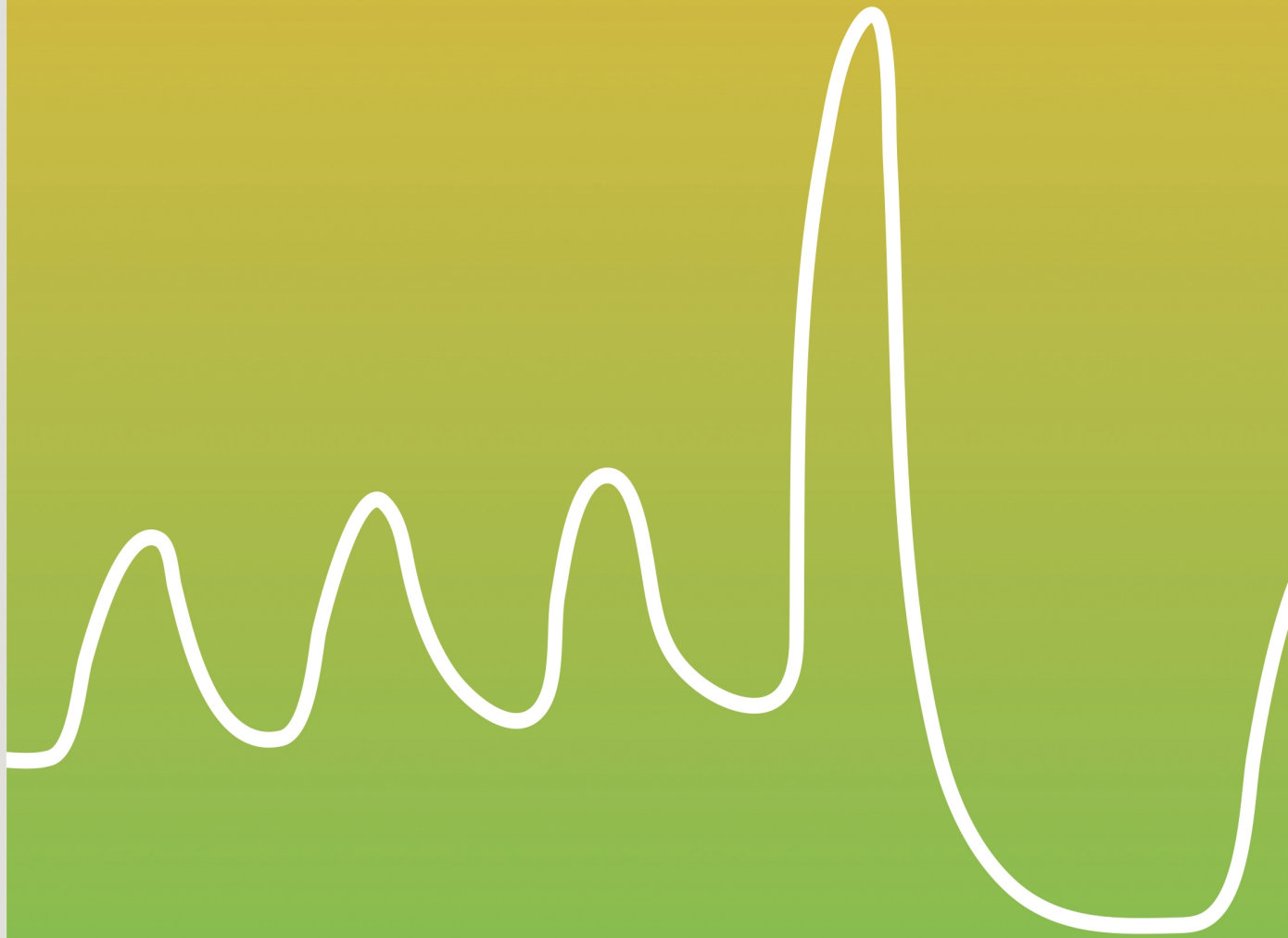




Human Physiology Experiments

Volume 2



ALB-HP2

Vernier

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Contents

Preface.....	v
About the Authors.....	vii
Equipment Used in Experiments.....	xi

Experiments

Blood Pressure and Autonomic Reflexes.....	1 - 1
Blood Pressure and Exercise.....	2 - 1
Diurnal Blood Pressure Variation.....	3 - 1
Pulse Transit Time.....	4 - 1
EKG and Electrode Position.....	5 - 1
Diving Reflex.....	6 - 1
Lung Volumes and Capacities.....	7 - 1
Spirometry and Body Position.....	8 - 1
Respiratory Response to Physiologic Challenges.....	9 - 1
Analysis of Lung Function.....	10 - 1
Simulating Asthma.....	11 - 1
Analysis of Barefoot Running.....	12 - 1
Biofeedback.....	13 - 1
Advanced Analysis of EMG.....	14 - 1
Analysis of Muscle Function.....	15 - 1

Appendices

Electronic Resources.....	A - 1
Equipment and Supplies.....	B - 1
An Introduction to Uncertainty and the Use of Statistics in Human Physiology.....	C - 1
Next Generation Science Standards (NGSS) Correlations.....	D - 1
International Baccalaureate (IB) Correlations.....	E - 1

Equipment Used in Experiments

		Blood Pressure	EKG	Respiration Belt	Spirometer	Hand Dynamometer
1	Blood Pressure and Autonomic Reflexes	X				
2	Blood Pressure and Exercise	X				
3	Diurnal Blood Pressure Variation	X				
4	Pulse Transit Time	X	X			
5	EKG and Electrode Position		X			
6	Diving Reflex		X	X		
7	Lung Volumes and Capacities*				X	
8	Spirometry and Body Position*				X	
9	Respiratory Response to Physiological Challenges*				X	
10	Analysis of Lung Function*				X	
11	Simulating Asthma*				X	
12	Analysis of Barefoot Running			X		
13	Biofeedback		X	X		
14	Advanced Analysis of EMG		X			X
15	Analysis of Muscle Function		X			

*Requires the use of bacterial filters and disposable cardboard mouthpieces.

Lung Volumes and Capacities

Measurement of lung volumes provides a tool for understanding normal function of the lungs as well as disease states. The breathing cycle is initiated by expansion of the chest. During quiet breathing, contraction of the diaphragm muscle causes it to flatten downward, increasing the vertical dimension of the thoracic cavity. Additional respiratory muscles in the chest (external intercostals) lift the ribs, expanding them outward and further increasing volume. The resulting increase in chest volume creates a negative pressure that draws air in through the nose and mouth. Normal exhalation is passive, resulting from "recoil" of the chest wall, diaphragm, and lung tissue. In contrast to passive breathing, active breathing uses additional muscles known as accessory respiratory muscles (including the sternocleidomastoid, scalenes, internal intercostals and abdominal muscle groups) to further expand and contract the thorax.

In normal breathing at rest, approximately one-tenth of the total lung capacity is used. Greater amounts are used as needed (e.g., with exercise). The following terms are used to describe lung volumes (see Figure 1):

Tidal Volume (TV)

The volume of air breathed in and out without conscious effort.

Inspiratory Reserve Volume (IRV)

The additional volume of air that can be inhaled with maximum effort after a normal inspiration.

Expiratory Reserve Volume (ERV)

The additional volume of air that can be forcibly exhaled after normal exhalation.

Vital Capacity (VC)

The total volume of air that can be exhaled after a maximum inhalation:

$$VC = TV + IRV + ERV$$

Residual Volume (RV)

The volume of air remaining in the lungs after maximum exhalation (the lungs can never be completely emptied).

Total Lung Capacity (TLC)

$$TLC = VC + RV$$

Minute Ventilation

The volume of air breathed in 1 minute:

$$\text{minute ventilation} = (TV \times \text{breaths/minute})$$

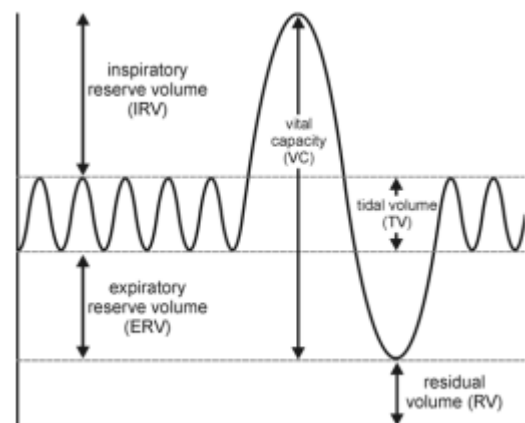


Figure 1

In this experiment, you will measure lung volumes during normal breathing and with maximum effort. You will correlate lung volumes with a variety of clinical scenarios.

Lung Volumes and Capacities

Important: The equipment used in this experiment is for educational purposes only and should not be used to diagnose medical conditions.

OBJECTIVES

- Obtain graphical representation of lung capacities and volumes.
- Compare lung volumes between males and females.
- Correlate lung volumes with clinical conditions.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Spirometer
disposable mouthpiece
disposable bacterial filter
nose clip

PROCEDURE

Select one person from your group to be the subject. **Important:** Do not volunteer to be the subject if you are currently suffering from a respiratory ailment such as a cold or the flu.

1. Launch Graphical Analysis. Connect Go Direct Spirometer to your Chromebook, computer, or mobile device.
2. Set up the data-collection mode.
 - a. Click or tap Mode to open Data Collection Settings.
 - b. Change End Collection to 60 s.
 - c. Click or tap Done.
3. Attach the larger diameter side of a bacterial filter to the "Inlet" side of the spirometer. Attach a disposable mouthpiece to the other end of the bacterial filter (see Figure 2). **Important:** The mouthpiece and bacterial filter must not be shared. If data are collected for multiple subjects, each person must have their own.

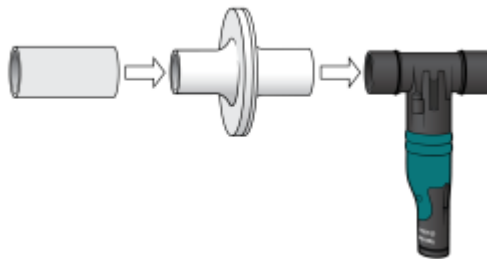




Figure 2

4. Zero the sensor.
 - a. Instruct the subject to hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The spirometer must be held straight up and down (see Figure 2). Do not breathe through the spirometer while it is being zeroed.
 - b. Click or tap the Flow Rate meter and choose Zero.
5. In this step, you will collect data. The spirometer is sensitive to the low air flow rates caused by moving the sensor, so it is important to follow the data-collection procedure carefully. Read through the following steps to become familiar with the process, and then collect data.
 - a. The subject should be seated comfortably and should put on the nose plug to ensure that he or she is only breathing through the mouth.
 - b. The subject should hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The subject should breathe normally, but should not start breathing through the spirometer until the next step. **Note:** The spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.
 - c. On the subject's inhale, instruct the subject to start breathing through the mouthpiece and click or tap Collect to start data collection.
 - d. After four cycles of normal inspirations and expirations, instruct the subject to inhale as deeply as possible (maximum inspiration) and then exhale as fully as possible (maximum expiration). *It is essential that maximum effort be expended.*
 - e. The subject should continue breathing normally after the deep breath. Allow data collection to continue until you have collected data for at least one recovery breath after the deep breath, and then stop data collection.
6. Determine tidal volume (TV).
 - a. Identify a representative peak and valley in the tidal volume (TV) portion of the graph.
 - b. Click or tap the peak and then drag to the valley that follows it.
 - c. Click or tap Graph Tools, , and choose View Statistics.
 - d. Enter the Δy value, to the nearest 0.1 L, as the total tidal volume (TV) in Table 1.
 - e. Dismiss the Statistics box.
7. Determine vital capacity (VC).
 - a. Click or tap the peak that represents the maximum inspiration, then drag to the valley that follows it.
 - b. Click or tap Graph Tools, , and choose View Statistics.
 - c. Enter the Δy value, to the nearest 0.1 L, as the vital capacity (VC) in Table 1.
 - d. Dismiss the Statistics box.
8. Determine inspiratory reserve volume (IRV).
 - a. Click or tap the peak that represents your maximum inspiration. Note the volume value.
 - b. Click or tap the tidal volume peak just before maximum inspiration. Note the volume value.
 - c. Calculate the Δy value and record it, to the nearest 0.1 L, as the inspiratory reserve volume (IRV) in Table 1.

Lung Volumes and Capacities

9. Calculate expiratory reserve volume (ERV) and enter the total to the nearest 0.1 L in Table 1.

$$ERV = VC - (IRV + TV)$$

10. Calculate total lung capacity (TLC) and enter the total to the nearest 0.1 L in Table 1. (Use the value of 1.5 L for the RV.)

$$TLC = VC + RV$$

11. Share your data with your classmates and complete the class average columns in Table 1.

DATA

Volume measurement	Individual (L)	Class average (male) (L)	Class average (female) (L)
Tidal volume (TV)			
Inspiratory reserve (IRV)			
Expiratory reserve (ERV)			
Vital capacity (VC)			
Residual volume (RV)	~1.5	~1.5	~1.5
Total lung capacity (TLC)			

DATA ANALYSIS

1. What was the tidal volume (TV)? What would you expect the TV to be if you inhaled a foreign object that completely obstructed the right mainstem bronchus?
2. Describe the difference between lung volumes for males and females. What might account for this?
3. Calculate the minute ventilation at rest.

$$\text{minute ventilation at rest} = (TV \times \text{breaths/minute})$$

If someone were taking shallow breaths ($TV = 0.20$ L) to avoid severe pain from rib fractures, what respiratory rate will be required to achieve the same minute volume?

4. Exposure to occupational hazards such as coal dust, silica dust, and asbestos may lead to *fibrosis*, or scarring of lung tissue. With this condition, the lungs become stiff and have more recoil. What would happen to TLC and VC under these conditions?
5. In severe emphysema there is destruction of lung tissue and reduced recoil. What would you expect to happen to TLC and VC?
6. What would you expect to happen to the Expiratory Reserve Volume when someone is treading water in a lake?

EXTENSION

Repeat the experiment with the chest or abdomen constricted (use a girdle or ace bandage).



Advanced Analysis of EMG

Motor output (e.g., walking, jogging, or running) is the result of communication between the brain and individual muscle fibers of the musculoskeletal system. Electrical impulses from the brain are relayed to motor neurons in the spinal cord and peripheral nerves, when then travel to the neuromuscular junctions on muscle fibers.

A motor unit is defined as the muscle fibers that a single motor neuron innervates (see Figure 1). In mammals, each individual muscle fiber is only innervated by one motor neuron, but a single motor neuron can innervate many muscle fibers. All of the motor units that innervate a given muscle are referred to as a motor pool.

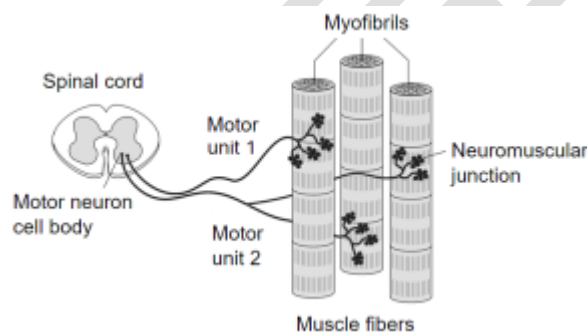


Figure 1

Within each motor unit, the individual muscle fibers contract with an all-or-none response when stimulated, meaning that the muscle fiber contracts to its maximum potential or not at all. The strength of contraction of a whole muscle depends on how many motor units are activated. The amount of force produced can be correlated with electrical activity measured over the muscle with a technique called electromyography, or EMG. Analyzing muscle activity can be complex. Patterns of muscle output (e.g., walking, jogging, or running) are related to how long different motor pools are active, not just how much force a given muscle produces

In this experiment, you will use a hand dynamometer to measure maximum grip strength and correlate the production of force with the electrical activity (EMG) of the muscles involved using an EKG sensor. You will use two different methods to analyze muscle activity: EMG amplitude and the integral of the EMG. EMG amplitude measures the height of the EMG signal, whereas the integral measures the area under the EMG graph.

Important: The equipment used in this experiment is for educational purposes only and should not be used to diagnose medical conditions.

OBJECTIVES

- Obtain graphical representation of the electrical activity of a muscle.
- Correlate grip strength duration with the integral of the EMG.
- Correlate grip strength amplitude with the integral of the EMG.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Hand Dynamometer
Go Direct EKG
electrode tabs

PROCEDURE

Select one person from your group to be the subject. **Important:** Do not volunteer to be the subject if you suffer from arthritis, or other conditions of the hand, wrist, forearm, or elbow.

Part I Grip Strength Duration and EMG activity

1. Connect and set up the sensors.
 - a. Launch Graphical Analysis.
 - b. Connect Go Direct EKG to your Chromebook, computer, or mobile device.
 - c. Click or tap Sensor Channels. Deselect the EKG channel and select the EMG Rectified channel.
 - d. Connect Go Direct Hand Dynamometer to your Chromebook, computer, or mobile device. The default channel is correct for this experiment.
 - e. Click or tap Done.
2. Zero the readings for the hand dynamometer.
 - a. Hold the hand dynamometer along the sides, in an upright position as in Figure 2, but do not put any force on the pads of the sensor.
 - b. When the readings stabilize, click or tap the Force meter and choose Zero. The readings for the sensor should be close to zero.
3. Attach three electrode tabs to one of your arms, as shown in Figure 3. 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. The third electrode tab should be placed on the upper arm.

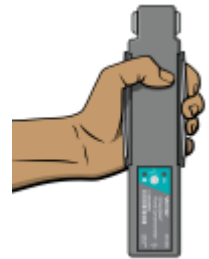


Figure 2

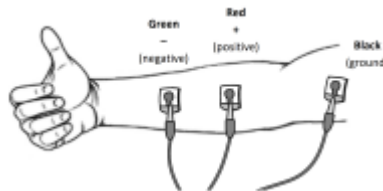





Figure 3


4. Attach the green and red EKG clips to the tabs on the ventral forearm. For this activity, the green and red clips are interchangeable. Attach the black clip to the upper arm.
5. Instruct the subject to sit with his or her back straight and feet flat on the floor. The subject's elbow should be at a 90° angle, with the arm unsupported.

6. Click or tap Collect to start data collection. Instruct the subject to wait for 2 seconds, and then grip the sensor with full strength for the rest of the data-collection period. Data collection will end after 10 seconds.
7. Determine the mean force exerted during maximal effort.
 - a. Select the data from 2–10 s on the force vs. time graph.
 - b. Click or tap Graph Tools, , and choose View Statistics.
 - c. Record the mean force in Table 1, rounding to the nearest 0.1 N.
 - d. Dismiss the Statistics box.
8. Using the EMG graph, repeat Step 7 to record the maximum, minimum, and Δ mV. Record the values in Table 1, rounding to the nearest 0.01 mV.
9. Determine the integral of the EMG graph.
 - a. Using the EMG graph, click or tap Graph Tools, , and choose View Integral.
 - b. Record the area in Table 1, rounding to the nearest 0.01 mV•s.
10. Instruct the subject to sit with his or her back straight and feet flat on the floor. The subject's elbow should be at a 90° angle, with the arm unsupported.
11. Click or tap Collect to start data collection. Instruct the subject to wait for 5 seconds. Then have them grip the sensor with full strength for the rest of the data-collection period. Data collection will end after 10 seconds.
12. Repeat Steps 7–9, but select the data from 4–10 s on each graph. Record your data in the row for Trial 2.
13. Click or tap Collect to start data collection. Instruct the subject to wait for 7 seconds. Then have them grip the sensor with full strength for the rest of the data-collection period. Data collection will end after 10 seconds.
14. Repeat Steps 7–9, but select the data from 6–10 s on each graph. Record your data in the row for Trial 3.

Part II Grip Strength Amplitude and EMG Activity

15. Instruct the subject to sit with his or her back straight and feet flat on the floor. The subject's elbow should be at a 90° angle, with the arm unsupported. The hand dynamometer should be held in the same hand used in Part I of this experiment.
16. Click or tap Collect to start data collection. Instruct the subject to wait for 2 seconds and then grip the sensor with full strength throughout the rest of the data-collection period. Data collection will end after 10 seconds.
17. Determine the mean force exerted during maximal effort.
 - a. Select the data from 2 s to 10 s on the force vs. time graph.
 - b. Click or tap Graph Tools, , and choose View Statistics.

Advanced Analysis of EMG

- c. Record the mean force in Table 2, rounding to the nearest 0.1 N.
 - d. Dismiss the Statistics box.
18. Using the EMG graph, repeat Step 16 to record the ΔmV . Record the values in Table 2, rounding to the nearest 0.01 mV.
19. Determine the integral of the EMG graph.
- a. Click or tap Graph Tools, , and choose View Integral.
 - b. Record the area reported in Table 2, rounding to the nearest 0.01 mV•s.
20. In the next few steps, you will collect data for a force that corresponds to 50% and 25% of maximum effort for the subject. To get started, calculate the force that corresponds to 50% and 25% of maximum effort for the subject. Record these values in Table 2.
21. Collect data for the subject gripping at 50% of maximum.
- a. Refer to Table 2 to remind the group about the force that corresponds to 50% of maximal effort, and identify that value on the graph as well.
 - b. Click or tap Collect to start data collection. Instruct the subject to wait for 2 seconds and then grip the sensor at 50% of maximal effort.
 - c. Repeat Steps 16–18. Record your data in the row for Trial 2.
22. Collect data for the subject gripping at 25% of maximum.
- a. Refer to Table 2 to remind the group about the force that corresponds to 25% of maximal effort, and identify that value on the graph as well.
 - b. Click or tap Collect to start data collection. Instruct the subject to wait for 2 seconds and then grip the sensor at 25% of maximal effort.
 - c. Repeat Steps 16–18. Record your data in the row for Trial 3.

DATA

Trial	Duration (s)	Mean grip strength (N)	EMG data	
			Amplitude (ΔmV)	Area (mV•s)
1	8			
2	5			
3	3			

Trial	Percent of maximum force (%)	Mean grip strength (N)	EMG data	
			Amplitude (ΔmV)	Area ($mV \cdot s$)
1	100			
2	50			
3	25			

DATA ANALYSIS

1. Use the data in Table 1 to calculate the percent change in amplitude (ΔmV) in electrical activity that occurred with decreasing duration of activity. Use the amplitude (ΔmV) and duration in Trial 1 as 100%. Do you see a decrease in EMG amplitude as duration decreases?
2. Use the data in Table 1 to calculate the percent change in EMG area ($mV \cdot s$) in electrical activity that occurred with decreasing duration of activity. Use the area ($mV \cdot s$) and duration in Trial 1 as 100%. Do you see a decrease in EMG area as duration decreases?
3. Use the graphs and the data in Table 1 to explain if EMG amplitude or area is a better measure of muscle activity when considering the time a muscle is active?
4. Use the data in Table 2 to calculate the percent change in amplitude (ΔmV) in electrical activity that occurred with decreasing maximum force. Use the amplitude (ΔmV) in Trial 1 as 100%. Do you see a decrease in EMG amplitude as force decreases?
5. Use the data in Table 2 to calculate the percent change in EMG area ($mV \cdot s$) in electrical activity that occurred with decreasing percentage of maximum force. Use the area ($mV \cdot s$) in Trial 1 as 100%. Do you see a decrease in EMG area as force decreases?
6. Use the graphs and the data in Tables 1 and 2 to explain if EMG amplitude or area is a better measure of muscle activity when considering both the strength and duration of muscle activity.

EXTENSIONS

1. Plot the data in Table 1 as a series of graphs. Plot duration *vs.* amplitude, and then perform a linear fit to find the slope of this line. Then plot duration *vs.* area and perform a linear fit to find the slope of this line. Which line has the greatest slope?
2. Plot the data in Table 2 as a series of graphs. Plot grip strength *vs.* amplitude, then perform a linear fit to find the slope of this line. Then plot grip strength *vs.* area and perform a linear fit to find the slope of this line. Which line has the greatest slope?

Advanced Analysis of EMG

3. Record and analyze EMGs from different muscles.
4. Investigate and analyze grip strength and muscle fatigue using EMG area.

