Human Physiology with Vernier

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NSTA National 2018
Atlanta, GA

HANDS-ON ACTIVITIES

Grip Strength Comparison
- Hand Dynamometer

Analyzing the Heart with EKG
- Go Direct EKG

EMG and Muscle Fatigue
- EKG Sensor
- Hand Dynamometer

Heart Rate and Exercise
- Go Wireless Heart Rate

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Grip Strength Comparison

The importance of hand strength and function is evident in all aspects of our daily living, from eating and maintaining personal hygiene to keyboarding 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 the most mundane 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 gender, handedness, and height. In Part II you will analyze the pinch strength of each of your four fingers.

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.

Figure 1

OBJECTIVES

In this experiment, you will

- Measure and compare grip strength of your right and left hands.
- Correlate grip strength with gender and certain physical characteristics.
- Compare the pinch strengths of the individual fingers of the dominant hand.

MATERIALS

LabQuest
LabQuest App
Vernier Hand Dynamometer

PROCEDURE

Part I Hand Grip Strength

Each person in the group will take turns being subject and tester.

1. Connect the Hand Dynamomenter to LabQuest and choose New from the File menu.
2. On the Meter screen, tap Length. Change the data-collection length to 10 seconds. Select OK.
3. Zero the readings for the Hand Dynamometer.
   a. Hold the Hand Dynamometer along the sides, in an upright position (see Figure 2). Do not put any force on the pads of the Hand Dynamometer.
   b. When the readings stabilize, choose Zero from the Sensors menu. The readings for the sensor should be close to zero.

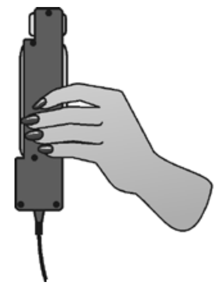

Figure 2

4. Have the subject sit with his or her back straight and feet flat on the floor. The Hand Dynamometer should be held in the right hand. The elbow should be at a 90° angle, with the arm unsupported (see Figure 1).
5. Have the subject close his or her eyes, or avert them from the screen.
6. Start data collection. After collecting 2 seconds of baseline data, instruct the subject to grip the sensor with full strength for the next 8 seconds. Data will be collected for 10 seconds.
7. Determine the maximum and mean force exerted by your hands during a portion of the data collection period.
   a. Tap and drag across the data from 4 s to 8 s.
   b. Choose Statistics from the Analyze menu.
   c. Record the maximum and mean force in Table 1.
8. Store the data from the first run by tapping the File Cabinet icon.
9. Repeat Step 3–7 with the left hand.
10. Work with your classmates to complete Tables 2–4. **Note**: In Table 4, round height to the nearest inch.

Part II Pinch Strength

11. Tap the Meter tab. Tap Length and change the data-collection length to 20 seconds. Select OK.

12. Have the subject sit with his or her back straight and feet flat on the floor, holding the Hand Dynamometer along the sides in the non-dominant hand (see Figure 3). **Note**: No additional force should be placed on the sensor by this hand.

Figure 3

13. Have the subject close his or her eyes, or avert them from the screen.

14. Zero the readings for the Hand Dynamometer.
    a. Hold the Hand Dynamometer along the sides, in an upright position. Do not put any force on the gray pads of the Hand Dynamometer.
    b. When the readings stabilize, choose Zero from the Sensors menu. The readings for the sensor should be close to zero.

15. Start data collection. Instruct the subject to immediately pinch the end of the sensor between the pads of the thumb and forefinger of his or her dominant hand, and hold for 5 seconds.

16. Instruct the subject to switch to successive fingers every 5 seconds. Data collection will stop after 20 seconds.

17. Determine the mean force applied during each pinch.
    a. Tap and drag across the first plateau on the graph, to select the data representing the pinch strength of the thumb and index finger (see Figure 4).
    b. Choose Statistics from the Analyze menu and record the mean pinch strength to the nearest 0.1 N in Table 5.
    c. Choose Statistics from the Analyze menu to turn off statistics.
    d. Select the data in the second plateau, representing the pinch strength of the thumb and middle finger. Choose Statistics from the Analyze menu.
    e. Record the mean pinch strength to the nearest 0.1 N in Table 5.
    f. Choose Statistics from the Analyze menu to turn off statistics.
    g. Repeat this process to obtain statistics for the remaining two pinch strengths.

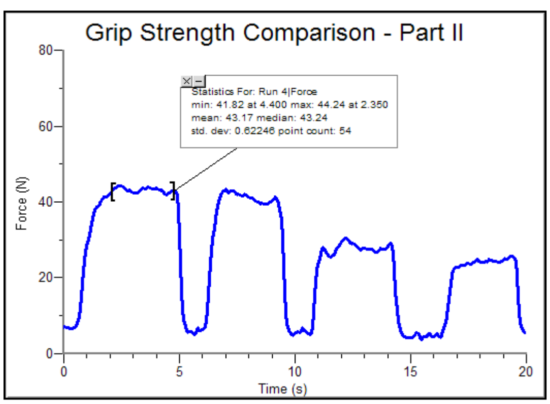

Figure 4

DATA

Table 1−Individual Grip Strength Data		
	Maximum force (N)	Mean force (N)
Right hand grip strength		
Left hand grip strength		

Table 2−Class Grip Strength Data	
	Average mean force (N)
Males (dominant hand grip strength)	
Females (dominant hand grip strength)	

Table 3−Class Grip Strength Data		
	Average mean force (N)	
	Right hand	Left hand
Right-handed individuals		
Left-handed individuals		

Table 4−Class Grip Strength Data	
Height (rounded to nearest inch)	Average mean grip strength of dominant hand (N)
1.52 m (5’) or below	
1.55−1.63 m (5’1”−5’4”)	
1.65–1.73 m (5’5”−5’8”)	
1.75–1.83 m (5’9”−6’)	
1.85 m (6’1”) and above	

Table 5−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 non-dominant hands? Are you surprised by the result?

2. Examining the data in Table 3, does there appear to be a correlation between "handedness" and grip strength? Are the results similar for right-handed and left-handed people?

3. Is there a difference between the grip strengths in the different categories of height for which data was collected in Table 4? What conclusion can you draw about the relationship between height and grip strength?

4. Does gender play a more significant role in grip strength than height? than "handedness?"

5. Using the pinch strength data in Table 5, describe the difference in strength between fingers. Where is the difference the largest?

6. 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 (Use an anatomy textbook or atlas to view the muscles of the forearm and hand).

EXTENSIONS

1. Plot a graph of the maximum and average grip strengths for each participant in each category. Do the results correspond with what you would expect in a human population?

2. 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.

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 your heart's electrical events. From this recording, you will identify the previously mentioned waveform components and determine the time intervals associated with each.

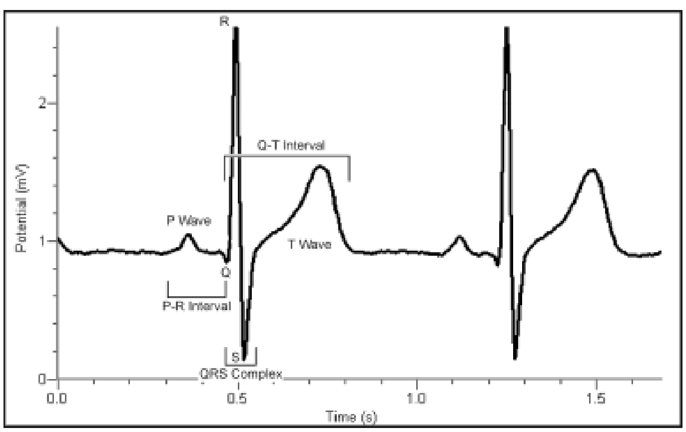

Figure 1

OBJECTIVES

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

MATERIALS

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

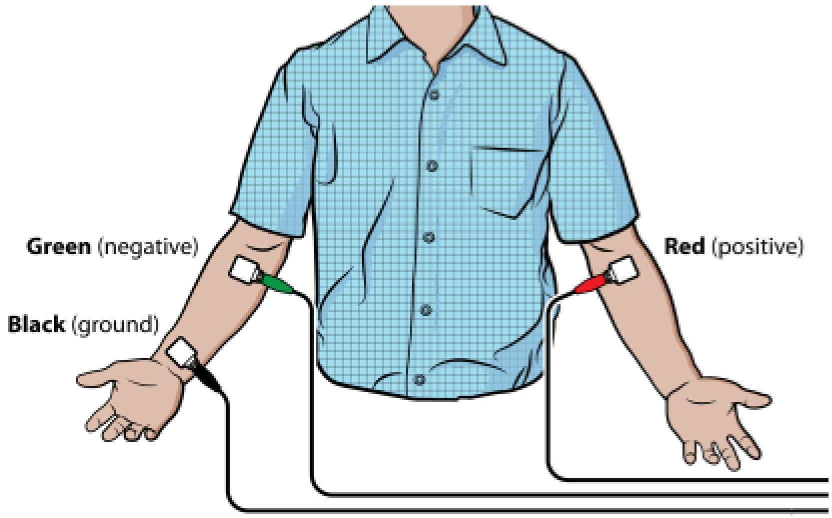

Figure 2

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 your arms, as shown in Figure 2. A single tab should be placed on the inside of the right wrist, on the inside of the right upper forearm (below elbow), and on the inside of the left upper forearm (below elbow).

4. Connect the three sensor leads to the electrode tabs as shown in Figure 2. Sit in a reclined position in a chair or lay flat on top of a lab table. Your arms should be hanging at the side unsupported.

5. Another member of the lab group should click or tap Collect to start data collection.

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 below.

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 4–6.

11. (optional) Print 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 1–8 to collect and analyze your electrocardiogram. When analyzing the data in Step 8, only determine the average Q-T interval.
c. Divide 60 seconds by the Q-T interval to calculate your maximum heart rate.

EMG and Muscle Fatigue

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 which travel down motor neurons (in the spine 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 the muscle fiber contracts to its maximum potential or not at all. The strength of contraction of a whole muscle depends on how many individual fibers are activated, and can be correlated with electrical activity measured over the muscle with an EMG sensor.

Regular exercise is important for maintaining muscle strength and conditioning. The most common form of non-aerobic exercise is *isotonic* (weight training). In isotonic exercise, the muscle changes length against a constant force. In *isometric* exercise the length of the muscle remains the same as greater demand is placed on it. An example of this is holding a barbell (or suitcase) in one position for an extended period of time. Muscle fatigue occurs with both forms of exercise.

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

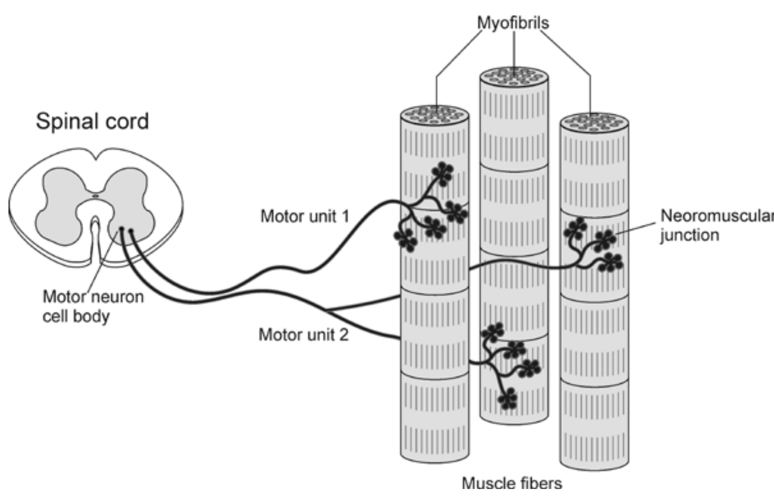

Figure 1

Important: Do not attempt this experiment if you suffer from arthritis, or other conditions of the hand, wrist, forearm, or elbow. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

OBJECTIVES

In this experiment, you will

- 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

LabQuest
LabQuest App
Vernier Hand Dynamometer
Vernier EKG Sensor
electrode tabs

PROCEDURE

Part I Grip Strength without Visual Feedback

Select one person from your lab group to be the subject.

1. Connect the Hand Dynamometer to LabQuest and choose New from the File menu.
2. On the Meter screen, tap Length. Change the data-collection length to 100 seconds and the data-collection rate to 100 samples/second. Select OK.
3. Zero the readings for the Hand Dynamometer.
   a. Hold the Hand Dynamometer along the sides, in an upright position (see Figure 2). Do not put any force on the pads of the Hand Dynamometer.
   b. When the readings stabilize, choose Zero from the Sensors menu. The readings for the sensor should be close to zero.

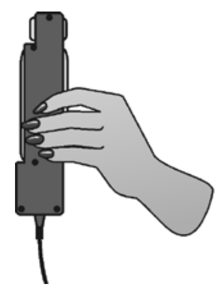

Figure 2

4. 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.
5. Attach the green and red leads to the tabs on ventral forearm. For this activity, the green and red leads are interchangeable. Attach the black lead to the upper arm.

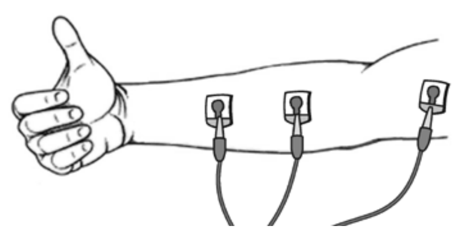

Figure 3

6. Have the subject sit with his/her back straight and feet flat on the floor. The elbow should be at a 90° angle, with the arm unsupported.
7. Have the subject close his/her eyes, or avert them from the screen.
8. Instruct the subject to grip the sensor with full strength and start data collection. The subject should exert maximum effort throughout the data-collection period.

9. At 80 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

10. Use the force *vs*. time graph to determine the mean force exerted during different time intervals.
    a. Tap and drag across the data from 0 s to 20 s.
    b. Choose Statistics from the Analyze menu.
    c. Record the mean force in Table 1, rounding to the nearest 0.1 N.
    d. Choose Statistics from the Analyze menu to turn off statistics.

11. Repeat Step 10 for two other 20 second intervals: 60−80 s and 80−100 s.

12. Repeat Step 10 to record the maximum and minimum mV during three intervals on the EMG graph: 0–20 s, 60−80 s, and 80−100 s. Rounding to the nearest 0.01 mV.

13. Calculate the difference between each minimum and maximum value and record this value in the ΔmV column in Table 1.

Part II Grip Strength with Visual Feedback

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

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

16. At 80 s, instruct the subject to watch the screen, and attempt to match his/her beginning grip strength (the level achieved in the first few seconds of the experiment) and to maintain this grip for the duration of the experiment. Data will be collected for 100 s.

17. Use the force *vs*. time graph to determine the mean force exerted during different time intervals.
    a. Tap and drag across the data from 0 s to 20 s.
    b. Choose Statistics from the Analyze menu.
    c. Record the mean force in Table 1, rounding to the nearest 0.1 N.
    d. Choose Statistics from the Analyze menu to turn off statistics.

18. Repeat Step 17 for two other 20 second intervals: 60−80 s and 80−100 s.

19. Repeat Step 18 to record the maximum and minimum mV during three intervals on the EMG graph: 0–20 s, 60−80 s, and 80−100 s. Rounding to the nearest 0.01 mV.

20. Calculate the difference between each minimum and maximum value and record this value in the ΔmV column in Table 1.

Part III Repetitive Grip Strength

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

22. Instruct the subject to rapidly grip and relax his/her grip on the sensor (approximately twice per second). Start data collection. The subject should exert maximum effort throughout the duration of data collection.

23. At 80 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

24. Use the force *vs*. time graph to determine the mean force exerted during different time intervals.
    a. Tap and drag across the data from 0 s to 20 s.
    b. Choose Statistics from the Analyze menu.
    c. Record the mean force in Table 1, rounding to the nearest 0.1 N.
    d. Choose Statistics from the Analyze menu to turn off statistics.

25. Repeat Step 24 for two other 20 second intervals: 60−80 s and 80−100 s.

26. Repeat Step 24 to record the maximum and minimum mV during three intervals on the EMG graph: 0–20 s, 60−80 s, and 80−100 s. Rounding to the nearest 0.01 mV.

27. Calculate the difference between each minimum and maximum value and record this value in the ΔmV column in Table 1.

DATA

Table 1–Continuous Grip Strength without Visual Feedback				
Time Interval	Mean grip strength (N)	EMG Data		
		Max (mV)	Min (mV)	∆mV
0–20 s				
60–80 s				
80–100 s				

Table 2–Continuous Grip Strength with Visual Feedback				
Time Interval	Mean grip strength (N)	EMG data		
		Max (mV)	Min (mV)	∆mV
0–20 s				
60–80 s				
80–100 s				

Table 3–Repetitive Grip Strength				
Time interval	Mean grip strength (N)	EMG data		
		Max (mV)	Min (mV)	∆mV
0–20 s				
60–80 s				
80–100 s				

DATA ANALYSIS

1. Use the data in Table 1 to calculate the percent loss of grip strength that occurs between the 0–20 s and 60–80 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 (∆mV) in electrical activity that occurs between the 0–20 s and 60–80 s intervals. Do the same for grip strength. What accounts for the difference in the percent change observed in grip strength and ∆mV for the two time intervals?

3. Compare mean grip strengths and ΔmV for the 0–20 s and 80–100 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 your data from 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 80-100 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 less for repetitive gripping (Table 3) because repetitive relaxation of the hand is averaged into the calculation.

   a. Compare your mean grip strength during the 0–20 s and 80–100 s time intervals in Tables 1 and 3. Was there a difference in your ability to recover strength with coaching during continuous *vs.* repetitive gripping?

   b. Calculate the percent change in mean grip strength between the 1–20 s and 60–80 s time intervals in Tables 1 and 3. Do your answers support brief relaxation of muscles to delay fatigue?

Heart Rate and Physical Fitness

The circulatory system is responsible for the internal transport of many vital substances in humans, including oxygen, carbon dioxide, and nutrients. The components of the circulatory system include the heart, blood vessels, and blood. Heartbeats result from electrical stimulation of the heart cells by the *pacemaker*, located in the heart's inner wall of the right atrium. Although the electrical activity of the pacemaker originates from within the heart, the rhythmic sequence of impulses produced by the pacemaker is influenced by nerves outside the heart. Many things might affect heart rate, including the physical fitness of the individual, the presence of drugs such as caffeine or nicotine in the blood, and the age of the person.

As a rule, the maximum heart rate of all individuals of the same age and sex is about the same. However, the time it takes individuals to reach that maximum level while exercising varies greatly. Since physically fit people can deliver a greater volume of blood in a single cardiac cycle than unfit individuals, they can usually sustain a greater work level before reaching the maximum heart rate. Physically fit people not only have less of an increase in their heart rate during exercise, but their heart rate recovers to the resting rate more rapidly than unfit people.

In this experiment, you will evaluate your physical fitness. An arbitrary rating system will be used to "score" fitness during a variety of situations. Tests will be made while in a resting position, in a prone position, as well as during and after physical exercise.

Important: Do not attempt this experiment if physical exertion will aggravate a health problem. Inform your instructor of any possible health problems that might be affected if you participate in this exercise.

OBJECTIVES

- Determine the effect of body position on heart rates.
- Determine the effect of exercise on heart rates.
- Determine your fitness level.
- Correlate the fitness level of individuals with factors such as smoking, the amount of daily exercise, and other factors identified by students.

MATERIALS

LabQuest
LabQuest App
Hand-Grip Heart Rate Monitor **or** Exercise Heart Rate Monitor
stepping stool, 45 cm (18 inches) high

PROCEDURE

1. Connect the receiver module of the Heart Rate Monitor to LabQuest and choose New from the File menu.

2. Each person in a lab group will take turns being the subject and the tester. When it is your turn to be the subject, your partner will be responsible for recording the data on your lab sheet.

3. Set up the sensor by following the directions for your device:

   Using a Hand-Grip Heart Rate Monitor

   a. If the hand grips use a Polar Transmitter Module, ensure that it is securely attached to the hand grips. The receiver is marked with a white alignment arrow as shown in Figure 1. Locate this arrow. If the handle is marked with an alignment arrow, locate this arrow as well.

   b. Have the subject grasp the handles of the Hand-Grip Heart Rate Monitor so that the metal electrodes are against their palms. Hold the handles vertically.

   c. Another group member should hold the receiver near the handles so that the alignment arrow is pointing up as shown in Figure 1. If the Hand Grips have alignment arrows, make sure that the arrow on the receiver and the arrow on the Hand Grips are aligned in the same direction. **Note**: The receiver must stay within 60 cm of the handles during data collection.

Figure 1

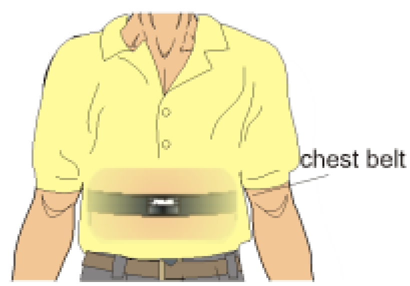

Figure 2

   Using an Exercise Heart Rate Monitor

   a. If the chest strap uses a Polar Transmitter Module, ensure that it is securely attached to the Exercise Heart Rate strap.

   b. Secure the Exercise Heart Rate Monitor against the skin directly, around the subject's chest as shown in Figure 2. Verify that the Polar logo is located in the center of the chest in an upright position. Attach the hook to the other end of the strap to secure the sensor and adjust the elastic strap to ensure a tight fit.

   c. Have another group member hold the receiver near the subject so that the alignment arrow is pointing up. **Note:** The receiver must stay within 60 cm of the subject during data collection.

4. Start data collection.

5. Determine that the sensor is functioning correctly. The readings should be consistent and within the normal range of the individual, usually between 55 and 80 beats per minute. When you have determined that the equipment is operating properly, stop data collection.

Part I Standing heart rate

6. Start data collection. Instruct the subject to stand upright for 2 minutes.

7. When the 2 minutes have passed, record the subject's heart rate in Table 6.

8. Locate the subject's heart rate in Table 1 and record the corresponding fitness point value in Table 6.

Table 1: Standing Heart Rate			
Beats/min	Points	Beats/min	Points
60–70	12	101–110	8
71–80	11	111–120	7
81–90	10	121–130	6
91–100	9	131–140	4

Part II Reclining heart rate

9. Instruct the subject to recline on a clean surface or table for 2 minutes.

10. When the 2 minutes have passed, record the subject's heart rate in Table 6.

11. Locate the subject's heart rate in Table 2 and record the corresponding fitness point value in Table 6.

Table 2: Reclining Heart Rate			
Beats/min	Points	Beats/min	Points
50–60	12	81–90	8
61–70	11	91–100	6
71–80	10	101–110	4

Part III Heart rate change from reclining to standing

12. Instruct the subject to quickly stand up and remain standing still.

13. Immediately record the subject's peak heart rate in Table 6.

14. Subtract the reclining rate heart rate recorded in Step 10 from the heart rate in Step 13 to find the heart rate increase after standing.

15. Locate the row corresponding to the reclining heart rate in Table 3 and use the heart rate increase value to determine the proper fitness points. In Table 6, record the fitness points.

16. Stop data collection. Instruct the subject to rest for 2 minutes.

Table 3

Reclining rate (beats/min)	Heart rate increase after standing (beats)				
	0–10	11–17	18–24	25–33	34+
50–60	12	11	10	8	6
61–70	12	10	8	6	4
71–80	11	9	6	4	2
81–90	10	8	4	2	0
91–100	8	6	2	0	0
101–110	6	4	0	0	0

Part IV Step test

17. Start data collection. Before performing the step test, record the subject's heart rate (Pre-exercise) in Table 6.

18. Perform a step test using the following procedure:

    a. Place the right foot on the top step of the stool.
    b. Place the left foot completely on the top step of the stool next to the right foot.
    c. Place the right foot back on the floor.
    d. Place the left foot completely on the floor next to the right foot.
    e. This stepping cycle should take 3 seconds to complete.
    f. Continue the step cycle 5 times.

19. When five step cycles have been completed, record the heart rate in Table 6. Quickly move to the next step.

Part V Recovery rate

20. With a stopwatch or clock, begin timing to determine the subject's recovery time. During the recovery period, the subject should remain standing and relatively still.

21. Monitor the heart rate readings and stop timing when the readings return to the pre-exercise heart rate value recorded in Step 17. Record the recovery time in Table 6.

22. Stop data collection.

23. Locate the subject's recovery time in Table 4 and record the corresponding fitness point value in Table 6. If the subject's heart rate did not return to within 10 beats/min from their pre-exercise heart rate, record a value of 6 points.

Table 4: Recovery Time	
Time (sec)	Points
0–30	14
31–60	12
61–90	10
91–120	8

Part VI Step test for endurance

24. Subtract the subject's pre-exercise heart rate (from Step 17) from their heart rate after 5 steps of exercise. Record this heart rate increase in the endurance row of Table 6.

25. Locate the row corresponding to the pre-exercise heart rate in Table 5 and use the heart rate increase value to determine the proper fitness points. In Table 6, record the fitness points.

Table 5					
Pre-exercise heart rate (beats/min)	Heart rate increase after exercise (beats)				
	0–10	11–20	21–30	31–40	41+
60–70	12	12	10	8	6
71–80	12	10	8	6	4
81–90	12	10	7	4	2
91–100	10	8	6	2	0
101–110	8	6	4	1	0
111–120	8	4	2	1	0
121–130	6	2	1	0	0
131+	5	1	0	0	0

26. Total all the fitness points recorded in Table 6. Determine the subject's personal fitness level using the scale in Figure 3.

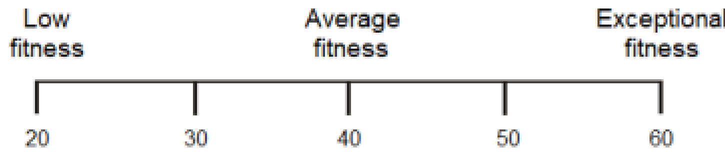

Figure 3

DATA

Table 6

Condition	Rate or time	Points
Standing heart rate	beats/min	
Reclining heart rate	beats/min	
Reclining to standing	beats/min	
Pre-exercise heart rate	beats/min	
After 5 steps	beats/min	
Recovery time	seconds	
Endurance	beats/min	
		Total points:

QUESTIONS

1. How did your heart rate change after moving from a standing position to a reclining position? Is this what you expected? How do you account for this?

2. How did your heart rate change after moving from a reclining position back to a standing position? Is this what you expected? How do you account for this?

3. Predict what your heart rate might be if you had exercised for twice the length of time that you actually did. Explain.

4. How does your maximum heart rate compare to other students in your group. Is this what you expected? How do you account for this?

5. Why would athletes need to work longer and harder before their heart rates were at the maximum value?

6. In examining the results of your physical fitness test, were you surprised by any of the findings? If you were, how might you explain them? Based on the results of the test, what behaviors in your life would you continue to practice? What behaviors might you think about changing?

7. Current research indicates that most heart attacks occur as people get out of bed after sleep. Account for this observation.

EXTENSIONS

1. Using a sphygmomanometer, learn how to measure blood pressure. Compare a person's blood pressure when reclining, to that of the same person immediately after standing from a reclined position. Relate the change in blood pressure to the heart rate values measured when going from reclining to standing.

2. Design an anonymous survey to be taken by each member of your class. In the survey, ask questions that you think might influence the test results. Examples might include:

   - Did you have more than six hours of sleep last night?
   - Gender? Age?
   - Do you smoke? If so, how many packs per week do you smoke?
   - What was your total number of fitness points?

3. Try to determine whether any of the variables from your survey show a statistical link to fitness. You may want to use a statistical T-Test to determine whether a relationship between the variable and physical fitness is due to chance.

Control of Human Respiration

Your respiratory system allows you to obtain oxygen, eliminate carbon dioxide, and regulate the blood's pH level. 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.

You will learn how to use the Respiration Belt to monitor the respiratory patterns of one member of your group 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 4 app
Go Direct Respiration
small paper bag

PROCEDURE

1. Launch Graphical Analysis. Connect the 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 test subject sit upright in a chair and breath 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 has been collected for 60 seconds, have the test subject hold his or her breath for 30 to 45 seconds.

7. The test subject should breathe normally for the remainder of the data collection once breath has been released.

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

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

Part II Rebreathing of air

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

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

14. Collect respiration data for the full 300 seconds while breathing into the sack. **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.

15. Once you have finished collecting data, calculate the maximum height of the respiration waveforms for the intervals of 0 to 30 seconds, 120 to 150 seconds, and 240 to 270 seconds.

    a. Select the time interval on the graph you are examining to select these data points.
    b. Click or tap Graph Tools, , and choose Statistics.
    c. Click or tap Apply Curve Fit.
    d. Subtract the minimum force from the maximum force to calculate the amplitude. Record this value in Table 2.
    e. Repeat this process for the other time intervals.

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 test subject change after holding his or her 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 test subject's breath? Explain.
3. What would be the significance of an increase in the amplitude and frequency of the waveform while the test subject was breathing into the bag?
4. How did the respiratory waveforms change while the test subject was breathing into the bag? How would you interpret this result?
5. Explain how you think carbon dioxide affects your breathing.

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. Contraction of the diaphragm causes it to flatten downward. If chest muscles are used, the ribs expand outward. 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 normal breathing at rest, approximately one-tenth of the total lung capacity is used. Greater amounts are used as needed (i.e., 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

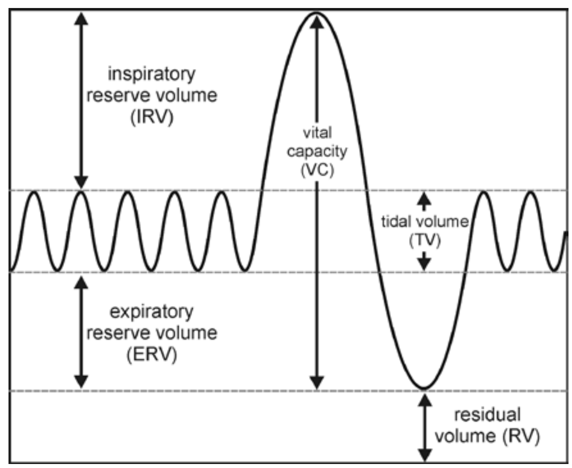

Figure 1

Minute Ventilation

The volume of air breathed in 1 minute: (TV)(breaths/minute)

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.

OBJECTIVES

In this experiment, you will

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

MATERIALS

LabQuest	disposable mouthpiece
LabQuest App	disposable bacterial filter
Vernier Spirometer	nose clip

PROCEDURE

Important: Do not attempt this experiment if you are currently suffering from a respiratory ailment such as the cold or flu.

1. Connect the Spirometer to LabQuest and choose New from the File menu.

2. On the Meter screen, tap Rate. Change the data-collection rate to 100 samples/second and the data-collection length to 60 seconds. Select OK.

3. Attach the larger diameter side of a bacterial filter to the “Inlet” side of the Spirometer. Attach a gray disposable mouthpiece to the other end of the bacterial filter (see Figure 2).

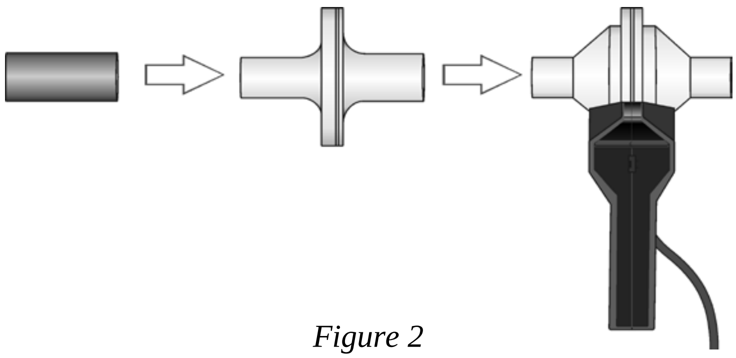

Figure 2

4. Hold the Spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table, and choose Zero from the Sensors menu. **Note**: The Spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

5. Collect inhalation and exhalation data.
   a. Put on the nose plug.
   b. Start data collection.
   c. Taking normal breaths, begin data collection with an inhalation and continue to breathe in and out. After 4 cycles of normal inspirations and expirations fill your lungs as deeply as possible (maximum inspiration) and exhale as fully as possible (maximum expiration). *It is essential that maximum effort be expended when performing tests of lung volumes*.
   d. Follow this with at least one additional recovery breath.

6. Stop data collection.

7. To view a graph of volume *vs*. time, tap the y-axis label and select Volume. If the baseline on your graph has drifted, choose Baseline Adjustment from the Analyze menu to bring the baseline volumes closer to zero, as in Figure 3. Select OK.

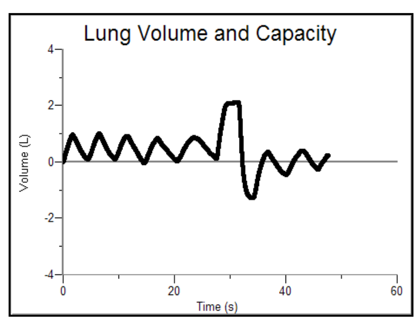

Figure 3

8. Determine the Tidal Volume
   a. Find a representative peak and valley in the Tidal Volume portion of your graph.
   b. Tap the peak and then drag to the valley that follows it.
   c. Choose Statistics from the Analyze menu. Select Volume.
   d. Enter the Δy value to the nearest 0.1 L as Tidal Volume in Table 1.
   e. Choose Statistics from the Analyze Menu. Deselect Volume.
9. Determine the Vital Capacity
   a. Find the peak that represents your maximum inspiration.
   b. Tap the peak and then drag down the side of the peak until you reach the valley that represents your maximum expiration.
   c. Choose Statistics from the Analyze menu. Select Volume.
   d. Enter the Δy value to the nearest 0.1 L as Vital Capacity in Table 1.
   e. Choose Statistics from the Analyze Menu. Deselect Volume.
10. Determine the Inspiratory Reserve Volume
    a. Find the peak that represents the last peak in the Tidal Volume portion of your graph.
    b. Tap the peak and then drag up to the peak that represents your maximum inspiration.
    c. Choose Statistics from the Analyze menu. Select Volume
    d. Enter the Δy value to the nearest 0.1 L as Inspiratory Reserve Volume in Table 1.
    e. Choose Statistics from the Analyze Menu. Deselect Volume.
11. Calculate the Expiratory Reserve Volume and enter to the nearest 0.1 L in Table 1.

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

12. Calculate the Total Lung Capacity and enter to the nearest 0.1 L in Table 1. (Use the value of 1.5 L for the RV.)

$$TLC = VC + RV$$

13. Share your data with your classmates and complete the Class Average columns in Table 1.

DATA

Table 1			
Volume measurement (L)	Individual (L)	Class average (Male) (L)	Class average (Female) (L)
Tidal Volume (TV)			
Inspiratory Reserve Volume (IRV)			
Expiratory Reserve Volume (ERV)			
Vital Capacity (VC)			
Residual Volume (RV)	≈1.5	≈1.5	≈1.5
Total Lung Capacity (TLC)			

DATA ANALYSIS

1. What was your Tidal Volume (TV)? What would you expect your TV to be if you inhaled a foreign object which completely obstructed your right mainstem bronchus?

2. Describe the difference between lung volumes for males and females. What might account for this?

3. Calculate your Minute Volume at rest.

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

   If you are 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 your Expiratory Reserve Volume when you are treading water in a lake?

EXTENSION

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