Lab 5. Skeletal Muscle Function and Reflexes  
(designed by Heather E. M. Liwanag with T.M. Williams)

PART 1. NEUROMUSCULAR REFLEXES

Objectives
1. Obtain a graphical representation of the electrical activity of a muscle activated by a reflex arc through nerves to and from the spinal cord.

2. Associate muscle activity with involuntary activation.

3. Observe the effect of central nervous system influence on reflex amplitude.

Background
The automatic response of a muscle to a stimulus is called a reflex. The patellar reflex results from tapping the patellar tendon below the knee with a reflex hammer. This causes contraction of the quadriceps muscle and extension of the leg. Stretching of the muscle activates nerve impulses which travel to the spinal cord. Here the incoming impulses activate motor neurons, which travel back to the muscle and result in muscle contraction. This reflex arc is primarily a spinal reflex, but is influenced by other pathways to and from the brain (Figure 1).
A reflex may be reinforced (a term used by neurologists to mean enhanced) by slight voluntary contraction of muscles other than the one being tested. For example, voluntary activation of arm muscles by motor neurons in the central nervous system “spills over” to cause a slight activation of the leg muscles as well. This results in the enhancement of the patellar reflex. There are other examples of central nervous system influences on reflexes. Health care professionals use knowledge of these influences to aid in diagnosis of conditions such as acute stroke and herniated lumbar disk, where reflexes may be absent; and spinal cord injury and multiple sclerosis, which may result in exuberant reflexes.

In this experiment, you will use an EKG Sensor to measure the relative strength (amplitude) of the impulse generated by a stimulus with and without reinforcement. This sensor, developed to measure the electrical events occurring within the heart, can be used to measure the electrical activity resulting from the contraction of other muscles as well. This method, used to record motor action potentials, is called surface electromyography (EMG). When muscle fibers in the vicinity of the recording electrodes are active, currents originating as action potentials in the fibers travel through the extracellular fluid and are detected by the electrodes. Because the recording electrodes are in different locations, the currents reach them at slightly different times, and an electrical potential difference is created between them. This electrical potential difference is the EMG tracing.

In addition to detecting currents in the extracellular fluid, the recording electrodes also pick up random electrical “noise.” If included in the final tracing, this noise would obscure the electrical signals arising from the muscle fibers. To reduce the noise, a ground electrode is attached to the skin away from the muscle. The ground picks up the same noise detected by the recording electrodes. The signal from the ground is then subtracted (by the instrumentation) from the signals of the recording electrodes, yielding a tracing that is assumed to represent just the electrical activity of the muscle.

In this experiment the EMG tracing will be relatively simple because it will be caused by single action potentials in a small group of muscle fibers. It is important to remember that the EMG tracing does not show action potentials of just one muscle fiber. It is the summation of currents arising from all action potentials arising in the vicinity of the recording electrodes. The muscle fibers closest to the recording electrodes will make the largest contribution to the EMG signal; currents arising from distant fibers may not be detected at all.

Important: Do not attempt this experiment if you have pain in or around the knee. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

Procedure

Each person in your group will take turns being subject and tester. Remember that you can choose whether or not you wish to be a subject, but you need to participate actively in data collection. * Note that subjects should wear loose pants or shorts, so that the area above the knee can be easily exposed for the attachment of electrodes (see Figure 2).
1. Connect the **EKG Sensor** to the Vernier computer interface.

2. Open the **Bio131** folder on the desktop, then open the **Vernier Physiology** folder. Double-click the file **14B Reflexes without ACC**.

3. Have the subject sit comfortably in a chair that is high enough to allow his/her legs to dangle freely above the floor.

4. Attach two electrode tabs above one knee along the line of the quadriceps muscle between the knee and the hip. The tabs should be 5 and 13 cm, from the middle of the patella (see Figure 2). A third electrode tab should be placed on the lower leg.

5. Locate the subject’s patellar tendon by feeling for the narrow band of tissue that connects the lower aspect of the patella to the tibia. Place a pen mark in the center of the tendon, which can be identified by its softness compared with the bones above and below (see Figure 3).

6. Attach the red and green leads to the electrode tabs above the knee with the red electrode closest to the knee. Attach the black lead (ground) to the electrode tab on the lower leg.

7. Click **Collect** to begin data collection. If your graph has a stable baseline, as shown in Figure 4, click **Stop** and continue to Step 8. If your graph has an unstable baseline, click **Stop** and repeat data collection until you have obtained a stable baseline for 5 s.
8. Collect patellar reflex data without and with reinforcement. **Note:** Read this entire step before collecting data to familiarize yourself with the process.

   a. Have the subject close his/her eyes, or avert them from the screen.
   b. Click [Collect].
   c. After recording a stable baseline for 5 s, swing the reflex hammer briskly to contact the mark on the subject’s tendon. If this does not result in a visible reflex, aim toward other areas of the tendon until the reflex is obtained.
   d. After 5 or 6 successful reflexes have been obtained, have the subject reinforce the reflex by hooking together his/her flexed fingers and pulling apart at chest level, with elbows extending outward (see Figure 5).
   e. Continue obtaining reflexes until data collection is completed at 30 s. A total of 10–15 reflexes should appear on the graph.

![Figure 5](image)

9. Determine the average amplitude of the **reinforced** and **unreinforced** reflexes.

   a. Click the Statistics button, \[
   \bar{V}
   \].
   b. Move the brackets to frame the first area of increased amplitude (depolarization) in this run (see Figure 6).
   c. Record the minimum, maximum and \(\Delta y\) value (amplitude) for this depolarization in **Table 1**, rounding to the nearest 0.01 mV.
   d. Close the Statistics box by clicking on the \(\times\) in the corner of the box.
   e. Repeat this process for 5 unreinforced and 5 reinforced depolarization events. Ignore rebound responses. Record the appropriate values in **Table 1**.
   f. Determine the average amplitude of the reinforced and unreinforced depolarization events examined. Record these values in **Table 1**.

![Figure 6](image)
Data

| Table 1 |
|------------------|------------------|------------------|
| Reflex response  | Reflex without reinforcement | Reflex with reinforcement |
|                  | Max (mV) | Min (mV) | ∆mV | Max (mV) | Min (mV) | ∆mV |
| 1                 |          |          |     |          |          |     |
| 2                 |          |          |     |          |          |     |
| 3                 |          |          |     |          |          |     |
| 4                 |          |          |     |          |          |     |
| 5                 |          |          |     |          |          |     |
| Average values    |          |          |     |          |          |     |

The effects of conscious observation

Perform the experiment with the subject watching the reflex hammer as it hits the patellar tendon. Compare these data to data gathered while the subject is focusing on an object elsewhere in the room.

PART 1. PROVIDE SHORT ANSWERS TO THE FOLLOWING: (1/2 page total)

1. Describe the differences between the wave forms resulting from a reflex stimulus with and without reinforcement. What can you hypothesize about the number of nerve fibers involved in a reinforced reflex as compared to one without reinforcement?

2. Compare the data you obtained in this experiment among the members of your group. Can individual differences be attributed to any physical differences (body shape/size, muscle mass, physical fitness level)?
PART 2 . SKELETAL MUSCLES AND FATIGUE

OBJECTIVES

1. Obtain graphical representation of the electrical activity of a muscle.
2. Correlate grip strength measurements with electrical activity data.
3. Correlate measurements of grip strength and electrical activity with muscle fatigue.
4. Observe the effect on grip strength of a conscious effort to overcome fatigue.

BACKGROUND

Voluntary muscle contraction is the result of communication between the brain and individual muscle fibers of the musculoskeletal system. A thought is transformed into electrical impulses which travel down motor neurons (in the spine and peripheral nerves) to the neuromuscular junctions that form a motor unit (see Figure 7).

The individual muscle fibers within each motor unit contract with an “all or none” response when stimulated, meaning the muscle fiber contracts to its maximum potential or not at all. The strength of contraction of a whole muscle depends on how many individual fibers are activated, and can be correlated with electrical activity measured over the muscle with an EMG sensor.

Regular exercise is important for maintaining muscle strength and conditioning. The most common form of non-aerobic exercise is isotonic (weight training). In isotonic exercise, the muscle changes length against a constant force. In isometric exercise the length of the muscle remains the same as greater demand is placed on it. An example of this is holding a barbell (or suitcase) in one position for an extended period of time. Muscle fatigue occurs with both forms of exercise.

Figure 7
In this experiment, you will use a Vernier Hand Dynamometer to measure maximum grip strength and correlate this with electrical activity of the muscles involved as measured using the Vernier EKG Sensor. You will see if electrical activity changes as a muscle fatigues during continuous maximal effort. Finally, you will observe the results of a conscious effort to overcome fatigue in the muscles being tested.

**Important:** Do not attempt this experiment if you suffer from arthritis, or other conditions of the hand, wrist, forearm, or elbow. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

**PROCEDURE**

Select one person from your lab group to be the subject.

**Grip Strength without Visual Feedback**

1. Connect the Hand Dynamometer and the EKG Sensor to the Vernier computer interface. Open the file “18 EMG and Muscle Fatigue” from the *Human Physiology with Vernier* folder.

2. Zero the readings for the Hand Dynamometer.
   a. Click the Zero button, \[
   \text{Zero}
   \]
   b. Hold the Hand Dynamometer along the sides, in an upright position (see Figure 8). Do not put any force on the pads of the Hand Dynamometer.
   c. Click the box in front of Hand Dynamometer to select it and click \[
   \text{OK}
   \].

3. Attach three electrode tabs to one of your arms, as shown in Figure 9. Two tabs should be placed on the ventral forearm, 5 cm and 10 cm from the medial epicondyle along an imaginary line connecting the epicondyle and the middle finger.

4. Attach the green and red leads to the tabs on ventral forearm. For this activity, the green and red leads are interchangeable. Attach the black lead to the upper arm.

5. Have the subject sit with his/her back straight and feet flat on the floor. The elbow should be at a 90° angle, with the arm unsupported.

6. Have the subject close his/her eyes, or avert them from the screen.

7. Instruct the subject to grip the sensor with full strength and click \[
   \text{Collect}
   \] to begin data collection. The subject should exert maximum effort throughout the data-collection period.

8. At 80 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

9. Record statistical information about the grip strength data.
a. Position the cursor at 0 s on the Grip Strength graph (the top graph). Click and drag to highlight 0–20 s on the graph. Click the Statistics button, . Record the mean force during that interval in Table 1, rounding to the nearest 0.1 N.

b. Move the statistics brackets to highlight the time interval between 60 and 80 s on the same graph. Record the mean force during that interval in Table 1 (round to the nearest 0.1 N).

c. Move the statistics brackets to highlight the time interval between 80 and 100 s. Record the mean force during that interval in Table 1, rounding to the nearest 0.1 N.

10. Record statistical information about the EMG data.

   a. Position the cursor at 0 s on the EMG graph (the bottom graph). Click and drag to highlight 0–20 s on the graph. Click the Statistics button, . Record the maximum and minimum mV during that interval in Table 1, rounding to the nearest 0.01 mV.

   b. Move the statistics brackets to highlight the time interval between 60 and 80 s on the same graph. Record the maximum and minimum mV during that interval in Table 1, rounding to the nearest 0.01 mV.

   c. Move the statistics brackets to highlight the time interval between 80 and 100 s on the EMG graph. Record the maximum and minimum mV during that interval in Table 1, rounding to the nearest 0.01 mV.

   d. Calculate the difference between each minimum and maximum value and record this value in the ∆mV column in Table 1.

**Part II  Grip Strength with Visual Feedback**

11. Have the subject sit with his/her back straight and feet flat on the floor. The Hand Dynamometer should be held in the same hand used in Part I of this experiment. Instruct the subject to position his/her elbow at a 90° angle, with the arm unsupported, and to close his/her eyes, or avert them from the screen.

12. Instruct the subject to grip the sensor with full strength and click  to begin data collection. The subject should exert near maximum effort throughout the duration of the experiment.

13. At 80 s, instruct the subject to watch the screen, and attempt to match his/her beginning grip strength (the level achieved in the first few seconds of the experiment) and to maintain this grip for the duration of the experiment. Data will be collected for 100 s.

14. Record statistical information about the grip strength data.

   a. Position the cursor at 0 s on the Grip Strength graph (the top graph). Click and drag to highlight 0–20 s on the graph. Click on the Statistics button, . Record the mean force during that interval in Table 2, rounding to the nearest 0.1 N.

   b. Move the statistics brackets to highlight the time interval between 60 and 80 s on the same graph. Record the mean force during that interval in Table 2, rounding to the nearest 0.1 N.

   c. Move the statistics brackets to highlight the time interval between 80 and 100 s on the same graph. Record the mean force during that interval in Table 2, rounding to the nearest 0.1 N.

15. Record statistical information about the EMG data.
a. Position the cursor at 0 s on the EMG graph (the bottom graph). Click and drag to highlight 0–20 s on the graph. Click on the Statistics button. Record the maximum and minimum mV during that interval in Table 2, rounding to the nearest 0.01 mV.

b. Move the statistics brackets to highlight the time interval between 60 and 80 s on the same graph. Record the maximum and minimum mV during that interval in Table 2, rounding to the nearest 0.01 mV.

c. Move the statistics brackets to highlight the time interval between 80 and 100 s on the same graph. Record the maximum and minimum mV during that interval in Table 2, rounding to the nearest 0.01 mV.

d. Calculate the difference between each minimum and maximum value and record this value in the ΔmV column in Table 2.

**DATA**

<table>
<thead>
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<th>Table 1–Continuous Grip Strength without Visual Feedback</th>
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<tr>
<td>Time Interval</td>
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<td>60–80 s</td>
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<table>
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<th>Table 2–Continuous Grip Strength with Visual Feedback</th>
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PART 2. PROVIDE SHORT ANSWERS TO THE FOLLOWING:  
(1/2 page total)

DATA ANALYSIS

1. Use the data in Table 1 to calculate the percent loss of grip strength that occurs between the 0–20 s and 60–80 s intervals. Describe a situation in which such a loss of grip strength is noticeable in your day-to-day life.

2. Compare mean grip strengths and $\Delta mV$ for the 0–20 s and 80–100 s in Table 1. Do your findings support or refute the practice of “coaching from the sidelines” at sporting events?

3. Compare the data in Tables 1 and 2. Explain any differences seen in the 80-100 s time intervals between the two tables. What does this tell you about the brain’s role in fatigue?