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. During quiet breathing, contraction of the diaphragm muscle causes it to flatten downward, increasing the vertical dimension of the thoracic cavity. Additional respiratory muscles in the chest (external intercostals) lift the ribs, expanding them outward and further increasing volume. 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 contrast to passive breathing, active breathing uses additional muscles known as accessory respiratory muscles (including the sternocleidomastoid, scalenes, internal intercostals and abdominal muscle groups) to further expand and contract the thorax.

In normal breathing at rest, approximately one-tenth of the total lung capacity is used. Greater amounts are used as needed (e.g., 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)

TLC = VC + RV

Minute Ventilation

The volume of air breathed in 1 minute:

Minute Ventilation = (TV × breaths/minute)

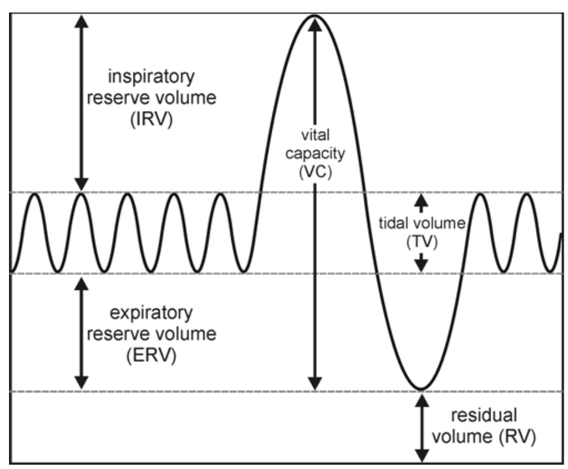

Figure 1

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.

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OBJECTIVES

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

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Spirometer
disposable mouthpiece
disposable bacterial filter
nose clip

PROCEDURE

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

1. Launch Graphical Analysis. Connect Go Direct Spirometer to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change End Collection to 60 s.
   c. Click or tap Done.

3. Attach the larger diameter side of a bacterial filter to the "Inlet" side of the Spirometer. Attach a gray disposable mouthpiece to the other end of the bacterial filter (see Figure 2).

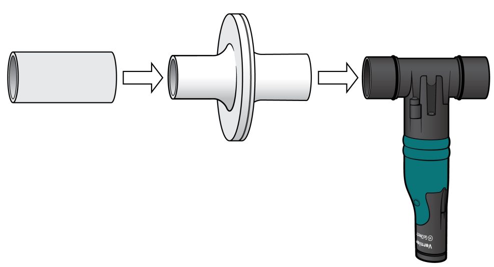

Figure 2

4. Collect inhalation and exhalation data.
   a. Put on the nose plug.
   b. Hold the Spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table. **Note**: The Spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.
   c. Click or tap Collect to start data collection.

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d. 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*.

e. Follow this with at least one additional recovery breath.

5. Stop data collection.

6. To view a graph of volume *vs*. time, click or tap the y-axis label. Select Volume and deselect the columns you do not want displayed.

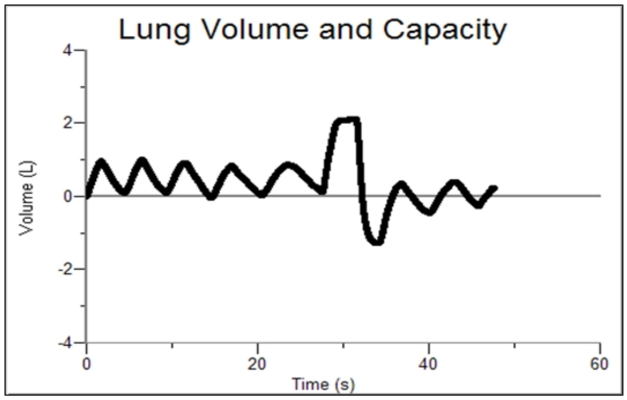

Figure 3

7. Determine Tidal Volume.
   a. Identify a representative peak and valley in the Tidal Volume portion of your graph.
   b. Click or tap the data point at the peak and note the volume value.
   c. Click or tap the data point at the bottom of the valley that follows the peak and note the volume value.
   d. Calculate the Δy value and record it, to the nearest 0.1 L, as the total Tidal Volume in Table 1.

8. Determine Vital Capacity.
   a. Click or tap the peak that represents your maximum inspiration and note the volume value.
   b. Using the level of the peaks graphed during normal breathing from Step 7, calculate the Δy value and record it, to the nearest 0.1 L, as the Vital Capacity in Table 1.

9. Determine Inspiratory Reserve Volume.
   a. Click or tap the valley that represents your maximum expiration and note the volume value.
   b. Using the level of the valleys graphed during normal breathing from Step 7, calculate the Δy value and record it, to the nearest 0.1 L, as the Inspiratory Reserve Volume in Table 1.

10. Calculate the Expiratory Reserve Volume and enter the total to the nearest 0.1 L in Table 1.

$$ERV = VC - (IRV + TV)$$

11. 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.)

$$TLC = VC + RV$$

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

DATA

Table 1			
Volume measurement	Individual (L)	Class average (Male) (L)	Class average (Female) (L)
Tidal Volume (TV)			
Inspiratory Reserve (IRV)			
Expiratory Reserve (ERV)			
Vital Capacity (VC)			
Residual Volume (RV)	≈1.5	≈1.5	≈1.5
Total Lung Capacity (TLC)			

DATA ANALYSIS

1. What was your Tidal Volume (TV)? What would you expect your TV to be if you inhaled a foreign object which completely obstructed your right mainstem bronchus?
2. Describe the difference between lung volumes for males and females. What might account for this?
3. Calculate your Minute Ventilation at rest.

   $$\text{Minute Ventilation at rest} = (TV \times \text{breaths/minute})$$

   If you are taking shallow breaths (TV = 0.20 L) to avoid severe pain from rib fractures, what respiratory rate will be required to achieve the same minute volume?
4. Exposure to occupational hazards such as coal dust, silica dust, and asbestos may lead to *fibrosis*, or scarring of lung tissue. With this condition, the lungs become stiff and have more "recoil." What would happen to TLC and VC under these conditions?
5. In severe emphysema there is destruction of lung tissue and reduced recoil. What would you expect to happen to TLC and VC?
6. What would you expect to happen to your Expiratory Reserve Volume when you are treading water in a lake?

EXTENSION

Repeat the experiment with the chest or abdomen constricted (use a girdle or ace bandage).

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