

NSTA National 2022 Houston, TX

Let's Get Physical: Human Physiology Experiments

Experiments:

Limb Position and Grip Strength

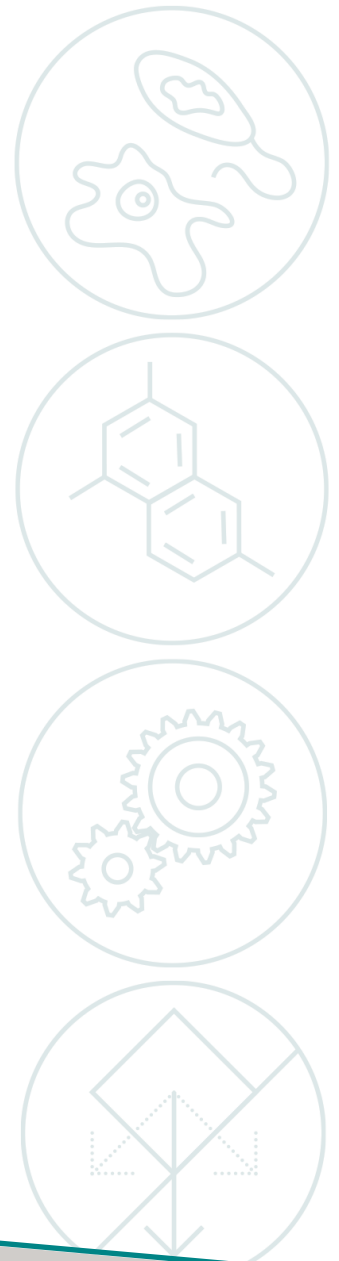
- Go Direct Hand Dynamometer

Introduction to Electrocardiography

- Go Direct EKG

Introduction to Electromyography

- Go Direct Hand Dynamometer
- Go Direct EKG

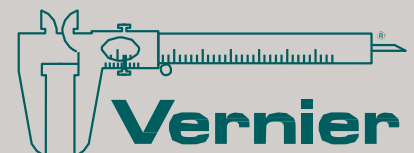


Workshop presenters:

Coleen McDaniel

Nüsret Hisim

biology@vernier.com



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 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.

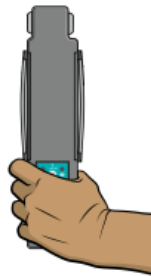


Figure 1

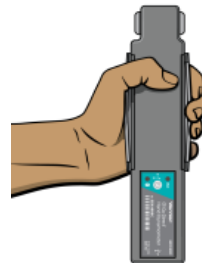



Figure 2

4. Have the subject sit with his or her 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 his or her eyes or avert them from the screen.
6. Click or tap Collect to 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 hand during a portion of the data-collection period.
 - a. Select the data from 4 s to 8 s.
 - b. Click or tap Graph Tools, , 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

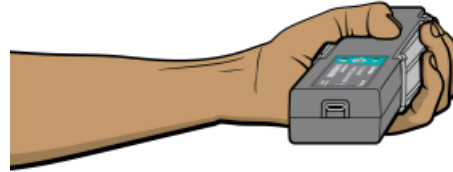


Figure 4

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 his or her 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.

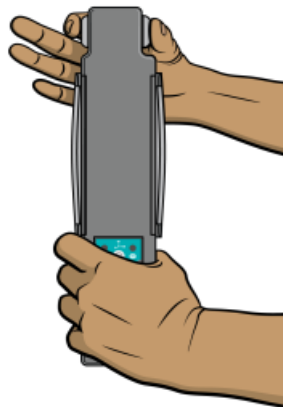




Figure 5

15. Have the subject close his or her 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.

Limb Position and Grip Strength

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 his or her dominant hand, and hold for 5 seconds.
18. Instruct the subject to switch to successive fingers every 5 seconds. Data collection will stop after 30 seconds.
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 Tools, , 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 Tools, , 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.

Introduction to Electrocardiography

An electrocardiogram (ECG or EKG) is a graphical recording of the electrical events occurring within the heart. In a healthy heart there is a natural pacemaker in the right atrium (the *sinoatrial node*) which initiates an electrical sequence. This impulse then passes down natural conduction pathways between the atria to the atrioventricular node and from there to both ventricles. The natural conduction pathways facilitate orderly spread of the impulse and coordinated contraction of first the atria and then the ventricles. The electrical journey creates unique deflections in the EKG that tell a story about heart function and health (Figure 1). Even more information is obtained by looking at the story from different angles, which is accomplished by placing electrodes in various positions on the chest and extremities. A positive deflection in an EKG tracing represents electrical activity moving toward the active lead (the green lead in this experiment).

Five components of a single beat are traditionally recognized and labeled P, Q, R, S, and T. The P wave represents the start of the electrical journey as the impulse spreads from the sinoatrial node downward from the atria through the atrioventricular node and to the ventricles. Ventricular activation is represented by the QRS complex. The T wave results from ventricular repolarization, which is a recovery of the ventricular muscle tissue to its resting state. By looking at several beats you can also calculate the rate for each component.

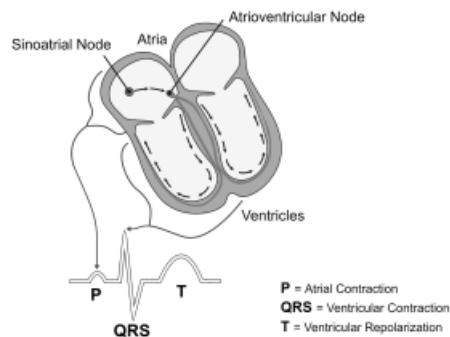


Figure 1

Doctors and other trained personnel can look at an EKG tracing and see evidence for disorders of the heart such as abnormal slowing, speeding, irregular rhythms, injury to muscle tissue (*angina*), and death of muscle tissue (*myocardial infarction*). The length of an interval indicates whether an impulse is following its normal pathway. A long interval reveals that an impulse has been slowed or has taken a longer route. A short interval reflects an impulse which followed a shorter route. If a complex is absent, the electrical impulse did not rise normally, or was blocked at that part of the heart. Lack of normal depolarization of the atria leads to an absent P wave. An absent QRS complex after a normal P wave indicates the electrical impulse was blocked before it reached the ventricles. Abnormally shaped complexes result from abnormal spread of the impulse through the muscle tissue, such as in myocardial infarction where the impulse cannot follow its normal pathway because of tissue death or injury. Electrical patterns may also be changed by metabolic abnormalities and by various medications.

Introduction to Electrocardiography

In this experiment, you will use the EKG sensor to make a five second graphical recording of the heart's electrical activity, and then switch the red and green leads to simulate the change in electrical activity that can occur with a myocardial infarction (heart attack). You will identify the different components of the waveforms and use them to determine heart rate.

OBJECTIVES

- Obtain graphical representation of the electrical activity of the heart over a period of time.
- Learn to recognize the different waveforms seen in an EKG and associate these waveforms with activity of the heart.
- Determine the heart rate by determining the rate of individual waveforms in the EKG.
- Compare waveforms generated by alternate EKG lead placements.

MATERIALS

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

PROCEDURE

Part I Standard limb lead EKG

1. Launch Graphical Analysis. Connect Go Direct EKG to your Chromebook, computer, or mobile device.
2. Attach three electrode tabs to your 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).

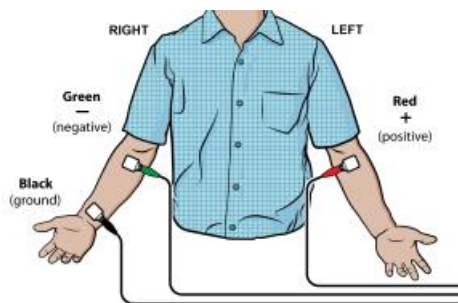


Figure 2

3. Connect the EKG clips to the electrode tabs as shown in Figure 2. Sit in a relaxed position in a chair, with your forearms resting on your legs or on the arms of the chair. When you are properly positioned, have someone click or tap Collect to start data collection. Data collection will stop after 3 seconds.

4. Determine the length of each of the intervals listed in Table 1. Use Figure 3 as your guide when determining these intervals.
 - a. Click or tap the data point at the beginning of the interval and record the time component of this point.
 - b. Click or tap the point at the end of the interval and record the time component of this point.
 - c. Determine the difference between the two time values and record this value to the nearest 0.01 s as the duration of the interval in Table 1.
5. Calculate the heart rate in beats/min using the EKG data. Record the heart rate to the nearest whole number in Table 1.

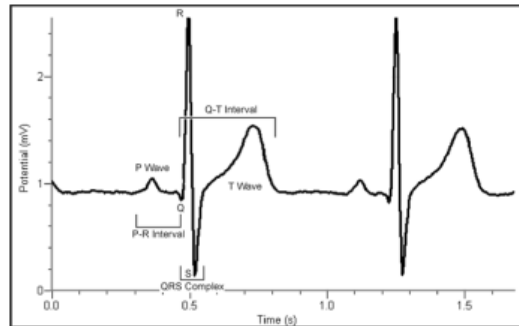


Figure 3

- **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

Part II Alternate limb lead EKG

6. Exchange the red and green EKG clips so that the green clip is now attached to the electrode tab on the left arm and the red clip is on the right arm. . Sit in a relaxed position in a chair, with your forearms resting on your legs or on the arms of the chair. When you are properly positioned, have someone click or tap Collect to start data collection. Data collection will stop after 3 seconds. **Note:** The previous data set is automatically saved.
7. Export, print, or sketch the tracing for alternate limb lead placement only.

DATA

Table 1			
Interval	Beginning time (s)	Ending time (s)	Time (s)
P-R			
QRS			
Q-T			
R-R			

Heart rate (bpm)	
------------------	--

Table 2: Standard Resting Electrocardiogram Interval Times	
P–R interval	0.12 to 0.20 s
QRS interval	less than 0.12 s
Q–T interval	0.30 to 0.40 s

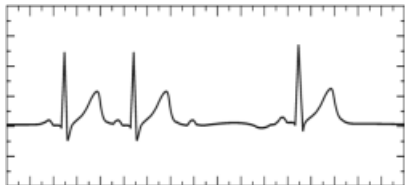
DATA ANALYSIS

Health-care professionals ask the following questions when interpreting an EKG:

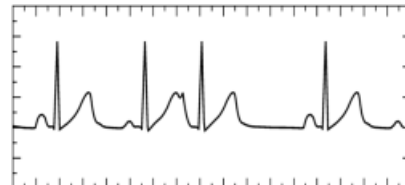
- Can all components be identified in each beat?
- Are the intervals between each component and each complex consistent?
- Are there clear abnormalities of any of the wave components?

Using these questions as guides, analyze each of the following three-beat EKG tracings and record your conclusions in Table 3 (indicate presence or absence of the P wave, and whether other intervals and/or shapes are normal or abnormal). The first analysis (a) is done for you.

a.



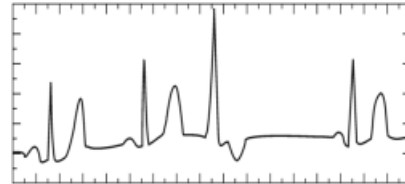
b.



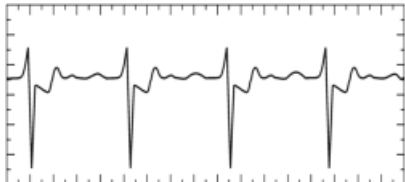
c.



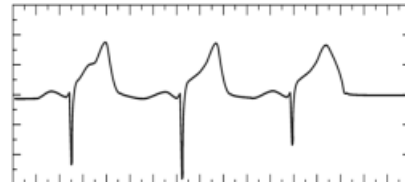
d.



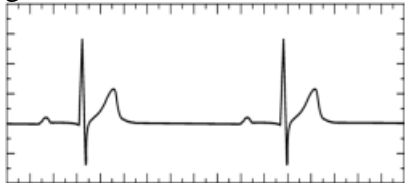
e.



f.



g.



h.

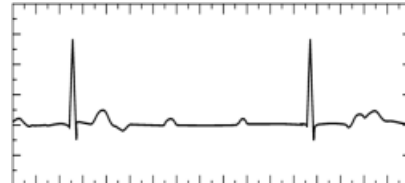


Table 3											
		P Wave		PR Interval		QRS Interval		QRS Shape		T Wave	
ECG	Beat	Pres.	Abs.	Nml.	Abs./Abn.	Nml.	Abs./Abn.	Nml.	Abn.	Nml.	Abs./Abn.
a	1	X		X		X		X		X	
	2	X		X		X		X		X	
	3	X			X		X		X		X
b	1										
	2										
	3										
c	1										
	2										
	3										
d	1										
	2										
	3										
e	1										
	2										
	3										
f	1										
	2										
	3										
g	1										
	2										
	3										
h	1										
	2										
	3										

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.

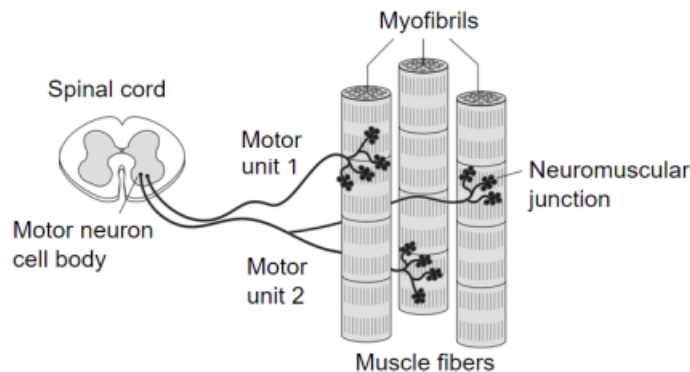


Figure 1

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
 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 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. 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.

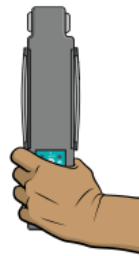


Figure 2

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.

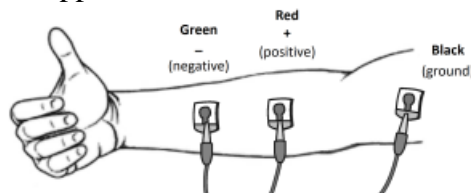





Figure 3

5. Have the subject sit with his or her 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 his or her 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 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.
 - e. Repeat this process to find the mean force for two other intervals: 20–40 s and 40–60 s.
10. Using the EMG 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 his or 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 or her elbow at a 90° angle, with the arm unsupported, and to close his or her 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 his or her 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 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.
 - 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 his or her 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 his or her elbow at a 90° angle, with the arm unsupported, and to close his or her eyes or avert them from the screen.
17. Instruct the subject to rapidly grip and relax his or her 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 Tools, , and choose 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 EMG 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?