displayed on the **Main** window. On one screen width, display the recording from the time before and to 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 the section of the recording before the stack of textbooks was placed on the bulb. Place the other cursor on the section after the textbooks were placed on the bulb.
7. Right-click on the data display area of the **Force** (CH3) channel. Select **Units** from the **right-click** menu. Type zero (0) in the box next to the voltage value of the first cursor; type 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 the **OK** button.

Exercise 1: EMG Intensity and Force

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

Procedure

1. The subject should sit quietly with his or her dominant forearm resting on the table top. Explain the procedure to the subject. The subject will clench his or her fist around the hand dynamometer four times, each clench is 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 by the procedure outlined in the previous step. After the last two second relaxation of the last clench cycle, click the **Stop** button.

3 Click the **AutoScale** buttons for the **EMG** (CH 1), **EMG Integral** (CH 2), and **Force** (CH3) channels. The recording should be similar to Figure 3-2 on page 4.

4 Select **Save As** in the **File** menu, type a name for the file. Choose a destination on the computer in which to save the file(e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

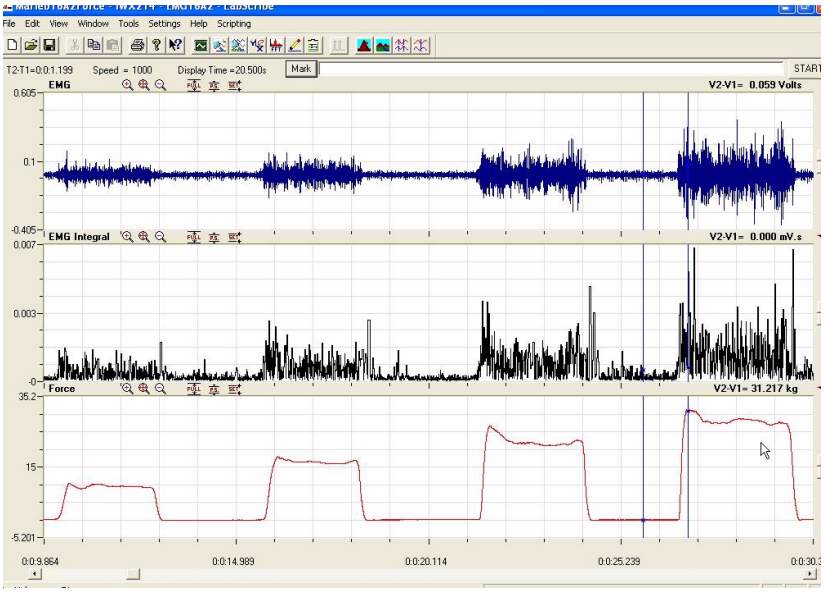

Figure 3-2: The EMG (upper), EMG absolute integral (middle), and clenching force (lower) for four progressively stronger clenches displayed in the Main window.

Data Analysis

1 Adjust the time displayed on the **Main** window to display the subject’s four clenches on the screen (Figure 3-2 on page 4). Use the **Display Time** icons on the LabScribe toolbar (Figure 3-3 on page 5), or the **Display Time** box on the **Channels** page of the **Preferences** dialogue window on the **Edit** menu, to set the proper screen width. exceed the total number of points in the data block. Click **OK**.

2 Click the **2-cursor** icon on the toolbar. Place the two cursors on either side of the four clench cycles displayed in the **Main** window. Click the **Analysis** icon on the toolbar to send the data to the **Analysis** window.

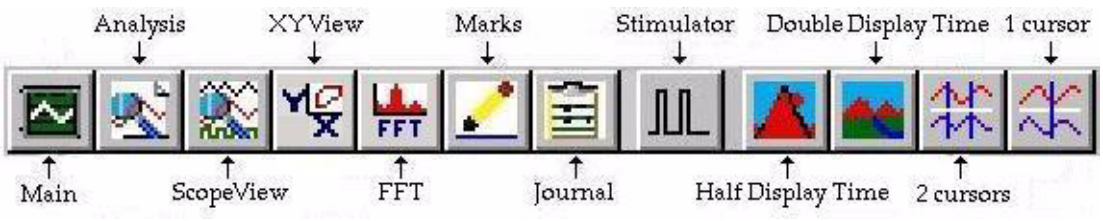

Figure 3-3: The LabScribe toolbar.

3 Select **EMG** and **EMG Integral** from the **Display Channels** menu, **EMG Integral** on the **Value from Ch** pull-down menu, and **Title** and **Area** from the **Table Functions** menu. Place the two cursors on the **Analysis** window on either edge of the first raw EMG cluster (Figure 3-4 on page 5). Record the value for **Area** in the **Journal**. Do not move the cursors from their positions around the first EMG cluster.

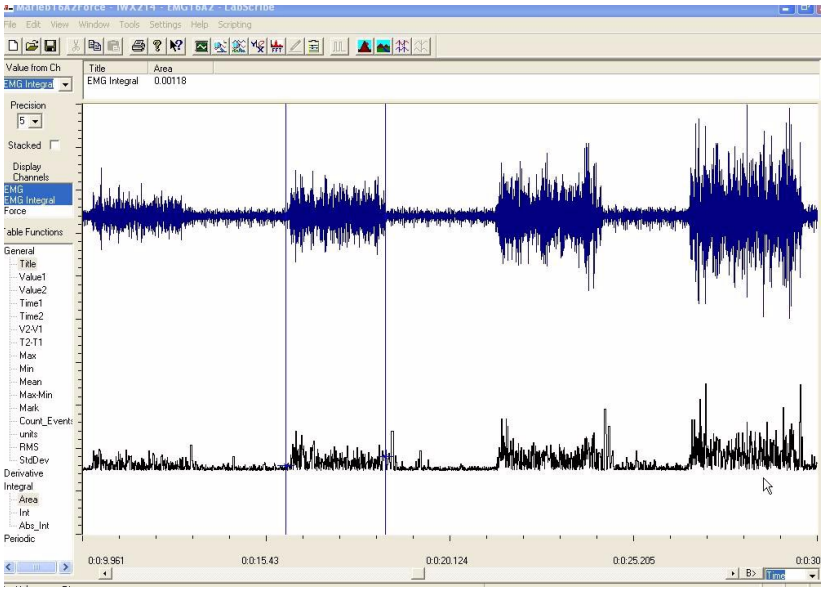

Figure 3-4: The EMG and EMG absolute integral displayed in the Analysis window. The cursors are placed on the margins of the second cluster of EMG signals. The area of the EMG Integral is taken from the region between the cursors on the second channel.

4 Data can be entered into the **Journal** by either typing the titles and values directly or by using the **right-click** menu. Place the cursors to take measurements; then, select **Add Title to Journal** or **Add Data to Journal** from the right click menu to add the measurements to the **Journal.**

5 Control-click on **Force** in the **Display Channels** menu to add this channel to the display on the **Analysis** window. Select **Force** on the **Value from Ch** pull-down menu, and **Title** and **Mean** from the **Table Functions** menu. Place the two cursors on the **Analysis** window at either end of the maximum force plateau on the **Force** channel (CH3) as indicated in Figure 3-5 on page 6. Record the value for the **Mean** in the **Journal**.

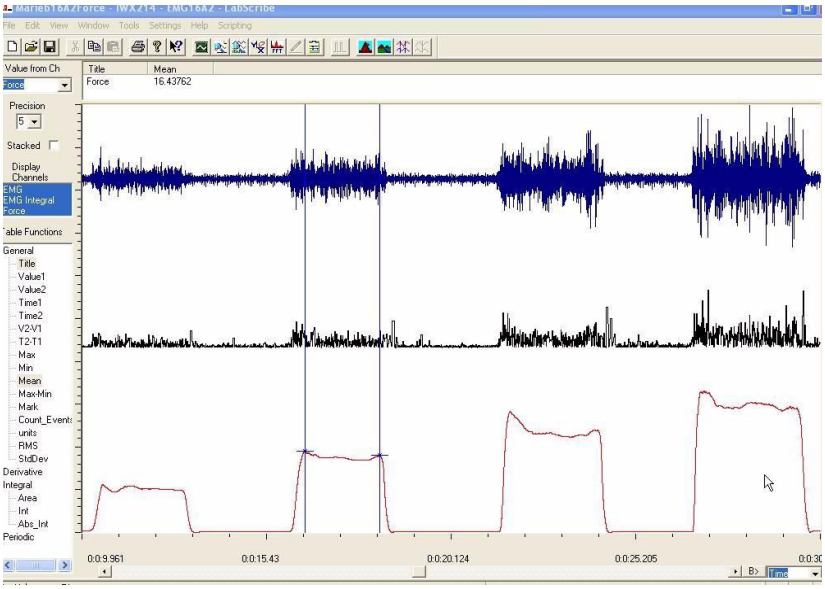

Figure 3-5: Recording of the EMG, EMG absolute integral, and clench force displayed in the Analysis window. The cursors are placed on the Force channel so that the average amplitude on the plateau can be measured.

6 Move the cursors on the **Analysis** window to either end of the force plateau for the second fist clench and repeat Steps 3, 4, and 5

7 Repeat Steps 3, 4, 5, and 6 for the two other fist clenches in the set.

Questions

1 Plot the force of the muscle clenches as a function of the areas under the EMG absolute integral for each muscle clench.

2 Is there a linear relationship between the area under EMG absolute integral for each clench and the force of the clench?

3 Do muscle fibers have a refractory period like nerve fibers?

4 Does the amplitude of the EMG signal and the force of contraction increase because a finite number of fibers are firing more often, or because more fibers are recruited to fire as the intensity of signals in the motorneurons increases, or a combination of these two?

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.

Procedure

1. The subject should sit quietly with his or her dominant forearm on the table top. Explain the procedure to the subject. 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.
2. Click the **Start** button on the LabScribe **Main** window to begin recording. record a baseline for a few seconds, then the subject should clench the hand dynamometer with maximum force. Click the **AutoScale** buttons on all three recording channels. Continue to record the fatigue of the subject's forearm until the force of the muscle contraction drops below 50% of the maximum; at that time, click the **Stop** button.
3. Use a tailor's tape measure to determine the circumference of the widest part of the subject's dominant forearm. Record your findings in the **Journal**.
4. Select **Save** in the **File** menu.

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 on the LabScribe toolbar (Figure 3-3 on page 5). Place one cursor on the relaxation period that precedes the fatigue exercise. Place the second cursor to the right of the point when the subject released the bulb of the hand dynamometer. Click the **Analysis** icon on the toolbar to send the data to the **Analysis** window (Figure 3-6 on page 8).
3. Select **Force** from the **Display Channels** menu, and **Title**, **V2-V1**, and **T2-T1** from the **Table Functions** menu. Place one cursor on the relaxation period before the maximum contraction and the second cursor on the peak of the muscle contraction. The difference in amplitude (**V2-V1**) is the maximum clench force of the subject, which should be recorded in the **Journal**.
4. Data can be entered into the **Journal** by either typing the titles and values directly or by using the **right-click** menu. Place the cursors to take measurements; then, select **Add Title to Journal** or **Add Data to Journal** from the right click menu to add the measurements to the **Journal.**
5. Divide the maximum clench force by 2. Enter this value in the **Journal** as the half-maximum clench force.

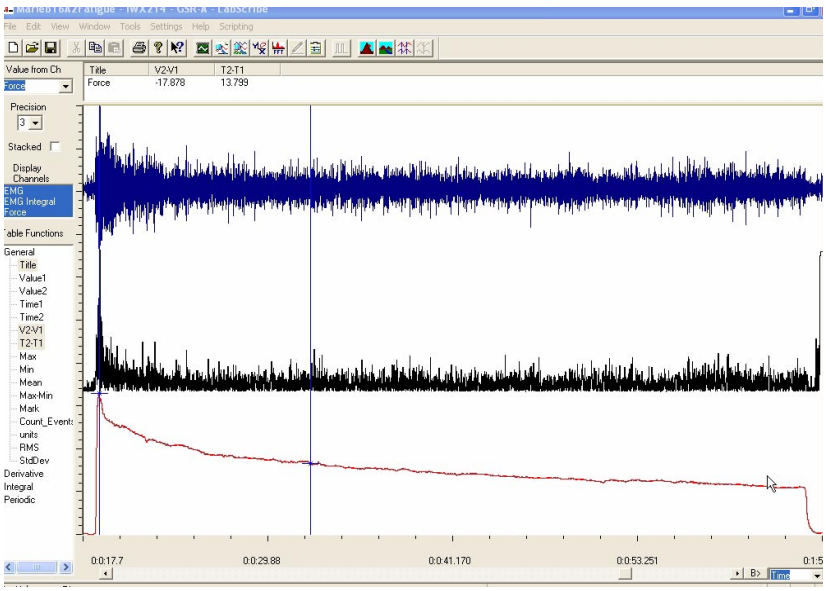

Figure 3-6: The EMG (upper), EMG absolute integral (middle), and clench force (lower) during a prolonged muscle contraction as displayed in the Analysis window. The cursors are placed to measure the time needed to lose 50% of his maximum clench strength.

6 Determine the time it takes the subject's forearm to fatigue to half its strength.

- Put one cursor on the peak of the muscle contraction.
- Move the other cursor to the right of the peak until the value for **V2-V1** in the table at the top of the **Analysis** window is equal to the half-maximum clench force.
- The value for **T2-T1** when the cursors are in these two positions is the time it takes the subject's forearm muscles to fatigue to half of their strength. Enter this value in the **Journal** as the time to the half-maximum clench force.

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 to record data from the subject's non-dominant forearm.

Data Analysis

Analyze the data from the subject's non-dominant forearm as it was done in Exercise 1. Use the information from Exercises 1 and 3 to answer the following questions.

Questions

1. Is one of the subject's forearms stronger than the other? Use the maximum grip strength from each arm to determine this answer. Calculate the percent difference in maximum grip strength from each arm.
2. Does the stronger forearm have a higher ratio of average maximum grip strength to area of the EMG absolute integral than the weaker forearm? Use the slopes of the force-EMG activity graphs for each forearm to determine this answer. Calculate the percent difference in the slope of the force-EMG activity graph from each arm.

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 the fatigue data from the subject's non-dominant forearm as it was done in Exercise 2. Use the information from Exercises 2 and 4 to answer the following questions.

Questions

1. Is there a difference in the maximum forces generated by the dominant and the non dominant forearms? Calculate the percent difference between the forces.
2. Is there a difference between the circumference of the dominant and non-dominant forearms? Calculate the percent difference between the circumferences.
3. Is there a relationship between the circumference of the forearm and the maximum force developed? If there is, what is it?
4. If there is a difference in the circumference of the forearms is it caused by a difference in the number of muscle fibers in the forearm or the diameter of each muscle fiber in the forearm? Explain.
5. How does the time to fatigue to half-strength in the dominant forearm compare to the same parameter for the non-dominant forearm?