Human Respiratory Physiology

Background

In this laboratory you will study several aspects of respiratory function, which is concerned with the delivery of O_2 and removal of CO_2 from body tissues. Because of their important roles in cell function, the partial pressures of these gases in the lungs and blood are finely controlled by various receptors, reflexes, and feedback processes that regulate respiratory patterns. By studying a person's respiratory movements under a variety of experimental conditions, you can gain insight into some of these control processes.

The rate and depth of respiration are controlled by respiratory centers, containing inspiratory and expiratory areas, located in the brainstem (medulla oblongata). These areas receive inputs from higher brain centers (e.g. pons, cerebellum, cerebral cortex) and from peripheral receptors, most importantly the chemoreceptors in the carotid and aortic bodies and the stretch receptors in the lungs. Depending on the needs of the body, inputs from peripheral receptors can adjust the rate of depth of breathing.

Note: Students with cardiovascular difficulties should not participate as subjects but should co-ordinate the exercises.

Experimental Setup

1. Firmly push the two airflow tubes onto the two outlets on the flow head.
2. Firmly push the other ends of the airflow tubes onto the two outlets of the SP-304 spirometer. Ensure the spirometer is connected to the **Channel 4** outlet.
3. Click **Settings** and select **Human Respiration**.
4. Left-click on the **Vol.Human** Channel and select **Setup Function**. Enter the appropriate spirometer calibration value, which is located on the rear of SP-304 spirometer amplifier.
5. Allow the SP-304 to warm up for 10 minutes before recording for the first time. Do not hold the SP-304 in your hand; the heat of your hand will alter the volumes recorded.
6. Press **Record**. Watch the display as the subject inhales. Use **AutoScale** to increase the size of the trace and determine which opening of the flowhead results in the wave displayed on the Airflow channel deflecting upwards during inhalation.

Note: The rubber tube connector on the flow head should always be positioned horizontally to avoid developing condensation within the airflow tubes. Use a clip to prevent air from entering or leaving the nose as the subject is breathing, since air that passes through the nose is not included in the volume measurement. Turbulence in the flow head will produce a noisy signal. To reduce turbulence, the subject should place their lips around the outside of the opening of the mouthpiece.

Record breathing patterns under the following conditions. After each exercise, please save your work with a proper label, close the file and open an appropriate new setting for the next exercise. For each exercise, have the subject hold the flowhead at mouth level, but in a position that prevents breath or any other airflow from moving through the flowhead.

Exercises

1) **Eupnea (normal quiet breathing):** The goal of this exercise is to record normal respiration for about 30 seconds while the subject is seated. The subject should not watch the screen, and should just let breathing happen naturally (i.e. they should not attempt to alter the normal breathing pattern). The subject should be relaxed with eyes closed if the environment is too distracting.

Click **Record**. Type "Resting" in the comment line to the right of the **Mark** button. Wait five seconds for the Volume Channel to zero before breathing into the flowhead. The subject will now place the flowhead in the mouth and begin breathing while blocking his/her nose. Once breathing begins, press **Enter** to mark the point. Record at least 10 breaths during normal, quiet breathing. Finally, inhale and exhale as deeply as possible, using maximum effort for each. Click **Stop.**

Using the Volume Channel, measure the following parameters:

Tidal Volume (TV): the amplitude of a normal breath in the breathing cycle. Using **two-cursor** mode, place one cursor at the lowest point in the trough prior to inhalation and the second at the peak of the cycle. **V2-V1** is the Tidal Volume. Measure the tidal volume of five breaths and calculate the average tidal volume.

Period: the duration of each breathing cycle. The duration is easiest to measure between peaks or troughs on the Volume record. The value, **T2-T1** is the Period. Measure the period of five breaths and calculate the average period.

Breathing Frequency (Breaths/minute) = 60 [seconds/minute] / average breath period [seconds/breath].

Vital Capacity: the maximum lung volume available for breathing. Using **two-cursor** mode, place one cursor at the peak after maximum inhalation and the second at the lowest point in the trough after maximum exhalation. **V2-V1** is the Vital Capacity.

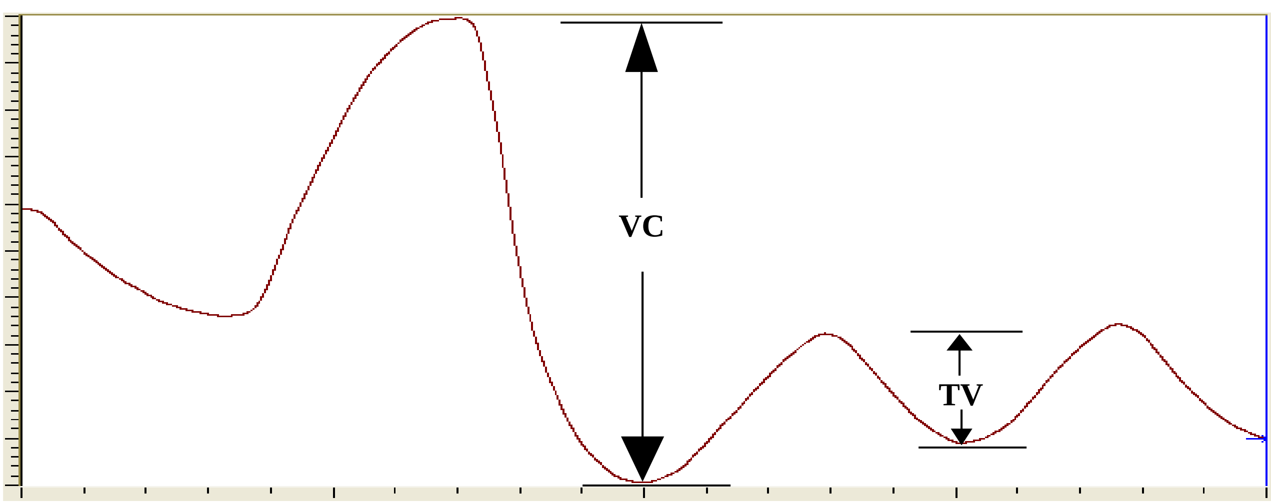

Figure 1. Volume displayed in the Analysis window. An upward deflection represents inspiration. Tidal volume (TV) and vital capacity (VC) are shown.

2) **Mental concentration:** While recording normal respiration have the subject concentrate on saying the alphabet backwards in their mind (without making any sounds) for one minute. Observe and describe modifications of respiration.

3) **Hyperventilation:** Record normal ventilation for about 1 minute. At a given signal, stop the recording and have the subject breathe as fast and as deeply as possible for 30 seconds. This will tend to reduce the arterial CO_2 levels. At the end of this period, record for at least 60 seconds. Pay close attention to the after-effects of the hyperventilation and note your observations. The subject should breathe normally in an involuntary fashion during the post hyperventilation period (as in Exercise 1). If the subject gets dizzy while hyperventilating, he/she should stop hyperventilating and breathe normally, but continue to record the respiratory response.

4) **Rebreathing:** Experimental increases in arterial CO_2 levels can be created by rebreathing into a closed space. Close the subjects' nose with a nose clip and, while recording, instruct the subject to breathe into and out of a small plastic bag tightly covering the end of flowhead. Try to avoid any air leaks via the nose or mouth. The subject should continue rebreathing from the bag until no longer tolerated, and then the bag should be removed while the subject continues to breathe through the flowhead. Continue recording until recovery is complete such that breathing comes back to normal.

5) **Breath holding:** Hypoventilation of the lungs causes a net gain of CO_2 in body fluids. Hypoventilation may be produced voluntarily by breath holding (voluntary apnea). While recording normal respiratory cycles, instruct the subject to hold his or her breath at the following times:

a) At the end of a normal inspiration
b) At the end of a normal expiration
c) At the end of a deep inspiration
d) At the end of a deep expiration

Determine the length of time the breath can be held (i.e. duration of voluntary apnea) in each case. Allow for adequate recovery time between each procedure and report your findings.

6) **Effect of exercise:** Record respiratory patterns after the subject has exercised by pedaling on a stationary bicycle for 5 minutes. The tension control should be set to 5 and the subject should pedal at a rate that causes increased ventilation (this rate may vary between individuals). Begin recording breathing immediately after exercise, and continue recording until recovery is complete such that breathing returns to normal. Note the different breathing pattern (breathing frequency and tidal volume) that is observed as a result of exercise, and note the time it takes for recovery.

Questions for Analysis

For all questions, discuss the control mechanisms involved.

1. How did vital capacity compare to resting tidal volume? What does this indicate about the ability of the respiratory system to increase breathing when the demands for gas exchange increase?

2. What are the effects of mental concentration on breathing frequency and tidal volume? What does this demonstrate about inputs to the respiratory centers from the cerebral cortex?

3. What are the after-effects of hyperventilation on subsequent breathing frequency and tidal volume? Does apnea (lack of breathing) or shallow breathing develop?

4. What changes in breathing frequency and tidal volume occurred during and after rebreathing, while the arterial partial pressure of CO_2 was elevated above normal?

5. Rebreathing from a closed bag also reduces the arterial partial pressure of O_2, which stimulates respiration. Which stimulus (low O_2 or high CO_2) has a more powerful effect on breathing?

6. In exercise 5, after which procedure is the duration of voluntary apnea longest? Why?

7. What is the effect of exercise on breathing and how long does it take to recover? Why does breathing remain elevated after exercise, when the muscle is no longer contracting?