PULMONARY FUNCTION TEST (PFT)

Objectives:

By the end of the present lab, students should be able to:

1. Record lung volumes and capacities and compare them with those of a typical person of the same gender, height and age.

2. Perform and describe some of the pulmonary function tests (FVC, FEV1, FEV1%, and peak expiratory flow) and compare them with those of a typical person of the same gender, height and age.

3. Differentiate between normal, obstructive, and restrictive pattern spiromgrams.
PULMONARY FUNCTION TEST

The efficiency of gas exchange between air and blood, which occurs in the alveoli, is dependent on ventilation (alternating inflation and deflation of the lungs.)
The efficiency of ventilation, on the other hand, is dependent on the integrity of airways, alveoli, thoracic cage (bones and muscles) and the respiratory control mechanisms.
PFT includes:

- Test for ventilation (SPIROMETRY).
- Test for gas exchange (lung diffusing capacity - Dlco).
- Blood gas analysis.
- Exercise test.
- Special tests like bronchodilator test, PFT for children....
Spirometry is used for:

- Check up
  - Periodic health check up.
  - Physical fitness.
  - Preoperative.

- Diagnosis of lung diseases
  - Obstructive lung disease (asthma and chronic bronchitis).
  - Restrictive lung disease (pulmonary fibrosis).

- Follow up of treatment in chronic lung diseases.
Spirometry (measuring of breath)

• The most common PFT.

• It measures the amount (volume) and/or the speed (flow) of air that can be inhaled and exhaled.

• Spirometry is becoming more and more important, as respiratory diseases are increasing worldwide.
• Studies suggest that Chronic Obstructive Pulmonary Disease (COPD) could climb to be the 3rd leading killer by 2020.

• Most COPD cases are completely avoidable; 85-90% of cases are caused by tobacco smoking.
Development of Spirometry

The water spirometer measuring vital capacity was developed by a surgeon named John Hutchinson, in 1846.
• Spirometer was then developed into dry types.
  • Vitalograph
  • Vicatest
Modern Spirometers

*Computer based
*More accurate

Turbine

Modern, computer based spirometer
Whole body plethysmograph

• This type of spirometer gives a more accurate measurement for the components of lung volumes as compared to other conventional spirometers.

• A person is enclosed in a small space when the measurement is taken.
Data acquisition with a PowerLab system

In 1980s

- Personal computer
- Digital electronics
- Record electrical signals and convert them from Analog to Digital (A to D) and then, with appropriate software, display & analyze this information on the computer screen.
The PowerLab pneumotachometer

This spirometer measures the flow rate of gases by detecting pressure differences across the fine mesh. One advantage of this spirometer is that the subject under investigation can breathe in fresh air during the experiment.
Lung volumes and capacities
• In resting adult, the normal rate of breathing (breaths/minute or BPM) is approximately 15.

• The product of BPM and VT (tidal volume) is the Expired Minute Volume (minute ventilation), the amount of air exhaled in one minute of breathing.
Note that the volume of air remaining in the lungs after a full expiration, residual volume (RV), cannot be measured by spirometry as a volunteer is unable to exhale any further. Other common lung volumes and capacities are shown in the table below.
<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation / Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration Rate</td>
<td>RR</td>
<td>breaths/min (BPM)</td>
</tr>
<tr>
<td>Expired Minute Volume</td>
<td>$V_E = RR \times V_T$</td>
<td>L/min</td>
</tr>
</tbody>
</table>

**Lung Volumes**

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Volume</td>
<td>$V_T$</td>
<td>L</td>
</tr>
<tr>
<td>Inspiratory Reserve Volume</td>
<td>IRV</td>
<td>L</td>
</tr>
<tr>
<td>Expiratory Reserve Volume</td>
<td>ERV</td>
<td>L</td>
</tr>
<tr>
<td>Residual Volume</td>
<td>RV (predicted)</td>
<td>L</td>
</tr>
</tbody>
</table>

**Lung Capacities**

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspiratory Capacity</td>
<td>IC = $V_T + IRV$</td>
<td>L</td>
</tr>
<tr>
<td>Expiratory Capacity</td>
<td>EC = $V_T + ERV$</td>
<td>L</td>
</tr>
<tr>
<td>Vital Capacity</td>
<td>VC = IRV + $V_T + ERV$</td>
<td>L</td>
</tr>
<tr>
<td>Functional Residual Capacity</td>
<td>FRC = ERV + RV</td>
<td>L</td>
</tr>
<tr>
<td>Total Lung Capacity</td>
<td>TLC = VC + RV</td>
<td>L</td>
</tr>
</tbody>
</table>

**Pulmonary Function Tests**

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Inspiratory Flow</td>
<td>PIF</td>
<td>L/min</td>
</tr>
<tr>
<td>Peak Expiratory Flow</td>
<td>PEF</td>
<td>L/min</td>
</tr>
<tr>
<td>Forced Vital Capacity</td>
<td>FVC</td>
<td>L</td>
</tr>
<tr>
<td>Forced Expiratory Volume (1 second)</td>
<td>FEV$_1$</td>
<td>L</td>
</tr>
<tr>
<td>% FVC expired in one second</td>
<td>FEV$_1$ / FVC x 100</td>
<td></td>
</tr>
</tbody>
</table>
SUBJECTS, APPARATUS AND PROCEDURE

• Subjects
  • Pre-test instructions and demonstration.

• Apparatus
  • Use the Pneumotach Spirometer (PowerLab System) for lung volumes measurement.
  • Use the Dry Type Spirometer (Vitalograph) for forced expiratory flow measurements (FVC, FEV1, FEV1%, PIF & PEF).
  • Spirometer chart (spirogram).
  • Nose clip.
  • Tape measure.
  • Nomogram chart (to obtain predicted-ideal FVC).
• Procedure

1. Normal breathing maneuver (use the PowerLab Pneumotachometer):
   • Ask the volunteer subject to breathe normally (tidal breathing) followed by a single full inspiration then full expiration.

2. Forced expiration maneuver (use the Dry Type Sirometer-Vitalograph):
   • Forced expiration maneuver (use dry type sirometer-Vitalograph):
     • Ask the subject to take max inspiration then followed by a single as forceful and as deep as possible expiration (from TLC to RV).

Subjects should wear nose clip. Repeat each test twice again in order to choose the best trial.
MEASUREMENTS AND CALCULATIONS

1. Lung volumes and capacities:

- Use the Labtutor software to obtain the measured Lung volumes and capacities (see the table above). Compare with the predicted values which are provided based on the Goldman and Becklake equations (cited from the John Hopkins Pulmonary Laboratory).

- Normal measured values are expected to differ from the predicted ideal values by about (±10-15 %).
2. Obtain the **FVC** from the spirogram.

- Correct the FVC from **ATPS** (ambient temperature and pressure saturated with water vapour) to **BTPS** (body temperature and pressure saturated with water vapour) by multiplying it with the **correction factor** obtained from special chart depending on lab. temperature.
• Compare the corrected FVC with the predicted FVC obtained from the nomogram or special prediction equations.

• Normal measured values differs from the predicted ideal values by about (±10-15%).
  • FVC is decreased in restricted lung disease (e.g. Pulmonary fibrosis) with normal FEV1%.
  • FVC may be normal in obstructive lung disease.
• Obtain the **FEV1** from the spirogram.

• Calculate the **FEV\(_1\)%** from the following equation:

\[ \text{FEV}_{1\%} = \frac{\text{FEV1}}{\text{FVC}} \times 100 \]

• **FEV\(_1\)%** is decreased in obstructive lung disease.

• **FEV\(_1\)%** is normal in restrictive lung disease.
DISCUSSION

• Enumerate the factors which affect the different lung function parameters.

• Discuss the advantage of the modern spirometers in comparison with the old ones.

• How you can use the forced spirogram to differentiate between obstructive and restrictive pulmonary diseases.