Respiratory Response to Physiologic Challenges

Introduction

The respiratory cycle of inspiration and expiration is controlled by complex mechanisms involving neurons in the cerebral cortex, brain stem, and peripheral nervous system, as well as central and peripheral receptors. These receptors respond to a variety of stimuli including chemicals and pressure. Central respiratory control (respiratory drive) occurs in the pons and medulla oblongata, which respond directly to chemical influences. Other input is received from stretch receptors in the lungs and chemoreceptors located in the carotid and aortic bodies.

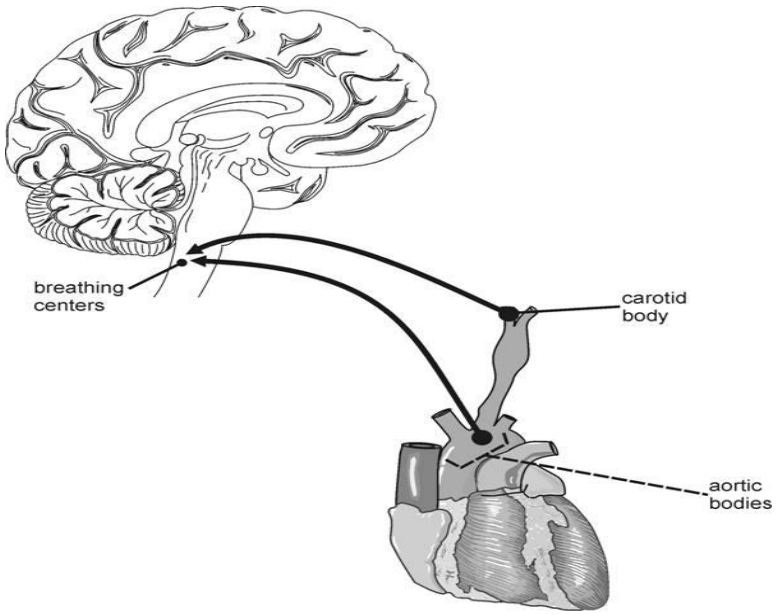
At rest, the average adult male produces approximately 200 mL of CO_2 each minute, this rate may increase to over 2000 mL/minute with exercise or heavy work. Hyperventilation lowers CO_2 levels due to an increased opportunity for gas exchange in the lungs. Holding one's breath or re-breathing air (such as breathing into a paper bag) raises CO_2 levels because there is less opportunity for gas exchange.Chemoreceptors respond most sensitively and rapidly to carbon dioxide, but they also respond to oxygen and pH (acidity). Constant adjustments in the respiratory cycle occur throughout the day to allow gas exchange in the lungs to maintain a steady level of CO_2 in the bloodstream. An increase in the CO_2 level stimulates breathing, while a decrease inhibits it. If the deviation from the "set point" is large enough, you may experience shortness of breath. The oxygen level can also influence the respiratory cycle, but larger deviations are required before its influence is felt.

In this experiment, you will alter CO_2 levels by holding your breath (hypoventilation), rapid breathing (hyperventilation), and exercise. You will compare the respiratory rate, tidal volume, and minute ventilation that result from each physiologic challenge to homeostasis.

Important: The equipment used in this experiment is for educational purposes only and should not be used to diagnose medical conditions.

Objectives

- Obtain graphical representation of normal tidal volume.
- Compare tidal volumes generated by various physiologic challenges.



MATERIALS

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct Spirometer

disposable mouthpiece

disposable bacterial filter

nose clip

PROCEDURE

Select one person from your group to be the subject. Important: Do not volunteer to be the subject if you are currently suffering from a respiratory ailment such as a cold or the flu.

Part 1 Tidal Volume Response to Breath Holding

1. Set up the data-collection equipment.

a. Launch Graphical Analysis.

b. Connect Go Direct Spirometer to your Chromebook, computer, or mobile device.

c. Click or tap Sensor Channels for the spirometer.

d. Select the Adjusted Volume channel.

e. Click or tap Done.

2. Adjust the view and graphs.

a. Click or tap View, B, and select 2 Graphs.

b. The first graph needs to be a graph of volume vs. time. Click or tap the y-axis label of the top graph and select Volume. Deselect the data you do not want displayed, and click or tap the graph to dismiss the menu.

c. The second graph needs to be a graph of adjusted volume vs. time. Click or tap the y-axis label for the second graph. Select Adjusted Volume and deselect all other columns. Click or tap the graph to dismiss the menu.

3. Set up the data-collection mode.

a. Click or tap Mode to open Data Collection Settings.

b. Change End Collection to 120 seconds. Click or tap Done.

4. Attach the larger diameter side of a bacterial filter to the "Inlet" side of the spirometer. Attach a disposable mouthpiece to the other end of the bacterial filter (see Figure 2). Important: The mouthpiece and bacterial filter must not be shared. If data are collected for multiple subjects, each person must have their own

5. Zero the sensor

a. Instruct the subject to hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The spirometer must be held straight up and down as shown in Figure 2. The subject should not breathe through the spirometer while it is being zeroed.

b. Click or tap the Flow Rate meter and choose Zero.

6. In this step, you will collect data. The spirometer is sensitive to the low air flow rates caused by moving the sensor, so it is important to follow the data-collection procedure carefully. Read through the following steps to become familiar with the process, and then collect data.

a. The subject should be seated comfortably and should put on the nose plug to ensure that he or she is only breathing through the mouth.

b. The subject should hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The subject should breathe normally, but should not start breathing through the spirometer until the next step. Note: The spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

c. On the subject's inhale, instruct the subject to start breathing through the mouthpiece and click or tap Collect to start data collection.

d. After four cycles of normal inspirations and expirations, instruct the subject to inhale as deeply as possible (maximum inspiration) and then hold his or her breath for 40 s.

e. After 40 s of breath holding, the subject should resume breathing normally. Data will be collected for 120 s.

7. Determine the tidal volume for the portion of the graph prior to the onset of breath holding.

a. Identify a representative peak and valley in the Adjusted Volume portion of the graph prior to the onset of breath holding.

b. Click or tap the peak and note the volume value.

c. Click or tap the bottom of the valley that follows it and note the volume value.
d. Calculate the Ay value and enter it, to the nearest 0.1 L, as the total Before Challenge volume in Table 1. tidal

e. Dismiss the Statistics box.

8. Determine the respiratory rate prior to the onset of breath holding.

a. Identify two adjacent peaks in the portion of the graph prior to the onset of breath holding.

b. Click or tap the first peak and note the volume value.

c. Click or tap the second peak and note the volume value.

d. Use the two values to calculate the respiratory rate in breaths/minute. Enter this value to the nearest 0.1 breaths/min as the Before Challenge respiratory rate in Table 1.

e. Dismiss the Statistics box.

9. Repeat Steps 7 and 8, selecting regions in the portion of your graph after normal breathing had been resumed (between 60 and 80 s). Enter the values in the After Challenge section in Table 1.

10. Calculate the minute ventilation values for before and after the challenge and enter the results to the nearest 0.1 L in Table 1.

(tidal volume)(respiration rate) = minute ventilation

Part II Tidal Volume Response to Rapid Breathing

11. Hold the spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table. Click or tap the Flow Rate meter and choose Zero. Note: The spirometer must be held straight up and down (as in Figure 2) during data collection.

12. Collect data for rapid breathing. Review the procedure and note the change in breathing pattern for this part. When everyone understands the procedure, collect data.

a. The subject should be seated comfortably and should put on the nose plug to ensure that he or she is only breathing through the mouth.

b. The subject should hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The subject should breathe normally, but should not start breathing through the spirometer until the next step. Note: The spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

c. On the subject's inhale, instruct the subject to start breathing through the mouthpiece and click or tap Collect to start data collection.

d. After four cycles of normal inspirations and expirations, instruct the subject to breathe deeply and rapidly for 40 s. Note: If the subject begins to feel faint, he or she should slow the breathing rate.

e. After 40s of rapid breathing, instruct the subject to resume normal breathing. Data will be collected for 120 s.

13. Determine the tidal volume for the portion of the graph prior to the onset of rapid breathing.

a. Identify a representative peak and valley in the Adjusted Volume portion of the graph prior to the onset of rapid breathing.

b. Click or tap the peak and note the volume value

c. Calculate the Ay value and record it, to the nearest 0.1 L, as the total Before Challenge tidal volume in Table 1.

14. Determine the Respiratory Rate prior to the onset of rapid breathing.

a. Identify two adjacent peaks in the portion of the graph prior to the onset of rapid breathing.

b. Click or tap the first peak and note the volume value.

c. Click or tap the second peak and note the volume value.

d. Use the two values to calculate the respiratory rate in breaths/minute. Enter this value, to the nearest 0.1 breaths/min, as the Before Challenge respiratory rate in Table 1.

15. Repeat Steps 13 and 14, selecting regions in the portion of your graph after normal breathing had been resumed (between 60 and 80 s). Enter the values in the After Challenge section in Table 1. 16. Calculate the minute ventilation values for before and after the challenge and enter the results to the nearest 0.1 L in Table 1

Part III Tidal Volume Response to Exercise

17. Zero the sensor.

a. Instruct the subject to hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The spirometer must be held straight up and down as shown in Figure 2. The subject should not breathe through the spirometer while it is being zeroed.

b. Click or tap the Flow Rate meter and choose Zero.

18. Collect data for rapid breathing. Review the procedure and note the change in the procedure for this part. When everyone understands the steps, collect data.

a. The subject should put on the nose plug to ensure that he or she is only breathing through the mouth.

b. The subject should hold the spirometer in one or both hands with the arm(s) braced against a solid surface, such as a table. The subject should breathe normally, but should not start breathing through the spirometer until the next step. Note: The spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

c. On the subject's inhale, instruct the subject to start breathing through the mouthpiece and click or tap Collect to start data collection.

d. After four cycles of normal inspirations and expirations, instruct the subject to begin running in place for 40 s. Note: If the subject begins to feel faint, he or she should slow the breathing rate.

e. After 40 s of running in place, instruct the subject to resume normal breathing. Data will be collected for 120 s.

19. Determine the tidal volume for the portion of your graph prior to the onset of exercise.

a. Identify a representative peak and valley in the Adjusted Volume portion of the graph prior to the onset of exercise.

b. Click or tap the peak and note the volume value. value.

d. Calculate the Ay value and record it, to the nearest 0.1 L, as the total Before Challenge tidal volume in Table 1.

c. Click or tap the bottom of the valley that follows it and note the volume

20. Determine the respiratory rate prior to the onset of exercise.

a. Identify two adjacent peaks in the portion of the graph prior to the onset of exercise.

b. Click or tap the first peak and note the volume value. c. Click or tap the second peak and note the volume value.

d. Use the two values to calculate the respiratory rate in breaths/minute. Enter this value, to the nearest 0.1 breaths/min, as the Before Challenge respiratory rate in Table 1.

21. Repeat Steps 19 and 20 two times. The first time, select regions in the portion of your graph during the challenge and the second time select regions after normal breathing had been resumed. Enter the values in the During Challenge and After Challenge sections in Table 2.

22. Calculate the minute ventilation values for before, during, and after the challenge, and enter the results, to the nearest 0.1 L, in Table 2

Table 1 Breathing Patterns		
	Holding breath	Rapid breathing
Before Challenge		
Tidal volume (L)		
Respiratory rate (breaths/min)		
Initial minute ventilation (L/min)		
Post Challenge		
Tidal volume (L)		
Respiratory rate (breaths/min)		
Minute ventilation (L/min)		

Table 2 Exercise	
Before Challenge	
Tidal volume (L)	
Respiratory rate (breaths/min)	
Minute ventilation (L/min)	
During Challenge	
Tidal volume (L)	
Respiratory rate (breaths/min)	
Minute ventilation (L/min)	
After Challenge	
Tidal volume (L)	
Respiratory rate (breaths/min)	
Minute ventilation (L/min)	

DATA ANALYSIS

1. Describe the changes in respiratory rates, tidal volumes, and minute ventilations that occurred after each of the following physiologic challenges in terms of CO_2 levels and their effect on respiratory drive:

a. breath holding

b. rapid breathing

c. exercise

2. Which challenge caused the greatest change in respiratory rate (pre-challenge versus post challenge)? Tidal volume? Minute ventilation? Did respiratory rate or tidal volume change the most relative to its resting value?

3. How might breathing into a paper bag help someone who is extremely anxious and hyperventilating?

4. Some patients with severe emphysema have constant high levels of CO_2 because of inadequate ventilation. The central nervous system breathing center in these patients becomes insensitive to CO_2 and more dependent on the level of O_2, which is low. These patients are said to have "oxygen-dependent respiratory drive." What might happen if you give such a person high levels of supplemental O_2?

5. Would breathing pure O_2 help the air hunger experienced by athletes who have just completed a race? Why or why not?

EXTENSION

Repeat the experiment, rebreathing (breathing in and out of a paper bag) from 20 to 60 **s**