Heart Rate, Blood Pressure, and Exercise

The adaptability of the heart can be observed during exercise, when the metabolic activity of skeletal muscles increases. The cardiovascular system, consisting of the heart and blood vessels, responds to exercise with an increase in heart rate and strength of contraction with each beat, resulting in a higher cardiac output (cardiac output = quantity of blood pumped through the heart per unit of time) and blood pressure. Positive pressure is created by forceful contraction of the left ventricle of the heart, measured as systole. It is maintained during relaxation of the ventricle by closure of the aortic valve and recoil of arteries, measured as diastole (see Figure 1).

Mean arterial pressure (MAP) is a useful measure of the adequacy of tissue perfusion, and is not a simple average of systolic and diastolic blood pressures. This is because diastole continues for twice as long as systole. MAP can be reasonably approximated using the equation:

\[
\frac{(systole + 2(diastole))}{3} = MAP
\]

The mean arterial pressure is directly proportional to cardiac output and inversely proportional to total peripheral resistance, where:

Cardiac output is the amount of blood pumped out of the heart with each beat (called the stroke volume), multiplied by the number of beats per minute.

Total peripheral resistance depends on blood viscosity, length of the arterial system, diameter and elasticity of the blood vessels, and the pressure entering versus leaving the arterial system (systolic pressure minus the pressure in the venous system).

Figure 1
In this experiment, you will observe how the heart responds to the increased metabolic demand of muscles during exercise. You will compare heart rate and blood pressure readings taken before and after exercise and measure changes in systolic, diastolic and mean arterial pressures. You will also consider the effect that exercise has on cardiac output and peripheral vascular resistance.

**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 exacerbated if you participate in this exercise.

**OBJECTIVES**
In this experiment, you will
- Obtain graphic representation of heart rate and blood pressure.
- Determine the effect of exercise on heart rate, and systolic, diastolic and mean arterial pressures.
- Use blood pressure readings and pulse to infer changes in cardiac output and peripheral vascular resistance with exercise.
- Correlate the fitness level of individuals with amount of daily exercise.

**MATERIALS**

<table>
<thead>
<tr>
<th>Computer</th>
<th>Vernier Hand-Grip Heart Rate Monitor or Vernier Exercise Heart Rate Monitor</th>
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</thead>
<tbody>
<tr>
<td>Vernier computer interface</td>
<td>Vernier Blood Pressure Sensor</td>
</tr>
<tr>
<td>Logger Pro</td>
<td>saline solution in dropper bottle</td>
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<td>(only for use with the Exercise HR Monitor)</td>
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</table>

**PROCEDURE**

**Part I Baseline Blood Pressure**

1. Connect the Blood Pressure Sensor to Channel 1 of the Vernier computer interface. Open the file “11a Heart Rate BP Exercise” from the *Human Physiology with Vernier* folder.

2. Attach the Blood Pressure Sensor to the blood pressure cuff if it is not already attached. There are two rubber tubes connected to the cuff. One tube has a black Luer-lock connector at the end and the other tube has a bulb pump attached. Connect the Luer-lock connector to the stem on the Blood Pressure Sensor with a gentle half turn.

3. Attach the Blood Pressure cuff to the upper arm, approximately 2 cm above the elbow. The two rubber hoses from the cuff should be positioned over the biceps muscle (brachial artery) and not under the arm (see Figure 2).

4. The subject should sit quietly in a chair and avoid moving his or her arm or hand during blood pressure measurements.
5. Click \( \text{Collect} \) to begin data collection. Immediately begin to pump until the cuff pressure reaches at least 160 mm Hg. Stop pumping.

6. During this time the systolic, diastolic, and mean arterial pressures will be calculated by the software. These values will be displayed on the computer screen. When the blood pressure readings have stabilized (after the pressure drops to 50 mm Hg), the program will stop calculating blood pressure. At this point, you can terminate data collection by clicking \( \text{Stop} \). Release the pressure from the cuff, but do not remove it.

7. Enter the pulse and the systolic, diastolic, and mean arterial pressures in Table 1.

**Part II Heart Rate and Blood Pressure after Exercise**

8. Connect the receiver module of the Heart Rate Monitor to Channel 2 of the Vernier computer interface. Open the file “11b Heart Rate BP Exercise” from the Human Physiology with Vernier folder.

9. 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 3. 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 4. 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 3. **Note:** The receiver must stay within 60 cm of the handles during data collection.

**Using an Exercise Heart Rate Monitor**

a. 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.

b. Wet each of the electrodes (the two textured oval areas on the underside of the transmitter belt) with 3 drops of saline solution.

c. Secure the transmitter belt against the skin directly over the base of the rib cage (see Figure 5). The POLAR logo on the front of the belt should be centered. Adjust the elastic strap to ensure a tight fit.

d. 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.

10. Stand quietly facing your table or lab bench.
11. To determine that everything is set up correctly, click \textit{\textbf{\textcolor{red}{Start}}} to begin monitoring heart rate. Note that there may be up to a 30 second delay before data are seen. The readings should be within the normal range of the individual, usually between 55 and 80 beats per minute. Click \textit{\textbf{\textcolor{red}{Stop}}} when you have determined that the equipment is operating properly, and proceed to Step 12.

12. Click \textit{\textbf{\textcolor{red}{Collect}}} to begin data collection. If the baseline appears stable, begin to run in place at 40 s. Continue data collection while running in place for the next 2 minutes.

13. At approximately 160 s, stop running. Stand still. Do not move during blood pressure measurement.

14. Immediately begin to pump the blood pressure cuff until the cuff pressure reaches at least 160 mm Hg. Stop pumping.

15. During this time the systolic, diastolic, and mean arterial pressures will be calculated by the software. These values will be displayed on the computer screen. When the blood pressure readings have stabilized (after the pressure drops to 50 mm Hg), the program will stop calculating blood pressure. At this point, release the pressure from the cuff.

16. Enter the systolic, diastolic, and mean arterial pressures in Table 2.

17. The subject should continue to stand in place while his/her heart rate slows toward its resting pre-exercise value. Data will be collected for 280 s.

18. Click and drag over the area of the graph where the resting heart rate is displayed (from 0 to approximately 40 s). This will highlight the region of interest.

19. Click the Statistics button, \textit{\textbf{\textcolor{red}{Statistics}}} Record the mean resting heart rate in Table 3.

20. Drag the right hand bracket to the right edge of the graph, until all the data points are highlighted. The values in the Statistics box will be adjusted based on the data within the brackets. Record the maximum heart rate in Table 2 (under “pulse”) and in Table 3.

21. Move the statistics brackets to highlight the area of the graph beginning with the maximum heart rate and ending with the first data point that matches the initial baseline value (or the last point graphed, if baseline is not achieved). Record the $\Delta x$ value displayed at the lower left corner of the graph as the recovery time in Table 3.
DATA

Table 1–Baseline Blood Pressure

<table>
<thead>
<tr>
<th>Systolic pressure (mm Hg)</th>
<th>Diastolic pressure (mm Hg)</th>
<th>Mean arterial pressure (mm Hg)</th>
<th>Pulse (bpm)</th>
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Table 2–Blood Pressure After Exercise

<table>
<thead>
<tr>
<th>Systolic pressure (mm Hg)</th>
<th>Diastolic pressure (mm Hg)</th>
<th>Mean arterial pressure (mm Hg)</th>
<th>Pulse (bpm)</th>
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Table 3–Heart Rate

<table>
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<th>Condition</th>
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<tr>
<td>Resting heart rate (bpm)</td>
</tr>
<tr>
<td>Maximum heart rate (bpm)</td>
</tr>
<tr>
<td>Recovery time (s)</td>
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</table>

DATA ANALYSIS

1. Describe the trends that occurred in the systolic pressure, diastolic pressure, mean arterial pressure and pulse with exercise. Assume that the stroke volume increased from 75 mL/beat to 100 mL/beat. Use this information and the change in pulse with exercise to calculate the change in cardiac output (stroke volume × heart rate) that occurred per minute.

2. Pulse pressure is the difference between systolic pressure (peak pressure during active contraction of the ventricles) and diastolic pressure (the pressure that is maintained even while the left ventricle is relaxing). Describe the change in pulse pressure seen with exercise. Which component of the blood pressure is most responsible for this change?
3. A change in pulse pressure can be seen in a variety of medical conditions. What would you expect to happen to the pulse pressure in the following examples?

(a) In atherosclerosis there is a hardening of the arterial walls.

(b) A damaged aortic valve does not seal properly and allows blood to flow back into the ventricle during diastole.

4. Normal resting heart rates range from 55–100 beats per minute. What was your/the subject’s resting heart rate? How much did your/the subject’s heart rate increase above resting rate with exercise? What percent increase was this?

5. How does your/the subject’s maximum heart rate compare with other students in your group/class? Is this what you expected?

6. Recovery time has been shown to correlate with degree of physical fitness. How does your/the subject’s recovery rate compare to that of your classmates? Is this what you expected?

7. Congestive heart failure is a condition in which the strength of contraction with each beat may be significantly reduced. For example, the ventricle may pump only half the usual volume of blood with each beat. Would you expect a person with congestive heart failure to have a faster or slower heart rate at rest? With exercise?

8. Medications are available which can slow the heart or speed it up. If a patient complains of feeling poorly and has a heart rate of 120 beats per minute, should you administer a medicine to slow the rate?
EXTENSIONS

1. Exercise for varying lengths of time and use page 2 of the experiment file to compare the heart rate and blood pressure readings taken after each exercise period.

2. Measure heart rate and blood pressure 5, 10, and 15 minutes after stopping exercise, and use Page 2 of the experiment file to compare readings.

3. Measure heart rate and blood pressure while lifting a weight with the opposite arm.

4. 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: gender, age, exercise regimen, coffee drinking within 2 hours of experiment, smoking status). Compare and contrast resting heart rates and recovery rates after exercise within and among these groups.
Vernier Lab Safety Instructions Disclaimer

THIS IS AN EVALUATION COPY OF THE VERNIER STUDENT LAB.

This copy does not include:

- Safety information
- Essential instructor background information
- Directions for preparing solutions
- Important tips for successfully doing these labs

The complete *Human Physiology with Vernier* lab manual includes 24 labs and essential teacher information. The full lab book is available for purchase at:
http://www.vernier.com/cmat/hpa.html