Experiment 9: Electromyogram (EMG) Activity in Antagonistic Muscles

Background

The movement of parts of the body is accomplished through a system of levers composed of skeletal muscles and bones. In a lever, the muscle attached to the bone provides the effort or force that moves the bone. As the muscle contracts and relaxes, the bone, functioning as the actual lever, rotates around a joint in the skeletal system. In relation to the muscle, the bone, and the body part being moved, the joint is the fixed point that functions as the fulcrum for the lever. The body part being moved is the load in the lever (Figure 3-1 on page 1).

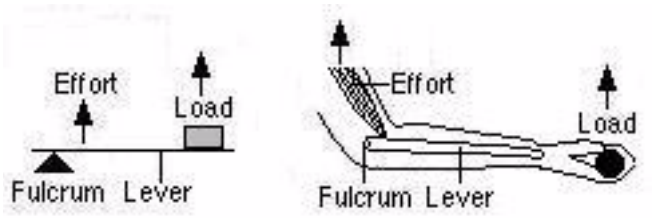

Figure 3-1: A Third Class lever and a counterpart in the human body. The insertion of the muscle on the bone in the forearm places the effort between the wrist (fulcrum) and the hand load).

All levers, including the ones in the body, can be categorized into one of three classes, which are based on the position of the fulcrum in relation to the positions of the effort and the load:

- In First Class levers, the fulcrum is between the effort and the load, like on a see-saw. In the body, an example of this class is the extension of the forearm by the triceps muscle.
- In Second Class levers, the load is between the effort and the fulcrum, like a wheel barrow. In the body, an example of this class is standing on tiptoe by using the gastrocnemius muscle.
- In Third Class levers, the effort is between the fulcrum and the load, like tweezers. In the body, an example is the flexion of the forearm by the biceps muscle.

Body parts are moved in different directions by muscles that act on the same bone from different directions. A simple example is the movement of the forearm. When the biceps muscle contracts, the forearm and the hand move toward the shoulder in a motion called flexion. When the triceps muscle contracts, the forearm and hand move away from the shoulder in a motion called extension. Since these two muscles move the forearm in different directions, they are antagonistic muscles. These muscles relax and contract in a coordinated manner to place the forearm and hand in the desired position. If the effort exerted on the bone by each muscle is equal in magnitude and opposite in direction, the forearm remains stationary.Even though they are antagonistic, the biceps and triceps muscles are from two different classes of levers. The biceps is part of a third class lever, and the triceps is part of a first class lever.

By recording the EMG activity in a muscle during the movement or positioning of a body part, it can be determined if the muscle is involved. In this experiment, you will record EMG activity from muscles on the anterior and posterior sides of the forearm to determine which ones are responsible for flexion and extension of the hand. Recording of EMG activity from these muscles will also be done while a weight is lifted by the hand. In another exercise, you will EMG activity from the anterior and posterior sides of the lower leg to determine which muscles are active during movements or positioning that are more complex, like leaning forward, standing on toes, or rocking on heels.

Equipment Required

PC Computer

iWorx unit, and USB or serial cable

AAMI cable and five EMG leads

Disposable electrodes

Small weight

Alcohol swabs

Equipment Setup

1. Connect the iWorx unit to the computer (described in Chapter 1).
2. Attach the AAMI connector on end of the EMG recording cable to the isolated Channel 1 and 2 inputs on the iWorx unit (Figure 3-2 on page 2).
3. Attach five color-coded snap leads to the Channel 1, Channel 2, and ground inputs on the lead pedestal.

Start the Software

1. Click the Windows **Start** menu, move the cursor to **Programs** and then to the **iWorx** folder and select **LabScribe**; or click on the LabScribe icon on the Desktop.
2. When the program opens, select **Load Group** from the **Settings** menu.
3. When the dialog box appears, select **AddedLabs.iws**. Click **Load**.
4. Click on the **Settings** menu again and select the **AntagonisticMuscles** settings file.
5. After a short time, LabScribe will appear on the computer screen as configured by the **AntagonisticMuscles** settings.

Exercise 1: Antagonistic Muscles in Forearm

Aim: To study the EMG activity in muscles that work in opposition to each other to flex or extend the hand.

Procedure

1 The subjects should remove all jewelry from their wrists.

2 Locate the muscles of the forearm over which the recording electrodes will be placed. Muscles can be located by flexing or extending the hand and noting the areas of the forearm where the muscles are tense during these hand positions:

• One pair of recording electrodes will be placed over the flexor muscles on the anterior surface of the forearm. The first electrode in this pair will be placed about 8 centimeters below the inside of the elbow and about 4 centimeters from the medial margin of the forearm. The second electrode in this pair will be placed about 8 centimeters below the other electrode along the midline of the anterior surface of the forearm.

• A second pair of electrodes will be placed over the extensor muscles on the posterior surface of the forearm. The first electrode in this pair will be placed about 9 centimeters below the tip of the elbow along the midline of the posterior surface of the forearm. The second electrode in this pair will be placed about 6 centimeters below the first electrode and about 3 centimeters from the lateral margin of the posterior surface of the forearm.

• A fifth electrode, used as the ground, is centered between the positions of the four recording electrodes.

3 Use an alcohol swab to clean and scrub the areas where the electrodes will be placed (Figure 3-2 on page 2). Let the areas dry before attaching the electrodes.

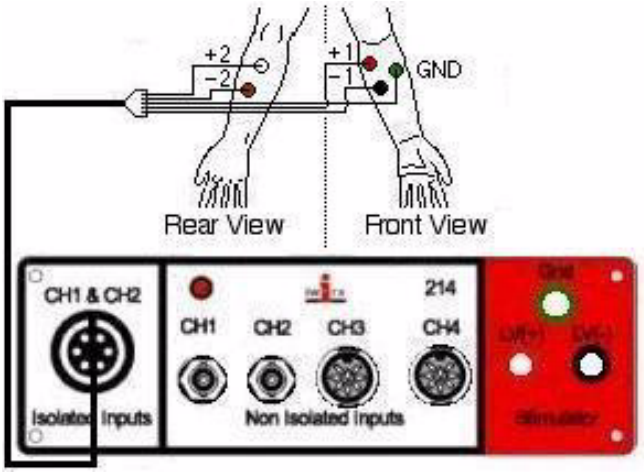

Figure 3-2: Position of electrodes used to record EMG from muscles in the forearm during flexion and extension.

4 Remove the plastic disk from a disposable electrode and apply it to one of the scrubbed areas.

5 Snap the recording lead wires onto the electrodes, so that:

• the red “+1” lead is attached to the electrode on the anterior forearm that is nearest the elbow.

• the black “-1” lead is attached to the electrode on the anterior forearm closest to the middle of the forearm.

• the white “+2” lead is attached to the electrode on the posterior forearm that is nearest the elbow.

• the brown “-2” lead is attached to the electrode on the posterior forearm closest to the middle of the forearm.

• the green “C” lead (the ground) is attached to the electrode in the center of the box formed by the positions of the four recording electrodes.

6 Instruct the subject to do the following:

• Before the recording begins, the subject should extend his or her arm in front of their body with the palm facing upward. This position is defined as the neutral position.

• Keep his or her hand open during the recording.

• Move his or her hand upward (flexion) from the neutral position as far as possible and hold it in this position for two seconds (Figure 3-3 on page 2).

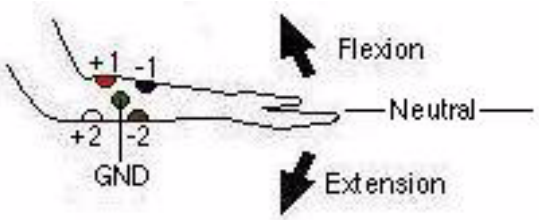

Figure 3-3: Movements performed while recording from muscles of the forearm responsible for flexion and extension of the hand.

• Return the hand to the neutral position for two seconds.

• Move the hand downward (extension) as far as possible and hold it in this position for two seconds.

• Return the hand to the neutral position for two seconds.

7 Repeat the cycle of flexion and extension two or three more times.

8 When the subject is ready to do the exercise, click **Start**. Click **AutoScale** on all channels to amplify signals. Mark the recording to indicate when the subject’s hand was flexed, extended, or in the neutral position. When the last cycle is completed, click **Stop** to halt recording.

9 Repeat the exercise described in Steps 6 and 7, but while the subject has his or her fist closed.

10 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(e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

Data Analysis

1 Scroll to the data where the EMG activity of the anterior and posterior forearm muscles was recorded while the fingers were extended (Figure 3-4 on page 3).

2 Adjust the time displayed on the **Main** window to display the three bursts of EMG activity from both the anterior and posterior muscles on the screen at the same time. Use the **Display Time** icons on the LabScribe toolbar (Figure 3-5 on page 3), or the **Display Time** box on the **Channels** page of the **Preferences** dialogue window on the **Edit** menu, to set the proper screen width. Click **OK**.

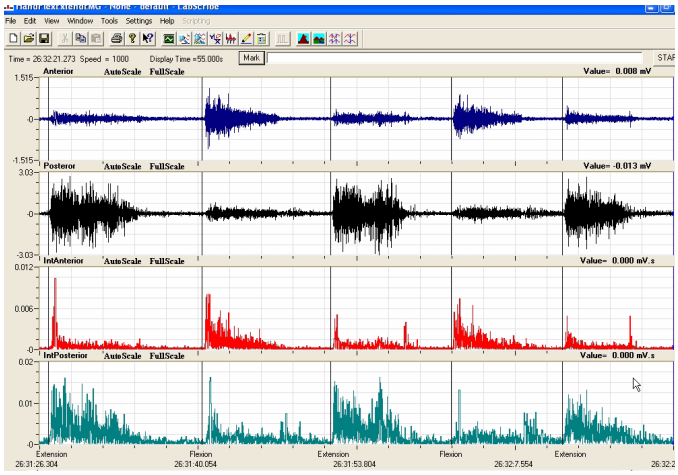

Figure 3-4: Recordings from anterior (top) and posterior (second from the top) muscles of the forearm during flexion and extension, while the subject's fingers are extended. The absolute integrals of EMG activity from the anterior and posterior muscles are displayed on the third and fourth channels.

3 Click the **2-cursor** icon on the toolbar (Figure 3-5 on page 3). Place the two cursors on the **Main** window so that at least three EMG bursts from each EMG channel (Channels 1 and 2) are included between the two cursors.

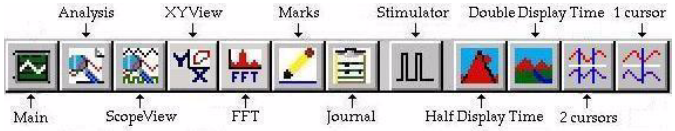

Figure 3-5: The LabScribe toolbar.

4 Click the **Analysis** icon to open the **Analysis** window. Display all channels. Select **IntegralAnt** from the **Value from Ch** list on the left side of the **Analysis** window, a **Precision** of **5**, and **Title** and **Area** from the **Table Functions** list.

5 Drag one cursor to the beginning of the absolute integral of the first EMG burst and the second cursor to the end of the integral of that burst. The **Area** under the plot of the absolute integral for the burst is a measure of the relative strength of the EMG activity during the contraction of the muscles in the anterior forearm.

6 This data can be entered into the **Journal** by either typing the titles and values directly or by using the **right-click menu**. Place the cursors to take measurements; then, select **Add Title to Journal** or **Add Data to Journal** from the **right-click** menu to add the measurements to the **Journal**.

7 Repeat Steps 5 and 6 to measure and record the Area under the absolute integrals of the two additional EMG bursts from the muscles in the anterior forearm. Average the values of the **Area** for these three bursts and record the mean in the **Journal** and on Table 3-1 on page 4.

8 Select **IntegralPost** from the **Value from Ch** list on the left side of the **Analysis** window. Use the same technique described in Steps 5, 6, and 7 to measure and record the **Area** under the absolute integrals of the three EMG bursts recorded from the muscles of the posterior forearm.

Average the values of the **Area** for these three bursts and record the mean in the **Journal** and on Table 3-1 on page 4.

Questions

1 Which muscles, anterior or posterior, had the most EMG activity during flexion?

2 Which muscles, anterior or posterior, had the most EMG activity during extension?

3 Does flexion or extension of the fingers affect the strength of EMG activity in either group of muscles?

Exercise 2: Antagonistic Muscles Doing Work

Aim: To study the EMG activity in muscles that lift weight by flexion or by extension.

Procedure

1 Use the same experimental setup used in Exercise 1.

2 Instruct the subject to rest his or her forearm, with the electrodes, on a flat surface with the palm up.

3 Place a weight (2-3kg) in the palm of the subject's hand (Figure 3-6 on page 3).

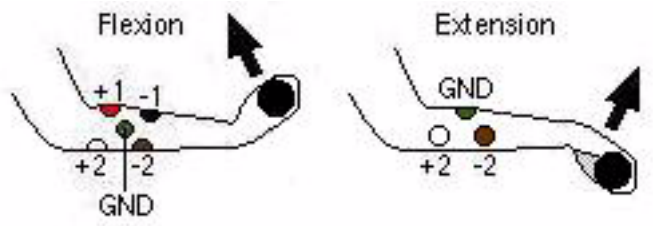

Figure 3-6: Hand in the palm-up position for lifting the weight by flexion (on the left), and the hand in the palm-down position for lifting the weight by extension (on the right).

4 Click **Start**. Record the EMG activity from the muscles of the forearm as the subject lifts the weight by the flexion. The subject should raise and hold the weight up for two seconds and then return the weight to the table top for two seconds. Repeat this cycle two or three more times. Click **Stop** to halt the recording.

5 Instruct the subject to rest his or her forearm on a flat surface with the palm down (Figure 3-6 on page 3).

6 Have the subject grip the same weight (2-3kg).

7 Click **Start**. Record the EMG activity from the muscles of the forearm as the subject lifts the weight by extension. The subject should raise and hold the weight up for two seconds and then return the weight to the table top for two seconds. Repeat this cycle two or three more times.

8 Click **Stop** to halt the recording.

9 Select **Save** in the **File** menu.

Data Analysis

1 Scroll to the data where EMG activity was recorded from the

anterior and posterior forearm muscles while a weight was lifted by flexion (Figure 3-7 on page 4).

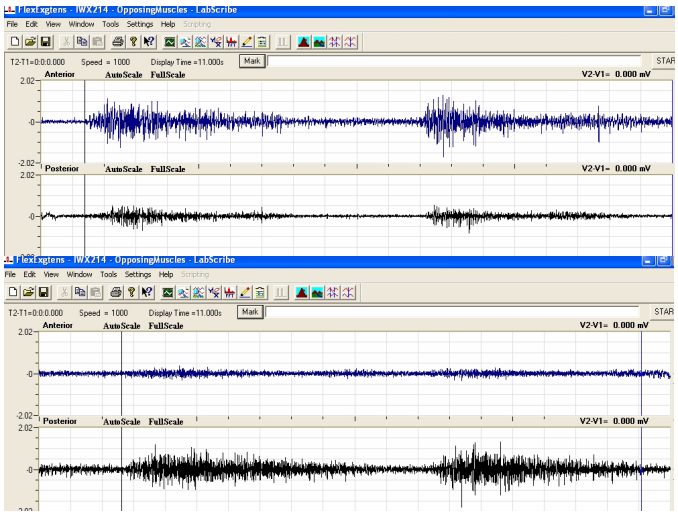

Figure 3-7: EMG activity during the lifting of a weight by flexion and extension: anterior muscles during flexion (top); posterior muscles during flexion (2nd from the top); anterior muscles during extension (3rd from the top); and, posterior muscles during extension (bottom).

2 Use the same procedures used in Exercise 1 to measure and record the relative strengths of the EMG bursts while the weight was lifted by flexion and by extension.

3 Enter the means in Table 3-1 on page 4.

Table 3-1:

	Area under the Absolute Integral of the EMG Bursts for the Listed Actions (in V.secs)	
Forearm Action	Anterior Muscles	Posterior Muscles
Flexion, Hand Open		
Extension, Hand Open		
Flexion, Fist Closed		
Extension, Fist Closed		
Flexion, Lifting Weight		
Extension, Lifting Weight		

Questions

1 Does the strength of the EMG activity in the muscles of the anterior forearm differ between flexion with a weight and without a weight?

2 Does the strength of the EMG activity in the muscles of the posterior forearm differ between extension with a weight and without a weight?

Exercise 3: Antagonistic Muscles in Lower Leg

Aim: To study muscles working in opposition to each other to maintain balance while standing.

Procedure

1 Locate the muscles of the lower leg over which the recording electrodes will be attached. Muscles can be located by performing dorsiflexion or plantar flexion of the foot and noting the areas of the lower leg where the muscles are tense during each flexion:

• One pair of recording electrodes will be placed over the anterior tibialis muscle. This muscle is located just lateral to the tibia (shinbone) in the upper part of the calf (Figure 3-8 on page 5). To locate the tibialis anterior, feel for the subject's tibia. Place your fingers 2 cm to the lateral side of the margin of the tibia and 8-12 cm below the kneecap. As the subject points his or her foot inward (supination) and upward (dorsiflexion) their foot, you should be able to see and feel the contraction of the anterior tibialis muscle beneath the skin. The first electrode in this pair will be placed about 10 centimeters below the knee on the midline of the muscle. The second electrode in this pair will be placed on the midline of the muscle, about 10 centimeters below the first electrode.

• A second pair of recording electrodes will be placed over the gastrocnemius (calf) muscle on the back of the lower leg. The first electrode in this pair will be placed about 8 centimeters below the back of the knee, along the midline of the calf muscle. The second electrode in this pair will be placed in the middle of the calf muscle along its midline, about 10 centimeters below the first electrode.

• A fifth electrode, used as the ground, is placed on the inside of the lower leg just above the ankle.

2 Use an alcohol swab to clean and scrub the areas where the electrodes will be placed (Figure 3-8 on page 5). Let the areas dry before attaching the electrodes.

3 Remove the plastic disk from a disposable electrode and apply it to one of the scrubbed areas.

4 Snap the recording lead wires onto the electrodes, so that:

• the red “+1” lead is placed on the electrode in the upper portion of the tibialis anterior.

• the black “-1” lead is placed on the electrode in the middle portion of the tibialis anterior.

• the white “+2” lead is attached to the electrode near the back of the knee.

• the brown “-2” lead is attached to the electrode in the middle of the calf muscle.

• the green “C” lead (the ground) is attached to the electrode above the ankle.

5 While the subject is sitting, click **Start**. Have the subject alternate between plantar flexion and dorsiflexion of their foot. **Click AutoScale** on all channels to amplify signals. Click **Stop**.

6 Have the subject stand erect. Click **Start**. Have the subject rock on their feet from heels to toes and back to heels, 3 or 4 times. Notice the alternating contractions of the gastrocnemius and anterior tibialis muscles when the subject rocks forward and backward.

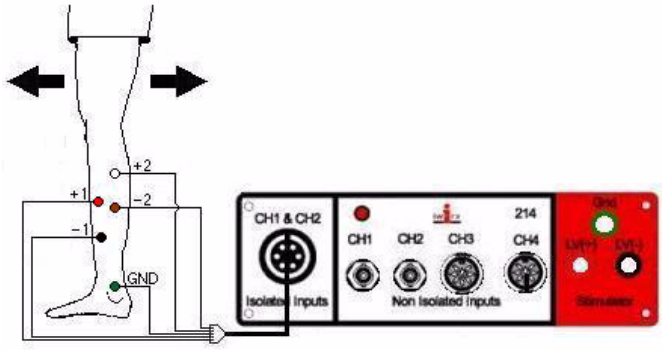

Figure 3-8: Position of electrodes used to record EMG from muscles in the lower leg during plantar flexion and dorsiflexion.

7 Have the subject rock backward and forward, 3 or 4 times, while putting more weight on the leg with the electrodes. Even though one muscle may dominate the record, the other muscle is also somewhat active.

8 Have the subject stand on one foot and remain motionless. Co-contraction of the antagonistic muscles mechanically stabilizes the joints when the subject is motionless. The stretch reflexes prevent twisting and slipping and help to maintain balance.

9 Joint stabilization is particularly important to leg and postural muscles involved in bipedal locomotion. Within the limits of artifacts induced by leg movement and cable lengths, explore the activity of the ankle flexors. Have the subject either squat or stretch upward on his/her toes.

10 Click **Stop** to halt recording.

11 Select **Save** in the **File** menu.

Data Analysis

1 Scroll to the data where EMG activity was recorded from the muscles of the anterior and posterior lower leg (Figure 3-9 on page 5).

2 Use the same procedures used in Exercise 1 to measure and record the relative strengths of the three EMG bursts from anterior and posterior muscles while the subject moved his or her legs and body in different directions:

- Standing erect on both legs;
- Rocking back and forth on both legs;
- Rocking back and forth on the leg with the electrodes;
- Standing erect on the leg with the electrodes;
- Ankle flexing by squatting or standing on the toes

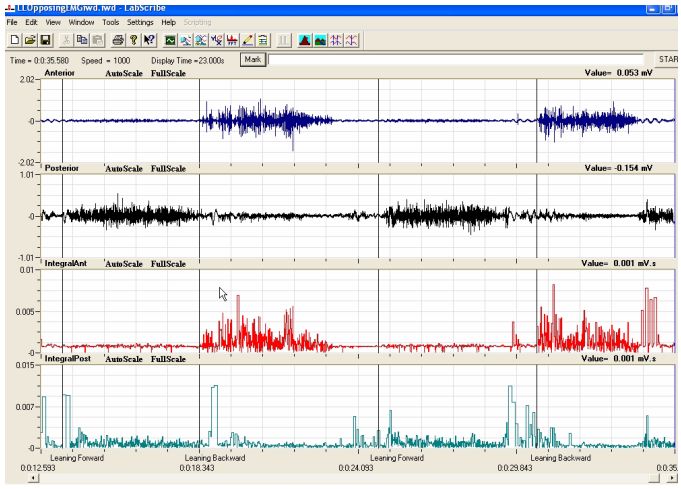

Figure 3-9: Recordings from anterior (top) and posterior (second from the top) muscles of the lower leg while the subject is leaning forward and backward. The absolute integrals of EMG activity during these flexions (plantar and dorsi) are displayed on the third and fourth channels.

Questions

1 Compare the **Areas** of the EMG integrals from the tibialis anterior during each of the activities. When was tibialis anterior activity the greatest? The least?

2 Compare the **Areas** of the EMG integrals from the gastrocnemius during each of the activities. When was gastrocnemius activity the greatest? The least?

3 How does EMG activity in the gastrocnemius correlate to EMG activity in the tibialis anterior?