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

In this experiment, you will

- 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
Vernier Hand-Grip Heart Rate Monitor **or**
Vernier Exercise Heart Rate Monitor
stepping stool, 45 cm (18 inches) high
dropper bottle with saline solution
(only for use with the Exercise HRM)

PROCEDURE

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.

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

1. On the Meter screen, tap Length. Change the data-collection length to 600 seconds. Select OK.

3. Set up the Heart Rate Monitor. Follow the directions for your type of Heart Rate Monitor.

Using a Hand-Grip Heart Rate Monitor

a. The receiver and one of the handles are marked with a white alignment arrow as shown in Figure 1. Locate these two arrows.
b. Have the subject grasp the handles of the Hand-Grip Heart Rate Monitor so that their fingers are in the reference areas indicated in Figure 2. Hold the handles vertically.
c. Have someone else hold the receiver near the handles so that the two alignment arrows are pointing in the same direction and are at approximately the same height as shown in Figure 1. **Note:** The receiver must stay within 60 cm of the handles during data collection.

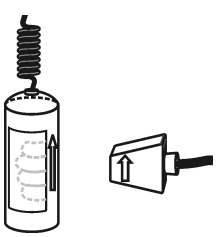

Figure 1

Figure 2

Using an Exercise Heart Rate Monitor

a. If you have an older sensor that does not auto-ID, manually set up the sensor.
b. Depending upon your size, select a small- or large-size elastic strap. Secure one of the plastic ends of the elastic strap to the transmitter belt. It is important that the strap provide a snug fit of the transmitter belt.
c. Wet each of the electrodes (the two textured oval areas on the underside of the transmitter belt) with 3 drops of saline solution.

Figure 3

d. Secure the transmitter belt against the skin directly over the base of the rib cage (see Figure 3). The POLAR logo on the front of the belt should be centered. Adjust the elastic strap to ensure a tight fit.
e. Take the receiver module of the Heart Rate Monitor in your right hand. Remember that the receiver must be within 80 cm of the transmitter in the Heart Rate Monitor belt.

4. Start data collection to determine that everything is set up 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 and proceed to Step 5.

Standing heart rate

5. Instruct the subject to stand upright for 2 minutes. Start data collection. When the 2 minutes have passed, record the subject's heart rate in Table 6.

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

Table 1

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

Reclining heart rate

7. Instruct the subject to recline on a clean surface or table for 2 minutes. When the 2 minutes have passed, record the subject's heart rate in Table 6. **Note:** If using the Hand-Grip Heart Rate Monitor, remember to move the receiver along with the handles to keep the arrows aligned.

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

Table 2

Beats/min	Points	Beats/min	Points
50–60	12	81–90	8
61–70	11	91–100	6
71–80	10	101–110	4

Heart rate change from reclining to standing

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

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

11. Subtract the reclining rate heart rate recorded in Step 6 from the heart rate in Step 9 to find the heart rate increase after standing. 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. Stop data collection. Instruct the subject to rest for 2 minutes then proceed to Step 11.

Table 3					
Reclining heart rate	Heart rate increase after standing				
	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

Step test

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

13. 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.

14. When five steps have been completed, record the heart rate in Table 6. Quickly move to Step 15.

Recovery rate

15. 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. Monitor the heart rate readings and stop timing when the readings return to the pre-exercise heart rate value recorded in Step 11. Record the recovery time in Table 6.

16. Stop data collection.

17. 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	
Time (sec)	Points
0–30	14
31–60	12
61–90	10
91–120	8

Step test for endurance

18. Subtract the subject's pre-exercise heart rate (from Step 11) from their heart rate after 5 steps of exercise. Record this heart rate increase in the endurance row of Table 6.

19. 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	Heart rate increase after exercise				
	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

20. Total all the fitness points recorded in Table 6. Determine the subject's personal fitness level using the scale below.

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. How do you evaluate your physical fitness? Do you agree with the rating obtained from this experiment? Explain.

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

EXTENSION

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 6 hours of sleep last night?
   - Do you smoke? If so, how many packs per week do you smoke?
   - Gender? Age?

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.

TEACHER INFORMATION

Heart Rate and Physical Fitness

1. This experiment correlates with Lab 10: Exercise 10B in the 2001 College Board's AP Biology Lab Manual.

2. The student pages with complete instructions for data-collection using LabQuest App, Logger *Pro* (computers), and EasyData (calculators) can be found on the CD that accompanies this book. See *Appendix A* for more information.

3. This experiment works equally well with either a Hand-Grip Heart Rate Monitor or an Exercise Heart Rate Monitor.

4. The receiver module of either type of Heart Rate Monitors will receive signals from the closest transmitter source. To avoid confusion or erroneous readings, have the test subjects from different lab teams stay at least 2 m apart.

5. Computer monitors can be a source of electrical interference. Keep the receiver module of the Heart Rate Monitor as far as possible from any computer monitors in the class.

6. It is possible to alter your heart rate by simply decreasing your respiratory rate and relaxing. Encourage students to stay alert and to breathe normally.

7. The Exercise Heart Rate Monitor includes a transmitter belt, receiver module, large elastic strap, and small elastic strap.

8. It is important to have good contact between the transmitter belt and the test subject when using the Exercise Heart Rate Monitor. It is very important that the belt fit snugly, but not too tight. Both electrodes should be wet with either saline solution or contact lens solution. A 5% salt solution works well and can be prepared by adding 5 g of NaCl per 100 mL of solution. Typical symptoms of inadequate contact with the electrodes are a noisy signal with erroneous peaks, missing heart beat readings, or a flat-line display. If the students receive a flat reading with no heart rate detected, have them move the transmitter and the receiver closer together. The range of the transmitter in the chest belt is 80 cm.

SAMPLE RESULTS

Sample data from two students are listed below. The first student was a 17 year old male and the second was a 16 year old female.

Table 6
Sample Student Data

Condition	Rate, Student 1 (beats/min) or time	Points	Rate, Student 2 (beats/min) or time	Points
Standing heart rate	73	11	93	9
Reclining heart rate	54	12	69	11
Reclining to standing	69	11	84	8
Pre-exercise heart rate	72		93	
After 5 steps	87		116	
Recovery rate	57 s	12	98 s	10
Endurance	14	10	23	2
Total		56		40

ANSWERS TO QUESTIONS

1. The heart rate generally lowers when a student moves from a standing position to a reclining position. The forces of gravity do not have to be overcome for blood to flow while in a reclining position.

2. The heart rate generally increases when a student moves from a reclining position to a standing position. The forces of gravity do have to be overcome while in a standing position.

3. The heart rate generally increases when a student exercises twice as long. It will not increase to twice the rate, however, because the heart will adjust to the new stress and increase the blood flow to meet the body's needs. The blood flow is proportional to the heart rate. When the blood flow is appropriate, the heart rate will no longer continue increasing.

4. Answers will vary. Factors such as weight, regular exercise, health, etc., may play a part in determining the maximum heart rate of a student.

5. An athletes heart is more efficient at moving blood through the body. Each contraction of an athlete's heart moves a greater volume of blood than an average individual. More blood per contraction means more oxygen for the body's cells. Because of this athletes must work harder to increase their heart rate to its maximum values.

6. Answers will vary.

7. The heart rate increases significantly when an individual moves from a reclining position to a standing position. The force of gravity on the blood makes the heart work harder, as in Question 2. This increased stress might provoke a heart attack in susceptible people.