Lab #6: Electromyography (EMG)

Read from Eckert ch. 10 (readings): Mechanics of Muscle Contraction 375-379, Active State, Twitch and Tetanus 391- 392, Motor Control vertebrate 410 - 411

Introduction

We will explore the electrical activity of skeletal muscle in relation to the generation of force and movement. In this experiment you will record electromyograms in human subjects during voluntary muscle action. We will explore various properties of motor control and the activity of opposing muscle groups.

Background

Each skeletal muscle fiber is innervated by a branch of a motor axon or neuron. Each motor neuron innervates many muscle fibers. The motor neuron and all of the fibers it innervates is called a "motor unit". All of the motor neurons that innervate a single muscle is called a "motor pool".

When an action potential travels down a motor neuron, the action potential typically activates all of the muscle fibers it innervates, resulting in contraction of all the muscle fibers in the motor unit. During a contraction, therefore, there is synchronous activity in a number of fibers in the same muscle. The electrical signal recorded from a contracting muscle is called an electromyogram or EMG. Like the electrocardiogram (ECG), this activity can be detected by electrodes placed on the skin. A voluntary muscle contraction is produced by one or more action potentials in many fibers. Activation or "recruitment" of greater numbers of motor units result in greater numbers of fibers contracting and therefore greater muscle force. Another way to increase force output is to increase the frequency of firing. A single muscle contraction is transitory and called a "twitch" but a train of action potentials will result in a fused "tetanus" and sustained contraction. In either case, the EMG activity is not a regular series of waves like the ECG, but a chaotic burst of overlapping spike-like signals. *Why do you think this is the case?*

In this experiment, you will record EMG activity during voluntary contractions of skeletal muscle groups, focusing on the biceps and triceps muscles of the arm, which are antagonistic muscles that control movement at the elbow. The raw EMG signal during voluntary contractions may be processed in various ways to indicate the intensity of EMG activity. In the method used here, the negative portions of the EMG are inverted, and then the whole signal is integrated in such a way as to smooth out individual spikes, and make the time course of changing activity much clearer.

Set up

- PowerLab with Bio Amp and cable
- 4 EMG recording electrodes and dry earth strap
- electrode cream
- alcohol swabs (if needed; 70% ethanol on cotton wool or paper tissue)
- ballpoint pen
- masking tape
- weights (books)

Subject preparation

1. Have the subject remove all jewelry or metal objects in contact with their skin. Visually inspect all of the cup electrodes and make sure that the cups are clean and bare for a good electrical signal. If necessary, clean them gently (they are fragile) - ask your TA for help.

2. Plug the lead of the dry earth strap into the Earth connection of the Bio Amp cable. Firmly attach the dry earth strap (electrode) around the palm or wrist of the volunteer. Ensure that the fuzzy side of the dry earth strap is in full contact with the skin.

3. Use firmly swab the skin with alcohol where electrodes will be placed (Figure 1).

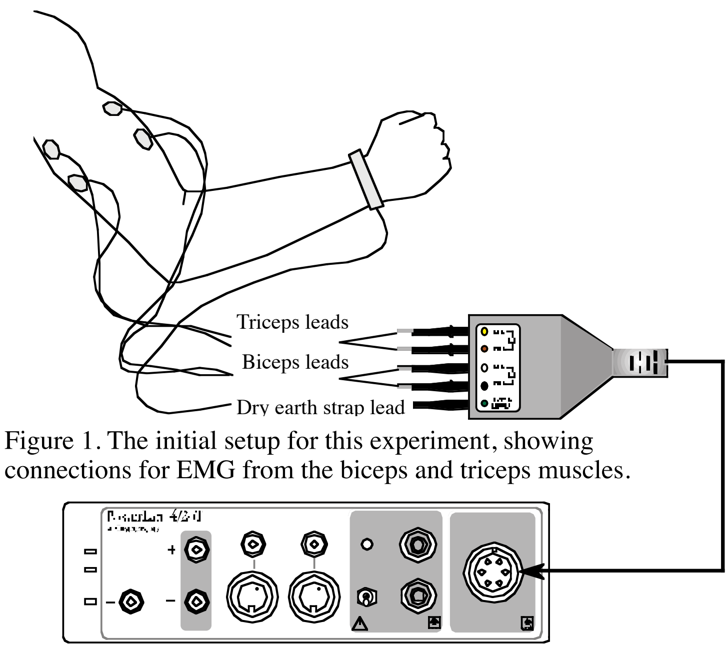

Figure 1. The initial setup for this experiment, showing connections for EMG from the biceps and triceps muscles.

4.With a ballpoint pen, mark two small crosses where the electrodes will be placed on the biceps muscle (Figure 1). The crosses should be 2–5 cm apart and aligned with the long axis of the arm (along the length of the muscle). Do the same for the triceps muscle.

5.Fill each disk electrode with electrode cream. Place the electrodes onto the skin over the crosses, and fasten them firmly in place with masking tape.

6.Plug the leads of the EMG recording electrodes into the Bio Amp cable, as shown in Figure 1. Polarity doesn't matter for EMG, but do make sure that the two leads (+ & -) for each channel are attached to the same muscle.

7. Check that all electrodes are properly connected before proceeding.

Starting the software

1. Start Chart using the EMG lab settings file. Three channels should appear: the push button (to mark events on the experiment), the raw EMG signal, and the absolute integrals of the raw EMG.

2. Make sure that the raw EMG channel is set to the "Bioamp", and that the computed input (integral of the EMG) is reading the channel for the raw EMG channel. To do this, under the "Setup" menu choose "setup channels" and check that the input is "Bioamp" (and not "Input Amplifier"). You may have to change the inputs to match the correct channel number. If you are using the new setup, you may have to change and restart Chart (several times) with the Bioamp cable connected for it to appear in the menu. If you are using the old setup, the little green light on the front of the Bioamp should be on. In either case, the channel setup window should indicate "Bioamp". Ask your TA for help if needed.

Exercise 1: Activation with increasing demand

Objectives To explore voluntary muscle contractions with increasing demand, and how activation of motor neurons changes to meet demand. (Think about what is happening physiologically).

Procedure

1. The volunteer should sit in a relaxed position, with elbow bent to 90° with the palm facing upwards. He or she should use the other hand to grasp the wrist of the recorded arm.

2. Choose the Bio Amplifier… command from the raw EMG Channel pop-up menu and make sure the range is set to 2mV, High Pass to 10Hz, and Low Pass to 200Hz.

3. Ask the volunteer to make a strong contraction of their muscle. For biceps muscle, a strong contraction can be generated by trying to bend the recorded arm further and resisting this movement with his or her other arm. (For triceps muscle, a strong contraction can be produced by trying to straighten out the recorded arm and resisting this movement with his or her other arm.) Observe the signal (Figure 2).

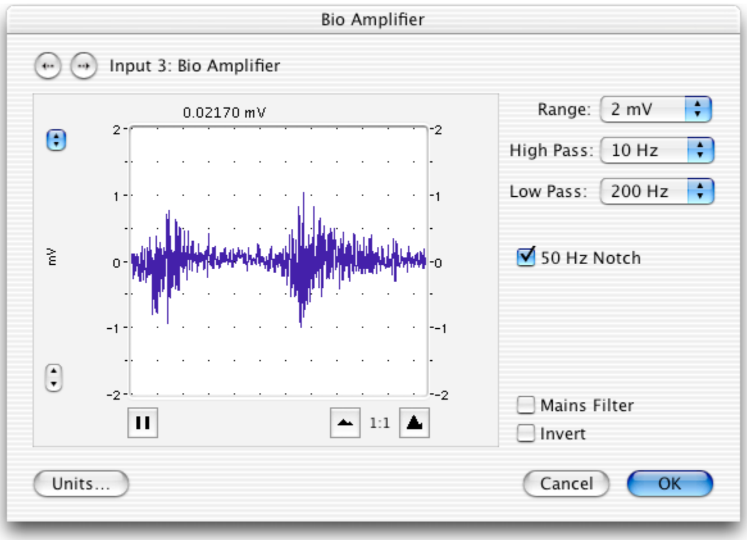

Figure 2. Strong muscle contractions shown in BioAmp box.

4. Adjust the value in the Range pop-up menu of the Bio Amplifier dialog box so that the maximal electrical response occupies about a half to two thirds of full scale.

5. Start recording. The volunteer should perform a maximum contraction of the muscles with the EMG electrodes attached. Stop recording, and check that the integrated signal traces are clearly visible in the Chart window and look something like Figure 3. If not, use the Amplitude Axis controls in their channels to adjust the vertical scale so that they are visible.

6. The volunteer should once more sit in a relaxed position, with his or her elbow unsupported and bent to 90° with the palm facing upwards.

7. Resume recording. After a few seconds, place one weight (a book) on the hand of the subject. Leave it on for two to three seconds to record the change in the EMG, then remove the weight. Repeat this process for two, then three, then four books, for a series of increasing weights. Stop recording.

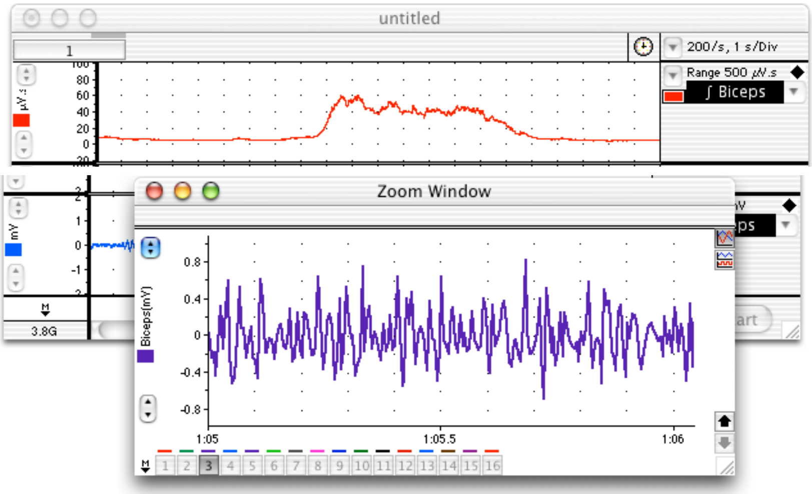

Figure 3. Burst of EMG activity in biceps muscle while supporting a weight: Channel 1 (∫Biceps) is the integrated signal; the Zoom window shows part of the raw EMG activity in the biceps muscle.

Analysis

1. Scroll through the recorded data and note the changes in activity in the raw biceps channel (Biceps). Note also that placing weights on the hand gives rise to little or no activity in the triceps muscle. Select a small part of the 'Biceps' activity and examine it in the Zoom window. The raw EMG signal is composed of many up and down spikes.

2. Note the relationship between the raw trace (Biceps) and integrated trace (∫Biceps). The height of the integrated trace reflects the overall activity of the raw EMG signal, and gives a simpler view of the muscle's electrical activity.

3. Note the changes in the integrated trace as weights were added and removed. The height of the trace correlates with the electrical activity produced to activate the muscle.

Exercise 2: Alternating activity and coactivation

Objectives

To examine the activity of antagonist muscles and the phenomenon of coactivation.

Procedure

1. Use the following settings: sampling rate = 200 m/s, digital filter (low pass) = 100Hz. Connect the push button switch to one of the channels on the PowerLab to record the start and end of each muscle flexion.

2. The volunteer should sit in a relaxed position, with his or her elbow bent to 90° with the palm facing upwards. He or she should use the other hand to grasp the wrist of the recorded arm.

3. Ask the volunteer to activate the biceps and triceps alternately. The biceps muscle can be activated by trying to bend the recorded arm further and resisting this movement with the other arm. The triceps muscle can be activated by trying to straighten out the recorded arm and resisting this movement with the other arm. The volunteer should practice this alternating pattern until it feels like both muscles are being equally activated in turn. Use

the pushbutton switch to mark the start and end of each muscle flexion. This will be important for comparing the timing of biceps and triceps action.

4. You will be recording from one muscle at a time so that you can be sure that the signal is from one muscle only. Unplug one set of electrode leads from the bioamp cable (leave electrodes on the arm) and test that you get a good EMG from the triceps first. Now test the the biceps leads. Start the experiment with EMG from the biceps.

5. Click Start to begin recording. Ask the volunteer to use the alternating pattern of activation for 20 to 30 seconds. Click Stop and save the data file.

6. Switch the EMG electrode leads plugged into the bioamp cable from biceps to triceps and repeat the last step.

Analysis

1. Scroll through the recorded data and observe the EMG traces for both the biceps and triceps. Note the large-scale alternation of activity in the biceps and triceps relative to the marker at the start of each muscle contraction.

2. Note also that when the biceps muscle is activated forcefully, there is a minor increase of activity in the triceps. Correspondingly, there is a minor increase of activity in the biceps trace when the triceps is activated. This phenomenon is called ‘coactivation’. It is thought to stabilize the elbow joint.

Additional Exercises

Below is a list of additional exercises to do. Pick several of these (at least 3) and develop appropriate experimental approaches to understanding how muscle EMGs vary as a result of each of these factors.

- Isometric contraction (contraction without any change in muscle length)
- EMG during exercise of a muscle group to exhaustion (and after recovery)
- EMGs from different volunteers with different muscle mass or athletic training (don‘t forget to take some measurement of the muscle mass differences, etc. for the comparison)
- EMGs during muscle contraction of different speeds (e.g. lifting book slowly vs quickly)
- Your own exercise

Food For Thought

• Unlike the discrete waveform from an electrocardiogram, the electromyogram waveform is irregular. Why do you suppose that is?

• How did the EMG trace change when you added weights (increased load)? What do your results indicate?

• What is coactivation? Why do you think this phenomenon occurs?