Respiratory air flow and volume

An experiment examining respiratory variables during resting conditions and forced breathing.

Introduction

The aim of this teaching experiment is to introduce students to the PowerLab Spirometry arrangement for recording respiratory variables and analysing a recording to derive respiratory parameters. The experiment is suitable for introductory undergraduate physiology or medical students. In this experiment the students examine lung volumes and capacities, as well as the basic tests of pulmonary function.

Background

Gas exchange between air and blood occurs in the alveolar air sacs. The efficiency of gas exchange is dependent on ventilation: cyclical breathing movements that alternately inflate and deflate the volume of the alveolar air sacs. Inspiration refills the alveoli with fresh atmospheric air and expiration removes stale air, which has reduced oxygen and increased carbon dioxide concentrations.

Many important aspects of lung function can be determined by measuring air flow and the corresponding changes in lung volume. In the past this was commonly done by breathing into a bell spirometer, in which the level of a floating bell tank gave a measure of lung volume changes. Flow, $F$, was then calculated from the slope (rate of change) of the volume, $V$:

$$F = \frac{dV}{dt}$$  \hspace{1cm} \textit{Equation 1}

More conveniently, air flow can be measured directly with a pneumotachometer (the word is derived from Greek roots meaning ‘breath speed measuring device’). The PowerLab pneumotachometer arrangement is shown in Figure 2. The flow head contains a fine mesh. Air breathed through the mesh gives rise to a small pressure difference that is (within certain limits) proportional to flow rate. Two small plastic tubes transmit the pressure difference to the Spirometer front-end, where a transducer converts the pressure signal into a changing voltage that is recorded by the PowerLab and displayed with the Chart software. The volume, $V$, is then calculated as the integral of flow:

$$V = \int F \, dt$$  \hspace{1cm} \textit{Equation 2}

The integration here represents a kind of summation over time; the volume traces that you will see in the Chart window during the experiment are obtained by adding successive sampled values of the flow signal and scaling the sum appropriately. The integral is initialised to zero every time a recording is started.
A complication in the volume measurement is caused by the difference in air temperature between the Spirometer front-end or Pod (at ambient temperature) and the air exhaled from the lungs (at body temperature). The volume of gas expands with warming, therefore the air volume expired from the lungs will be slightly greater than that inspired. Thus a volume trace, as calculated by integration of flow, drifts in the expiratory direction. To reduce the drift, the flow has to be integrated separately during inspiration and expiration, with the inspiratory volume being corrected by a factor related to the BTPS factor (body temperature, atmospheric pressure, saturated with water vapour). The Chart extension ‘Spirometry’ can make this correction.

Spirometry allows many components of pulmonary function (as shown in Figure 1) to be visualised, measured, and calculated. Respiration consists of repeating cycles of inspiration followed by expiration. During the respiratory cycle, a specific volume of air is drawn into and then expired out of the lungs; this volume is the Tidal Volume ($V_T$). In normal ventilation, the breathing frequency ($f$) is approximately 15 respiratory cycles per minute. This value varies with the level of activity. The product of $f$ and $V_T$ is the Expired Minute Volume ($\dot{V}_E$), the amount of air exhaled in one minute of breathing. This parameter also changes according to the level of activity.

The total capacity of the lungs is comprised of four functionally separate lung volumes; Tidal Volume ($V_T$), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), and Residual Volume (RV). There are five pulmonary capacities that are the sum of two or more lung volumes; Inspiratory Capacity (IC), Expiratory Capacity (EC), Functional Residual Capacity (FRC), Total Lung Capacity (TLC), and Vital Capacity (VC). Note that RV, FRC, and TLC cannot be measured by spirometry. However, these values can be predicted using equations.

Forced parameters, which assess the ability to ventilate the lungs with maximal voluntary effort, are often of greater clinical value than simple lung volumes and capacities. Forced Expired Volume in one second (FEV$_1$), Peak Inspiratory Flow (PIF), and Peak Expiratory Flow (PEF) are strongly affected by airway resistance, and are important in the detection and monitoring of obstructive disorders (bronchitis, emphysema, and asthma). Forced Vital Capacity (FVC) is similar to

![Lung volumes and capacities.](image-url)
VC, but is obtained from measurement of a single expiration; it is reduced in restrictive disorders such as pulmonary fibrosis. The FVC is graphically represented as larger than VC in Figure 1, but the FVC is often smaller than the VC in practice.

**Setting up the experiment**

The experiment has been designed for and tested on a PowerLab 4/20T system, although it can easily be adapted for other PowerLab systems (see Appendix B). The equipment required for these exercises is:

- PowerLab 4/20T [ML860]
- Spirometer front-end [ML140], or Spirometer Pod [ML311]
- Respiratory flow head, and connection tubes [MLT1000L]
- Tubing adaptor
- Disposable filters [MLA304]
- Disposable vinyl mouthpieces [MLA1026]
- Nose clip [MLA1008]
- A tape measure or wall chart for measuring height
- If available, tables or graphs of predicted vital capacity for males and females (we recommend the tables in Gaensler and Wright¹)

**Connecting the equipment**

The Spirometer front-end or Pod should be connected to your PowerLab, as described in the owner’s guide supplied with the hardware. The Spirometer front-end or Pod should be connected to input 1 on the PowerLab. The PowerLab should then be connected to your computer and turned on. Since the Spirometer is sensitive to temperature and tends to drift during warm-up, we recommend that the PowerLab and Spirometer be turned on for at least 15 minutes before use (if you are using the Spirometer Pod 5 minutes should be sufficient). Place the Spirometer front-end or Pod on a shelf or beside the PowerLab, away from the PowerLab power supply to avoid heating (which can cause the Spirometer signal to drift).

Connect the two plastic tubes from the flow head to the short pipes on the front panel of the Spirometer front-end, as shown in Figure 2 (the pipes are found on the back panel of a Spirometer Pod). Attach a filter and mouthpiece to the flow head.

**Hygiene**

A clean mouthpiece and air filter should be supplied for each volunteer. If required, the vinyl mouthpiece can be cleaned between uses by soaking it in boiling water or a suitable disinfectant. If you are suffering from a respiratory infection, we suggest that you do not volunteer for this experiment.
Starting the software

If you are not sure how to locate and start Chart, your tutor should provide instructions. The same file is used for all the exercises in this experiment. If your tutor has prepared a settings file, open the prepared file. Otherwise, create a new Chart file and set it up. Suggested settings are given in Appendix A of this experiment — check there now. Some settings are discussed in more detail below.

Setting up the Spirometer

1. The flow head must be left undisturbed on the bench during the zeroing process. Choose the Spirometer… item from the Flow (Channel 1) Channel Function pop-up menu. The Spirometer Amplifier dialog box appears, as shown in Figure 3. (If you have a Spirometer Pod connected, choose the Spirometer Pod… item. The Spirometer Pod dialog box will open. As shown in Figure 4, it has a slightly different appearance to the dialog box for the Spirometer.) Click the Zero button.

2. When zeroing has finished, have the volunteer breathe out gently through the flow head, and note the recorded signal in the data display area (Figures 3 and 4). If the signal is downward-going (that is, negative), you do not need to invert it and can go to step 4.

3. If the signal is upward-going, you need to invert it. Click the Invert checkbox once to toggle its state. Note: the signal can also be inverted by reversing the orientation of the flow head, or by swapping the tubular connections to the Spirometer front-end or Pod. The Invert checkbox is simply more convenient.
4. There should be no need to adjust the range. Click the OK button to close the dialog box and return to the Chart window.

**Exercise 1: Familiarisation**

**Objectives**

To understand the principles of spirometry, and to understand how integration of the flow signal gives a volume.

**Procedure**

1. The volunteer should put the mouthpiece in his or her mouth, and hold the flow head carefully with both hands. The two plastic tubes should be uppermost. Put the nose clip on the volunteer’s nose. This ensures that all air breathed passes through the mouthpiece, filter, and flow head (see Figure 5).

2. After the volunteer has become accustomed to the apparatus and is able to breathe normally, you are ready to begin.

3. Click Chart’s Start button to begin recording.

4. Record tidal breathing for approximately one minute. You should observe data being recorded on Channel 1, but none on Channel 2. During that time
you should perform two full expirations, one near the start of recording, and one near the end.

5. Click Chart’s Stop button to end recording. The volunteer can stop breathing through the flow head and remove the nose clip.

Setting up the Spirometry extension

The Spirometry extension processes the raw voltage signal from the Spirometer, applies a volume correction factor to improve accuracy, and displays calibrated Flow (L/s) and Volume (L) traces. It takes over from units conversion. The trace that you recorded in this exercise will provide reference points for the Spirometry extension that allow it to calculate and perform corrections on the trace.

1. Select the entire recording of tidal breathing data including the two forced expirations by double-clicking in the Time axis. (This selects a block of data.)

2. Choose the Spirometry Flow... item from the Flow (Channel 1) Channel Function pop-up menu. The Spirometry Flow dialog box appears (Figure 6). Flow (Channel 1) should be selected in the Raw Flow Channel pop-up menu. MLT 1000L should be selected in the Flow Head Calibration pop-up menu.

3. When you are finished and the settings are the same as in Figure 6, click the OK button to close the dialog box.
4. Choose the Spirometry Volume… item from the Volume (Channel 2) Channel Function pop-up menu. The Spirometry Volume dialog box appears (Figure 7).

5. Flow (Channel 1) should be selected in the Spirometry Flow Channel pop-up menu. Click the Use button to allow the extension to use the volume correction ratio that it has calculated from your data.

![Figure 7](The Spirometry Volume dialog box.)

6. When you are finished, click the OK button to close the dialog box. The Chart window should now appear with calculated volume data on Channel 2.

7. Choose Set Scale… from the Flow (Channel 1) Amplitude axis Scale pop-up menu. Make the top value 15 L/s and the bottom value –15 L/s.

8. Choose Set Scale… from the Volume (Channel 2) Amplitude axis Scale pop-up menu. Make the top value 5 L and the bottom value –5 L.

**Examine your data**

1. When examining your data, use the scroll buttons if required to show parts of the trace that have scrolled out of sight.

2. Drag in the Time axis to select data from both channels and open the Zoom window. Note the relation between Flow and Volume. When the flow signal is positive (inspiration), the Volume trace rises; when the flow is negative (expiration), the Volume trace falls.

3. In the Zoom window trace, find a part of the recording where the flow is zero. Note that at this time the Volume trace does not change (it is horizontal) because integrating a zero signal does not add anything to the integral.

4. The volume trace is calculated by the extension in such a way that the displayed volumes at the end of the two full expirations equal. In subsequent recordings, the volume correction is unlikely to be exact: you will notice a tendency for the volume to drift, typically by 1–2 L over 1–2 minutes. To see the effect of having no correction, turn off the Volume Correction checkbox in the Spirometry Volume dialog box (see Figure 7), and examine the volume trace. Remember to turn Volume Correction back on again.
Exercise 2: Lung volumes and capacities

Objectives

To examine the respiratory cycle and to measure flow and volume changes.

Procedure

It is important when recording normal respiration that the volunteer is facing away from the computer screen, and is not consciously controlling breathing. The volunteer may have to stare out a window or read a book to avoid conscious control of respiration.

1. Choose the Spirometer… or Spirometer Pod… item from the ‘Flow’ Channel Function pop-up menu. The flow head must be left undisturbed on the bench during the zeroing process. Click the Zero button to re-zero the Spirometer (or Pod). When zeroing has finished, click the OK button to return to the Chart window.

2. Note the time and click Chart’s Start button to begin recording. Ask the volunteer to replace the nose clip and breathe normally through the flow head. Record normal tidal breathing for at least 20 seconds. Add the comment ‘Normal tidal breathing’ to the Chart trace. Click Chart’s Stop button to end recording.

Have a member of the lab group, someone other than the volunteer, observe the number of times the volunteer breathes over 15–20 seconds. Calculate how many breaths there would be in a one-minute period \(f\). Record \(f\) (l/min) in the table provided at the end of this experiment (or one like it). Also record \(f\) in the units of Hz (divide the number of breaths in one minute by 60).

3. Click Chart’s Start button to begin recording.

4. Type the comment ‘IRV procedure’ to prepare it. At the end of a normal tidal inspiration ask the volunteer to breathe in as deeply as possible and then to breathe normally. Press the Return key to add the comment to the Chart trace.

5. Type the comment ‘ERV procedure’ to prepare it. At the end of a normal tidal expiration ask the volunteer to exhale as deeply as possible and then to breathe normally. Press the Return key to add the comment.

Examine your data

1. Examine the Flow trace, using the scroll buttons as required to show parts of the trace that have scrolled out of sight. In quiet spontaneous breathing, inspiration is normally followed immediately by expiration, but there is a clear interval before the next inspiration. Does the volunteer show this pattern?
2. In quiet breathing, muscular effort is used mainly in inspiration, and expiration is largely passive, due to elastic recoil of the lung. Can you relate this fact to the pattern of expiratory and inspiratory flow mentioned in Question 1? (Hint: the normal pattern of breathing is efficient in that it requires muscular effort for only a short time.)

**Analysis**

Before you begin analysing your data you may find it useful to adjust the vertical axis so that the signal occupies about a half to two thirds of the vertical axis, or change the horizontal compression. Ask your demonstrator for help if you need it. There is a table near the end of this experiment in which you can record your measured and calculated values.

1. Drag the Marker from its box at the bottom left of the Chart window to the Volume trace at the start of an ‘ordinary’ quiet inspiration (see Figure 8). Move the Waveform Cursor to the next peak of the Volume trace (this should be 0.5 to 1.5 s to the right of the Marker). Read off the numerical value of Volume from the Range/Amplitude display at right.

The number has a Δ symbol in front of it, indicating that it is the difference between the volume at the pointer position and the volume at the Marker’s position. If you have both the Marker and the pointer in the right places, the value shown is the Tidal Volume ($V_T$) for that breath. Record the value in the table at the end of this experiment.

2. Return the Marker to its box at bottom left, by double-clicking the Marker, dragging it back, or clicking its box.

![Figure 8](image)

A typical tidal breathing record, displayed at 10:1 horizontal compression. The Marker and Waveform cursor are positioned to measure the Tidal Volume of a single breath.
3. Using the number of breaths, \( f \) (per minute), observed over a one-minute period, and the value for \( V_T \), calculate the Minute Volume (\( \dot{V}_E \)) using Equation 3. Record your value for \( \dot{V}_E \) in the table.

\[
\dot{V}_E = V_T \times f \quad \text{(L/min)}
\]  

Equation 3

4. Find the comment containing ‘IRV procedure’. Place the Marker on the peak of the inspiratory volume of the previous tidal breath and move the Waveform Cursor along to the peak of the volume trace from the full-depth breath (Figure 9). The difference displayed in the Range/Amplitude display is the Inspiratory Reserve Volume (IRV). Record your value (disregard the delta symbol).

5. Calculate the Inspiratory Capacity (IC) using Equation 4.

\[
IC = V_T + IRV \quad \text{(L)}
\]

Equation 4

6. Return the Marker to its box at bottom left, by double-clicking the Marker, dragging it back, or clicking its box.

7. Find the comment containing ‘ERV procedure’. Place the Marker on the trough of the expiratory volume of the previous tidal breath and move the Waveform Cursor along to the trough of the volume from the forceful exhalation. Figure 9 shows where to make the measurement. The difference that will be displayed in the Range/Amplitude display is the Expiratory Reserve Volume (ERV), disregard the delta symbol and the negative sign.


\[
EC = V_T + ERV \quad \text{(L)}
\]

Equation 5

9. Use the tables\(^1\) or graphs made available in the laboratory to determine the volunteer’s predicted Vital Capacity (VC). The predicted value varies according to the volunteer’s sex, height, and age.

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\( \text{Figure 9} \)

Record containing both full inhalation and exhalation. The Marker and Waveform Cursor are positioned to measure IRV.
10. Calculate the volunteer’s measured VC using the experimentally derived values for IRV, ERV, and \( V_T \) (Equation 6).

\[
VC = IRV + ERV + V_T \quad (L)
\]  

*Equation 6*

11. Residual Volume (RV) is the volume of gas remaining in the lungs after a maximal expiration. The RV cannot be determined by spirometric recording. Using Equation 7, determine the predicted RV value for the volunteer. This equation predicts RV for 16–34 year old subjects of either sex\(^1\). (See Gaensler and Wright\(^1\) for equations for older age groups.)

\[
RV = \text{predicted } VC \times 0.25 \quad (L)
\]  

*Equation 7*

12. The Total Lung Capacity (TLC) is the sum of the vital capacity and residual volume. Calculate the predicted TLC for the volunteer (Equation 8) using the predicted values for VC and RV.

\[
TLC = \text{predicted } VC + RV \quad (L)
\]  

*Equation 8*

13. Functional Residual Capacity (FRC) is the volume of gas remaining in the lungs at the end of a normal tidal expiration (the sum of the RV and ERV). Calculate the FRC value for the volunteer using Equation 9.

\[
FRC = ERV + RV \quad (L)
\]  

*Equation 9*

14. Select an area of the Chart window that contains normal breathing, making sure to select across complete respiratory cycles. Choose the Report command from the Spirometry menu. The Report window contains various parameters calculated by the Spirometry extension from the data selection (Figure 10). Copy the results for the \( V_E \), \( V_T \), and \( f \) into the table at the end of the experiment.

**Figure 10**
The Spirometry Report window, listing the parameters calculated from the data selection.

**Discussion topics**

1. Compare your experimental findings with your predicted results and those of the Spirometry extension. Do any of the parameters differ significantly? If so, what factors do you think influenced the results? How could you improve the accuracy of the measurements?
Exercise 3: Pulmonary function tests

Objectives

To measure parameters of forced expiration used in evaluating pulmonary function. Note that the Spirometry extension is not intended for clinical evaluation of lung function.

Procedure

1. Choose the Spirometer… or Spirometer Pod… item from the Flow (Channel 1) Channel Function pop-up menu. The flow head must be left undisturbed on the bench during the zeroing process. Click the Zero button. When zeroing is complete, Click the OK button to close the dialog box and return to the Chart window.

2. Click Chart’s Start button to begin recording.

3. Type the comment ‘Forced breathing’ to prepare it.

4. The volunteer should breathe normally for a short while. Ask the volunteer to inhale maximally and then exhale as forcefully and fully as possible (that is, inhale as much as possible and then exhale until no more air can be expired). Press the Return key to add the comment. After a few seconds the volunteer should let his or her breathing return to normal. Click Chart’s Stop button to end recording.

5. Repeat steps 2–4, until you have three separate forced breath recordings. Your recording should resemble Figure 11.

Examine your data

Scroll through your data and examine the forced breaths. The forced breaths were repeated in this exercise so that performance and reproducibility could be determined.

Analysis

1. In the last data block of your Chart recording, move the Waveform Cursor to the maximal forced inspiration on the Flow trace. The absolute value displayed in the Range/Amplitude display is the Peak Inspiratory Flow (PIF). Multiply the value by 60 to convert from L/s to the commonly-used alternative units L/min.

2. From the Flow trace, measure the Peak Expiratory Flow (PEF) for the forced expiration. Multiply the value by 60 to convert from L/s to the commonly-used alternative units L/min. (Disregard the negative sign.)
3. To calculate the Forced Vital Capacity (FVC), place the Marker on the peak inhalation of the Volume trace (Figure 11) and move the Waveform Cursor to the maximal expiration. Read off the result from the Range/Amplitude display. (Disregard the negative sign and delta symbol.)

4. Return the Marker to its box at bottom left, by double-clicking the Marker, dragging it back, or clicking its box.

5. To measure Forced Expired Volume in 1 second (FEV₁), place the Marker on the peak of the Volume trace, move the pointer to a time 1.0 s from the peak, and read off the volume value. If you find it hard to adjust the mouse position with enough precision, a time value anywhere from 0.96 to 1.04 s gives enough accuracy. (Disregard the negative sign and delta symbol.)

6. Return the Marker to its box at bottom left, by double-clicking the Marker, dragging it back, or clicking the box.

7. Make a selection from the last recorded data block that includes a couple of normal breaths, the forced breath, and a few normal breaths (as in Figure 12). Choose the Spirometry Data item from the Spirometry menu. The Spirometry Data window opens showing the locations of PIF, PEF, FVC, and FEV₁ (Figure 12). If the values aren’t displayed, check that you have included a forced breath in your selection. If your selection is correct but the parameters are still not displayed, you will need to ask your teaching demonstrator for help.

8. Open the Spirometry Report. The report lists the values calculated for those parameters. Add the report values to the table.

9. Repeat the analysis until all three forced breaths have been analysed, both manually and with the Spirometry extension.
10. Calculate the percentage ratio of FEV\textsubscript{1} to FVC for your experimental and Spirometry extension results using Equation 10. Use the maximum recorded values of FEV\textsubscript{1} and FVC.

\[
\frac{(\text{FEV}_1/\text{FVC}) \times 100}{\%}
\]

*Equation 10*

**Discussion Topics**

1. Comment on the reproducibility of the forced parameters.

**Exercise 4: Forced expiration in different volunteers**

**Objectives**

To compare the parameters of forced expiration measured in different volunteers.

**Procedure**

1. Replace the disposable filter and mouthpiece.

2. Re-zero the Spirometer (or Spirometer Pod).

3. The new volunteer should repeat the steps for procedure and analysis, as in Exercise 3.

4. Repeat steps 1–3 until the forced expiration parameters (PIF, PEF, FVC, and FEV\textsubscript{1}) have been measured for all volunteers.

Since any number of volunteers could be participating, you should draw up your own table in which to record your results.
Reference


Appendix A — Software settings

Complete details on setting up and using ADInstruments hardware and software are given in the documentation that accompanies the products. For more information on the Chart software, consult the *Getting Started with PowerLab* manual, supplied with every PowerLab. For specific PowerLab 4/20T features in the software, see the owner’s guide for the hardware. For Chart extensions, see the application notes on the www.adinstruments.com web site.

*Software.* Chart for Windows, v4.0.4 or later.

Chart settings

Before applying the Chart settings listed below, ensure that the new Chart document you will be working with has Chart’s default settings. To do this, open Chart (if it is not open already), and choose Default Settings… from the Edit menu. The Default Document Settings dialog box will appear. Click the Revert button to apply Chart’s default settings, and close the Chart document if one is open (click No if an alert box asks you if you want to save changes to the document). Choose New from the File menu. A new Chart document with Chart’s default settings will appear. Apply the Chart settings below.

*Sampling rate.* 100 samples per second.
*View compression.* 10:1, to start with; change as required.
*Time Format.* From start of block.
*Channel Settings.* Two channels displayed, Flow and Volume.
Channel 1: name ‘Flow’, Spirometer Amplifier — Range 500 mV, Low Pass 10 Hz.
Channel 2: name ‘Volume’, channel off.

Chart extension settings

*Spirometry.* The default settings.

Save this file as a Chart Settings File with a suitable name, such as ‘TLW13a Settings File’.

Appendix B — Hardware

Any PowerLab model could be substituted for the PowerLab 4/20T. If you intend to use older PowerLab models that do not have Pod inputs on the front panel, we recommend using the ML305 Pod Expander, which adds Pod capabilities to your PowerLab.
Table 1
Respiratory parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental &amp; calculated values</th>
<th>Spirometry extension values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>$f$ /min</td>
<td></td>
</tr>
<tr>
<td>Tidal Volume</td>
<td>$V_T$ (L)</td>
<td></td>
</tr>
<tr>
<td>Expired Minute Volume</td>
<td>$V_E = V_T \times f$ (L/min)</td>
<td></td>
</tr>
<tr>
<td>Inspiratory Reserve Volume</td>
<td>$IRV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Inspiratory Capacity</td>
<td>$IC = V_T + IRV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Expiratory Reserve Volume</td>
<td>$ERV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Expiratory Capacity</td>
<td>$EC = V_T + ERV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Vital Capacity</td>
<td>$VC$ (from tables) (L)</td>
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</tr>
<tr>
<td>Residual Volume</td>
<td>$RV = \text{pred. VC} \times 0.25$ (L)</td>
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</tr>
<tr>
<td>Total Lung Capacity</td>
<td>$TLC = VC + RV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Functional Residual Capacity</td>
<td>$FRC = ERV + RV$ (L)</td>
<td></td>
</tr>
<tr>
<td>Peak Inspiratory Flow</td>
<td>$PIF$ (L/min)</td>
<td></td>
</tr>
<tr>
<td>Peak Expiratory Flow</td>
<td>$PEF$ (L/min)</td>
<td></td>
</tr>
<tr>
<td>Forced Vital Capacity</td>
<td>$FVC$ (L)</td>
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<td>Forced Expired Volume in one second</td>
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<td>$FEV_1/FVC \times 100$ (%)</td>
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