Experiment 1 and 2: Stretch Receptors and Reflexes

Background
Studying the vertebrate stretch reflex is a good way to introduce you to the topics of stretch receptors, nerve conduction velocity, electromyograms (EMG), and motor control. Specialized receptors in the muscle respond to the stretching of the tendon attached to the muscle, and then send signals to motorneurons through a single synapse. The muscle fibers depolarize and twitch (contract) in response to the incoming impulse from the motorneuron.

The Stretch Receptor
Skeletal muscles have specialized receptors which convey information about muscle length, tension, and pressure to the central nervous system. The sensory receptors responsible for providing information about the length, or the rate of change of the length, of a muscle are called muscle spindles. Arranged in parallel with muscle fibers (Figure 1), the spindles are stretched when the muscle is stretched by an external force. Therefore, these receptors play a significant role in developing antigravity reflexes and maintaining muscle tone. Muscle spindles contain a small bundle of intrafusal fibers which do not contribute to the overall tension of the muscle, but regulate the excitability of the sensory afferent spindle nerves by mechanically deforming the receptors. These fibers are innervated by gamma motor neurons. The majority of a muscle consists of extrafusal fibers, which are innervated by alpha motor neurons and are responsible for developing muscle tension.

Figure 1: A monosynaptic stretch reflex arc.
The Stretch Reflex

When a muscle is stretched, excitation of its muscle spindles causes a reflex contraction of the muscle. This reflex response is known as a stretch (myotatic) reflex. The minimal delay between the muscle stretching and the reflex contraction is due to its monosynaptic pathway. The sensory afferent nerves from the spindles synapse directly with motor neurons; there are no interneurons. This pathway constitutes the shortest possible reflex arc.

![Figure 2: The major extensors and flexors of the human knee and ankle joints. The stretch reflexes used in this exercise are elicited by striking the patellar tendon or the Achilles tendon.](image)

As an example of the stretch reflex, consider the reflex response that occurs when a person jumps from a low stool to the floor. The extensor muscles of the legs (Figure 2) are stretched on landing, lengthening all their muscle spindles. The discharge of the muscle spindles is conveyed to the central nervous system through the fast-conducting afferent axons. These sensory axons enter the spinal cord through the dorsal root and synapse with the motor neurons of the same extensor muscle. In turn, the motor neurons trigger the contraction of the extensor muscle to oppose the stretch produced by landing, completing the reflex arc. This reflex is one of the main reasons you keep your balance and do not fall down when changing certain body positions.

You will record electromyograms (EMGs), the summation of asynchronous electrical activity (muscle action potentials) in the multiple fibers in the muscle, and use them to determine the time between the stretch of the tendon and the arrival of the motor impulse at the muscle. Two reflexes in a human subject will be studied: the Achilles tendon reflex, and the patellar tendon (knee-jerk) reflex. Conduction times and nerve velocities for each reflex arc will be determined and compared. The effect of pre-existing tension in the effector muscle, or motor activity in other muscle groups, upon reflex responses will be measured. The coordination of motor activity in antagonistic muscles will also be studied.
Setup

Today we will be measuring latency of response in both the Achilles Tendon Reflex and the Patellar Stretch Reflex.

To start the program:

1) Make sure the USB cable is plugged in to the computer and attached to the IWorks TA machine (console).
2) Plug it in. Make sure machine is on prior to starting program.
3) Open Lab Scribe in Applications
4) Select Mode: Teaching
5) Pull down settings menu and select Load Group (PLMv4.iwxgrp)

Machine Setup:

Figure 3: Hammer Pulse recorder, attach to the hammer.

Plug the hammer pulse recorder (Figure 3) into channel A5. Use the Velcro to attach the opposite end onto a reflex hammer head.

Use the color coding to plug each lead wire into the pulse transducer (or iWire EMG). See Figure 4.

Figure 4: iWire EMG cable with lead wires that will attach to ECG stickers.

Next plug the iWire EMG cable into the pulse transducer using iWire #1 plug (Figure 5).
Figure 5: Everything hooked up.

**Exercise 1: Patellar Tendon (Knee Jerk) Reflex**

**Aim:** To determine conduction time from tendon tap to response of the quadriceps muscle in the patellar tendon reflex arc.

**Software Changes**
1. Click on the Settings menu again and select the PatellarStretchReflex-LS2 settings file.
2. After a short time, LabScribe will appear on the computer screen as configured by the PatellarStretchReflex-LS2 settings.

**Procedure**
1. Instruct the subject to sit on a lab bench so that the subject’s thighs are supported by the top of the bench and his/her calves hang freely.
2. Remove the lead wires of the EMG recording cable from the electrodes over the subject’s calf muscle. Keep these electrodes on the subject’s calf muscle.
3. Place a new set of recording electrodes on the **right quadriceps** muscle of the subject on the medial side of the thigh (Figure 6), so that:
   - the black (-1) lead wire is attached to an electrode which is about 12 cm from the knee.
   - the red (+1) lead wire is attached to an electrode which is about 10 cm above the negative electrode.
   - the green (C) lead wire is attached to the electrode on the knee that functions as the ground, **inner knee**.
4. Feel the position of the patellar tendon just below the kneecap. Place one hand on the patella (kneecap), and use the other hand to tap the patellar tendon with the reflex hammer. Find the point on the patellar tendon that causes the greatest response from the quadriceps muscle.
Figure 6: Circuit diagram for recording EMGs from the thigh muscles. Note: All electrodes can be on the side of thigh, not directly center. The knee (green) is on the inside of the knee not on the kneecap. The lower thigh (black) is 12 cm. above the knee, and the upper thigh (red) is 10 cm. above the black.

5. Click **Record** and then instruct the subject to raise and lower his or her lower leg to demonstrate the type of EMG that occurs during quadriceps contraction and relaxation. Click AutoScale on the EMG Quad channel. Click **Stop** to halt the recording.
6. Type Patellar Tendon Reflex in the Mark box that is to the right of the Mark button.
7. Click **Record**. Press the Enter key on the keyboard to mark the recording.
8. Instruct the subject to relax his or her quadriceps muscle and that the exercise has begun.
9. Tap the subject’s patellar tendon to elicit the stretch reflex. Record a total of ten trials using the same tapping force.
10. After the tenth trial, click **Stop** to halt recording.
11. Select Save in the File menu.
12. Repeat this exercise on the same subject while the subject is voluntarily contracting his or her quadriceps.
13. Repeat this exercise on the same subject while the subject is performing Jendrassik’s Maneuver.
   To perform this muscle activity:
   • The subject should curl the fingers of each hand toward its palm form a cup-shaped grip.
   • The subject should hold his or her hands and arms in front of his or her chest so that elbows are pointed out.
   • The subject should interlock his or her hands using the cup-shaped grip.
   • While the subject’s patellar tendon reflex is recorded, the subject attempts to pull his or her hands apart. Jendrassik’s Maneuver is an isometric contraction, in which motor activity that may affect reflex responses, occurs in another part of the body (the arm and shoulder muscles).

**Data Analysis**
1. Once all tests are done save your test on the desktop to be able to analyze data and notify your TA that the machine is ready to be moved to the next table. Only the TA will move the machine.
2. Scroll to the beginning of the data recorded for Exercise 1 to display the first trial on the Main window.

3. Measure and record the conductions times of the subject’s patellar reflex, patellar reflex with quadriceps muscle tension, and patellar reflex with Jendrassik’s Maneuver.

4. Enter the mean reflex conduction times and velocities for this exercise in Table 1.

5. Use the Display Time icons to adjust the Display Time of the Main window to show both the signal made by tapping the tendon and the EMG response on the Main window. This trial can also be selected by:
   - Placing one cursor before the beginning of the signal from the tendon tap and the second cursor after the subject’s EMG response; and
   - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the complete reaction trial to the width of the Main window (Figure 7).

6. Scroll to the beginning of the data recorded for Exercise 1 to display the first trial on the Main window.

![Figure 7](image)

**Figure 7:** An example Achilles tendon reflex response and patellar hammer signal displayed on the Main window. The cursors are in position to measure the reflex conduction time. Top panel is the response, bottom panel is the hammer force.

**Note:** If the response is upside-down, use the Invert button under the down arrow to the left of the EMG channel.

7. Click on the Analysis window icon in the toolbar (Figure 8) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure 9).
8. Look at the Function Table that is above the display of the EMG Calf channel displayed in the Analysis window. The mathematical function, T2-T1, should appear in this table. The value for T2-T1 is seen in the table across the top margin of the EMG Calf channel (To the right on the top panel).

9. Use the mouse to click on and drag a cursor to the onset (start) of the signal recorded from plethysmograph on the reflex hammer which is displayed on the Tendon Tap channel. Drag the other cursor to the beginning of the EMG wave (peak) which is recorded on the EMG Calf channel.

10. Once the cursors are placed in the correct positions for determining the reflex conduction time, record the value for T2-T1 in your Excel table.

Figure 9: An example Achilles tendon reflex response and patellar hammer signal displayed on the Analysis window. The cursors are in position to measure the reflex conduction time. Top panel is the response; bottom panel is the hammer force.
11. Repeat Steps 5 through 7 on the data from the second trial.
12. Use the same techniques used in Steps 5 through 8 to measure the reflex conduction times from the other eight trials.
13. Once the reaction times in all ten trials have been measured and recorded. Discard the longest and shortest times from the data set, and determine the average of the eight remaining reaction times. Record the mean reflex conduction time, after calculating in Excel for the Achilles reflex at this relative strength of tap in Table 1.
14. Measure the distance between the belly of the subject's calf muscle and the site of the sensorymotor synapse in the spinal cord. For the purpose of this exercise, assume that the sensorymotor synapse is at spinal segments L5 and S1, which are just above the top of the hip bone. Multiply this measurement by 2 to determine the total length of the nerve path.
15. Even though this stretch reflex is known as a monosynaptic reflex, the pathway includes the neuromuscular synapse (NMJ) as well. Assume that synaptic transmission takes about 0.5 msec, calculate the conduction velocity in the nerves composing this reflex pathway by the equation:

\[
\text{Conduction Velocity (m/sec)} = \frac{\text{Total path length (mm)}}{\left(\frac{\text{Mean reflex time (msec)}}{2}\right) - 0.5\text{msec}}
\]

16. Record the conduction velocities for the Patellar reflex recorded from the three different tapping strengths in Table 1.

**Questions to think about for your Discussion:**
1. Which muscle groups are involved in plantar flexion and in dorsiflexion of the ankle?
2. Does the subject’s reflex time change with different stimulus strengths? Why does it or doesn’t it change?

**Exercise 1: Achilles Tendon Reflex**
Aim: To determine conduction time from tendon tap to response of the gastrocnemius muscle in the Achilles tendon reflex arc.

**Software Changes**
1. Click on the Settings menu again and select the AchillesStretchReflex-LS2 settings file.
2. After a short time, LabScribe will appear on the computer screen as configured by the AchillesStretchReflex-LS2 settings.

**Procedure**
1. Instruct the subject to sit on a lab bench so that the subject’s thighs are supported by the top of the bench and his or her calves hang freely. The subject could also kneel on a padded chair with the subject’s ankles and feet hanging over the edge of the seat.
2. Place a new set of recording electrodes on the left calf muscle of the subject (Figure 9), so that:
   - the black (-1) lead wire is attached to an electrode in the center of the calf muscle.
   - the red (+1) lead wire is attached to an electrode which is below the innerknee towards the inner thigh.
   - the green (C) lead wire is attached to the electrode on the ankle above the bone that functions as the ground, outer ankle.
3. The Achilles tendon is located above the heel and connects the gastrocnemius muscle to the tarsal bone of the foot. Tap the tendon with the wide end of the reflex hammer a few times to
locate a point on the tendon which produces a consistent contraction of the gastrocnemius muscle and a downward movement of the foot (plantar flexion). The opposite, upward movement is known as dorsiflexion. Place patches on the leg as in Figure 10.

Figure 10: Circuit diagram for recording electromyograms from the calf muscles. Note: Make sure the ankle (green) one is on the side of the ankle, the calf (black) is in the center of the calf muscle, and the knee (red) is just underneath the knee.

4. Click **Record** and then instruct the subject to move his or her foot up and down to demonstrate the type of EMG that occurs during plantar flexion and dorsiflexion. Click AutoScale on the EMG Calf channel.
5. Type `<Subject’s Name> Achilles Tendon Reflex` in the Mark box that is to the right of the Mark button. Press the Enter key on the keyboard to mark the recording. Continue recording.
6. Instruct the subject that the exercise has begun and that his or her tendon could be tapped at any time.
7. Hold the shin to prevent forward leg motion prior and during tapping of the subject’s Achilles tendon to elicit the stretch reflex. Record a total of ten trials using the same tapping force.
8. After the tenth trial, click **Stop** to halt recording.
9. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file, like your lab group folder. Designate the file type as *.iwxdata. Click on the Save button to save the data file.
10. Repeat this exercise on the same subject using three different amounts of force.

**Data Analysis**

1. Use the same technique explained in Exercise 1 to measure and record the conduction times of the subject’s Achilles reflex with a light tap of hammer, Achilles reflex with medium tap of hammer, and Achilles reflex with hard hammer tap.
2. Enter the mean reflex conduction times and velocities for this exercise in Table 1.

**Questions to think about for your Discussion:**

1. Compare the average reflex times of the Achilles and patellar tendon reflexes. What factors contribute to the difference between the two reflex times?
2. Is the patellar reflex inhibited or enhanced by voluntary muscle activity in the quadriceps? Speculate on the mechanism of inhibition or enhancement.
3. Is the patellar reflex retarded or facilitated during the Jendrassik’s Maneuver (voluntary muscle activity on another part of the body)? Speculate on the mechanism of retardation or facilitation.

4. Besides excitatory inputs from stretch receptors, what synaptic inputs might influence the activity of spinal motorneurons?

### Table 1: Reflex Conduction Times and Velocities for Achilles and Patellar Tendon Reflexes.

<table>
<thead>
<tr>
<th>Reflex</th>
<th>Mean Reflex Conduction Time (ms)</th>
<th>Reflex Conduction Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles Tendon - Light Tap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achilles Tendon - Medium Tap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achilles Tendon - Heavy Tap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellar Tendon – Quadriceps Relaxed</td>
<td></td>
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<tr>
<td>Patellar Tendon – Quadriceps Tensed</td>
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<td></td>
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<tr>
<td>Patellar Tendon - Jendrassik’s Maneuver</td>
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