Measuring Respiratory Volumes

Student Objectives
In this activity you will have the opportunity to
• Use the lung-volume bag and spirometer methods to measure lung volumes
• Graph and interpret a respiratory profile chart
• Generate and test hypotheses regarding relationships between human characteristics and lung capacity
• Calculate data averages, ranges, and t-test values comparing different groups
• Telecommunicate results to other classes
• Suggest further information and experiments needed to contribute to sustaining life in a regenerative life-support system

Background Information
A respiratory profile consists of measurements of different volumes within your lungs. How much air you breathe is determined by your activity level. The amount of air you inhale in a normal breath while at rest is called your tidal volume (TV). Your body needs more oxygen when performing strenuous work or exercise tasks. The inspiratory reserve volume (IRV) is the maximum additional lung volume available to a person in an inhalation beyond a normal breath. The maximum additional air you can exhale beyond a normal exhalation is your expiratory reserve volume (ERV). The sum of these three volumes is called your vital capacity (VC), meaning the largest breath you could ever take. The residual volume (RV) is the quantity of air that can never be exhaled without collapsing your lungs and trachea (sometimes called “dead space” because this air can’t be replaced with fresh air). The total of all the lung volumes is called the total lung capacity (TLC). Three ways of delivering extra air to the body during times of increased oxygen needs are: more rapid breathing (increasing respiration rate), inhaling more deeply (using your inspiratory reserve volume), and exhaling more deeply (using more of your expiratory reserve volume). Figure 1 at the end of this activity shows the volumes in one individual’s respiratory profile (adapted from Lujan and White, 1994).

Scientists and physicians have obtained a residual volume (RV) value of 1200 mL for a normal adult, and this is the value that you will use in your personal respiratory profile. The tidal volume (TV) is obtained by measuring a normal exhalation 3 times, then taking the average. The expiratory reserve volume (ERV) is measured after exhaling your normal breath, by continuing your exhalation into a measuring device such as the calibrated lung bag. The highest of 3 readings is used since the ERV is a maximum value. The maximum amount of air that you inhale above a normal breath is called the inspiratory reserve volume (IRV). Measuring inspiration requires a different device than those used for this lab, however your IRV can be calculated from the other measurements you will obtain. The vital capacity (VC) is the sum of the inspiratory reserve volume, the tidal volume, and the expiratory reserve volume, but can also be measured directly by first taking the deepest possible breath, then measuring the maximum volume of air that can be exhaled. The highest of three values is used since VC is a maximum value. Inspiratory capacity (IC) is the sum of the inspiratory reserve volume and the tidal
volume. **Functional residual capacity (FRC)** is the sum of the residual volume and the expiratory reserve volume. The **total lung capacity (TLC)** is the sum of all of the lung volumes. The term **capacity** indicates a value that is the sum of other values. **Minute Volume (V_E)** is the volume of air that is inhaled in one minute.

Brainstorm what you already know about your breathing. Propose relationships between vital capacity (maximum amount of air that can be exhaled after the deepest inspiration) and human characteristics. Research the lung to find out approximately how much air remains within the lung after a deep exhalation. Approximately how much air is inhaled with each breath? Approximately how many breaths are taken per minute? Per hour? Per day? Per week? Per month? Per year? Prepare a bar graph of time periods and approximate quantities of air breathed.

**Problems to Be Investigated**
What is your tidal volume (TV)? Is there a relationship between tidal volume and height? Between tidal volume and sex? What is your vital capacity (VC)? Is there a relationship between vital capacity and height? Between vital capacity and sex? Is there a relationship between vital capacity and another human characteristic (weight, smoking, etc.)?

**Hypothesis**
Hypotheses are complete-sentence answers to the questions such as those above that predict the outcome of your experiment. A hypothesis predicts the effect of the known independent variable (such as height or sex) on the dependent variable to be measured (tidal volume or vital capacity). Make sure that data can be gathered to test your hypothesis using the procedure that follows, or modify the procedure as needed.

**Materials**
lung bags (from a Delta “You and Your Lungs” kit or from a Carolina Biological “Lung Volume Bags” set)
rubber bands
mouthpieces
mouthpiece holders
meter stick
spirometer and spirometer mouthpieces
rulers
tape
magic markers

**Cautions**
- Do not share mouthpieces.
- Do not inhale through any of the lung measurement devices.
- Spirometers are fragile. Handle them with care.
- The Lung bag punctures easily. Be careful not to step on or slide a chair over it.
**Procedures**

**Height**
1. Attach a paper to the wall to facilitate measuring heights. Calibrate in cm with labeled tick marks using a meter stick.
2. Take turns with your partner measuring each other's heights. Record your names and heights on your own table and on the class Respiratory Measurement Table.

**Lung Bag Method**
1. Assemble the lung bag by attaching the mouthpiece holder to the bag with the rubber band.
2. Place a mouthpiece into the holder.

**Tidal Volume (TV)**
1. Take a series of normal breaths. Holding the mouthpiece holder in one hand, put your lips around the mouthpiece, plug your nose with the other hand, and exhale normally (not deeply).
2. Carefully flatten the bag along a smooth table edge to force the air into the bottom of the bag. Record the measurement to the nearest 0.05 L in your Respiratory Measurements Table under tidal volume.
3. Repeat steps (1) and (2) two more times. Calculate the average of the 3 numbers. This is your Tidal Volume.

**Expiratory Reserve Volume (ERV)**
1. Take a series of normal breaths. After a normal inhalation, put your lips around the mouthpiece, plug your nose with the other hand, and exhale as deeply as possible.
2. Record the measurement in your Respiratory Measurements Table.
3. Repeat steps (1) and (2) two more times. Enter a formula into the spreadsheet column labeled ERV that subtracts your tidal volume from the highest of the 3 new measurements to obtain your Expiratory Reserve Volume.

**Vital Capacity (VC)**
1. Take the deepest breath possible. Placing your mouth over the mouthpiece and plugging your nose, exhale as much air as possible into the bag.
2. Record the measurement under vital capacity.
3. Repeat steps (1) and (2) two more times, then use the highest of the three numbers as your vital capacity.
4. Dispose of your mouthpiece.
5. Your partner should attach a new mouthpiece and perform steps all three of the above sets of measurements for tidal volume, expiratory reserve volume, and vital capacity.

**Inspiratory Reserve Volume (IRV)**
Enter a formula into your spreadsheet that calculates the IRV using your lung volume measurements.
**Total Lung Capacity (TLC)**
Enter a formula into your spreadsheet that will add 1.2 L (a measurement obtained by scientists for the Residual Volume - an amount you cannot measure) to your vital lung capacity value.

**Spirometer Method**

**Vital Capacity (VC)**
1. Put a clean mouthpiece on the Spirometer.
2. Set the Spirometer dial to 0.
3. Take the deepest breath possible. Placing your mouth over the mouthpiece and plugging your nose, exhale as deeply as possible through the spirometer.
4. Record the number in your Respiratory Measurements Table.
5. Repeat steps (2) through (4) two more times. Record the highest of the 3 numbers as your Vital Capacity.

**Construct Your Respiratory Profile**
Use a piece of graph paper to sketch the actual values obtained for your personal respiratory profile, using Figure 1 as a model. All student diagrams should be different.

**Results**

**Table**
After entering the respiration class data into a spreadsheet, sort your table by sex, calculate male and female averages, and run a t-test on the female versus male vital capacity data. Is there a significant difference? Include the averages and t-test values in your data table. Refer to the “t-Test Activity” on the BioBLAST CD for instructions on performing the t-test.

**Graph**
Make line graphs of height versus vital capacity. Try to include 2 lines on the graph (one for the female data and one of the male data). Make sure the data points are indicated with 2 different symbols, and that a legend is included to differentiate "Female " and "Male" data.

**Summary of Results**
Give a brief statement describing the results (averages for each group and whether or not the t-test values comparing the groups are statistically significant).

**Discussion of Results**

**Significance of Results**
Discuss the significance of any differences found between the male and female lung volume measurements. Do the results differ depending on what equipment was used? Did your individual results differ from the class averages? Can you explain why? Also discuss possible sources of errors in your measurements, suggestions for making the experiment more accurate and easier to perform, and any disagreements over the results.

**Applications to Advanced Life-Support Research**
Discuss how the results you obtained could apply to advanced life-support research.
**Future Experiments**
Considering the results and the new questions they have raised, suggest possible future experiments that will help solve the overall mission of meeting the survival needs of the crew in their lunar habitat.

**Conclusion**
A conclusion is a simple statement of whether the data supported or refuted the hypothesis. Avoid the word “proof.” One experiment is unlikely to prove anything, and it can distract one from seeking alternative explanations which may be more appropriate than the first ones considered.

**Publish!**
Now is a good time to post the results of your experiments to your school's Web site and to check out the postings of other schools' sites to see whether their data ranges and averages are similar to yours.

**Compare Your Results to Those of Another Class**
1. Select data from another school's Web site. School Web addresses can be found on the BioBLAST Web site.
2. Copy the other school's data into a new table with your own data.
3. Plot your data and the other school's data as separate lines on the same graph.
4. Discuss reasons for any differences, referring to the other school's posted procedures and discussion sections.
5. Add the two-line graph and your discussion to your lab report and post it on your school's Web site, so that other schools can see your results.

**Journal Entry**
Make entries into your research journal, noting important human requirements concepts, questions, and ideas for future experiments. Sections may be cut and pasted into your journal from parts of the experiment, or from simulations. Did any of the other classes collect data that support or refute your hypothesis?

**Additional Activities**
1. Software simulations of external respiration (breathing) and internal respiration (breakdown of foods inside cells), such as the Muscle Metabolism section of the A.D.A.M. interactive physiology CD (Branstrom, 1995). These simulations show how oxygen is used to break down the chemical bonds in food so that energy is released to perform activities. The simulations also show how the different organ systems of the body are involved in the process of respiration.
2. Required reading on the difference between internal and external respiration in the “Calories, Exercise, and Metabolism” paper on the BioBLAST CD.
3. If possible, have a visitor from the American Heart Association or the Red Cross, or a local hospital, police or fire department give your class a CPR course.
4. Arrange for a respiratory therapist to come to your school with some equipment and/or a mobile cart. Obtain some of the percent oxygen and carbon dioxide readings that your classroom equipment could not detect. Use a Wright respirometer to obtain minute volumes \( V_E \) and duplicate some of the other lung volume measurements from your experiments. Do any of the new results differ from your own?
5. Research environmental conditions and respiratory disorders that could affect oxygen requirements for in an ALS.

6. Additional reading on respiratory volumes in Physiology of exercise (Lamb, 1985).

References