Human Physiology

with Vernier

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Vernier

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Blood Pressure as a Vital Sign

Blood pressure is a measure of the changing fluid pressure within the circulatory system. It varies from a peak pressure produced by contraction of the left ventricle, to a low pressure, which is maintained by closure of the aortic valve and elastic recoil of the arterial system. The peak pressure is called *systole*, and the pressure that is maintained even while the left ventricle is relaxing is called *diastole* (see Figure 1).

Mean arterial pressure (MAP) is not a simple average of the two pressures, because the duration of diastole is twice that of systole. MAP is used by emergency room and intensive care unit personnel as a measure of the adequacy of blood supplied to vital tissues (such as the brain, heart, and kidneys) when the blood pressure is dangerously low.

Blood pressure is traditionally reported with the *systolic* pressure stated first and the *diastolic* pressure stated second. In adults, 120/80 and below is considered normal blood pressure. High blood pressure is 140/90 or above. The seriousness of low blood pressure, as well as the health risks of high blood pressure (also called *hypertension*), have been elucidated over the past several decades. High blood pressure is a major risk factor for a number of health problems including strokes and congestive heart failure. Diet and exercise are beneficial, but many people require medication for optimal blood pressure control.

In this experiment, you will examine your blood pressure using the Vernier Blood Pressure Sensor. You will compare blood pressures taken before and after exposure to cold. The cold stimulus activates the sympathetic nervous system, resulting in hemodynamic changes that prepare the body for a “fight or flight” response (i.e., when fighting or running from danger).

The sensitivity of blood pressure to harmful external or internal injuries makes it useful as a *vital sign*, an indicator of health, disease, excitement, and stress.

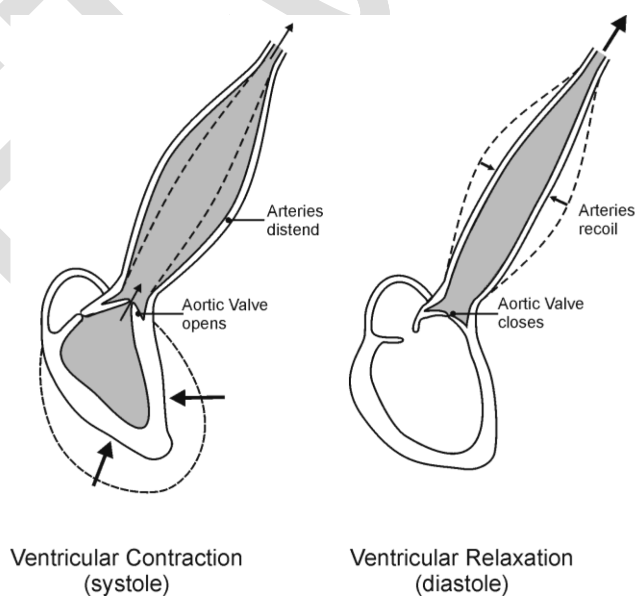

Figure 1

OBJECTIVES

In this experiment, you will

- Obtain graphical representation of heart rate and blood pressure.
- Compare blood pressure before and after exposure to cold stimulus.
- Observe an example of sympathetic nervous system activation (“fight or flight” response).

MATERIALS

LabQuest	ice water bath
LabQuest App	towel (paper or cloth)
Vernier Blood Pressure Sensor	

PROCEDURE

Part I Baseline Blood Pressure

1. Connect the Blood Pressure Sensor to LabQuest. There are two rubber tubes connected to the pressure 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.

2. Choose New from the File menu.

3. Attach the Blood Pressure cuff firmly around 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. Have the subject sit quietly in a chair with his or her forearm resting on a table surface. *The person having his or her blood pressure measured must remain still during data collection; there should be no movement of the arm or hand during measurements.*

5. Start data collection. Immediately pump the bulb pump until the cuff pressure reaches at least 160 mm Hg. Stop pumping. The cuff will slowly deflate and the pressure will fall. When the cuff pressure drops below 50 mm Hg, the program will calculate blood pressure. At this point, you can stop data collection. Release the pressure from the cuff, but do not remove it. Data collection will stop automatically after 100 seconds. If the final pressure value recorded was not below 50 mm Hg, repeat this step to collect another run.

Figure 2

6. Tap the Meter tab. Record the pulse and the systolic, diastolic, and mean arterial pressures.

Part II Blood Pressure Response to Cold

7. Prepare an ice water bath for use in the next step. The subject will be instructed to place his or her opposite hand (the one to which the Blood Pressure cuff is not attached) in the ice water bath for 15 s.

8. Collect data to examine the body’s response to cold.

   a. With the cuff still attached, have the subject from Part I put the hand of his or her non-cuffed arm in the ice water bath.

b. As soon as the subject's hand enters the ice water bath, start data collection.
c. Pump the bulb until the cuff pressure reaches at least 160 mm Hg, then stop pumping.
d. When data have been collected for 15 s, have the subject remove his or her hand from the ice water bath.
e. 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 stop data collection. Release the pressure from the cuff, and remove the cuff from the subject's arm.

9. Tap the Meter tab. Record the systolic, diastolic, and mean arterial pressures, and the pulse.

DATA

Table 1–Baseline Blood Pressure			
Systolic pressure (mm Hg)	Diastolic pressure (mm Hg)	Mean arterial pressure (mm Hg)	Pulse (beats/minute)

Table 2–Blood Pressure Response to Cold			
Systolic pressure (mm Hg)	Diastolic pressure (mm Hg)	Mean arterial pressure (mm Hg)	Pulse (beats/minute)

DATA ANALYSIS

1. Describe the trends that occurred in the systolic pressure, diastolic pressure, mean arterial pressure, and pulse with cold stimulus. How might these be useful in a "fight or flight" response?

2. *Vasovagal syncope* is a condition in which severe pain or fright activates the parasympathetic nervous system instead of the sympathetic nervous system, resulting in fainting. Keeping in mind that the parasympathetic system causes a response opposite to that of the sympathetic system, describe the hemodynamic changes that would explain this.

3. As a vital sign, blood pressure is an indicator of general health. A high blood pressure (140/90 or higher) increases the risk of cardiovascular disease and strokes. Collect the systolic and diastolic pressures for the class and calculate the average for each. Rate the class average blood pressure using the following scale:

Blood Pressure	Category
140/90 or higher	High
120–139/80–89	Pre-hypertension
119/79 or below	Normal

EXTENSION

Blood pressure is traditionally obtained by using a stethoscope to listen to the brachial artery. The pumping of air into the blood pressure cuff acts to stop the blood flow through this artery. As the pressure is released, the blood again is allowed to flow. When the blood begins to flow, pulsations can be heard through the stethoscope. The pressure in the cuff at that time can be noted, and corresponds closely to the systolic blood pressure. As pressure continues to be released from the cuff, the pulsations of the artery become less audible. The pressure at which they disappear has been found to approximate the diastolic pressure. These sounds are known as *Korotkoff Sounds*.

With a stethoscope, obtain the blood pressure of a classmate by listening for the appearance and disappearance of pulsations as the pressure in the cuff is released. Compare this to the blood pressure you obtained with the Vernier Blood Pressure Sensor.

Oxygen and Aerobic Metabolism

Oxygen plays a key role in aerobic cellular metabolism, facilitating the conversion of glucose, protein, and lipids into usable energy. For every 6 molecules of oxygen used in the breakdown of glucose, 6 molecules of carbon dioxide are produced, along with water and adenosine triphosphate (ATP), according to the following equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\ H_2O + \text{energy (heat or ATP)}$$

The average person uses 200–250 mL of O_2 per minute at rest. This may increase to 2–3 L per minute during heavy exercise and to twice that amount in highly trained athletes. The increase of oxygen consumption is proportional to the amount of work performed up to a maximum level which is dependent on conditioning. At the start of exercise, anaerobic metabolism is used briefly, but this quickly changes to aerobic metabolism as blood flow to muscles increases.

As O_2 is consumed and CO_2 is produced by muscle cells (and other cells), a pressure gradient is created between the cells, the interstitial fluid, and the bloodstream. A marked lowering of O_2 in interstitial fluid as it is used up by cells leads to O_2 diffusion from the bloodstream. While dissolved O_2 provides an immediate supply to replenish the interstitial fluid and cells, the majority of O_2 is carried on hemoglobin molecules. Oxyhemoglobin dissociates more readily as the oxygen concentration is lowered (and CO_2 concentration increased), rapidly replenishing the supply of dissolved O_2. CO_2 diffuses from active cells (where it is produced in high concentration) to the interstitial fluid and bloodstream, where it is transported to the lungs mainly as bicarbonate. In the lungs, the opposite is true. O_2 follows a pressure gradient from the alveoli into the bloodstream, and CO_2 from the bloodstream into the alveoli.

In this experiment, you will measure tidal volumes and oxygen concentrations of deeply inhaled and exhaled air at rest and after exercise. You will use these measurements to calculate the resulting differences in oxygen consumption.

Important: Do not attempt this experiment if you have pulmonary or musculoskeletal problems that might be aggravated by exercise.

OBJECTIVES

In this experiment, you will

- Obtain graphical representation of tidal volume and change in O_2 concentration with breathing at rest and after exercise.
- Calculate oxygen consumption at rest and after exercise.
- Correlate your findings with clinical situations.

MATERIALS

LabQuest
LabQuest App
Vernier Spirometer
Vernier O_2 Sensor
Vernier O_2-Spirometer adapter
disposable bacterial filter
nose clip
4 cm (¾ in.) PVC pipe

PROCEDURE

Part I Oxygen utilization at rest

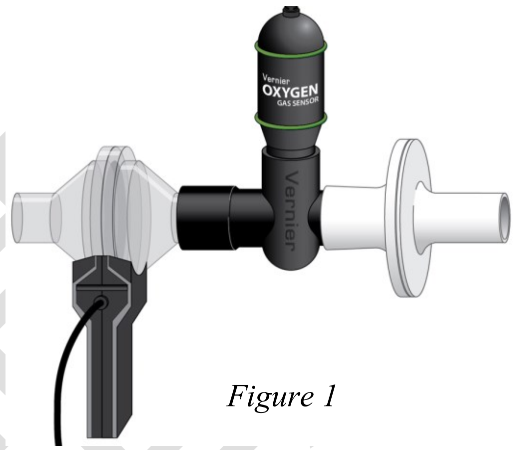

Figure 1

1. Connect the Spirometer and the O_2 Gas Sensor to LabQuest. 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 40 seconds. Select OK.

3. Assemble the apparatus (see Figure 1).
   a. Insert the O_2 Gas Sensor into the vertical opening of the O_2-Spirometer adapter.
   b. Identify the side of the Spirometer head marked “Inlet” and insert it into the adapter (the larger diameter side).
   c. Attach the bacterial filter to the smaller end of the adapter as shown. **Caution**: Do not puncture the filter material inside the bacterial filter.

4. Hold the apparatus in one or both hands. Brace your arm(s) against a solid surface, such as a table, and choose Zero ► Spirometer from the Sensors menu. *Do not zero the O_2 Sensor*. **Note**: The Spirometer must be held straight up and down during data collection (see Figure 1).

5. Collect inhalation and exhalation data.
   a. Put on the nose clip.
   b. Start data collection.
   c. Taking deep breaths, begin data collection with an inhalation and continue to breathe in and out. Each respiratory cycle should last 8–10 s (4–5 s per inhalation and 4–5 s per exhalation). Continue breathing in this fashion for the duration of the experiment. Data collection will continue for 40 s.

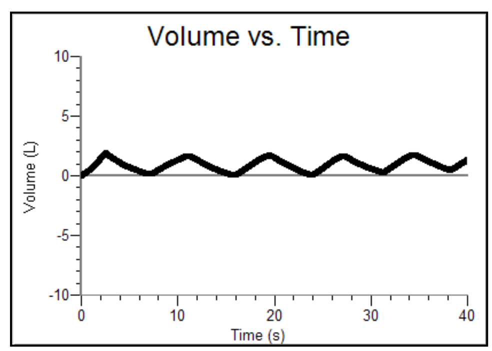

Figure 2

6. Tap the y-axis label of the flow rate *vs*. time graph and select Volume to display a graph of volume *vs*. time. 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 2. Select OK.

7. Determine the Δy for the volume *vs*. time graph.
   a. Tap the peak of the second peak of the volume graph and note the volume value.
   b. Tap the bottom of the valley that follows it and note the volume value.
   c. Calculate the Δy value and record it, to the nearest 0.1 L, as the total Breath 1 Pre-exercise Tidal Volume in Table 1.
8. Repeat Step 7 for a total of three breaths, entering the Δy values for each breath in Table 1.
9. Determine the Δy for the oxygen gas *vs*. time graph.
   a. Tap the peak of the second peak of the oxygen gas graph and note the oxygen gas value.
   b. Tap the bottom of the valley that follows it and note the oxygen gas value.
   c. Calculate the Δy value and record it, to the nearest 0.01 %, as the total Pre-exercise ΔO_2 Concentration in Table 1.
10. Repeat Step 9 for a total of three breaths, entering the Δy values for each breath in Table 1.

Part II Oxygen utilization during exercise

11. Begin running in place for two minutes, moving arms as well as legs.
12. At the end of two minutes, pick up the apparatus in one or both hands. Brace your arm(s) against a solid surface, such as a table, and choose Zero ► Spirometer from the Sensors menu. *Do not zero the O_2 Sensor*. **Note**: The Spirometer must be held straight up and down during data collection (see Figure 1).
13. Collect inhalation and exhalation data.
   a. Put on the nose clip.
   b. Start data collection.
   c. Taking deep breaths, begin data collection with an inhalation and continue to breathe in and out. Each respiratory cycle should last 8–10 s (4–5 s per inhalation and 4–5 s per exhalation). Continue breathing in this fashion for the duration of the experiment. Data collection will continue for 40 s.
14. If the baseline on your graph has drifted, choose Baseline Adjustment from the Analyze menu to bring the baseline volumes closer to zero. Select OK.
15. Determine the Δy for the volume *vs*. time graph.
   a. Tap the peak of the second peak of the volume graph and note the volume value.
   b. Tap the bottom of the valley that follows it and note the volume value.
   c. Calculate the Δy value and record it, to the nearest 0.1 L, as the total Breath 1 Post-exercise Tidal Volume in Table 1.
16. Repeat Step 15 for a total of three breaths, entering the Δy values for each breath in Table 1.
17. Determine the Δy for the oxygen gas *vs*. time graph.
   a. Tap the peak of the second peak of the oxygen gas graph and note the oxygen gas value.
   b. Tap the bottom of the valley that follows it and note the oxygen gas value.
   c. Calculate the Δy value and record it, to the nearest 0.01%, as the total Post-exercise ΔO_2 Concentration in Table 1.

18. Repeat Step 17 for a total of three breaths, entering the Δy values for each breath in Table 1.
19. Compute the average value for each of the parameters measured and enter those values in Table 1.

DATA

Table 1				
	Tidal volume (L)		ΔO_2 Concentration (%)	
Breath	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
1				
2				
3				
4				
Average				

DATA ANALYSIS

1. Compare the tidal volumes of the four breaths you analyzed both at rest and post-exercise. Is it important for this experiment that resting and post-exercise tidal volumes be similar?
2. Inhaled oxygen should have the same concentration at rest and post-exercise (approximately 21%), yet the peak oxygen concentration values in the post-exercise run never achieve this value. What aspect of the experimental design accounts for this finding?
3. Use the average values for Tidal Volume and ΔO_2 Concentration (%) from Table 1 to calculate the average O_2 consumed pre- and post-exercise per breath and over the combined four breaths:

$$\Delta O_2 \text{ Concentration (\%)} \times \text{Tidal Volume (L)} = O_2 \text{ consumed per breath}$$

$$O_2 \text{ consumed per breath} \times 4 \text{ breaths} = O_2 \text{ consumed over that time interval}$$

4. CO_2 was not measured. What would you expect the volume of exhaled CO_2 to be in this experiment at rest and after exercise?

EXTENSIONS

1. Oxygen consumption with exercise is directly proportional to the muscle mass being used. Demonstrate this principle by performing this experiment exercising with your legs only and/or with your arms only.
2. Perform this experiment after exercising for varying lengths of time (1 minute or 5 minutes).