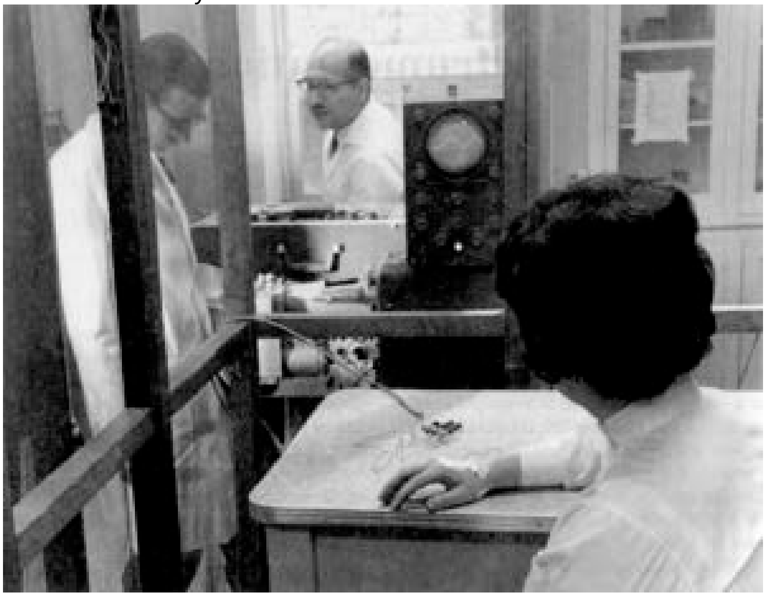
Introduction

In this laboratory, you will explore the electrical activity of skeletal muscle by recording an electromyogram (EMG) from a volunteer. You will examine the EMG of both voluntary and evoked muscle action, and measure nerve conduction velocity.



An early surface EMG recording.
John Basmajian, the pioneer of this technique,
is in the middle of the photograph

Learning Objectives

By the end of today's laboratory you will be able to:

- Record EMG during voluntary muscle contractions, and investigate how contractile force changes with increasing demand
- Examine the activity of antagonist muscles and the phenomenon of coactivation
- Record EMG responses evoked by stimulating the median nerve at the wrist
- Measure nerve conduction velocity from the difference in latencies between responses evoked by nerve stimulation at the wrist and the elbow

Procedure

Caution!

Some exercises involve application of electrical shocks to muscle through electrodes placed on the skin.

People who have cardiac pacemakers or who suffer from neurological or cardiac disorders should **not** volunteer for such exercises.

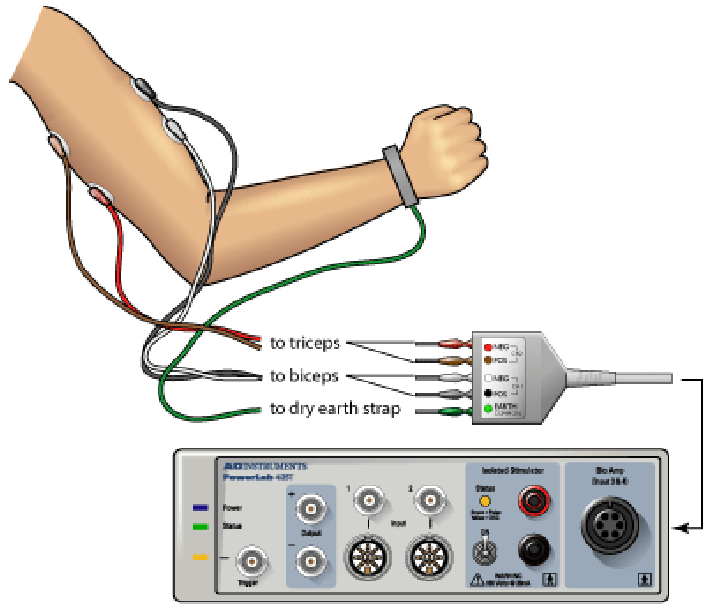
If the volunteer feels major discomfort during the exercises, **discontinue the exercise immediately** and consult your instructor.

Electrode attachment:

1. Remove any watch, jewelry, etc. from your wrists.
2. Plug the five-lead Bio Amp cable into the Bio Amp socket on the PowerLab unit.
3. Plug the five color-coded lead wires into the Bio Amp cable, as shown.
4. Firmly attach the dry earth strap around your palm or wrist. The fuzzy side of the dry earth strap needs to make full contact with the skin. Attach the green lead wire to the earth strap. If the dry earth strap has a single connector lead wire it should be inserted onto the pin nearest the Earth label.
5. If alcohol swabs are available, firmly swab the skin with them in each area where electrodes will be placed. Lightly mark two small crosses on the skin overlying the biceps muscle, in the position for the biceps recording electrodes, as shown. The crosses should be 2-5 cm apart and aligned with the long axis of the arm. Lightly abrade the skin at these areas with abrasive gel or a pad.

   This is an essential step as it decreases the electrical resistance of the outer layer of skin and ensures good electrical contact.

6. Prepare the skin over the triceps for attaching the electrodes as outlined in step 5 for the biceps. The position for the triceps recording electrodes is shown in the figure.
7. Prepare the disposable ECG electrodes by removing the backing film. Place the electrodes onto the skin over the crosses so they adhere well.
8. Plug the four shielded lead wires into the Bio Amp cable ports for positive and negative, CH1 and CH2.
9. Snap the lead wires from CH1 on the Bio Amp cable onto the electrodes on the subject's biceps. Snap the lead wires from CH2 on the Bio Amp cable onto the electrodes on the subject's triceps. It does not matter which is positive and which is negative.
10. Check that all four electrodes and the dry earth strap are properly connected to the volunteer and the Bio Amp cable before proceeding.
11. Make sure the PowerLab is connected and turned on.



Exercise 1

You will record electrical activity during voluntary muscle contractions, and investigate how it changes with increasing demand.

The two lower channels in the LabTutor panel show raw activity; the two upper channels display integrated activity (RMS), calculated from the raw signal. Integrated activity is commonly used in the assessment of muscle function because it is easier to quantitate.

Procedure

During the experiment, use Autoscale whenever necessary to ensure you can see all the data recorded.

1. Sit in a relaxed position, with your elbow bent to 90° and the palm facing upwards. Use your other hand to grasp the wrist of the arm from which the signal is being recorded.
2. Add a comment to the data file with your name.
3. Click Start.
4. Add the comment "biceps contraction", and immediately make a *moderate* contraction of the biceps muscle, by trying to bend the arm further and resisting this movement with your other arm. Observe the signal.
5. Enter the comment "triceps contraction", and immediately make a *moderate* contraction of the triceps muscle by trying to straighten out the arm and resisting this movement with your other arm.
6. Repeat steps 3 to 5, but this time make a *maximal* contraction of the biceps and then the triceps muscles.
7. Click Stop.

Remember to click Autoscale if the recorded signal traces are not all clearly visible in the LabTutor panel.

8. Once again sit in a relaxed position, with your elbow unsupported and bent to 90° with the palm facing upwards.
9. Click Start to resume recording.
10. Have someone place a book or a similar weight on your hand and add the comment "one book".
11. Leave the book in place for two to three seconds to record the change in the EMG.
12. Remove the book.
13. Click Stop.
14. Repeat steps 9-13 for two, then three, then four books, to give a series of increasing weights, adding a comment each time.

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.
2. Choose a small part of the "Biceps" activity and examine it in more detail by setting the Horizontal compression to 1:1 and clicking Autoscale. Note that the raw EMG signal is composed of many partly-overlapping spikes.
3. Note the relationship between the raw trace (Biceps) and integrated trace (RMS 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.
4. Use the Waveform Cursor and Value panel to record in the table the amplitude of the integrated trace as weights were added and removed. The height of the trace correlates with the force produced by the muscle

Exercise 2

You will examine the activity of antagonist muscles and the phenomenon of coactivation.

Procedure

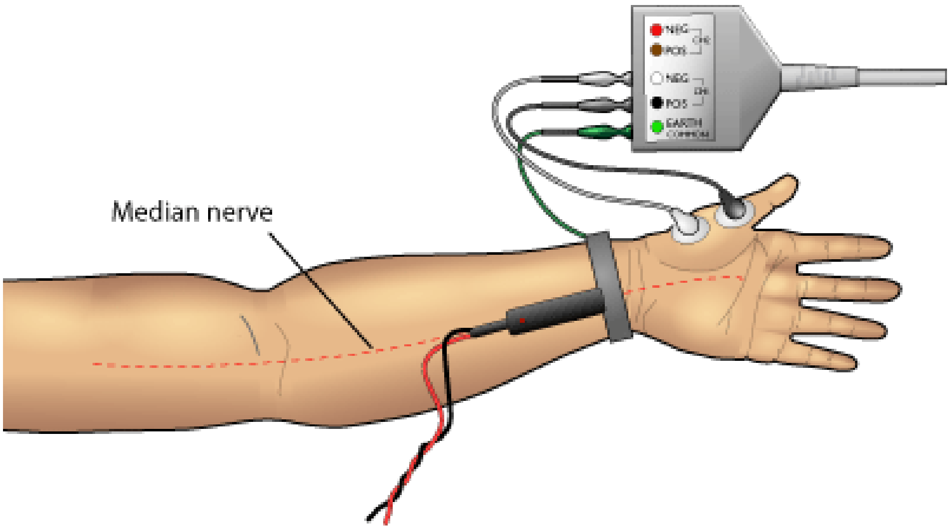
1. Sit in a relaxed position, with your elbow bent to 90° with the palm facing upwards. Use the other hand to grasp the wrist of the arm from which the signal is being recorded.
2. Activate the biceps and triceps alternately as you did for Exercise 1. Practice this alternating pattern until it feels to you that both muscles are being equally activated in turn.
3. Click Start.
4. Perform the alternating pattern of activation for 20 to 30 seconds.
5. Click Stop.
6. Examine your data. The waveforms should look something like those shown here.

Analysis

1. Scroll through the recorded data and observe the EMG traces for both the biceps and triceps.
2. Note the large-scale alternation of activity in the biceps and triceps.
3. Note 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 are activated.

This phenomenon is called 'coactivation'. Its physiological meaning is not well understood, although it perhaps serves to stabilize the elbow joint.

4. Measure and insert into the table the integrated EMG peaks for biceps and triceps during contraction of biceps and triceps. You do this using the two Value panels.



Procedure

For this next exercise, you will stimulate the median nerve at the wrist and record muscle activity from the Abductor pollicis brevis (a thumb muscle). You can continue with the same volunteer or choose someone else.

⚠ Muscle contraction and sensations such as tingling or brief pain, are associated with nerve stimulation.

Since only two of the four recording electrodes are needed in this exercise, do the following:

- disconnect the recording electrode leads from the Channel 2 sockets of the Bio Amp cable,and remove their electrodes from the triceps of the subject
- remove the electrodes from the biceps of the subject, but leave their leads connected to the Channel 1 sockets of the Bio Amp cable.

Now continue with the setup:

1. With a ballpoint pen, lightly mark two small crosses on the skin above the abductor pollicis brevis muscle, in the position for the recording electrodes shown in the figure. The crosses should be 2-3 cm apart.
2. Lightly abrade the marked skin to reduce its electrical resistance.
3. Obtain two new disposable ECG electrodes and trim the adhesive pad slightly so they will fit as shown in the figure.
4. Attach the electrodes to the skin over the crosses you marked. To reduce electrode movement, use adhesive tape to attach the wires to the skin close to the electrode.

   The dot on the back of the bar electrode indicates the positive electrode. Secure the electrode as shown in the figure, with the negative electrode closer to the wrist. The electrode should lie along the axis of the arm, with the leads pointing towards the hand.

5. Connect the Stimulating Bar Electrode to the Isolated Stimulator output of the PowerLab: the red (positive) connector to the red output and the black (negative) connector to the black output.
6. Place a small amount of electrode cream on the two silver pads of the stimulating bar.
7. Place the stimulus electrode over the volunteer's median nerve at the wrist (the approximate placing is shown in the figure).
8. Turn the Stimulator switch ON. The Isolated Stimulator only becomes active during sampling; it is switched off internally at all other times.

Exercise 3

You will stimulate the median nerve at the wrist and record muscle activity from the Abductor pollicis brevis (a thumb muscle).

Procedure

1. Set the pulse current in the Isolated Stimulator box to 8 mA by clicking the arrows or dragging the slider control. Recording will automatically stop after 0.05 seconds.
2. Click Start every time that you wish to stimulate. You should expect to see a waveform that looks something like this.
3. Apply manual pressure to the back of the stimulus electrode to ensure that the nerve is stimulated and that the electrode doesn't move around during the exercise.

- Adjust the electrode to find the best position for stimulation as judged by the amplitude of the response.
- If you cannot get a response, increase the pulse current to 10 or even 12 mA. If there is still no response try stimulating the ulnar nerve. (In some people, the abductor pollicis brevis is innervated by the ulnar nerve instead of the median nerve - an example of anatomical variation).

4. Once the electrode is optimally placed, increase the amplitude in 2 mA increments. Record the responses until either you reach 20 mA or the response no longer increases.
5. Turn the stimulator switch OFF.
6. Remove the stimulus electrode and mark with a pen the electrode indentation in the skin nearest to the hand.

Analysis

1. Use the scroll bar at the bottom of the LabTutor panel to review records recorded with stimulation at the wrist.
2. Measure the latency of a single waveform (the magnitude of the waveform is of no consequence).

'Latency' is the time elapsed from the start of the stimulus pulse (the start of each record) to the start of the evoked response. Note; you may see a very early deflection. This is the stimulus artifact and should be ignored.

3. Click at the point where the response begins.
4. Transfer the latency from the Value panel to the Latency (Wrist) column of the table. In the next exercise you will stimulate at the elbow and again measure the latency.

Exercise 4

You will measure responses evoked by nerve stimulation at the elbow. The latency of these responses is longer than those evoked by stimulation at the wrist. You will be able to calculate nerve conduction velocity from the difference in latencies.

Setup

1. Position the Bar Stimulus Electrode on the medial aspect of the front of the elbow as shown here. The electrode requires firmer pressure at the elbow than at the wrist because the nerve is deeper in the tissues. The orientation of the electrode should be the same as for wrist stimulation, with the red dot positioned closest to the elbow.
2. Turn the Stimulator switch ON.

Procedure

1. Set the current in the Stimulator panel to 8 mA.
2. Click Start every time you wish to stimulate. Do this several times, using these low-amplitude pulses to help to find the best position for the electrode.
3. If you cannot get a response, increase the stimulus current.

4. Once you have found the best position for the bar stimulus electrode, increase the stimulus to 15-20 mA.
5. Click Start.
6. Repeat several times.
7. Turn the stimulator switch OFF.
8. Remove the stimulus electrode and mark with a pen the electrode indentation in the skin nearest to the hand. Remove the other electrodes.

Analysis

1. Measure and record the distance between the marks at the elbow and at the wrist. This is the distance between stimulation sites.
2. Use the same steps as outlined for wrist stimulation to measure the latency of a single waveform in the LabTutor panel.
3. Record the latency value in the table.

The conduction velocity is calculated automatically in the table, using the equation:

$$Velocity = Distance \div Time$$

The units of velocity are mm/ms or, equivalently, m/s.

Study Questions

Exercise 1: Voluntary contraction

1. Unlike the discrete waveform from an electrocardiogram, the electromyogram waveform is irregular. Why do you suppose this is?
2. In your own words, explain how the EMG trace changed when you added weights to your arm? Based on the data you collected what can you infer is happening to the muscles as weight is added?

Exercise 2: Alternating activity and coactivation

3. In your own words what is coactivation? What are some explanations you can come up with for this phenomenon?
4. Coactivation of abdominal muscle and muscles supporting the spine has been shown to be essential for the bipedal posture of humans. Based on your data, is the coactivation of the triceps necessary for proper functioning of the biceps and vice versa?

Exercises 3 & 4: Evoked EMG & nerve conduction velocity

5. List the physiological events that occur between delivery of the stimulus and the start of the recorded response (i.e. during the latent period).
6. Which of the contributions to the latent period (that you listed in question 1 above) depends on the position of the stimulating electrode?
7. Based on your results and calculations for nerve conduction velocity, how long would it take for a nerve impulse to travel from the spinal cord to the big toe? Assume that the distance traveled is one meter.
8. Was there variability in the nerve conduction velocity amongst members of your group? What are some explanations for this?