Experiment HN-2: Stretch Receptors and Reflexes

Background

Studying the vertebrate stretch reflex is a good way to introduce students 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 HN-2-1 on page HN-2-1), 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.

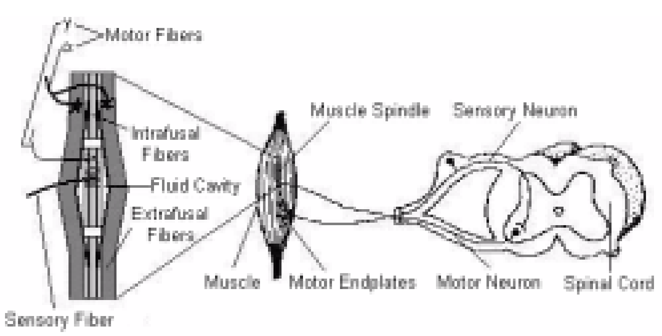

Figure HN-2-1: A monosynaptic stretch reflex arc.

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 HN-2-1 on page HN-2-1).

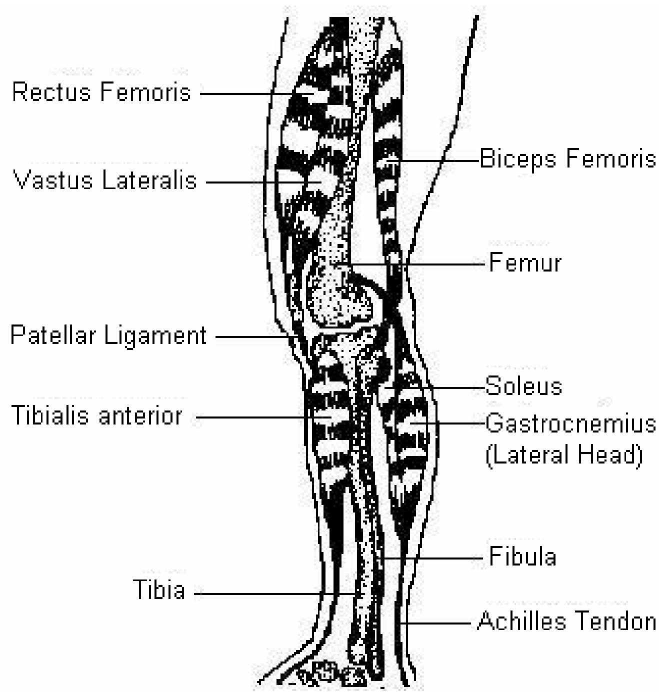

Figure HN-2-2: The major extensors and flexors of the human knee and ankle joints. The stretch reflexes used in this exercise are elicited by striking the patellar tendon or the Achilles tendon.

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 HN-2-2 on page HN-2-1) 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 Aα 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.

Students 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.

Equipment Required

PC Computer

IWX/214 data acquisition unit

USB cable

IWX/214 power supply

C-AAMI-504 ECG cable and electrode lead wires

Alcohol swabs

Disposable EMG electrodes

PRH-100 Patellar reflex hammer; or,

PT-104 pulse plethysmograph and reflex hammer

IWX/214 Setup

1 Place the IWX/214 on the bench, close to the computer.

2 Check Figure T-1-1 in the Tutorial Chapter for the location of the USB port and the power socket on the IWX/214.

3 Check Figure T-1-2 in the Tutorial Chapter for a picture of the IWX/214 power supply.

4 Use the USB cable to connect the computer to the USB port on the rear panel of the IWX/214.

5 Plug the power supply for the IWX/214 into the electrical outlet. Insert the plug on the end of the power supply cable into the labeled socket on the rear of the IWX/214. Use the power switch to turn on the unit. Confirm that the red power light is on.

Start the Software

1 Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows **Start menu**, move the cursor to **All Programs** and then to the listing for **iWorx**. Select **LabScribe** from the **iWorx submenu**. The LabScribe **Main window** will appear as the program opens.

1 On the **Main window**, pull down the **Settings menu** and select **Load Group.**

2 Locate the folder that contains the settings group, **IPLMv4.iwxgrp**. Select this group and click **Open**.

3 Pull down the **Settings menu** again. Select the **AchillesStretchReflex-LS2** settings file.

4 After a short time, LabScribe will appear on the computer screen as configured by the **AchillesStretchReflex-LS2** settings.

5 For your information, the settings used to configure the LabScribe software and the IWX/214 unit for this experiment are listed in Table HN-2-1 on page HN-2-2 These settings are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

Table HN-2-1: Settings on the Channel Window of the Preferences Dialog Used to Configure the iWorx Recording System for Experiment HN-2.

Parameter	Units/Title	Setting	Mode/ Function
Acquisition Mode		Chart	
Start		User	
Stop		User	
Display Time	Sec	10	
Speed	Samples/Sec	200	
Channel A1	EMG	S	3-10KHz
Channel A3	Tendon Tap	S	DIN8

EMG Cable and Reflex Hammer Setup

1 Locate the PT-104 pulse plethysmograph (Figure HN-2-3 on page HN-2-2) and C-AAMI-504 EMG cable and the electrode lead wires (Figure HN-2-4 on page HN-2-3) in the iWorx kit.

2 Plug the DIN8 connector to the PT-104 into the Channel 3 input of the IWX/214 (Figure HN-2-5 on page HN-2-3).

3 Insert the black AAMI connector on the end of the EMG cable into the isolated inputs of Channels 1 and 2 of the IWX/214 (Figure HN-2-5 on page HN-2-3).

4 Use an alcohol swab to clean and abrade three regions on the calf of the left leg for electrode attachment. One area is near the ankle, the second is in the middle of the calf muscle, and the third area is about 3 inches below the back of the knee. Let the areas dry.

5 Remove the plastic disk from a disposable electrode and apply it to one of the abraded areas. Repeat for the other two areas.

Figure HN-2-3: The PT-104 pulse plethysmograph.

Figure HN-2-4:The C-AAMI-504 EMG cable with three lead wires attached.

Figure HN-2-5: The EMG cable and pulse transducer connected to an IWX/ 214.

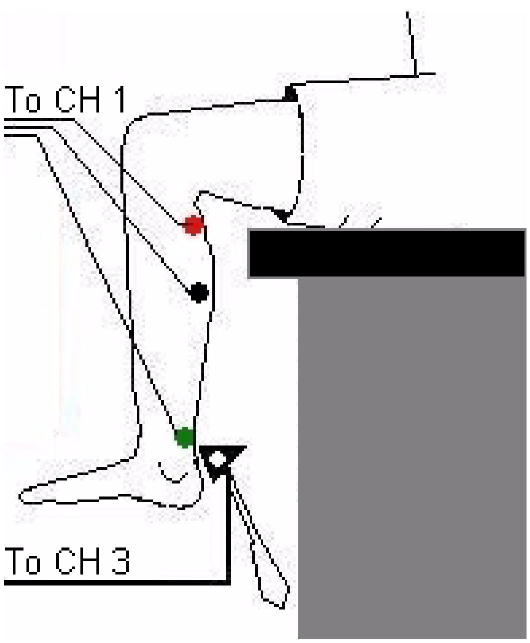

Figure HN-2-6: Circuit diagram for recording electromyograms from the calf muscles.

6 Attach three color-coded electrode leads to the ground and Channel 1 inputs on the lead pedestal and snap the other ends onto the disposable electrodes (Figure HN-2-6 on page HN-2-3), so that:

- the red (**+1**) lead wire is attached to the electrode near the back of the knee.
- the black (**-1**) lead wire is attached to the electrode in the middle of the calf muscle.
- the green (**C**) lead wire is attached to the electrode on the ankle that functions as the ground.

7 Attach the plethysmograph to the side of the head of the patellar hammer with its velcro strap. When the reflex hammer strikes the tendon, the plethysmograph will emit a signal which marks the recording on the **Tendon Tap channel** at the point in time when the tendon was struck.

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.

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. 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.
3. 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**.
4. 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.
5. Instruct the subject that the exercise has begun and that his or her tendon could be tapped at any time.
6. Tap the subject's Achilles tendon to elicit the stretch reflex. Record a total of ten trials using the same tapping force.
7. After the tenth trial, click **Stop** to halt recording.
8. 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.
9. Repeat this exercise on the same subject using different amounts of force.

Data Analysis

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

2 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 HN-2-7 on page HN-2-4).

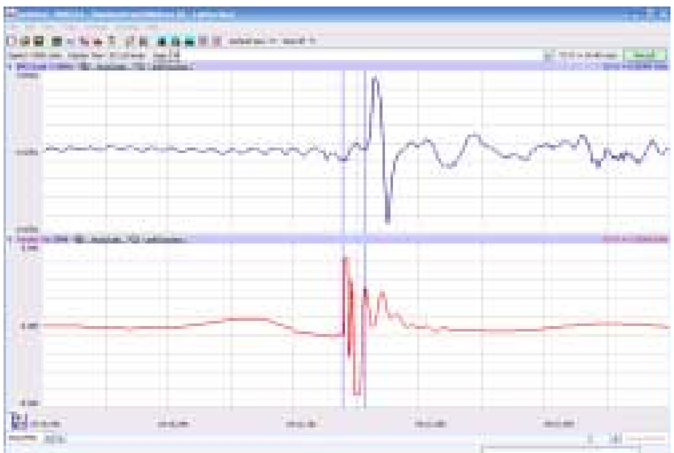

Figure HN-2-7: An Achilles tendon reflex response and patellar hammer signal displayed on the Main window. The cursors are in position to measure the reflex conduction time

3 Click on the **Analysis window** icon in the toolbar (Figure HN-2-8 on page HN-2-4) or select **Analysis** from the **Windows menu** to transfer the data displayed in the **Main window** to the **Analysis window** (Figure HN-2-9 on page HN-2-4).

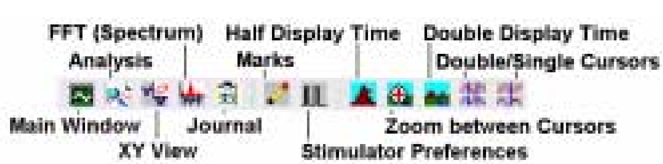

Figure HN-2-8: The LabScribe toolbar.

4 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**.

5 Use the mouse to click on and drag a cursor to the onset 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 which is recorded on the **EMG Calf channel.**

6 Once the cursors are placed in the correct positions for determining the reflex conduction time, record the value for **T2-T1** in the **Journal**. The value can be recorded in the on-line notebook of LabScribe by typing its name and value directly into the **Journal**. Values can also be recorded in separate data table.

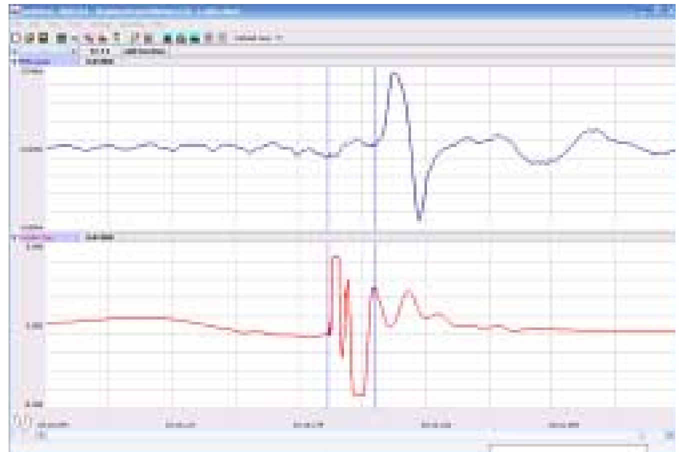

Figure HN-2-9: An Achilles tendon reflex response and patellar hammer signal displayed on the Analysis window. The cursors are in position to measure the reflex conduction time

7 The functions in the **channel pull-down menus** of the **Analysis window** can also be used to enter the name and value for **T2-T1** into the **Journal**. To use these functions:

- Place the cursors at the locations used to measure the reaction time.

- Transfer the name of the **T2-T1** function to the **Journal** using the **Add Title to Journal** function in the **Reaction Time Channel pull-down menu**.

- Transfer the value for **T2-T1** to the **Journal** using the **Add Ch. Data to Journal** function in the **Reaction Time Channel pull-down menu**.

8 Once the reflex conduction time in the first trial is measured and recorded, use the scroll bar at the bottom of the **Analysis window** to move the data from the second trial onto the window. If needed, use the **Display Time** icons to adjust the width of the **Analysis window** to show both the signal from the tendon tap and the subject's EMG response on the same window.

9 Repeat Steps 5 through 7 on the data from the second trial.

10 Use the same techniques used in Steps 5 through 8 to measure the reflex conduction times from the other eight trials.

11 Once the reaction times in all ten trials have been measured and recorded, open the **Journal** and use the values to determine the mean reflex conduction time of the subject. 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 for the Achilles reflex at this relative strength of tap in Table HN-2-2 on page HN-2-6.

12 Measure the distance between the belly of the subject's calf muscle and the site of the sensory-motor synapse in the spinal cord. For the purpose of this exercise, assume that the sensory-motor 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.

13 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:

$$\text{Conduction Velocity (m/sec)} = \frac{\text{Total path length (mm)}}{\text{(Mean reflex time (msec) - 0.5msec)}}$$

14 Record the conduction velocities for the Achilles reflex recorded from the three different tapping strengths in Table HN-2-2 on page HN-2-6.

Questions

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?

3 Design an experiment to measure the reflex time more precisely?

Exercise 2: 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 **Patellar-StretchReflex-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 or 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 quadriceps muscle of the subject on the medial side of the thigh (Figure HN-2-10 on page HN-2-5), so that:

- the black (**-1**) lead wire is attached to an electrode which is about 12cm from the knee.
- the red (**+1**) lead wire is attached to an electrode which is about 10cm above the negative electrode.
- the green (**C**) lead wire is attached to the electrode on the knee that functions as the ground.

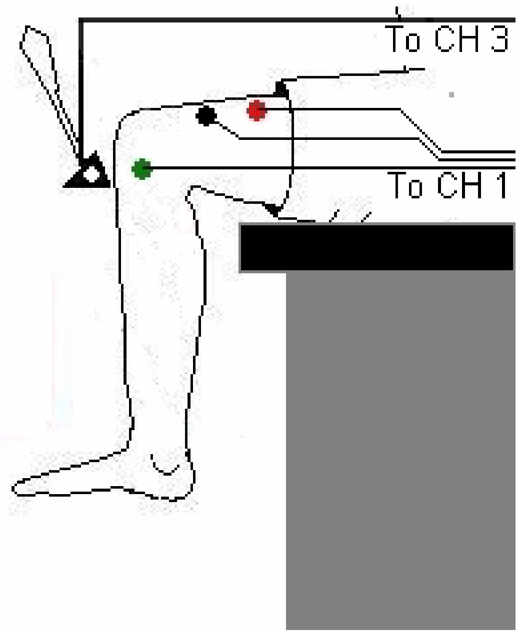

Figure HN-2-10: Circuit diagram for recording EMGs from the thigh muscles.

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.

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 Use the same technique explained in Exercise 1 to 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.

2 Enter the mean reflex conduction times and velocities for this exercise in Table HN-2-2 on page HN-2-6.

Questions

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 an 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 motor-neurons?

Table HN-2-2: Reflex Conduction Times and Velocities for Achilles and Patellar Tendon Reflexes.

Reflex	Mean Reflex Conduction Time (ms)	Reflex Conduction Velocity (m/s)
Achilles Tendon - Light Tap		
Achilles Tendon - Medium Tap		
Achilles Tendon - Heavy Tap		
Patellar Tendon - Quadriceps Relaxed		
Patellar Tendon - Quadriceps Tensed		
Patellar Tendon - Jendrassik's Maneuver		