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Philadelphia, PA

Exploring Health & Biomedical Science with Vernier: Tips, Tricks, and Best Practices

Experiments

Limb Position and Grip Strength

- Go Direct® Hand Dynamometer

Monitoring EKG

- Go Direct EKG Sensor

Introduction to Electromyography

- Go Direct EKG Sensor
- Go Direct Hand Dynamometer

Respiration and Ventilation

- Go Direct Respiration Belt

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Limb Position and Grip Strength

The importance of hand strength and function is evident in all aspects of our daily living, from eating and maintaining personal hygiene to typing at the computer, performing brain surgery, or playing tennis or the piano. People suffering from arthritis or hand injury quickly appreciate the difficulty of performing even simple tasks with reduced grip strength.

Testing of hand grip strength is used by orthopedic surgeons and physical therapists to evaluate the extent of an injury and the progress of recovery. Grip strength can also be used to diagnose neuromuscular problems such as stroke, herniated disks in the neck, carpal tunnel syndrome, and elbow tendonitis. Athletes are interested in grip strength because it relates to performance in many sports, such as tennis, golf, baseball, football, gymnastics, and rock climbing.

Pinch strength is a way for occupational therapists to measure loss of fine-motor strength in the thumb, fingers, and forearm. It is useful for analyzing the extent of an injury and the outcome from surgery or therapy.

In Part I of this experiment, you will measure and compare grip strength in your right and left hands. You will also correlate grip strength with arm position and handedness. In Part II you will analyze the pinch strength of each of your four fingers on your dominant hand.

OBJECTIVES

- Measure and compare grip strength of your right and left hands in three different lower arm positions.
- Compare grip strength of dominant hand and nondominant hand.
- Compare the pinch strengths of the individual fingers of the dominant hand.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Hand Dynamometer

PROCEDURE

Each person in the group will have a chance to be the subject. **Important**: Do not attempt this exercise if you have arthritis, carpal tunnel syndrome, or any ailment that might be exacerbated by using the muscles of your arm and hand.

Part I Hand grip strength

1. Launch Graphical Analysis. Connect the Go Direct Hand Dynamometer 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 Rate to 100 samples/s and End Collection to 10 s.

   c. Click or tap Done.

3. Zero the readings for the hand dynamometer.

   a. Have the subject hold the hand dynamometer in an upright position as in Figure 1; there should not be 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.

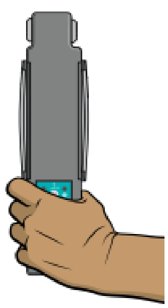

Figure 1

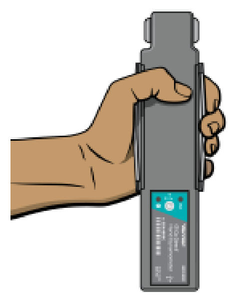

Figure 2

4. Have the subject sit with their back straight and feet flat on the floor. The hand dynamometer should be held in the left hand. The elbow should be at a 90° angle, with the arm unsupported and the hand in a neutral position (see Figure 2).

5. Have the subject close their eyes or avert them from the screen.

6. Click or tap Collect to start data collection. After collecting 2 s of baseline data, instruct the subject to grip the sensor with full strength for the next 8 s. Data will be collected for 10 s.

7. Determine the maximum and mean force exerted by your hand during a portion of the data-collection period.

   a. Select the data from 4 s to 8 s.

   b. Click or tap Graph Options, , and choose View Statistics.

   c. Record the maximum and mean force in Table 1.

   d. Dismiss the Statistics box.

8. Repeat Steps 3−7 with the right hand. **Note**: The previous data set is automatically saved.

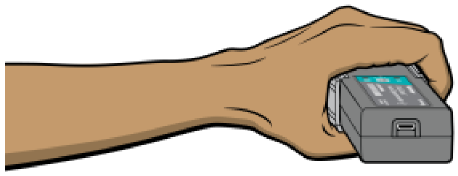

Figure 3

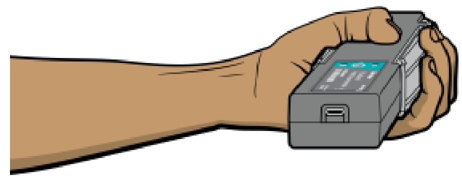

Figure 4

9. Repeat Steps 3−8 with the hand in a pronated position (palm down) (see Figure 3).
10. Repeat Steps 3−8 with the hand in a supinated position (palm up) (see Figure 4).
11. Repeat Steps 3–10 for each group member.
12. Work with your classmates to complete Table 2.

Part II Pinch strength

13. Change the data-collection duration.
    a. Click or tap Mode to open Data Collection Settings.
    b. Change End Collection to 30 s.
    c. Click or tap Done.
14. Have the subject sit with their back straight and feet flat on the floor, holding the base of the sensor with the nondominant hand (see Figure 5). **Note**: No additional force should be placed on the sensor by this hand.

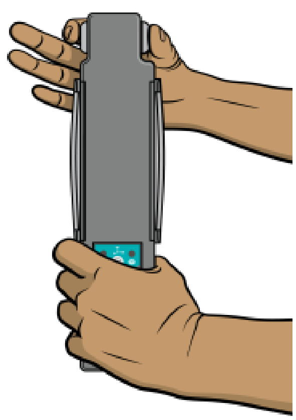

Figure 5

15. Have the subject close their eyes or avert them from the screen.
16. Zero the readings for the hand dynamometer.
    a. Hold the hand dynamometer at the base, in an upright position. Do not put any force on the pads of the hand dynamometer.
    b. When the readings stabilize, click or tap the Force meter and choose Zero. The readings for the sensor should be close to zero.

17. Click or tap Collect to start data collection. Instruct the subject to immediately pinch the end of the sensor between the pads of the thumb and forefinger of their dominant hand, and hold for 5 s.

18. Instruct the subject to switch to successive fingers every 5 s. Data collection will stop after 30 s.

19. Determine the mean force applied during each pinch.

    a. Select the data in the first plateau on the graph to select the data representing the pinch strength of the thumb and index finger.
    b. Click or tap Graph Options, , and choose View Statistics. Record the mean pinch strength to the nearest 0.1 N in Table 3.
    c. Select the data in the second plateau, representing the pinch strength of the thumb and middle finger.
    d. Click or tap Graph Options, , and choose View Statistics. Record the mean pinch strength to the nearest 0.1 N in Table 3.
    e. Repeat this process to obtain statistics for the pinch strengths of the remaining two fingers.

20. Repeat Steps 16–19 for each person in the group.

DATA

Table 1: Individual Grip Strength Data

	Maximum force (N)	Mean force (N)
Right hand grip strength: neutral		
Left hand grip strength: neutral		
Right hand grip strength: prone		
Left hand grip strength: prone		
Right hand grip strength: supine		
Left hand grip strength: supine		

Table 2: Class Grip Strength Data

	Average mean force: neutral (N)	
	Right hand	Left hand
Right-handed individuals		
Left-handed individuals		

Table 3: Individual Pinch Strength Data	
	Mean force (N)
Dominant hand index finger	
Dominant hand middle finger	
Dominant hand ring finger	
Dominant hand little finger	

DATA ANALYSIS

1. Is there a difference in grip strength in your dominant and nondominant hands? Are you surprised by the result?
2. Does there appear to be a correlation between grip strength and arm position? If so, in which position was grip the strongest? Weakest?
3. Examining the data in Table 2, does there appear to be a correlation between "handedness" and grip strength? Are the results similar for right-handed and left-handed people?
4. Using the pinch strength data in Table 3, describe the difference in strength between fingers. Where is the difference the largest?
5. List at least two possible reasons for the differences you see between the pinch strength of the first two fingers and the second two fingers. In your answer consider actions of the hand and musculature. **Note**: You can use an anatomy book or atlas to view the muscles of the forearm and hand.

EXTENSIONS

1. Perform daily hand-strengthening exercises to increase your grip and/or pinch strength (such as squeezing a rubber ball). Measure your grip and/or pinch strength after two weeks and after four weeks. Compare the results with your original data.
2. Design an experiment to explore whether there is a correlation between grip strength and other physical characteristics such as height or arm circumference.

Monitoring EKG

An electrocardiogram, or EKG, is a graphical recording of the electrical events occurring within the heart. A typical EKG tracing consists of five identifiable deflections. Each deflection is noted by one of the letters P, Q, R, S, or T. The P wave is the first waveform in a tracing and represents the depolarization of the heart's atria. The next waveform is a complex and consists of the Q, R, and S deflection. The QRS complex represents the depolarization of the heart's ventricles. The deflection that represents the repolarization of the atria is usually undetectable because of the intensity of the QRS waveform. The final waveform is the T wave and it represents the repolarization of the ventricles.

Because an EKG is a recording of the heart's electrical events, it is valuable in diagnosing diseases or ailments that damage the conductive abilities of the heart muscle. When cardiac muscle cells are damaged or destroyed, they are no longer able to conduct the electrical impulses that flow through them. This causes the electrical signal to terminate at the damaged tissue or directed away from the signal flow. The termination or redirection of the electrical signal will alter the manner in which the heart contracts. A cardiologist can look at a patient's electrocardiogram and determine the presence of damaged cardiac muscle based on the waveform as well as the time interval between electrical events.

In this activity, you will use the EKG sensor to make a five-second graphical recording of the heart's electrical events. From this recording, you will identify the previously mentioned waveform components and determine the time intervals associated with each.

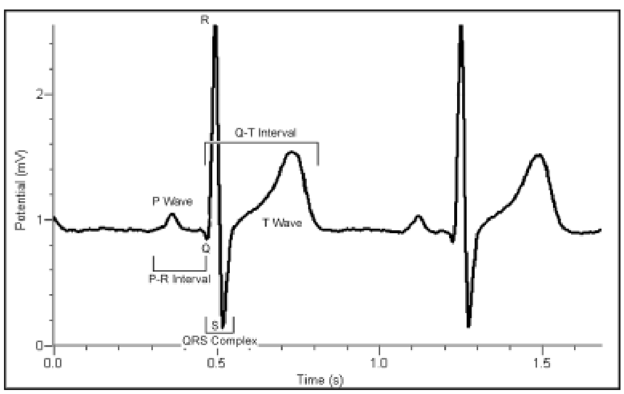

Figure 1

OBJECTIVES

- Use an EKG Sensor to graph the heart's electrical activity.
- Determine the time interval between EKG events.
- Calculate heart rate based on the EKG recording.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct EKG
disposable electrode tabs

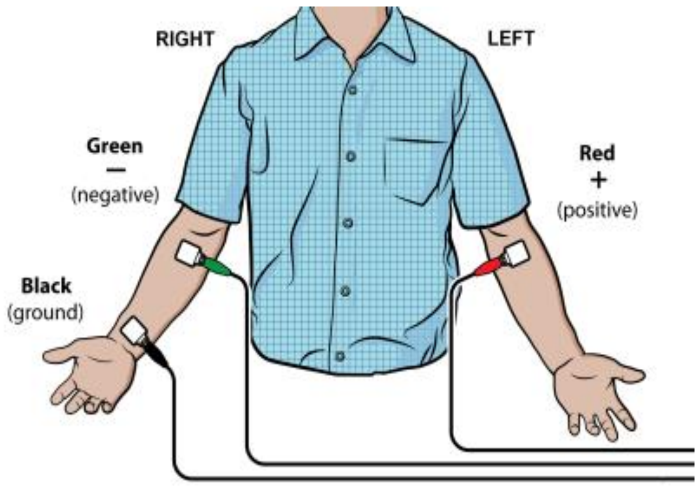

Figure 2

PROCEDURE

1. Launch Graphical Analysis. Connect the EKG Sensor to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Change End Collection to 5 s. Click or tap Done.

3. Attach three electrode tabs to the subject's arms, as shown in Figure 2. Place a single patch on the inside of the right wrist, on the inside of the right upper forearm (distal to the elbow), and on the inside of the left upper forearm (distal to elbow).

4. Connect the EKG clips to the electrode tabs as shown in Figure 2.

5. The subject should sit in a relaxed position in a chair, with forearms resting on his or her legs, on the tabletop, or on the arms of the chair. When the subject is properly positioned, click or tap Collect to start data collection. Data collection will stop after 3 seconds.

6. Once data have been collected, a graph with voltage and time values will be displayed. Click or tap the graph to examine the data. **Note**: You can also adjust the Examine line by dragging the line.

7. For at least two heartbeats, identify the various EKG waveforms using Figure 1 and determine the time intervals listed in Table 1.

Table 1	
Waveform	Time interval
P-R interval	Time from the beginning of P wave to the start of the QRS complex
QRS complex	Time from Q deflection to S deflection
Q-T interval	Time from Q deflection to the end of the T

8. Record the average for each set of time intervals in Table 2.

9. Calculate the heart rate in beats/min using the EKG data. Remember to include the time between the end of the T Wave and the beginning of the next P Wave. Use the total number of seconds for one full heart cycle in the equation. Record the heart rate in Table 2.

$$\frac{\#\text{ beats}}{\text{minute}} = \frac{1\text{ beat}}{\_\_\text{ seconds}} \times \frac{60\text{ seconds}}{1\text{ minute}}$$

10. If your EKG was unsatisfactory, repeat Steps 5 and 6.

11. (optional) Export a copy of your EKG graph. Identify and label the various waveforms on the graph.

DATA

Table 2	
Interval	Time (s)
P - R	
QRS	
Q - T	
Heart rate: ___________ beats/min	

QUESTIONS

1. The electrocardiogram is a powerful tool used to diagnose certain types of heart disease. Why is it important to look at the time intervals of the different waveforms?

2. What property of heart muscle must be altered for an EKG to detect a problem? Explain.

3. Based on what you have learned regarding electrocardiograms, can they be used to diagnose all heart diseases or defects? Explain.

4. Describe a cardiovascular problem that could be diagnosed by a cardiologist using an electrocardiogram.

EXTENSION

Using data collected with the EKG Sensor, it is possible to determine a more accurate maximum heart rate value for a person. The commonly used formula for calculating maximum heart rate is:

220 bpm – Individual's Age = Max Heart Rate

While this formula is sufficient for general purposes, it fails to take into account physical differences such as size, and fitness level. For example, an individual that engages in regular exercise will likely have a heart that operates more efficiently due to the effects of athletic training.

To calculate your maximum heart rate, do the following:

a. Run in place or perform some type of exercise, such as jump-n-jacks, for 1 minute.
b. Repeat Steps 1–9 to collect and analyze your electrocardiogram. When analyzing the data in Step 9, only determine the average Q-T interval.
c. Divide 60 seconds by the Q-T interval to calculate your maximum heart rate.

Introduction to Electromyography

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 that travel down interneurons and motor neurons (in the spinal cord and peripheral nerves) to the neuromuscular junctions that form a motor unit (see Figure 1).

The individual muscle fibers within each motor unit 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 and can be correlated with electrical activity measured over the muscle with a technique called electromyography, or EMG.

In this experiment, you will use the Hand Dynamometer to measure maximum grip strength and correlate this with electrical activity of the muscles involved as measured using the 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.

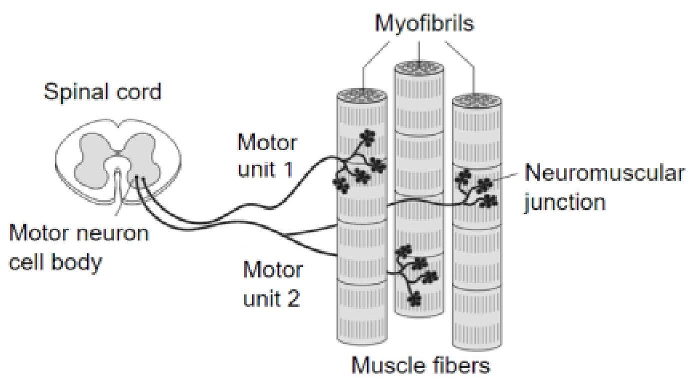

Figure 1

OBJECTIVES

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

MATERIALS

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

PROCEDURE

Part I Grip strength without visual feedback

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

1. Connect and set up the sensors.
    a. Launch Graphical Analysis.
    b. Connect the Go Direct EKG Sensor 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 the 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. Click or tap Mode to open Data Collection Settings. Change Rate to 100 samples/s and End Collection to 60 s. Click or tap Done.
3. Zero the readings for the hand dynamometer.
    a. Hold the hand dynamometer in an upright position as in Figure 2; 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.

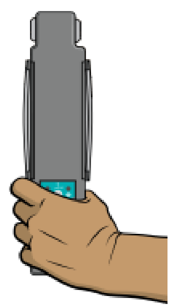

Figure 2

4. Set up the EKG sensor.
    a. 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 tab should be on the upper arm.
    b. Attach the green and red leads to the tabs on the ventral forearm. For this activity, the green and red leads are interchangeable.
    c. Attach the black lead to the upper arm.

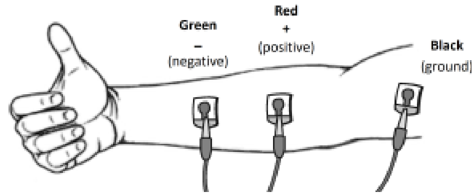

Figure 3

5. Have the subject sit with their 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 their eyes or avert them from the screen.

7. Instruct the subject to grip the sensor with full strength and click or tap Collect to start data collection. The subject should exert maximum effort throughout the data-collection period.

8. At 40 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 60 s.

9. Determine the mean force exerted during three time intervals.

   a. Select the data from 0 s to 20 s on the force *vs*. time graph.
   b. Click or tap Graph Options, , and choose View Statistics.
   c. Record the mean force in Table 1, rounding to the nearest 0.1 N.
   d. Dismiss the Statistics box.
   e. Repeat this process to find the mean force for two other intervals: 20−40 s and 40−60 s.

10. Using the Potential graph, repeat Step 9 to record the maximum, minimum, and ΔmV during three time intervals: 0–20 s, 20−40 s, and 40−60 s. Record the values in Table 1, rounding to the nearest 0.01 mV.

Part II Grip strength with visual feedback

11. Have the subject sit with their 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 their elbow at a 90° angle, with the arm unsupported, and to close their eyes, or avert them from the screen.

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

13. At 40 s, instruct the subject to watch the screen and attempt to match their beginning grip strength (the level achieved in the first few seconds of the experiment). The subject should maintain this grip for the duration of the data-collection period. Data will be collected for 60 s.

14. Determine the mean force exerted during three time intervals.

   a. Select the data from 0 s to 20 s on the force *vs*. time graph.
   b. Click or tap Graph Options, , and choose View Statistics.

c. Record the mean force in Table 1, rounding to the nearest 0.1 N.

d. Dismiss the Statistics box.

e. Repeat these steps to find the mean force for two other intervals: 20−40 s and 40−60 s.

15. Using the EMG graph, repeat Step 14 to record the maximum, minimum, and ΔmV during three time intervals: 0–20 s, 20−40 s, and 40−60 s. Record the values in Table 1, rounding to the nearest 0.01 mV.

Part III Repetitive grip strength

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

17. Instruct the subject to rapidly grip and relax their grip on the sensor (approximately twice per second). Click or tap Collect to start data collection. The subject should exert maximum effort throughout the duration of data collection.

18. At 40 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

19. Determine the mean force exerted during three time intervals.

    a. Select the data from 0 s to 20 s on the force *vs*. time graph.

    b. Click or tap Graph Options, , and choose View Statistics.

    c. Record the mean force in Table 1, rounding to the nearest 0.1 N.

    d. Dismiss the Statistics box.

    e. Repeat these steps to find the mean force for two other intervals: 20−40 s and 40−60 s.

20. Using the Potential graph, repeat Step 19 to record the maximum, minimum, and ΔmV during three time intervals: 0–20 s, 20−40 s, and 40−60 s. Record the values in Table 1, rounding to the nearest 0.01 mV.

DATA

Table 1: Continuous Grip Strength without Visual Feedback				
Time interval	Mean grip strength (N)	EMG data		
		Max (mV)	Min (mV)	ΔmV
0–20 s				
20–40 s				
40–60 s				

Table 2: Continuous Grip Strength with Visual Feedback				
Time interval	Mean grip strength (N)	EMG data		
		Max (mV)	Min (mV)	ΔmV
0–20 s				
20–40 s				
40–60 s				

Table 3: Repetitive Grip Strength				
Time interval	Mean grip strength (N)	EMG data		
		Max (mV)	Min (mV)	ΔmV
0–20 s				
20–40 s				
40–60 s				

DATA ANALYSIS

1. Use the data in Table 1 to calculate the percent loss of grip strength that occurred between the 0–20 s and 20–40 s intervals. Describe a situation in which such a loss of grip strength is noticeable in your day-to-day life.

2. Use the data in Table 1 to calculate the percent change in amplitude (ΔmV) in electrical activity that occurred between the 0–20 s and 20–40 s intervals. Do the same for grip strength. What accounts for the difference in the percent change observed in grip strength and ΔmV for the two time intervals?

3. Compare mean grip strengths and ΔmV for the 0–20 s and 40–60 s in Table 1. Do your findings support or refute the practice of "coaching from the sidelines" at sporting events?

4. Use the graphs and the data in Table 1 to explain how our neuromuscular systems attempt to overcome fatigue during heavy work or exercise. How might fatigue increase the risk of musculoskeletal injury?

5. Compare the data in Tables 1 and 2. Explain any differences seen in the 40–60 s time intervals between the two tables. What does this tell you about the brain's role in fatigue?

6. The mean grip strength is much lower for repetitive gripping (Table 3) than for continuous gripping because repetitive relaxation of the hand is averaged into the calculation.

   a. Compare your mean grip strength during the 0–20 s and 40–60 s time intervals in Tables 1 and 3. Comparing continuous gripping to repetitive gripping, was there a difference in your ability to recover strength with coaching?

   b. Calculate the percent change in mean grip strength between the 1–20 s and 20–40 s time intervals in Tables 1 and 3. Do your answers support brief relaxation of muscles to delay fatigue?

Respiration and Ventilation

Your respiratory system allows you to obtain oxygen, eliminate carbon dioxide, and regulate the blood's pH level. Ventilation refers to the movement of air between the lungs and the environment. The process of taking in air is known as *inspiration*, while the process of blowing out air is called *expiration*. A respiratory cycle consists of one inspiration and one expiration.

The rate at which your body performs a respiratory cycle is dependent upon the levels of oxygen and carbon dioxide in your blood, although the control of respiratory patterns by the brain is complex. The respiratory centers in the brain stem receive input from a variety of sources, including mechanoreceptors, chemoreceptors, the hypothalamus and the cerebral cortex. The respiratory centers can alter breathing to change both depth and rate of ventilation. While basic respiratory patterns fall under control of the autonomic nervous system (especially while sleeping), they can be overridden by the cerebral cortex to allow activities such as speaking, singing, or playing a wind instrument.

You will learn how to use a respiration belt to monitor respiratory patterns under different conditions. A respiration belt will be strapped around the test subject. Each respiratory cycle will be recorded, allowing you to calculate a respiratory rate for comparison at different conditions.

OBJECTIVES

- Use a respiration belt to monitor the respiratory rate of an individual.
- Evaluate the effect of holding of breath on the respiratory cycle.
- Evaluate the effect of rebreathing of air on the respiratory cycle.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Respiration Belt
small paper bag

PROCEDURE

1. Launch Graphical Analysis. Connect Go Direct Respiration Belt to your Chromebook, computer, or mobile device.

2. Select a member of your lab group as the test subject. Place the respiration belt around the subject's chest just below the sternum.

3. Tighten the belt until the tension indicator light, located in the bottom left corner of the sensor label, just below the check mark, turns green. **Note**: If the light is not on, tighten the strap until the light turns green. Loosen the strap if the light turns red. A red light indicates too much tension.

4. Have the subject sit upright in a chair and breathe normally. The test subject should be sitting and facing away from the device screen.

Part I Holding of breath

5. Click or tap Collect to start data collection.

6. When data have been collected for 60 s, have the subject hold their breath for 30 to 45 s. Once the breath has been released, the test subject should breathe normally for the remainder of the data-collection period.

7. Click or tap the graph to examine the data. **Note**: You can also adjust the Examine line by dragging the line.

8. Determine the respiration rate before and after the subject's breath was held. Record the values in Table 1.

Part II Rebreathing of air

Important: Anyone prone to dizziness or nausea should not be tested in this section of the experiment. If the test subject experiences dizziness, nausea, or a headache during data collection, testing should be stopped immediately.

9. Have the test subject cover their mouth with a small paper bag, tight enough to create an air-tight seal. The test subject should breathe normally into the bag throughout the course of the data collection process.

10. Click or tap Collect to start data collection. Again, the test subject should be sitting and facing away from the screen.

11. Collect respiration data for the full 300 s while the subject is breathing into the sack.

12. Once you have finished collecting data, calculate the maximum height of the respiration waveforms for the several time intervals.

    a. Select the data from 0 to 30 s.
    b. Click or tap Graph Options, , and choose View Statistics.
    c. Subtract the minimum force from the maximum force to calculate the amplitude. Record this value in Table 2.
    d. Dismiss the Statistics box.
    e. Repeat this process for two other time intervals: 120 to 150 s and 240 to 270 s.

DATA

Table 1: Holding of Breath	
	Rate (breaths/minute)
Before holding breath	
After holding breath	

Table 2: Rebreathing of Air	
Time interval (s)	Amplitudes of respiration waves (N)
0 to 30	
120 to 150	
240 to 270	

QUESTIONS

1. Did the respiratory rate of the subject change after they stopped holding their breath? If so, describe how it changed.

2. What is different about the size (amplitude) or shape (frequency) of the respiratory waveforms following the release of the subject's breath? Explain.

3. What would be the significance of an increase in the amplitude and frequency of the waveform while the subject was breathing into the bag?

4. How did the respiratory waveforms change while the subject was breathing into the bag? How would you interpret this result?

5. Explain how you think carbon dioxide affects your respiration rate.