Analysis of Lung Function

Spirometry is a valuable tool for analyzing the flow rate of air passing into and out of the lungs. Flow rates vary over the course of a *respiratory cycle* (a single inspiration followed by a single expiration) and are dependent upon a variety of factors. Maximal inspiration results from contraction of the diaphragm downward and the movement of the ribs upward and outward, both of which expand the chest cavity. Forced expiration is the result of the rapid contraction of chest and abdominal muscles, as well as the relaxation of the diaphragm.

Lung flow rates are graphed as a *flow volume loop*, in which air flow is graphed as a function of volume. Because volume (graphed on the x axis) is increased with inspiration and decreased with expiration, the completed graph forms a loop (see Figure 1). As is demonstrated in the flow volume loop, in normal lungs air is rapidly expelled early in the process of forced expiration, with a tapering of flow rate as the lungs are emptying. This latter part of the expiration curve represents the emptying of small airways (*terminal bronchioles*). Inspiration shows a different pattern, with the maximum air flow occurring halfway through the cycle.

Information about disease states can be obtained through examination of flow volume loop graphs. Data that can be obtained or calculated from the graph include:

- *forced vital capacity (FVC)*, the total exhaled air, from maximum inhalation to maximum exhalation;
- *forced expiratory volume (FEV₁)*, the volume of air expelled in the first second of a forced exhalation;
- FEV₁/FVC, measured as a percentage;
- *peak expiratory flow (PEF)*, the highest point on the exhalation graph.

Changes from expected values can be used to diagnose a variety of pulmonary conditions and to follow their progress over time.

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

- Obtain graphical representation of a flow volume loop.
- Find the forced expiratory volume at 1 s (FEV₁) and the forced vital capacity (FVC).
- Calculate FEV₁/FVC.
- Find the peak expiratory flow rate (PEF).
- Create flow volume loops for several clinical scenarios.

MATERIALS

- computer
- disposable mouthpiece
- Vernier computer interface
- disposable bacterial filter
- Vernier Spirometer
- nose clip
- Logger Pro

PROCEDURE

Select one person from your lab group to be the subject.

1. Connect the Spirometer to the Vernier computer interface. Open the file “21 Analyze Lung Function” from the Human Physiology with Vernier folder.

2. Attach the larger diameter side of a white bacterial filter to the side of the Spirometer head marked “Inlet.” Attach a disposable mouthpiece to the other end of the bacterial filter (see Figure 2).

3. Hold the Spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table, and click \( \) [Zero]. **Note:** The Spirometer must be held straight up and down (see Figure 2) and not moved during data collection.

4. Collect exhalation and inhalation data.
   a. Put on the nose clip and put your mouth against the mouthpiece.
   b. Click \( \) [Collect] to begin data collection.
   c. Take the deepest breath possible and exhale forcefully as quickly as possible through the Spirometer mouthpiece. **Important:** Force ALL of the air out of your lungs. Your exhalation will trigger data collection. Without removing your mouth from the mouthpiece, inhale as deeply as possible.
5. If your data does not approximate Figure 1, repeat Step 4. It is helpful to watch the screen while performing this test. **Important:** It is essential that maximum effort be expended when performing tests of air flow.

6. Find FEV₁ by scrolling down the data table to 1.00 s. Scroll to the right to see the volume. Record this value to the nearest 0.01 L in the data table.

7. Click the Examine button. Move the examine line to the rightmost point of the flow volume loop. This is the FVC. Record the volume value to the nearest 0.01 L in the data table. Close the Statistics box by clicking the X in the corner of the box.

8. Find FEV₁/FVC, multiply by 100, and enter the calculated value in the data table.

9. Click the Statistics button. Enter the maximum flow rate value to the nearest 0.01 L/s as **peak expiratory flow rate** (PEF) in the data table.

**DATA**

<table>
<thead>
<tr>
<th>FEV₁ (L)</th>
<th>FVC (L)</th>
<th>FEV₁/FVC (%)</th>
<th>PEF (L/s)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

**DATA ANALYSIS**

1. Using the flow volume loops pictured below as guides, superimpose loops for the following scenarios. In your answer consider whether the problem affects inspiration, expiration, or both; whether it is likely to affect the first half of the curve, the second half of the curve, or both. (Hint: It may be helpful to begin by estimating the maximum expected total lung capacity for each situation and drawing this point on the graph first.)

   a. There is a narrowing of the trachea, causing blockage in this large airway.

![Flow Rate vs Lung Volume Graph]
b. A small grape is lodged in the right mainstem bronchus, completely blocking off the right lung.

c. Emphysema reduces all flow rates, but has a greater effect on small airways, many of which are lost to the disease. (Acute asthma may show similar changes because of mucous obstruction of these same small airways.)

d. Severe osteoporosis may result in kyphoscoliosis, in which there is a curvature of the upper spine that limits the normal ability of the ribs to expand with inspiration.
2. Lung disease is often divided into two broad categories: obstructive disease and restrictive disease. Examples of obstructive disease are emphysema, chronic bronchitis, and asthma. Examples of restrictive disease are abnormalities of the spine and chest and diseases within the lungs that make them less elastic (“stiffer”), such as pulmonary fibrosis. Calculate the FEV₁/FVC in the table below for obstructive and restrictive disease and compare to your values. How might these values be helpful diagnostically?

<table>
<thead>
<tr>
<th>Volume (L)</th>
<th>Normal (your data)</th>
<th>Obstructive disease</th>
<th>Restrictive disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>FEV₁ (L)</td>
<td></td>
<td>1.8</td>
<td>3.5</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td></td>
<td></td>
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</tbody>
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