Group Members:

Mahdi Siami

Managing the experiment, working with labchart and saving data, writing report part 1

AliAkabr Mahmoodzadeh

Subject, writing report part 2

Alireza Zargaran

Helping subject to prepare, connecting wires and making the instruments stable and writing notes during the experiment.

How we did the experiment?

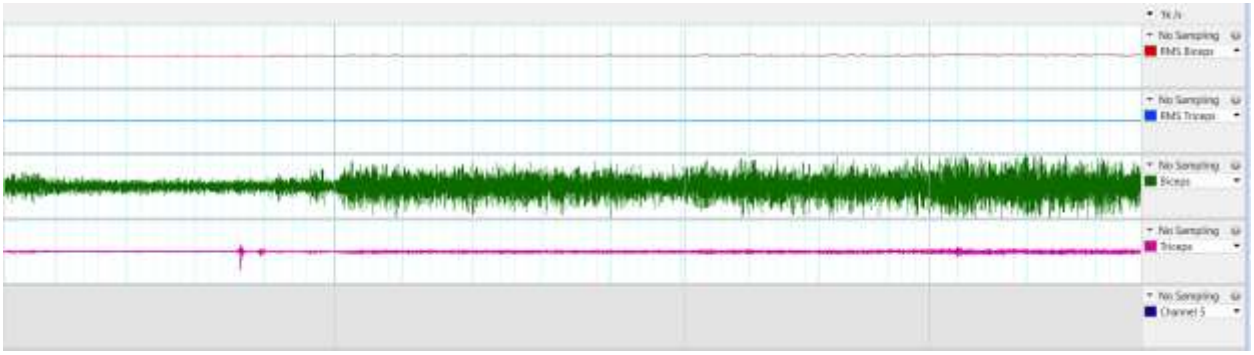
As described in protocol.

Challenges:

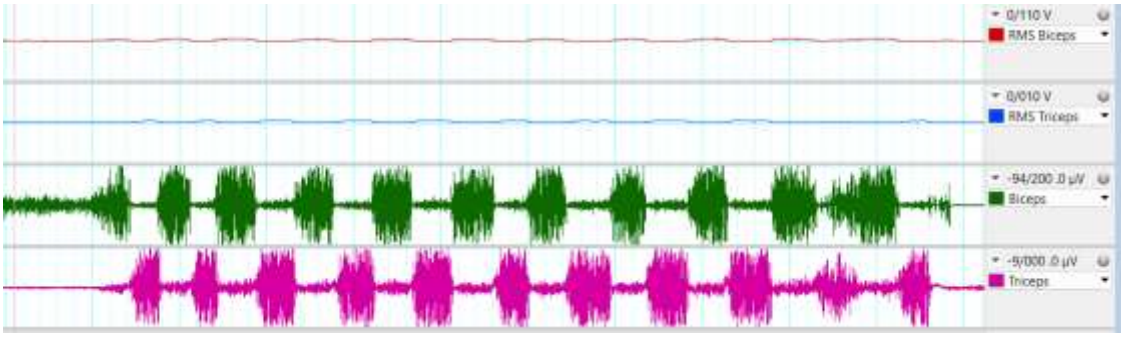
1. Pads wouldn’t stick so we had to use band glue for stabling them.
2. Some pads were too big for hand so we had to cut them.

Data recorded:

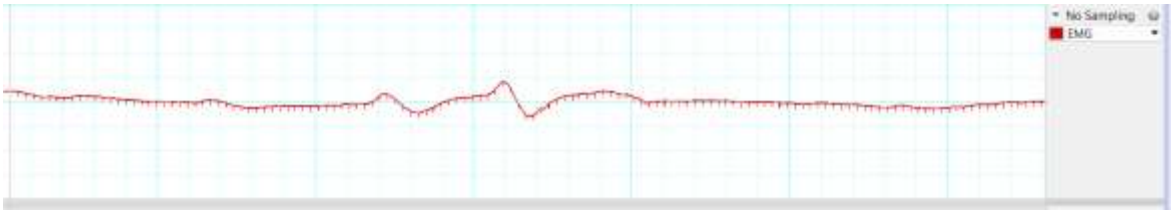
Part 1



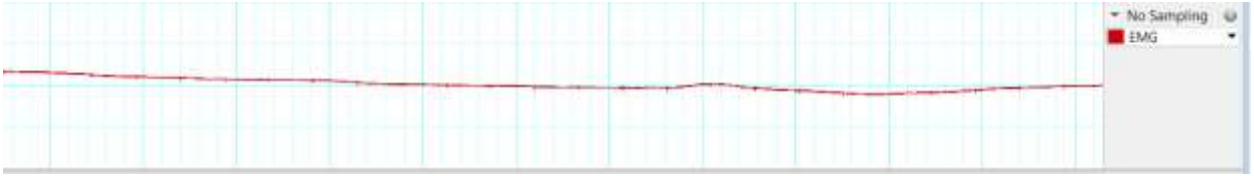
Part 2



Part 3



Part4



Electromyography

In this experiment, you will explore the electrical activity of skeletal muscle for both voluntary and evoked muscle actions and will learn how to record an electromyogram, or EMG. From the data you will attempt to measure nerve conduction velocity.

Written by staff of ADInstruments.

Background

Skeletal muscles do the majority of the work for locomotion and support of the animal skeleton. Each muscle is made up of individual muscle fibers organized in fascicles (Figure 1).

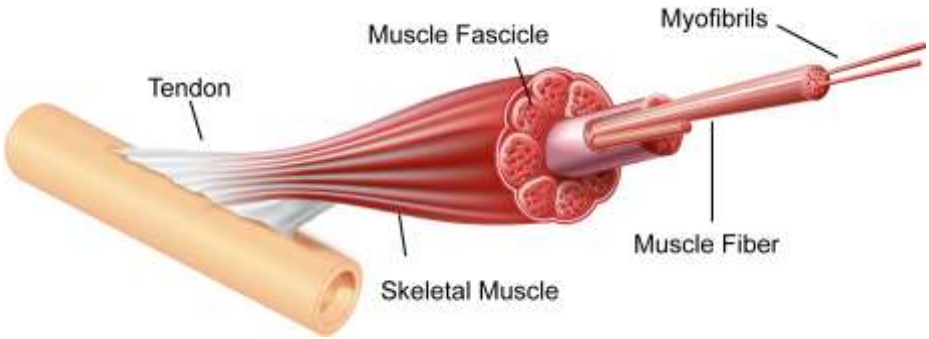


Figure 1. Skeletal muscle structure

Each individual fiber is innervated by a branch of a motor axon. Under normal circumstances, a neuronal action potential activates all of the muscle fibers innervated by the motor neuron and its axonal branches. The motor neuron, together with all of the individual muscle fibers that it innervates, is termed a motor unit (Figure 2). This activation process involves the initiation of an action potential, either voluntarily or as a result of electrical stimulation of a peripheral nerve, conduction of the action potential along the nerve fiber, release of neurotransmitter at the neuromuscular junction, and depolarization of the muscle membrane with resultant contraction of the muscle fibers.

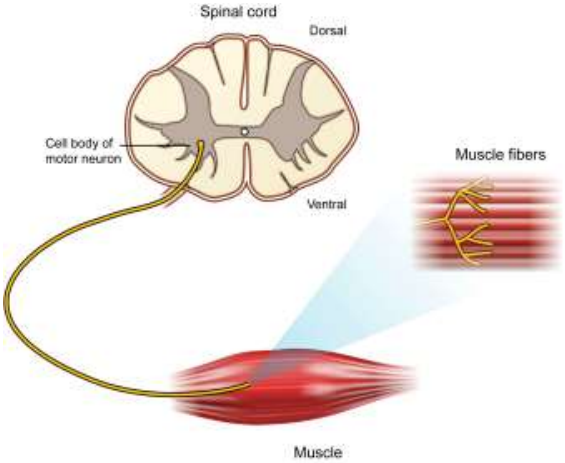


Figure 2. The components of a motor unit

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. The EMG provides a depiction of the timing and pattern of muscle activity during complex movements. The raw surface EMG signal reflects the electrical activity of the muscle fibers active at that time. Motor units fire asynchronously and it is sometimes possible, with exceedingly weak contractions, to detect the contributions of individual motor units to the EMG signal. As the strength of the muscular contraction increases, however, the density of action potentials increases and the raw signal at any time may represent the electrical activity of perhaps thousands of individual fibers.

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, known as the root mean square (RMS), the negative-going portions of the EMG are inverted by squaring the whole signal, and then the whole signal is averaged and the square root calculated. This process smoothes out individual spikes and makes the time course of changing activity much clearer. In this experiment you will examine coactivation, a phenomenon in which contraction of a muscle leads to more minor activity in the antagonist muscle. The physiological significance of this is not entirely clear, but it has been suggested that it helps to stabilize the joint.

You will also record EMG signals produced by electrical stimulation of a motor nerve supplying a muscle. The abductor pollicis brevis muscle is one of the thenar muscle group on the palmar surface of the hand. The motor nerve to this muscle, which is the median nerve, is easy to stimulate at the wrist and elbow. Brief electrical pulses are administered through the skin to the nerve, and the time it takes for the muscle to contract in response to the electrical pulse is recorded. The speed of the response is dependent on the conduction velocity. In general, the range of normal conduction velocities will be approximately 50 to 60 meters per second. However, the normal conduction velocity may vary from one individual to another and from one nerve to another.

Nerve and muscle disorders cause the muscles to react in abnormal ways. Measuring the electrical activity in muscles and nerves can help detect the presence, location and extent of diseases that damage muscle tissue (such as muscular dystrophy) or nerves (such as amyotrophic lateral sclerosis: Lou Gehrig's disease). In the case of nerve injury, the actual site of nerve damage can often be located. In a clinical setting, EMG and nerve conduction studies are usually conducted together.

Required Equipment

- LabChart software
- PowerLab Data Acquisition Unit
- 5 Lead Shielded Bio Amp Cable
- Shielded Lead Wires (5 Snap-on)
- Dry Earth Strap
- Disposable ECG Electrodes
- Stimulating Bar Electrode
- Electrode Cream or Paste
- Abrasive Gel or Pad
- Alcohol Swabs
- Gauze or cotton ball (or similar material)
- Ballpoint pen
- Scissors
- Four books or objects of similar weight (about 1 kg/2.2 lbs each)

Procedure

Equipment Setup and Electrode Attachment

1. Make sure the PowerLab is turned off and the USB cable is connected to the computer.

2. Connect the 5 Lead Shielded Bio Amp Cable to the Bio Amp Connector on the front panel of the PowerLab (Figure 3). The hardware needs to be connected before you open the settings file.

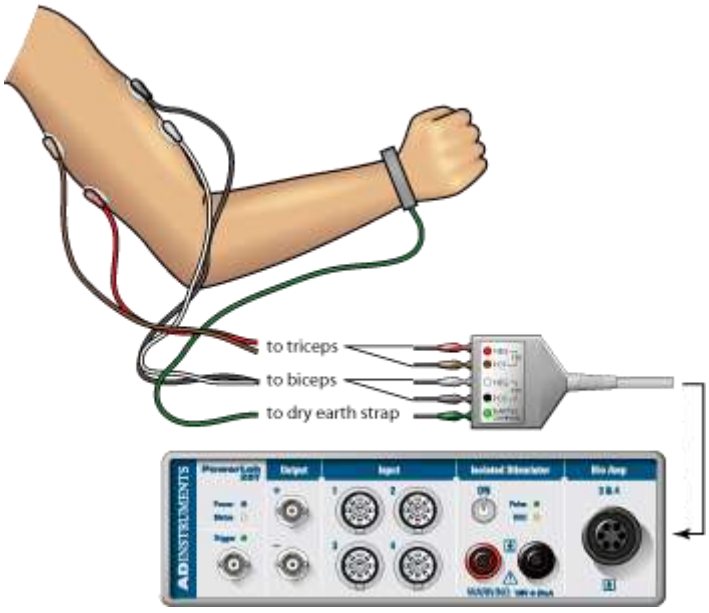


Figure 3. Equipment Setup for PowerLab 26T

3. Attach the Shielded Lead Wires to the Bio Amp Cable. Channel 1 will lead to the biceps, Channel 2 will lead to the triceps, and the Earth will be connected to the Dry Earth Strap. Attach the Disposable Electrodes to the end of the Channel 1 and Channel 2 wires and the Dry Earth Strap to the end of the Earth wire. Refer to Figure 3 for proper placement, but do not attach them to the volunteer. Follow the color scheme on the Bio Amp Cable.

4. Remove any jewelry from the volunteer's hand and arm. Use the ballpoint pen to mark two small crosses 2-3 cm apart on the skin above the biceps muscle and triceps muscle. Use Figures 3 and 4 as a guide. Abrade the skin with Abrasive Gel or Pad. This is important as abrasion helps reduce the skin's resistance.

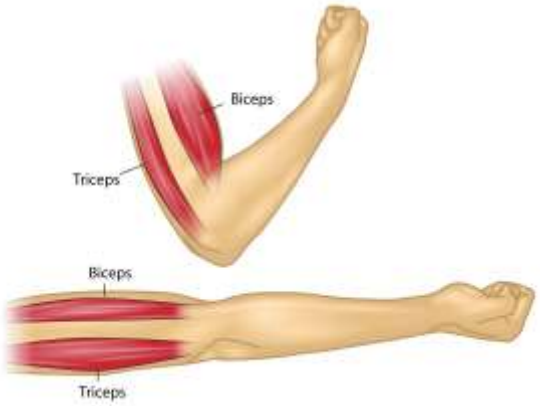


Figure 4. Skeletal muscle structure

5. After abrasion, clean the area with an Alcohol Swab to remove the dead skin cells. Wait for the skin to dry, and stick the Disposable Electrodes to the skin (Figure 3). Put the Dry Earth Strap around the volunteer's wrist, with the fuzzy side against the skin.

6. Check that all four electrodes and the Dry Earth Strap are properly connected to the volunteer and the Bio Amp Cable before proceeding. Turn on the PowerLab.

Exercise 1: Voluntary Change in Contractile Force

In this exercise, you will examine changes in voluntary muscle contraction and how contractile force changes with increasing demand.

1. Launch LabChart and open the settings file "Voluntary Change Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment.

Note: Channels 1 and 2 are the RMS activity of the biceps and triceps muscles. RMS activity is commonly used in the assessment of muscle function because it is easier to quantify. Use these two channels when completing your analysis.

2. Have the volunteer sit in a relaxed position with his/her elbow bent 90° and palm facing upward. Make sure the volunteer's elbow is not on the table. The volunteer's other hand should grasp the wrist of the recorded arm. Make sure the volunteer is facing away from the monitor.

3. Select **Bio Amp** from the Channel 3 Channel Function pop-up menu. Have the volunteer make a strong contraction of the biceps muscle. This is done by bending the recorded arm further while resisting this movement with the other arm. Observe the signal and adjust the range in the dialog so that the maximal electrical response occupies about one half to two-thirds of the full scale.

4. Repeat step 3 for the triceps signal in Channel 4. A strong contraction of the triceps muscle is made by trying to straighten the recorded arm while resisting this movement with the other arm.

5. **Start** recording. Add a **comment** with the volunteer's name. Have the volunteer make a strong contraction of the biceps and then the triceps. Add a **comment** at the start of each contraction. **Stop** recording.

6. Have the volunteer return to their original relaxed position. **Start** recording. The blue line in Chart View will help you indicate the change in procedure.

7. Prepare a comment with "one book." After a few seconds, add the **comment** and place one book on the hand of the subject. Leave it on for three seconds and remove it. Repeat this process with two books, then three, and then four books to give a series of increasing weights. Add a **comment** each time you add books. Save your data.

Exercise 2: Alternating Activity and Coactivation

In this exercise, you will examine the activity of antagonist muscles and the phenomenon of coactivation.

1. Open the settings file "Coactivation Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment. Make sure the data from Exercise 1 is saved.

2. Have the volunteer sit in a relaxed position with his/her elbow bent 90° and palm facing upward. Make sure the elbow is not on the table. The volunteer's other hand should grasp the wrist of the recorded arm. Make sure the volunteer is facing away from the monitor.

3. Have the volunteer practice activating the biceps and triceps immediately after one another. The volunteer should practice this until it feels like both muscles are being equally activated in turn. Pause shortly after each activation; this makes the data clearer.

4. **Start** recording. Add a **comment** with the volunteer's name, and record baseline EMG for 30 seconds.

5. Add a **comment** with "activation," and have the volunteer use the alternating pattern of activation for 30 seconds. Save your data when you are finished recording.

Equipment Setup

⚠ **Exercise 3 involves application of electrical shocks to muscle through electrodes placed on the skin. Students who have cardiac pacemakers or who suffer from neurological or cardiac disorders should not volunteer for this exercise. If the volunteer feels major discomfort during the exercise, discontinue the exercise and consult your instructor.**

1. Leave the Shielded Bio Amp Cable attached to the PowerLab. Remove the Channel 2 Lead Wires from the Cable and detach the Channel 1 Lead Wires from the Disposable Electrodes, leaving the wires connected to the Bio Amp Cable.

2. Use the ballpoint pen to mark two small crosses 2-3 cm apart on the skin above the abductor pollicis brevis muscle. Use Figures 5 and 6 as a guide. Make sure the negative electrode is closer to the wrist. Abrade the skin with Abrasive Gel or Pad. After abrasion, clean the area with an alcohol swab to remove the dead skin cells. Trim the Disposable Electrodes to match those in Figure 6 and stick

them to the skin. Put the Dry Earth Strap around the volunteer's wrist, with the fuzzy side against the skin (Figure 6).

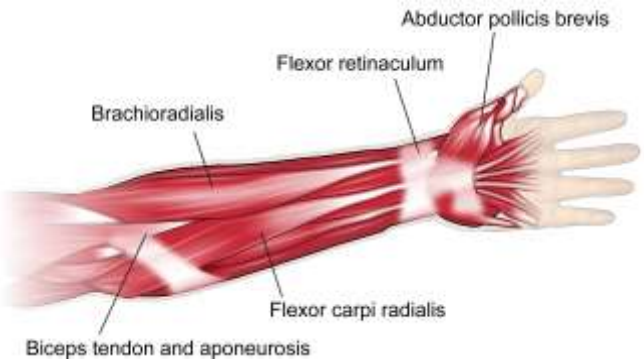


Figure 5. Some Muscles of the Forearm and Hand

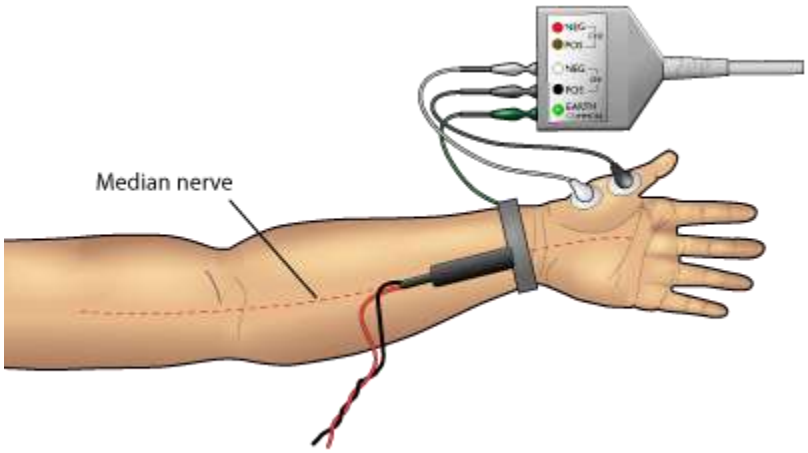


Figure 6. Evoked EMG Setup at the Wrist

3. Connect the Stimulating Electrode to the Isolated Stimulator output of the PowerLab. Make sure the red (positive) connector is in the red output and the black (negative) connector is in the black output.

4. Place a small amount of Electrode Cream or Electrode Paste on the two silver pads of the Stimulating Bar Electrode and place it over the volunteer's median nerve at the wrist (Figure 6). The Stimulating Bar Electrode should lie along the axis of the arm, with the leads pointing toward the hand – a red (positive) dot on the back of the bar should be placed away from the hand. Hold the electrode in place.

5. Turn on the Isolated Stimulator by flipping the switch on the PowerLab. Note that the Isolated Stimulator only becomes active during sampling.

Exercise 3: Evoked EMG Activity

In this exercise, you will electrically stimulate the volunteer's median nerve at the wrist and elbow to measure nerve conduction velocity.

1. Open the settings file "Evoked EMG Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment. Make sure the data from Exercise 2 is saved.

2. To set up stimulation, select **Stimulator** from the **Setup** menu. A dialog like the one in Figure 7 will appear. Change the settings to match the ones shown.

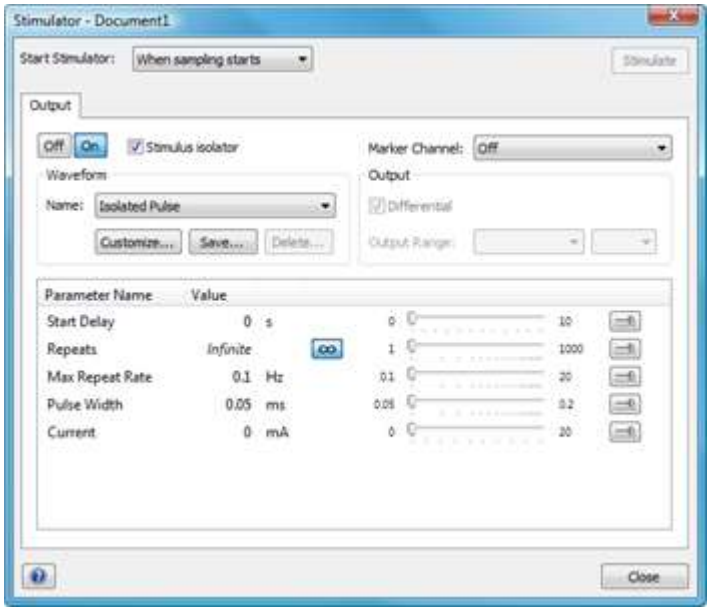


Figure 7. Stimulator Dialog

3. Make sure the volunteer is facing away from the monitor, and **Start** recording for about five seconds. Add a **comment** with the volunteer's name and "wrist" to denote the area being stimulated. Note that nothing happens. **Stop** recording, and open the **Stimulator** command again. Increase the Current amplitude to 8.0 mA.

4. Apply pressure to the Simulating Bar Electrode to make sure the nerve is stimulated and the electrode does not move. Keep holding the electrode throughout this exercise. Click **Start** to apply the stimulus. If a response is not recorded, move the electrode to a different spot on the nerve (Figure 8). If this does not work, try to increase the stimulus amplitude a little more. The lights next to the switch on the PowerLab will light up when a stimulus is made.

Note: Some volunteers may fail to show any response stimulating the median nerve. In some people, the abductor pollicis brevis muscle is innervated by the ulnar nerve instead of the median nerve. This is an example of anatomical variation. Try moving the Stimulating Bar Electrode to the ulnar nerve.

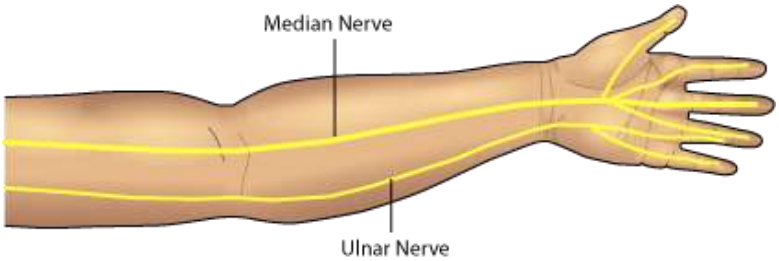


Figure 8. Position of the Median and Ulnar Nerves

5. Once you evoke a response, **Stop** recording and open **Stimulator Panel** from the **Setup** menu. This creates a miniwindow in the Chart View (Figure 9). Increase the amplitude by 2 mA and **Start** recording again. When the response is recorded, **Stop** recording. Continue increasing the amplitude by 2 mA until you reach 20 mA. Add a **comment** with the amplitude each time you begin recording.

Figure 9. Stimulator Panel

Note: The responses should increase with increasing stimuli until a maximal response is reached, after which increasing the stimulus does not further increase the response amplitude.

6. Turn off the Isolated Stimulator and move the Stimulating Electrode over the median nerve at the elbow. Refer to Figure 10 for proper placement. Mark the spot in between the pressure imprints on the skin. Everything else will remain the same.

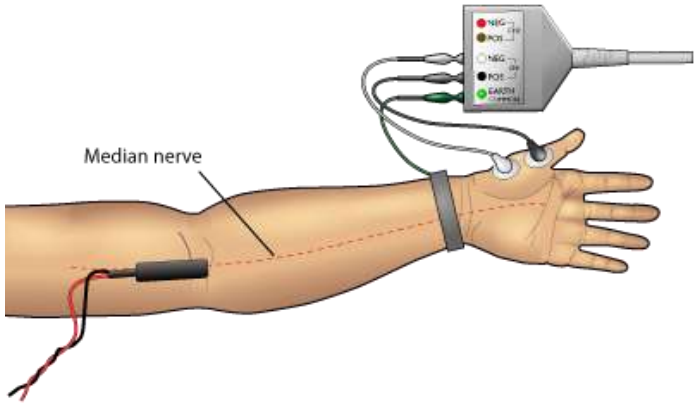


Figure 10. Evoked EMG Setup at the Elbow

7. Turn on the Isolated Stimulator and return the amplitude to 0 mA. Repeat steps 3-4.

8. Once you have found a response, increase the amplitude to maximum amplitude used at the wrist. This should be 18 to 20 mA. Add a **comment** with the amplitude used when you start recording. Record three responses at this amplitude.

9. Turn off the Isolated Stimulator. Mark the spot in between the pressure imprints on the skin and disconnect the equipment from the volunteer. Save your data.

Analysis

Exercise 1: Voluntary Change in Contractile Force

1. Examine the data in the Chart View. **Autoscale**, if necessary. Note the changes in activity in the "Biceps" channel. Note also that placing weights on the hand gives rise to little or no activity in the triceps muscle.

2. Select a small part of the "Biceps" activity and examine it in **Zoom View**. The raw EMG signal is composed of many up-and-down spikes (Figure 11).

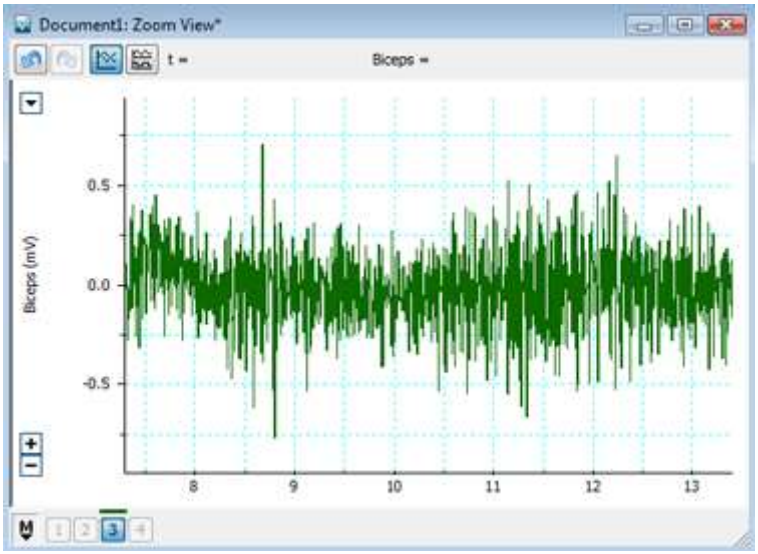


Figure 11. Raw EMG Signal

3. Note the relationship between the "Biceps" channel and the "RMS Biceps" channel. The height of the RMS trace reflects the overall activity of the raw EMG signal and gives a simpler view of the muscle's electrical activity. Note the changes in the RMS trace as books were added and removed.

4. Select data points from "RMS Biceps" when books were added. Enter these values in Table 1 of the Data Notebook. The height of the trace correlates with the force produced by the muscle.

Exercise 2: Alternating Activity and Coactivation

1. Examine the data in the Chart View for both the biceps and triceps, and **Autoscale**, if necessary. Note the large-scale alternation of activity.

2. Note when the biceps muscle is activated forcefully, there is a minor increase in the activity of the triceps. Correspondingly, there is a minor increase of activity in the biceps trace when the triceps are activated. This phenomenon is coactivation. Its physiological meaning is not well understood, but it is thought to stabilize the elbow joint.

3. Select data points from the RMS EMG peaks for both muscles during contraction of the biceps and contraction of the triceps. Enter these values in Table 2 of the Data Notebook.

Exercise 3: Evoked EMG Activity

1. Examine the data in the Chart View for the evoked response of the wrist and elbow at maximum amplitude.

2. Use **Zoom View** to measure the latency of a single waveform for each type of response (wrist and elbow). Latency is the time elapsed from the start of the stimulus (the start of each record) to the start of the evoked response. Record these values in Table 3 of the Data Notebook under "Latency." Then calculate the difference between the two latencies and enter the value in Table 3.

Note: You may see a very early deflection in response. This is a stimulus artifact and must be ignored when calculating the latency (Figure 12).

3. Measure and record the distance between the marks at the wrist and elbow and record it in Table 3 of the Data Notebook under "Distance." This is the distance between stimulation sites.

4. Using the conduction velocity equation given below, calculate the nerve conduction velocity of the volunteer. Enter the velocity under Table 3 of the Data Notebook.

$$\text{Velocity} = \frac{\text{Distance between stimulation sites (mm)}}{\text{Difference between latencies (ms)}}$$

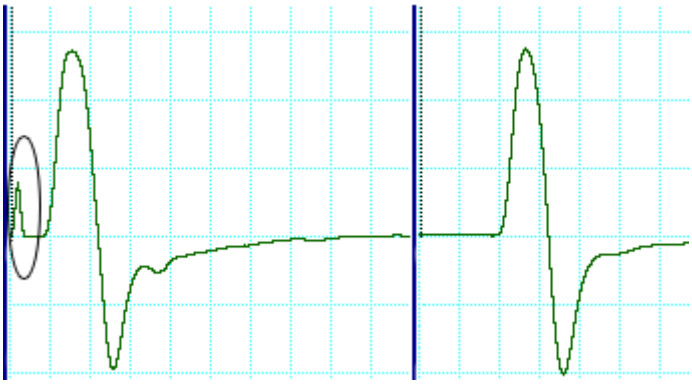


Figure 12. The Circle Denotes a Stimulus Artifact

5. Record the nerve conduction velocity from at least four other groups in Table 4. You will need this data to complete the laboratory report.

Data Notebook

Table 1. Force Produced by Adding Books

	RMS Biceps Amplitude (mV.s)
One Book	80 – 220 mV 120 mV most of the time
Two Books	110 – 380 mV 270-280 most of the time
Three Books	210 – 440 mV 310 – 330 most of the time
Four Books	280 – 610 mV 380 – 420 most of the time

Table 2. Coactivation

	RMS Biceps Amplitude (mV.s)	RMS Triceps Amplitude (mV.s)
Biceps Contracting	500 – 600	70 - 100
Triceps Contracting	40 – 80	500 - 650

Table 3. Evoked EMG

	Latency (ms)
Wrist	1
Elbow	3.5
Difference	2
Distance Between Stimulation Sites (mm)	243

$$\text{Velocity} = \frac{\text{Distance between stimulation sites (mm)}}{\text{Difference between latencies (ms)}}$$

Table 4. Nerve Conduction Velocity

Group	Nerve Conduction Velocity (m/s)
us	**97.2**

Study Questions

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

Contractions of heart muscles are rhythmic and without our control but othet controllable muscles are not like that so the electrical activity of them are different too.

2. What happened to the biceps EMG trace when you added weights to your arm? Was this expected?

Electrical activity of the muscles increased and we had bigger amplitudes in our EMG and it was expected due to increase the weight of books and demand for more force.

3. Explain the phenomenon of coactivation in your own words.

Muscle coactivation is the simultaneous activation of agonist and antagonist muscles for example when we hold our hand and try to pull and push it up and down and we hold our hand with another hand we are activating 2 muscles at the same time.

4. What happened to the triceps EMG trace when the biceps was activated? Does the data support the phenomenon of coactivation?

When we active biceps, amplitude of EMG gets bigger in triceps comparing to relaxing state and our data supports the coactivation phenomenon.

5. What was the nerve conduction velocity of the volunteer's nerve? How does it compare with the nerve conduction velocity of members of the other groups?

It was the velocity of transferring data through subjects nerves system in hand and our subject had large nerve conduction velocity comparing to other groups.

6. Based on the calculation for nerve conduction velocity, how long would it take for a nerve impulse to travel from the spinal cord to the big toe? Assume the distance traveled is 1 m and the nerve conduction velocity of a large motor fiber is 50 m/s.

$V = D/t \rightarrow t = D/V = 1/50 = 0.02\ s = 20\ ms$

Muscle Stimulation & Fatigue

In this experiment, you will explore muscle function through stimulation and fatigue. You will electrically stimulate the nerves in the forearm to demonstrate recruitment, summation, and tetanus.

Written by staff of ADInstruments.

Background

The skeleton provides support and articulation for the body. Bones act as support structures, and joints function as pivot points. Skeletal, or striated, muscles are connected to the bones either directly or by tendons, strong bundles of collagen fibers. Skeletal muscle is composed of long, multinucleate cells called fibers grouped into fascicles (Figure 1). Two or more muscles usually work antagonistically. In this arrangement, a contraction of one muscle stretches, or elongates, the other.

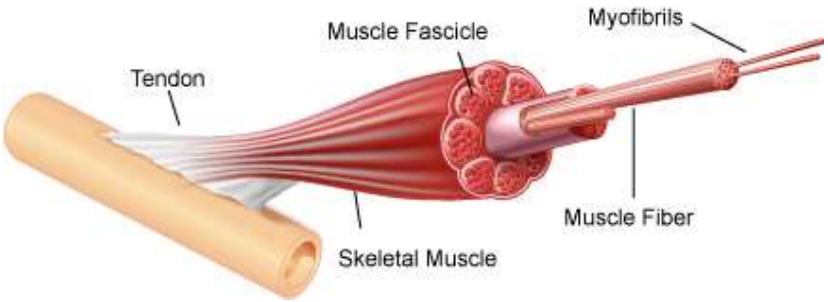


Figure 1. Skeletal Muscle Organization

Each individual fiber is innervated by a branch of a motor axon. Under normal circumstances, a neuronal action potential activates all of the muscle fibers innervated by the motor neuron and its axonal branches. A single motor neuron, and all the muscle fibers that it innervates, is known as a motor unit (Figure 2).

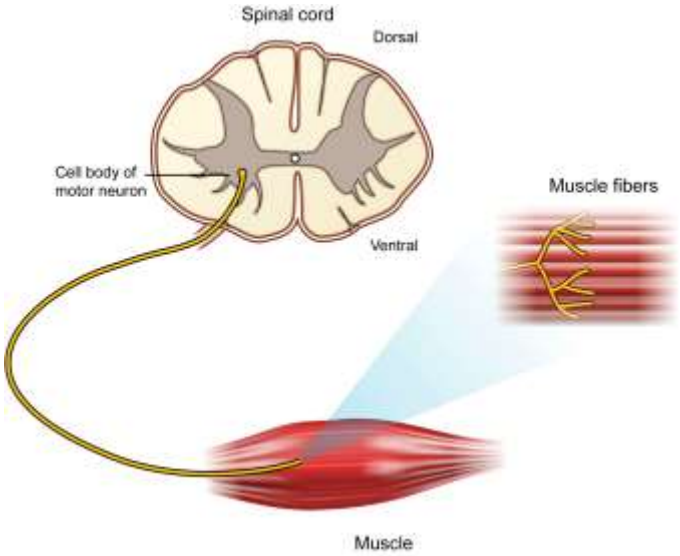


Figure 2. The components of a motor unit.

The activation process involves the initiation of an action potential (either voluntarily, or as a result of electrical stimulation of a peripheral nerve), conduction of the action potential along the nerve fiber, release of neurotransmitter, acetylcholine, into the neuromuscular junction and depolarization of the muscle membrane with resultant contraction of the muscle fibers. The muscle action potential causes a brief increase in the intracellular concentration of calcium ions, [Ca^{2+}], and activates the contractile molecular machinery inside the fiber. This requires the use of intracellular supplies of adenosine triphosphate (ATP) as the energy source. The result is a brief contraction called a *twitch*.

A whole muscle is controlled by the firing of up to hundreds of motor axons. These motor nerves control movement in a variety of ways. One way in which the nervous system controls a muscle is by adjusting the number of motor axons firing, thus controlling the number of twitching muscle fibers. This process is called *recruitment*. A second way the nervous system controls a muscle contraction is to vary the frequency of action potentials in the motor axons. At stimulation intervals greater than 200 ms, intracellular [Ca^{2+}] is restored to baseline levels between action potentials, and the contraction consists of separate twitches. At stimulation intervals between 200 and 75 ms, [Ca^{2+}] in the muscle is still above baseline levels when the next action potential arrives. The muscle fiber, therefore, has not completely relaxed and the next contraction is stronger than normal. This additive effect is called *summation*. At even higher stimulation frequencies, the muscle has no time to relax between successive stimuli. The result is a smooth contraction many times stronger than a single twitch, called a tetanic contraction. The muscle is now in a state of *tetanus*.

Required Equipment

- LabChart software
- PowerLab Data Acquisition Unit
- Finger Pulse Transducer
- Hand Dynamometer
- Stimulating Bar Electrode
- Electrode Cream or Paste
- Medical tape

Procedure

⚠ **This experiment involves application of electrical shocks to muscle through electrodes placed on the skin. Students who have cardiac pacemakers or who suffer from neurological or cardiac disorders should not volunteer for this exercise. If the volunteer feels major discomfort during the exercise, discontinue the exercise and consult your instructor.**

Equipment Setup

8. Make sure the PowerLab is turned off and the USB cable is connected to the computer.

9. Connect the Finger Pulse Transducer to Input 1 on the front panel of the PowerLab and the Stimulating Bar Electrode to the Isolated Stimulator output on the front panel (Figure 3). Make sure the red (positive) connector is in the red output and the black (negative) connector is in the black output. The hardware needs to be connected before you open the settings file.

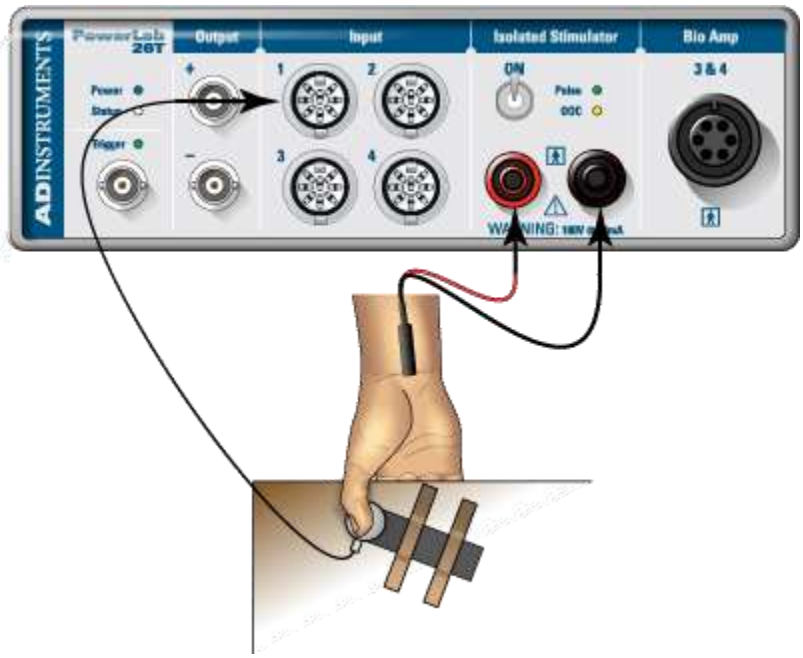


Figure 3. Equipment Setup for PowerLab 26T

10. Place the pressure pad of the Finger Pulse Transducer on the top of the table. Tape the transducer in place along the Velcro strap. The Finger Pulse Transducer needs to be close to the edge of the table (Figure 3). If the table is too thick for the volunteer to grasp, a different flat surface will have to be used.

11. Place a small amount of Electrode Cream or Electrode Paste on the two silver pads of the Stimulating Bar Electrode and place it over the volunteer's median nerve at the wrist (Figures 3 and 4). The Stimulating Bar Electrode should lie along the axis of the arm, with the leads pointing toward the hand – a red (positive) dot on the back of the bar should be placed away from the hand. Hold the Stimulating Bar Electrode in place.

12. Check that all connections are correct, and turn on the PowerLab.

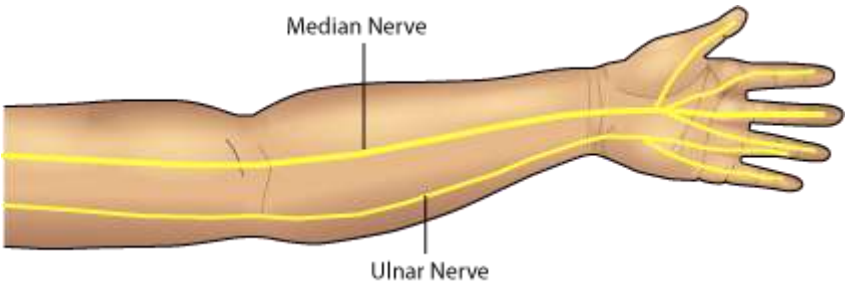


Figure 4. Position of the Median and Ulnar Nerves

Exercise 1: The Effects of Nerve Stimulation

In this exercise, you will explore the motor and sensory effects of electrical stimuli on the nerves of the forearm in a resting volunteer. In this exercise, the PowerLab acts as a stimulator, instead of a recorder. Muscular responses will be observed by watching the hand of the volunteer. Some motor effects that may be observed include:

- Movement of the thumb towards the fingers (due to stimulation of adductor pollicis and flexor muscles of the thumb)
- Bending of the wrist (due to the flexor carpi radialis and flexor carpi ulnaris muscles)
- Bending of the last segments of the fingers (due to the long finger flexor muscles)
- Movement of all fingers, combined with the pulling of the thumb towards the index finger (due to the intrinsic muscles of the hand innervated by the ulnar nerve)
- Lifting of the thumb (due to stimulation of abductor pollicis at the base of the thumb innervated by the median nerve)

13. Launch LabChart and open the settings file "Nerve Effect Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment. No data will be recorded in this file. Its purpose is to control the Isolated Stimulator.

14. Open the **Stimulator Panel** (Figure 5) from the **Setup** menu.

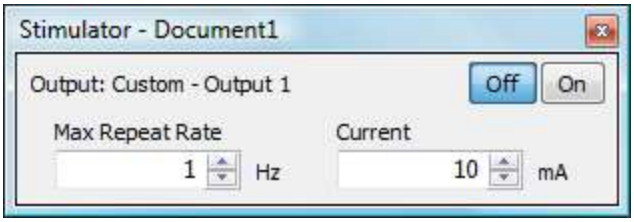


Figure 5. Stimulator Panel

15. Have the volunteer sit in a relaxed position. Make sure the volunteer is still holding the Stimulating Bar Electrode in place over the median nerve.

16. Turn on the Isolated Stimulator by flipping the switch on the PowerLab. The Isolated Stimulator only becomes active when the On button in the Stimulator Panel is selected.

17. Select the **On** button in the Stimulator Panel. Observe the volunteer's hand. Look for the twitch contractions affecting the thumb and fingers. Have the volunteer describe the effects he/she is experiencing. Examine the effect of small adjustments to the placing of the electrode, and locate the position giving the largest twitches. You can turn the isolated stimulator off at any time by selecting the **Off** button in the Stimulator Panel.

Note: If nothing happens, you may need to increase the stimulus amplitude (current) to observe a twitch. Increase the amplitude in the Stimulator Panel.

18. Explore the results of stimulating at other places in the forearm. Have the volunteer describe the effects he/she is experiencing. Each time you move the electrode to another location wipe away the residual Electrode Cream from the skin to prevent short-circuiting. Remember the two pads need to be aligned along the arm's length.

Note: Stimulation in most places gives rise to little discomfort. In some places, there is substantial sensory effect. There may be painful sensation in the forearm or hand away from the site of stimulation toward the fingers. At these places, a cutaneous sensory nerve is being stimulated.

19. Try stimulating the ulnar nerve at the level of the elbow. The nerve passes behind a bony prominence. The medial epicondyle, on the humerus. At this location, the nerve is exposed to minor mechanical injury and is known to children as the "funny bone." Stimulation at this site gives large and obvious motor effects.

20. Select the **Off** button in the Stimulator Panel to stop the stimulator. You do not need to save your data as nothing was recorded. Turn off the Isolated Stimulator by flipping the switch on the PowerLab. Record your observations in the Data Notebook.

Exercise 2: Twitch Response and Recruitment

In this exercise, you will measure the muscular twitch response to nerve stimulation and show recruitment in the twitch response as the stimulus strength increases.

1. Open the settings file "Stimuli Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment.

2. Have the volunteer place their hand as shown in Figure 6, with the fingers under the edge of the table, and the edge of the thumb resting lightly on the Finger Pulse Transducer.

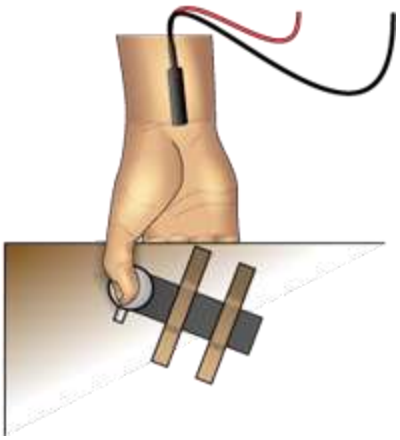


Figure 6. Position of the Hand

3. Select **Input Amplifier** from the Channel 1 Channel Function pop-up menu. The dialog should show a stable baseline reading in its display. A deflection of the trace should be seen when pressing lightly on the Finger Pulse Transducer.

4. Wipe the Electrode Cream from the volunteer's wrist. Apply a small amount of the cream to the pads of the Stimulating Bar Electrode, as you did in the Equipment Setup. Hold the electrode at the site of stimulation for the median nerve (Figure 6). Make sure the volunteer's thumb is resting lightly on the Finger Pulse Transducer.

5. Turn on the Isolated Stimulator by flipping the switch on the PowerLab.

6. To set up the Stimulator miniwindow, select **Stimulator Panel** from the **Setup** menu. This allows you to change the stimulus amplitude (current) without having to open the menu each time. Click-and-drag on the miniwindow to move it to a convenient position on the screen.

7. **Start** recording. LabChart will record for a fixed duration of 0.5 seconds and will stop automatically.

8. Increase the stimulus amplitude to 1.0 mA, and press **Start**. Continue to increase the amplitude in 1.0 mA increments, pressing **Start** after each one, until a response is recorded. For most volunteers, the *threshold stimulus* is in the range of 3-8 mA. A **comment** with the stimulus amplitude is added automatically to each recording.

9. Reduce the amplitude by 1.0 mA, and then increase it in 0.5 mA increments, a **comment** with the stimulus amplitude used is added automatically each time. Continue this range until the response no longer increases. For most volunteers, this *maximal stimulus* is in the range of 6-15 mA.

10. Save your data when you are finished recording. Turn off the Isolated Stimulator on the PowerLab. Your results should look similar to those in Figure 7.

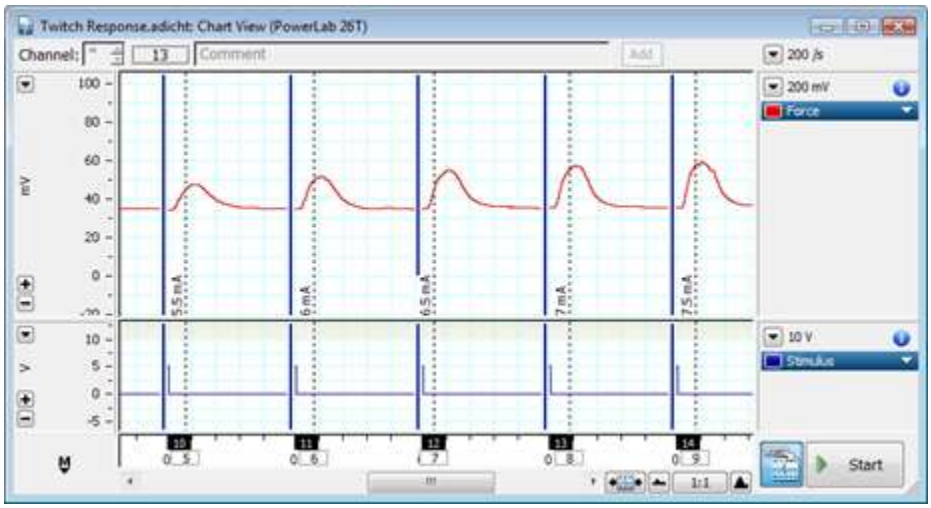


Figure 7. Sample Data Showing an Increase in Stimulus Strength

Exercise 3: Summation and Tetanus

In this exercise, you will demonstrate the effects of changing the interval between paired stimulus pulses and will observe a short tetanic contraction.

1. Open the settings file "Summation Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment. Make sure the data from Exercise 2 is saved.

2. Turn on the Isolated Stimulator on the PowerLab.

3. Select **Stimulator Panel** from the **Setup** menu (Figure 8). Move the miniwindow to a convenient position.

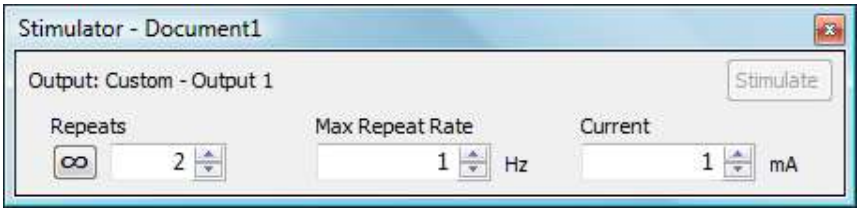


Figure 8. Stimulator Panel

4. Make sure the volunteer's hand is in the same position as before, with the thumb resting on the Finger Pulse Transducer and the Stimulating Bar Electrode on the median nerve.

5. In the Stimulator Panel, set the pulse current to 5.0 mA greater than the maximal stimulus value you determined in Exercise 2.

6. **Start** recording and press **Stimulate** in the Stimulator Panel miniwindow. LabChart will record for a fixed duration of five seconds and will stop automatically. Add a **comment** with "1 Hz" (i.e., the stimulus frequency) to the new block of data.

7. Increase the stimulus frequency to 2 Hz in the miniwindow, and press **Start**. Add a **comment** with "2 Hz" to the new block of data. Repeat the stimulation for the frequencies 5, 10, and 20 Hz, add a **comment** with the frequency each time.

8. In the Stimulator Panel change the number of pulses from two to three. **Start** recording and press **Stimulate** in the Stimulator Panel miniwindow. The volunteer should receive a burst of three stimuli at 20 Hz. Add a **comment** with "tetanic stimuli 3" to the new block of data. If three pulses did not cause the volunteer too much discomfort, use four pulses. Add a **comment** with "tetanic stimuli 4."

9. Save your data. Turn off the Isolated Stimulator on the PowerLab.

Exercise 4: Muscle Fatigue

In this exercise, you will observe the decline in maximal force during a sustained contraction and will examine some properties of muscle fatigue. First, you will calibrate the Hand Dynamometer with respect to the volunteer's maximal grip strength.

Equipment Setup and Calibration

1. Disconnect the Finger Pulse Transducer and Stimulating Bar Electrode from the PowerLab, and connect the Hand Dynamometer to Input 1 on the front panel of the PowerLab (Figure 9).

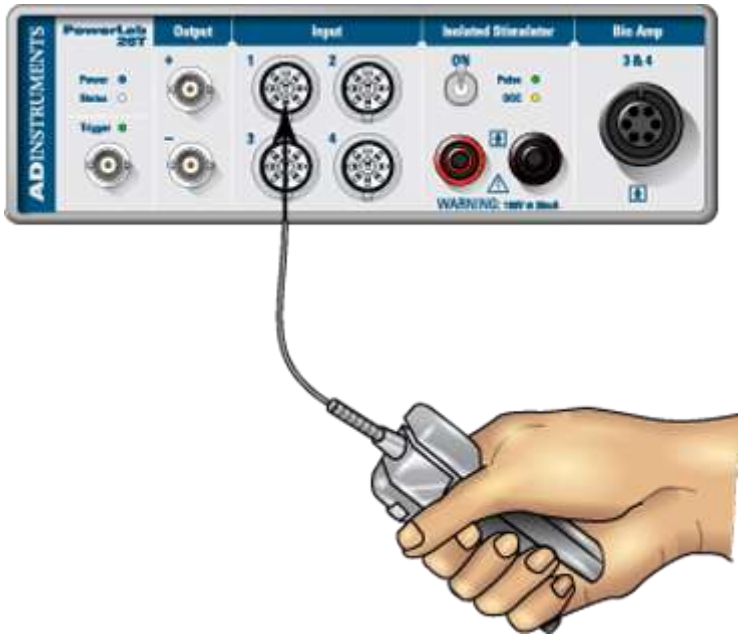


Figure 9. Equipment Setup for PowerLab 26T

2. Open the settings file "Fatigue Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment.

3. Have the volunteer loosely grip the Hand Dynamometer in the fist of their dominant hand, as shown in Figure 9.

4. **Start** recording. Have the volunteer squeeze the Hand Dynamometer as hard as possible for a second or two, and then relax their grip. After recording for a few seconds, have the volunteer repeat the maximum grip and then relax. **Stop** recording.

5. **Click-and-drag** over the largest response to select a range of data that includes both the relaxed and maximum force signals (Figure 10). Select **Units Conversion** from the Channel 1 Channel Function pop-up menu.

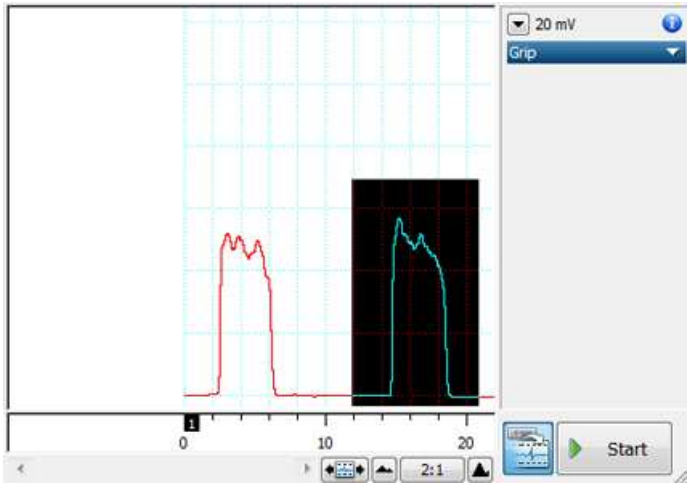


Figure 10. Data Selection for Units Conversion

6. In the **Units Conversion** dialog, select Units: %. Then select part of the trace where the force is zero, and click the Point 1 arrow. Enter 0 %. Then select part of the trace at the peak (Figure 11), click the Point 2 arrow and enter 100 %.

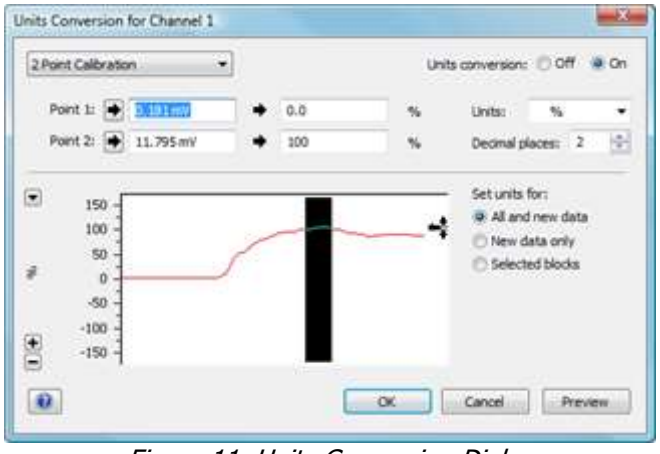


Figure 11. Units Conversion Dialog

7. Select Set units for: All and new data, then click OK to close the dialog.

Procedure

1. Adjust the scale for Channel 1 to show -20 to 120%.

2. Allow the volunteer to view the monitor. Start recording. Ask the volunteer to maintain 20% maximal grip strength while watching the recorded trace. The Range/Amplitude display for Channel 1 shows the percentage force applied. Add a **comment** with "20%."

3. After 20 seconds, tell the volunteer to relax. **Stop** recording.

4. Wait for 30 seconds to allow recovery of muscle function, and repeat steps 2-3 for contractions of 40%, 60%, 80%, and 100% of maximal grip strength. Allow the volunteer to rest for 30 seconds in between each contraction. Add a **comment** with the maximal grip strength percentage each time.

5. Have the volunteer rest for two minutes. Then have the volunteer turn away from the monitor so they cannot see the data trace.

6. **Start** recording. Ask the volunteer to produce a sustained maximal contraction. After 10 seconds, or when the force has obviously declined, instruct them to try harder. After another 10 seconds, repeat the encouragement. After five more seconds, tell the volunteer to relax. **Stop** recording. Allow the volunteer to rest briefly.

Note: Most volunteers can produce temporary increases in muscle force during a fatiguing contraction, when sufficiently motivated by verbal encouragement.

7. **Start** recording again. Ask the volunteer to produce a sustained maximal contraction as before. Every 10 seconds, allow the volunteer to relax very briefly for ½ second, and then have them return to maximal contraction. **Stop** recording after 30 to 40 seconds.

Note: Even brief periods of relaxation allow substantial recovery from fatigue, but the recovery is only temporary (Figure 12).

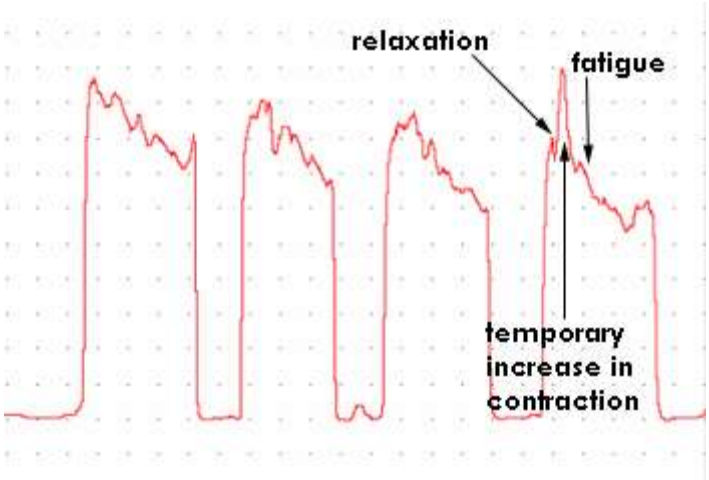


Figure 12. Fatiguing Contraction

8. Turn the volunteer so they can see the monitor again. **Start** recording. Ask the volunteer to produce a 40% contraction while watching the data trace. After 10 seconds, add a blank **comment** to denote the time.

9. Have the volunteer close their eyes and attempt to maintain exactly the same contraction force for the next 30 seconds.

10. After the elapsed time, have the volunteer open their eyes and adjust the contraction force back to 40%. **Stop** recording.

11. Record your observations in the Data Notebook.

Note: Almost all volunteers will show a declining force while their eyes are shut, which is very similar to fatigue. This is referred to as pseudo-fatigue. This is not true fatigue because the full 40% can be exerted easily, as can be seen when the volunteer's eyes are opened again.

Analysis

Exercise 1: The Effects of Nerve Stimulation

5. Record your observations in the Data Notebook.

Exercise 2: Twitch Response and Recruitment

4. Examine the data in the Chart View. Use the **View Buttons** to set the horizontal compression to 1:1.

5. Using the Marker and Waveform Cursor, measure the amplitude of each peak. Place the **Marker** on the baseline of the waveform, and place the **Waveform Cursor** on the peak. Refer to the comments in the Chart View to determine the current applied to produce each response.

6. Record your data in Table 1 of the Data Notebook.

Exercise 3: Summation and Tetanus

1. Examine the data in the Chart View, and **Autoscale**, if necessary.

2. Calculate the stimulus interval for each stimulation frequency using the following equation:

$$\text{interval (sec)} = \frac{1}{f},$$

where f is the stimulus frequency (Hz)

3. Using the Marker and Waveform Cursor, measure the amplitude of the first two responses at each stimulus interval. Place the **Marker** on the baseline of the waveform, and place the **Waveform Cursor** on the peak.

4. Record these values in Table 2 of the Data Notebook.

5. Examine the tetanic response. Calculate the stimulus interval, and record this value in Table 3 of the Data Notebook.

6. Click-and-drag the tetanic response, and examine it in **Zoom View**. Determine the maximum force amplitude using the **Marker** and **Waveform Cursor**, as before.

7. If the tetanus exercise was repeated with four pulses, repeat the analysis.

8. Record your data in Table 3 of the Data Notebook. If you did not use four pulses, leave this part of the table blank.

Exercise 4: Muscle Fatigue

1. Examine the data in the Chart View, and **Autoscale**, if necessary.

2. Record your observations in the Data Notebook.

Data Notebook

Exercise 1 Observations

a. What motor effects did you observe in the exercise? What part of the arm were you stimulating when you saw these effects? Were you able to stimulate the ulnar nerve at the level of the elbow?

قسمت‌های از بازو که شامل عصب مدین و اولنا بود و امتداد آن که حرکت انگشت‌ها را کنترل می‌کرد را در دو بخش گوناگون و جداگانه تحریک کردیم که اولی بر روی ساعد و در نزدیکی مچ بود و دومی در نزدیکی بازو

بله عصب اولنا را توانستیم تحریک کنیم و همچنین نشان‌های تحریک هم به صورت پالس در نمودارها ظاهر شدند که آنها را با فرمت‌های متفاوت ذخیره کردیم.

Table 1. Effects of Varying Stimulus Strength on Twitch Force

Stimulus	Response	Stimulus	Response	Stimulus	Response
0.0 mA	No	7.0 mA	Yes	14.0 mA	Yes
0.5 mA	No	7.5 mA	Yes	14.5 mA	Yes
1.0 mA	No	8.0 mA	Yes	15.0 mA	Yes
1.5 mA	No	8.5 mA	Yes	15.5 mA	Yes
2.0 mA	No	9.0 mA	Yes	16.0 mA	Yes
2.5 mA	No	9.5 mA	Yes	16.5 mA	Yes
3.0 mA	No	10.0 mA	Yes	17.0 mA	Yes
3.5 mA	No	10.5 mA	Yes	17.5 mA	Yes
4.0 mA	No	11.0 mA	Yes	18.0 mA	Yes
4.5 mA	No	11.5 mA	Yes	18.5 mA	Yes
5.0 mA	No	12.0 mA	Yes	19.0 mA	Yes
5.5 mA	Yes	12.5 mA	Yes	19.5 mA	Yes
6.0 mA	Yes	13.0 mA	Yes	20.0 mA	Yes

6.5 mA	**Yes**	**13.5 mA**	**Yes**		

Table 2. Summation

Stimulus Frequency (Hz)	Stimulus Interval (s)	Amplitude of First Response (mV)	Amplitude of Second Response (mV)
1	**1**	**5.00**	**5.00**
2	**0.5**	**5.10**	**5.10**
5	**0.2**	**5.12**	**5.12**
10	**0.1**	**5.12**	**5.12**
20	**0.05**	**5.20**	**5.20**

Table 3. Tetanus

Stimulus Frequency (Hz)	Stimulus Interval (s)	Number of Pulses	Amplitude of Response (mV)
20	**0.05**	**3**	**5.20**
20	**0.05**	**4**	**5.20**

Exercise 4 Observations

a. Was the volunteer able to maintain 20%, 40%, 60%, 80%, and 100% of maximal grip strength in the beginning of the exercise?

در حالتی که داوطلب خسته می‌شد رسیدن به مقادیر٪ ۸۰ به سختی ممکن بود و در نمودارها هم به صورت پایدار به این مقدار نرسیده است اما بقیه مقادیر ذکر شده (۲۰, ۴۰, ۶۰) را توانست برسد

b. Was the volunteer able to increase contraction with encouragement?

بله، تشویق کاملاِ اثر مثبت داشت بر روی داوطلب که باعث می‌شد افزایش درصد در نیرو و حفظ سطح آن را داشته باشد.

c. Could the volunteer maintain the same contraction force with their eyes closed? Were they able to return to the initial contraction with their eyes open again?

چشمان باز: وقتی به صفحه نمایش نگاه می‌کرد می‌توانست مقدار نیروی لازم را تا رسیدن به threshold ببیند برای همین می‌توانست حفظ کند مقدار نیروی خواسته شده را و ادامه بدهد

چشمان بسته: در این حالت چون داوطلب نمی‌دانست در چه سطحی است مقدار نیروی مورد نیاز را نیز نمی‌توانست حدس بزند به همین‌خاطر رسیدن به مقدار اولیه برای او مشکل بود و به خوبی نمی‌توانست به آن سطح برسد و در اغلب درصدها کمتر از مقدار اولیه بود. (در این حالت نیز با چشمان بسته، اثر تشویقی توانست نتایج را بهتر کند و افزایش نیرو داشته با شیم)

Study Questions

7. What was the threshold stimulus of the volunteer? What was the maximal stimulus?

برای تحریک مدین و اولنا این مقدار تا حد خوبی شبیه هم بود اما دقیقاً یکسان نبود، برای عصب مدین threshold برابر با ۵mA بود و مقدار بیشینه آن در حدود ۲۰mA بود که بیشتر از این می‌توانست خطرناک باشد، توجه شود این مقادیر برای حالتی است که فرکانس برابر با همان مقدار اولیه است و با افزایش مقدار فرکانس این مقادیر دست‌خوش تغییر می‌شوند

برای عصب اولنا این مقدار دارای threshold برابر با ۸mA بود و همچنین مقدار ماکسیم نیز همانند عصب قبلی دارای مقدار ۲۰mA است.

8. What can you conclude regarding the number of fibers contracting as the current was raised from threshold to that required for a maximal contraction?

با توجه به دیتاهای ضبط شده، اگر فاصله‌ی محرک کوتاه‌تر از زمان بهبودی برای فیبرهای عضلانی باشند، با اضافه شدن هر انقباض قبلی، عضله به کوتاه تر شدن ادامه می‌دهد، و در نهایت منجر به tetanus می‌شود

9. Why does varying the stimulus strength affect the twitch force?

با محرک‌های قوی‌تر، رشته‌های عصبی بیشتری تحریک می‌شوند و بنابر این واحدهای حرکتی بیشتری به کار گرفته می‌شوند(این آزمایش بخشی از آزمایشگاه عملکرد عضله اسکلتی گسترده‌تر است)

10. What are the two ways by which the nervous system can control the force generated by a muscle?

سیستم عصبی می‌تواند نیروی ایجاد شده توسط یک عضله را از طریق spaitial recruitment, temporal recruitment کنترل کند،

که اولي شامل انقباض واحدهاي حركتي بزرگ در كنار واحدهاي حركتي كوچك است، اينها به عضلات كمك مي كنند تا مقدار بسيار زيادي نيرو

توليد كنند، از سوي ديگر با انقباض مكرر عضلاني نيز مي‌تواند ايجاد شود با اين رويكرد، سپس انقباضات مكرر با هم تركيب مي‌شوند و كمتر اما با

نيروی بيشتر می‌شوند

11. During weak contractions, the firing frequency of muscle fibers is low, so that each fiber produces distinct twitches. The force produced by the whole muscle, however, is relatively smooth. How do you think this occurs?

میانگین بسیاری از انقباضات کوچک در کل عضله ممکن است منجر به انقباض صاف بشود، مشروط بر اینکه این انقباضات ناهمزمان باشند

12. What explanations can you think of for pseudo-fatigue?

در صورت عدم وجود اطلاعات در مورد نیروی واقعی تولید شده، إحساس خستگي دروني می‌تواند غالب باشد و منجر منجر به کاهش نیروی

ایجاد شده بشود

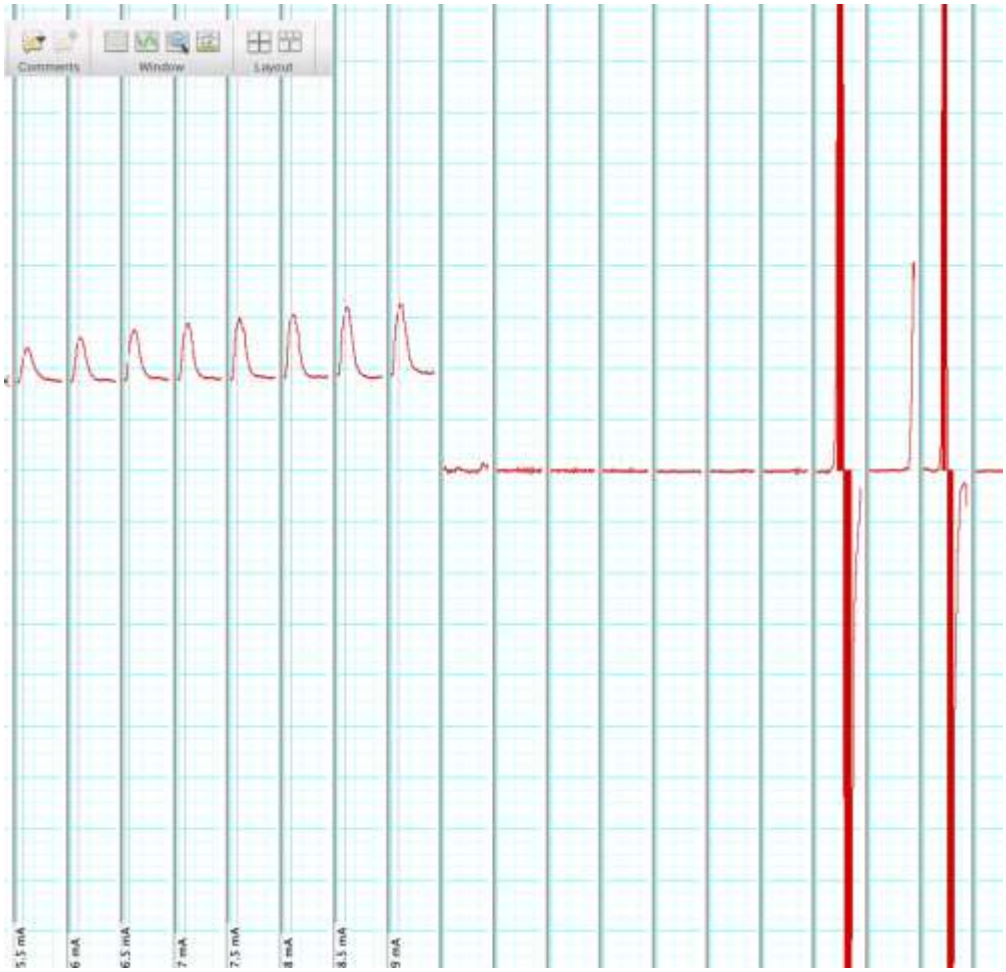
نحوه انجام آزمایش

**توجه شود در طول آزمایش از ژل رساننده و الکل استفاده کردیم و نکات ایمنی و بهداشتی نیز رعایت شده بودند

بخش اول)

اثر جریان بر روی شریان‌های عصبی مهم بر دست بود که با اعمال جریان از طریق وسایل به عصب‌های اولنا و مدیا، پاسخ ناشی از این جریان ها را که به صورت پرش انگشت شست بود را ضبط کردیم در این قسمت آقای محمودزاده به عنوان ازمایش شونده بودند و آقای صیامی نیز به عنوان آزمایش گیرنده در این بخش ما جریان‌های متفاوتی را اعمال کردیم تا بتوانیم متوجه شویم مینیم جریان در چه مقداری وارد شود تا ما بتوانیم response داشته باشیم. از طرف دیگر با تغغیر مقدار فرکانس که نشان دهنده اعمال جریان در واحد زمان بود responseها را مشاهده کردیم

با توجه به مشاهدات اعمال جریان به عصب مدین باعث حرکت شست می‌شد و همچنین اعمال جریان به اولنا باعث تحریک انگشت کوچک و کناری، توجه شود که این دو شریان در فاصله کمی از هم قرار دارند و با جابجایی کوچک انگشت‌های متفاوتی تحریک می‌شود.



بخش دوم)

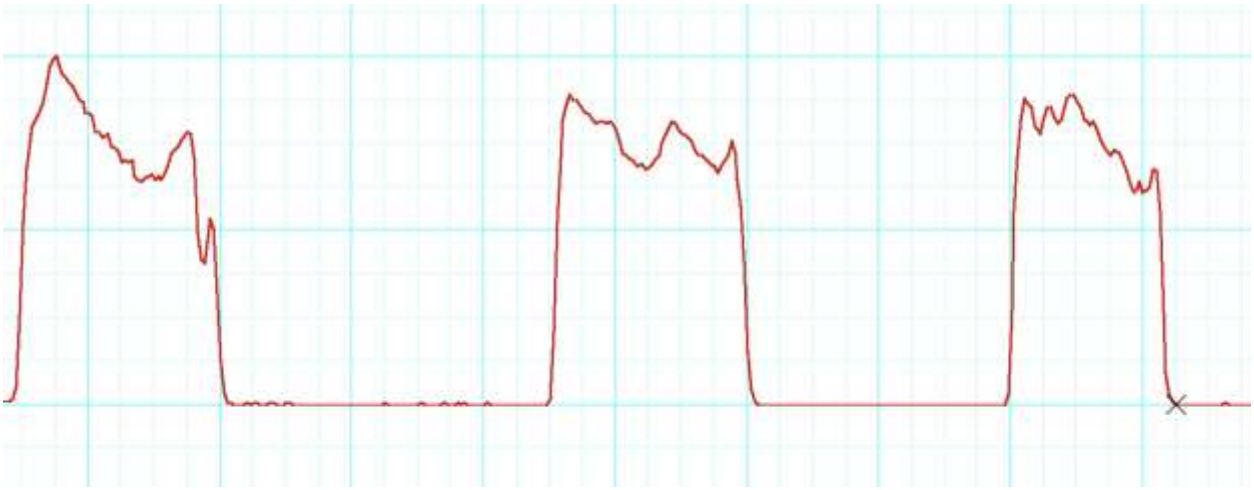
با تحریک مدین توسط جریان، شست حرکت ناگهانی پیدا می‌کند که این را در نتایج ذخیره شده هم به صورت یک تابع ضربه می‌توان مشاهده کرد، از طرفی دیگر در این بخش جریان‌های متفاوتی را اعمال کردیم تا یک threshold برای تحریک پیدا کنیم که این مقدار برای عصب مدین برابر با 5mA بود و برای عصب اولنا مقدار 8mA را داشت از طرفی با افزایش فرکانس این جریان‌ها با فاصله زمانی کمتری از همدیگر به دست آزمایش شونده اعمال می‌شد که این را هم در آزمایش مورد بررسی قرار دادیم، همچنین ماکسیمم مقدار جریان اعمال شده برابر با 20mA بود زیرا بیشتر از این مقدار برای ازمایش شونده خطرناک بود و تا قبل از این مقدار جریان ما تحریک‌های لازم را مشاهده می‌کردیم به وضوح. همچنین در این بخش ما با افزایش جریان در بازه‌های زمانی ثابت response ها را مشاهده می‌کردیم

بخش سوم)

در این حالت ما همانند دو حالت قبل و به شکل ترکیبی افزایش جریان را با افزایش فرکانس با مقادیر مشخص بررسی کردیم که این مقادیر در فرکانس‌های 1, 2, 5, 10, 20Hz انجام گرفت، همچنین جریان تحریک که در قسمت قبل بدست آوردیم را همانطور که ذکر کردیم با مقدار مشخص 5mA بیشتر به صورت ثابت به دست آزمایش شونده اعمال کردیم که نتایج آن را نیز ضبط کردیم

بخش چهارم)

در این بخش از آزمایش شونده در ابتدا می‌خواستیم که به یک جسم نیرویی وادر کند در محدوده‌های زمانی مشخص و سپس یک شکل موج را ورداشته از بازه (-20, 120) تقسیم کردیم، حال از آزمایش شونده می‌خواستیم که در بازه‌های زمانی که ما بهش می‌گفتیم تا درصدهای مشخصی نیرو را اعمال کند و این کار باعث خستگی عضلات می‌شد و این خستگی را به صورت افت دامنه می‌توانستیم مشاهده کنیم، از طرفی در بخش‌های بعدی آزمایش از آزمایش شونده خواستیم که چشم‌هایش را ببندد و به مقادیری که ما می‌گوییم نیرو وارد کند که تفاوتی با حالتی که به مانیتور نگاه می‌کرد داشت، چرا که نمی‌دانست چه مقدار نیرو کم یا اضافه دارد، در بخش‌های بعدی نیز از آزمایش شونده می‌خواستیم تا درصدی مشخص نیرو وارد کند و بعد که خسته می‌شد با دادن روحیه او را تشویق می‌کردیم و این باعث افزایش نیرو می‌شود با وجود خستگی آزمایش شونده که این هم در نمودارها با افزایش دامنه مشاهده می‌شد.



Exercise 1 Observations

a. What motor effects did you observe in the exercise? What part of the arm were you stimulating when you saw these effects? Were you able to stimulate the ulnar nerve at the level of the elbow?

قسمت‌های از بازو که شامل عصب مدین و اولنا بود و امتداد آن که حرکت انگشت‌ها را کنترل می‌کرد را در دو بخش گوناگون و جداگانه تحریک کردیم که اولی بر روی ساعد و در نزدیکی مچ بود و دومی در نزدیکی بازو

بله عصب اولنا را توانستیم تحریک کنیم و همچنین نشان‌های تحریک هم به صورت پالس در نمودارها ظاهر شدند که آنها را با فرمت‌های متفاوت ذخیره کردیم.