Lung Volumes and Capacities

Measurement of lung volumes provides a tool for understanding normal function of the lungs as well as disease states. The breathing cycle is initiated by expansion of the chest. Contraction of the diaphragm causes it to flatten downward. If chest muscles are used, the ribs expand outward. The resulting increase in chest volume creates a negative pressure that draws air in through the nose and mouth. Normal exhalation is passive, resulting from “recoil” of the chest wall, diaphragm, and lung tissue.

In normal breathing at rest, approximately one-tenth of the total lung capacity is used. Greater amounts are used as needed (i.e., with exercise). The following terms are used to describe lung volumes (see Figure 1):

- **Tidal Volume (TV):** The volume of air breathed in and out without conscious effort
- **Inspiratory Reserve Volume (IRV):** The additional volume of air that can be inhaled with maximum effort after a normal inspiration
- **Expiratory Reserve Volume (ERV):** The additional volume of air that can be forcibly exhaled after normal exhalation
- **Vital Capacity (VC):** The total volume of air that can be exhaled after a maximum inhalation: \( VC = TV + IRV + ERV \)
- **Residual Volume (RV):** The volume of air remaining in the lungs after maximum exhalation (the lungs can never be completely emptied)
- **Total Lung Capacity (TLC):** \( = VC + RV \)
- **Minute Ventilation:** The volume of air breathed in 1 minute: \( (TV)(breaths/minute) \)

![Figure 1](image)

In this experiment, you will measure lung volumes during normal breathing and with
maximum effort. You will correlate lung volumes with a variety of clinical scenarios.

**OBJECTIVES**

In this experiment, you will

- Obtain graphical representation of lung capacities and volumes.
- Compare lung volumes between males and females.
- Correlate lung volumes with clinical conditions.

**MATERIALS**

<table>
<thead>
<tr>
<th>LabQuest</th>
<th>disposable bacterial filter</th>
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<tr>
<td>Vernier Spirometer</td>
<td>nose clip</td>
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</table>

**PROCEDURE**

**Important:** Do not attempt this experiment if you are currently suffering from a respiratory ailment such as the cold or flu.

1. Connect the Spirometer into CH1 (on the top right side) on the LabQuest using the white square plug. Press the silver power button on the front of the LabQuest to turn it on. The software will recognize the spirometer and you will be ready to begin collecting data.

2. Attach the larger diameter side of a bacterial filter to the “Inlet” side of the spirometer.

4. Hold the spirometer in one hand. Brace your arm(s) against a solid surface, such as a table. To **zero** the spirometer, use the stylus to tap ‘Sensors’ at the top of the screen. Tap ‘Zero’ from the drop down menu and then ‘CH1.’ **Note:** The Spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

5. Collect inhalation and exhalation data.
   a. Put on the nose plug or hold your nose closed with a free hand.
   b. Use the stylus to tap the green collect button at the bottom left of the screen to begin data collection.
   c. Taking normal breaths begin data collection with an inhalation and continue to breathe in and out. After 4 cycles of normal inspirations and expirations fill your lungs as deeply as possible (maximum inspiration) and exhale as fully as possible (maximum expiration). **It is essential that maximum effort be expended when performing tests of lung volumes.**
   d. Follow this with at least one additional recovery breath.

6. Use the stylus to tap the collect button again to end data collection.
   a) **VERY IMPORTANT:** Discard the disposable bacterial filter into the biohazard bin in the lab and replace with a fresh one between each student usage. **Note:** If you are continuing this lab over 2 or 3 different lab periods,
please store your filter in a plastic bag with your name on it for reuse and place it into the bin provided on the lab cart. Discard filter in Biohazard bin on final lab day.

7. Using the stylus, tap ‘Analyze’ then ‘Delta’ then ‘Graph One.’ Select a representative peak and valley in the Tidal Volume portion of your graph. Place the stylus on the peak and drag down to the valley that follows it. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Tidal Volume in Table 1.

9. Move the stylus to the peak that represents your maximum inspiration. Tap and drag down the side of the peak until you reach the level of the peaks graphed during normal breathing. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Inspiratory Reserve Volume in Table 1.

10. Move the stylus to the valley that represents your maximum expiration. Tap and drag up the side of the peak until you reach the level of the valleys graphed during normal breathing. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Expiratory Reserve Volume in Table 1.

11. Press OK to exit Delta Analysis mode.

12. Calculate the Vital Capacity and enter the total to the nearest 0.1 L in Table 1.
   \[ VC = TV + IRV + ERV \]

13. Calculate the Total Lung Capacity and enter the total to the nearest 0.1 L in Table 1. (Use the value of 1.5 L for the RV.)
   \[ TLC = VC + RV \]

14. Share your data with your classmates and complete the Class Average columns in Table 1.

To EXPORT the data as a .txt file:
   a. Insert a USB drive or a SD card into the top of the LabQuest.
   b. Use the stylus to tap on 'File' at the top of the screen and then 'Export' from the drop down menu.
   c. Tap on the image of the USB drive or the SD card to entire that device. Tap ‘Untitled’ at the top of the screen and use the on screen keyboard to enter a new name for your file.
   d. Tap OK to finish exporting. The text file can be exported into Excel for data analysis.
When finished:

b) Hold down the silver power button until the device shuts down. If you did not want to save your data tap ‘Discard.’

c) Disconnect the spirometer from the LabQuest. Place the spirometer and all other equipment into the ANP storage bins. Please use the Velcro power chord tie wraps on all of the devices to roll up the chords before placing them in the storage bins.

Vernier Lab: Lung Volumes
Names: ____________________________________________
________________________________________________

DATA

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Volume measurement (L)</td>
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<tr>
<td>Tidal Volume (TV)</td>
</tr>
<tr>
<td>Inspiratory Reserve (IRV)</td>
</tr>
<tr>
<td>Expiratory Reserve (ERV)</td>
</tr>
<tr>
<td>Vital Capacity (VC)</td>
</tr>
<tr>
<td>Residual Volume (RV)</td>
</tr>
<tr>
<td>Total Lung Capacity (TLC)</td>
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</table>

Answer the following questions to analyze/discuss results from the lab work. Please work in groups to complete the questions below; write up your answers as a group, and attach the answers to this sheet.

1. After collecting class data, and finding the averages for Tidal Volume (TV), and respiration rate (RR), explain the following:
   • How would you explain the difference in the averages for TV between males and females?
   • Do you see a relationship between the average TV and the respiratory rate (RR) for males and females? If so, how would you explain this?
   • By extension, predict how the RR would be different (higher, lower) for an
infant, and explain why there would be a difference in rate between the infant and an adult.

2. Lung volumes in a person may vary based on many factors (you looked primarily at gender as a factor, but there are others). List several other factors and predict how these factors would affect lung volumes (you can stick to how total lung capacity or vital capacity would be affected). I’ll give you the first factor, age, for you to discuss, and you can come up with two or three additional factors.

3. Smokers frequently have an increase in TV while smoking, but TV returns to normal values after finishing a cigarette. How would you explain this? What implications does this change in breathing have in terms of how the substances in the smoke may be affecting the person’s lungs (is more or less of their lung surface area being exposed)?

4. In COPD (chronic obstructive pulmonary disease, which is primarily emphysema and chronic bronchitis), three lung volumes that are particularly important in terms of diagnosing and monitoring a person’s condition are vital capacity (VC), residual volume (RV), and total lung capacity (TLC).
   • How would VC, RV and TLC be affected in a person with emphysema? Explain.
   • People with emphysema are often put on oxygen (you can see them at the mall, wearing a canula—the nasal tubes supplying oxygen—and their portable oxygen tank). How is this oxygen compensating for changes in functional surface area in the lungs?

5. Asthma is another obstructive disease, but lung volumes in an asthmatic remain relatively normal. However, air flow rates decline significantly during an attack. A person with asthma (except in a severe attack—one that requires hospitalization) doesn’t usually require oxygen therapy, while a person who is suffering from other forms of COPD (like emphysema) does.
   • Although asthma and COPD are both considered “obstructive” diseases, what are some significant differences in your group’s informed opinion, about these two diseases. For starters, what anatomical structures are affected? What other differences exist?