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| **Activity 3.3.2: Measuring Lung Capacity**  |

Introduction

Oxygen is essential for human life. The lungs are responsible for bringing air into the body and facilitating the contact between the oxygen molecules in the air and the hemoglobin molecules in the red blood cells. Just how much air can the lungs hold? When you are out of breath and breathing harder than usual, is your lung capacity different from when you are at rest?

How often do you think about your breathing? Most likely the only time you think about it is when you are having difficulty breathing or when you are out of breath. Several times a minute, the muscles involved in the breathing process contract and relax, allowing you to inhale and exhale.

The primary muscle responsible for your breathing is the diaphragm. This is a powerful, dome-shaped muscle that separates the thoracic or chest cavity from the abdominal cavity. If you have been unable to catch a breath after falling or getting hit in the mid-section, most likely the reason for your breathing difficulty was disruption of the diaphragm muscle.

Contraction of the diaphragm causes it to flatten and expand the thoracic cavity. At the same time the intercostal muscles, which span the spaces between the ribs, contract to expand and lift the rib cage. The resulting increase in thoracic volume creates a negative pressure gradient, drawing air into the lungs. You have some voluntary control over these muscles so you can regulate your breathing to take deeper or shallower breaths. You can also contract and hold them in the contracted state in order to hold your breath. When the diaphragm and intercostal muscles relax the thoracic volume decreases, causing air to be exhaled. Normal exhalation is passive (does not require energy expenditure by cells) and results from the recoil of the chest wall, diaphragm, and lung tissue.

Singers, wind instrument musicians, and weight lifters use even more muscles when they breathe. For deep breaths, the large pectoral (chest) and abdominal muscles are used to further increase the size of the thoracic cavity so that even larger amounts of air can enter the lungs. With the larger volumes of air and controlled exhalation, the singer and musician can sing and play longer between breaths. The weight lifter may use the additional volume of air to reinforce his or her spinal column and assist the back muscles in order to lift heavy weights.

Take a moment to think about your breathing. As you were reading the paragraphs above, you were probably breathing at a slow, steady rate that was very rhythmic. Now take a large breath and hold it for a couple seconds. Now exhale as much air from your lungs as you can. Return to breathing normally. Was the volume of air you took into your lungs the same when you took the big breath as when you were reading? Did you feel different muscles working when you took the big breath? Did you feel your thoracic cavity get larger when you took the deep breath?

As you just observed, the volume of air taken into the lungs can be varied by consciously controlling the muscles to take shallow or deep breaths. There are multiple terms to describe the different volumes of air in the lungs. These terms are defined below.

* 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 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 maximal inhalation: VC = TV + IRV + ERV.
* Residual Volume (RV): The volume of air remaining in the lungs after maximum exhalation (under normal conditions, the lungs are never completely emptied).
* Total Lung Capacity (TLC): Total volume of the lungs is the sum of the vital capacity and the residual volume: TLC = VC + RV.
* Minute Volume: The volume of air breathed in one minute without conscious effort: MV = TV x (breaths/minute).

Most people, when at rest and breathing normally, are using only about 10% of their total lung capacity. Greater amounts of lung capacity are used as needed, for example, when a person is under stress or exercising. Lung capacity is affected by numerous disease and medical conditions including emphysema, asthma, and the common cold.

In this activity you will measure lung volumes during normal breathing and with maximum effort to calculate your tidal volume, vital capacity, and minute ventilation.

If you have a cold, flu, or other respiratory condition or concern, do not use the spirometer to measure your lung capacity; instead, use the measurements of someone else in your group to complete the activity. Also, it is best if each person uses his or her own bacterial filter and mouth piece.

This activity is a modification of “Experiment 19: Lung Volumes and Capacities” in Human Physiology with Vernier written by Diana Gordon and Steven L. Gordon and is used with permission.

Equipment

* Computer with Vernier Logger *Pro®*software
* Vernier LabQuest® Mini with USB cable
* Spirometer sensor
* Disposable Spirometer Bacterial Filters
* Disposable Spirometer Mouth Pieces
* Laboratory journal
* Nose clip (optional)

Procedure

1. Start the Logger *Pro* program.
2. Click on *File Open* and open the *Human Physiology with Vernier* folder.
3. Open the program titled *19 Lung Volumes*.
4. Connect the spirometer sensor into CH 1 of the LabQuest Mini.
5. Connect the LabQuest Mini to the computer using the USB cable.
6. Use a marker to write your initials or name on a bacterial filter and a mouth piece. You will use these today and save them to use another day for a different activity.
7. Attach the larger diameter end of the bacterial filter to the Inlet of the spirometer, and attach a gray disposable mouthpiece to the other end of the bacterial filter.



1. Place the nose clip over your nose, or pinch your nose closed using your fingers. You need to breathe through your mouth while using the spirometer. Do not breathe through the spirometer until directed to do so.
2. Hold the spirometer straight up and down; it may be helpful to brace your elbows against the table. Click Zero  to zero the sensor.
3. Note that the spirometer must be held straight up and down. It is important that the spirometer does not move during data collection.
4. Use your lips to naturally seal around the mouth piece and press the green *Collect* arrow in the top toolbar.
5. Taking normal breaths, begin data collection with an inhalation and continue to breathe in and out. After four cycles of normal inspirations and exhalations, fill your lungs as deeply as possible and exhale as fully as possible. It is essential that maximum effort be expended when performing tests of lung volumes.
6. Return to normal breathing for two inhalations and exhalations.
7. Click on the red *Stop* button.
8. Name and save the file when instructed to do so. Follow your teacher’s instructions regarding the file name and location to save the file.
9. Click the *Next Page* button on the toolbar  to see the lung volume data. If the baseline of your graph has drifted, use the baseline adjustment feature to bring the baseline volumes closer to zero. Click on the up or down arrows on the adjustment feature to move the graph up or down until the exhalation values are close to zero. See the sample graph below.



1. Examine the labeled diagram below. It is taken from a graph of lung volume (L) on the y axis and time (seconds) on the x axis. Use the diagram to determine how to calculate the tidal volume, inspiratory reserve volume, expiratory reserve volume, and vital capacity using the graph of your respiration data. Step 19 will walk you through an example analysis.



1. Make a chart in your Laboratory journal similar to the one below.

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| Volume measurement (L) | Individual (L) | Class average (Male) (L) | Class average (Female) (L) |
| Tidal Volume (TV)  | .43 |  |  |
| Inspiratory Reserve (IRV) | 2.72 |  |  |
| Expiratory Reserve (ERV) | 1.23 |  |  |
| Vital Capacity (VC) | 4.76 |  |  |
| Residual Volume (RV) | ≈1.5 | ≈1.5 | ≈1.5 |
| Total Lung Capacity (TLC) | 5.613 |  |  |
| Minute Volume (MV) at rest | n/a | n/a | n/a |

1. Select a representative peak and valley in the Tidal Volume portion of your graph. Place the cursor on the peak and click and drag 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 (TV) in your data table.



1. Use Step 19 as a guide as you determine Inspiratory Reserve (IRV) and Expiratory Reserve (ERV). Record these volumes in your data table.
2. Calculate the Vital Capacity using the equation listed in the Introduction and record the calculated value rounded to the nearest 0.1 L in the data table in your laboratory journal.
3. Using the equation listed in the Introduction and the lung volumes you recorded, compute your *Total Lung Capacity* (TLC). Show your calculations in your laboratory journal and record your results in your data chart.
4. Calculate your *Minute Volume* (MV) at rest. The equation for MV is found in the Introduction. Breathe normally and count the number of breaths you take in one minute. Then use the tidal volume you calculated and the number of breaths you took in one minute to calculate your Minute Volume. Show your calculations in your laboratory journal and record your results in your data chart.
5. Share your data with the class as directed by your teacher.
6. Calculate and record the class averages for males and females.
7. Store your bacterial filter and mouth piece as directed by your teacher so you can use it again in another activity.

Conclusion

1. Was there a difference between lung volumes for males and females? Propose an explanation for any difference or lack of difference.
2. How might the lung volume of an athlete, singer, or wind instrument musician be different from someone who does not participate in any of these activities?
3. Suppose you suffered a rib injury that inhibited your ability to take regular breaths due to the pain. If you needed to maintain the same minute volume as you calculated in this activity, and your tidal volume was 0.2 L due to the injury, what would your respiratory rate have to be? Show your calculations.
4. Exposure to environmental hazards such as coal dust, silica dust, and asbestos may lead to pulmonary fibrosis or scarring of the lung tissue. With this condition the lungs become stiff and have less elasticity. What would happen to the total lung capacity and vital capacity under these conditions? Explain your reasoning for your response.
5. Explain how a common cold might affect the tidal volume and the minute volume of a person.
6. Examine the table below that indicates the percentages of various molecules in the air before and after exhalation. Explain what is happening in the lungs and the body to cause the differences between the atmospheric air and the expired air.

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| Composition of atmospheric air and expired air for a typical human subject. |
| Component | Atmospheric Air (%) | Expired Air (%) |
| N2 (plus inert gases) | 78.62 | 74.9 |
| O2 | 20.85 | 15.3 |
| CO2 | 0.03 | 3.6 |
| H2O | 0.5 | 6.2 |
|   | 100.0% | 100.0% |

1. BONUS Question: Assume you will live to be 80 years old, and, unfortunately, you die on your birthday at exactly the same time as your current class time. Using your minute volume calculated above, find the volume of air your lungs will exchange between now and the time you die. Explain your work and show all of your calculations.