

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).

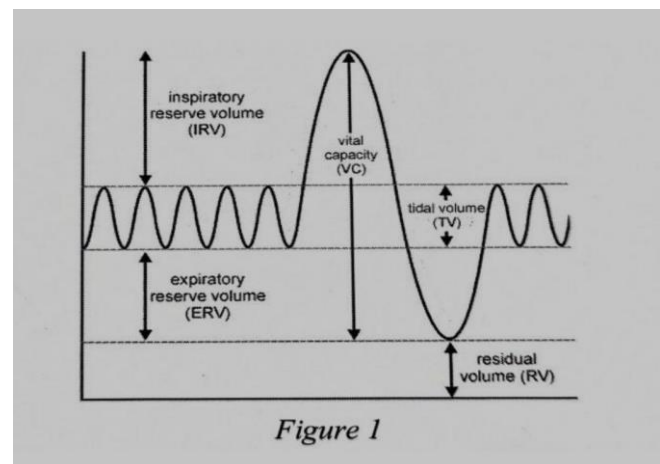
Total Lung Capacity (TLC)

$$TLC=VC+RV$$

Minute Ventilation

The volume of air breathed in 1 minute:

$$\text{minute ventilation} = (TV * \text{breaths/minute})$$



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.

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 lung capacities and volumes.
- Compare lung volumes between males and females.
- Correlate lung volumes with clinical conditions

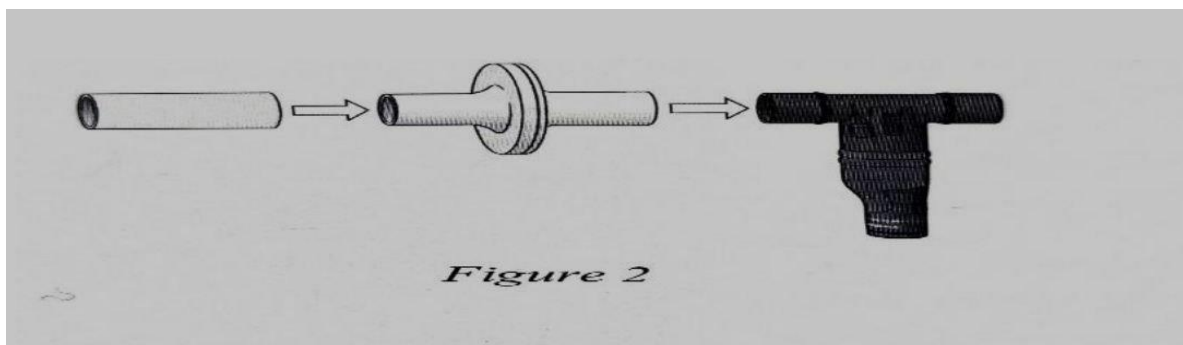
MATERIALS

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

PROCEDURE

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.

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 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.



4. 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 (see Figure 2). Do not breathe through the spirometer while it is being zeroed.
- b. Click or tap the Flow Rate meter and choose Zero.

5. 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 exhale as fully as possible (maximum expiration). It is essential that maximum effort be expended.
- e. The subject should continue breathing normally after the deep breath. Allow data collection to continue until you have collected data for at least one recovery breath after the deep breath, and then stop data collection.

6. Determine tidal volume (TV).

- a. Identify a representative peak and valley in the tidal volume (TV) portion of the graph.
- b. Click or tap the peak and then drag to the valley that follows it.
- c. Click or tap Graph Tools, and choose View Statistics
- d. Enter the Δy value, to the nearest 0.1 L., as the total tidal volume (TV) in Table 1.
- e. Dismiss the Statistics box.

7. Determine vital capacity (VC)

- a. Click or tap the peak that represents the maximum inspiration, then drag to the valley that follows it
- b. Click or tap Graph Tools, and choose View Statistics.
- c. Enter the Δy value, to the nearest 0.1 L., as the vital capacity (VC) in Table 1.
- d. Dismiss the Statistics box.

8. Determine inspiratory reserve volume (IRV).

- a. Click or tap the peak that represents your maximum inspiration. Note the volume value. ~~tidak~~volume peak just before maximum inspiration. Note the volume value.
- b. Click or tap the c. Calculate the Δy value and record it, to the nearest 0.1 L., as the inspiratory reserve volume (IRV) in Table 1.

9. Calculate expiratory reserve volume (ERV) and enter the total to the nearest 0.1 L. in Table 1.
 $ERV = VC - (IRV + TV)$

10. Calculate total lung capacity (TLC) and enter the total to the nearest 0.1 L in Table 1. (Use value of 1.5 L for the RV.)

$$TLC=VC+RV$$

11. 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 the tidal volume (TV)? What would you expect the TV to be if you inhaled a foreign object that completely obstructed the right mainstem bronchus?
2. Describe the difference between lung volumes for males and females. What might account for this?
3. Calculate the minute ventilation at rest

$$\text{minute ventilation at rest} = (TV * \text{breaths/minute})$$

If someone were 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 the Expiratory Reserve Volume when someone is treading water in a lake?