Human physiology (II) laboratory

Lab2: spirometer and pulmonary function test

2.1 Introduction to mechanics of Breathing

The overall function of the respiratory system **is providing the body with oxygen and ridding it of carbon dioxide.** Multiple processes are involved in the delivery of oxygen to body tissues and the removal of carbon dioxide from body tissues. The respiration process involves 4 steps.

1. Pulmonary ventilation, or breathing, is the **movement of air into and out of the lungs**. Pulmonary ventilation, or **breathing, consists of two phases: inspiration, during which air is taken into the lungs, and expiration, during which air passes out of the lungs.**

2. External respiration is the **exchange of gases between the air and the blood**. It occurs in the alveoli of **the lungs.**

3. Gas transport is a function of the blood (cardiovascular system), and it is the process by which **oxygen is transported from the lungs to the tissues**, and carbon dioxide is transported from the tissues to the lungs.

4. Internal respiration is the exchange of gases **between the blood and cells of the tissues**. It occurs at capillary beds throughout the body.

Additionally, in the process called **cellular respiration**, individual cells **break down glucose in the presence of oxygen to produce water and energy in the form of ATP**; carbon dioxide is released as a waste product. **This process occurs in the mitochondria of cells.**

During pulmonary ventilation, air is moved in and out between the atmosphere and the lungs. Pulmonary ventilation is driven by **gradients between the air pressure in the atmosphere (atmospheric pressure) and the air pressure in the lungs (intrapulmonary pressure).** These pressure gradients result when the actions of **the respiratory muscles change the volume of the thoracic cavity and the lungs.**

Boyle's law explains the relationship between pressure and volume: The pressure of a gas in a closed container is inversely proportional to the volume of the container.

Therefore, when **lung volume increases during inspiration, intrapulmonary pressure decreases below that of atmospheric pressure, and air flows down the pressure gradient and into the lungs**.

By contrast, when **lung volume decreases during expiration, intrapulmonary pressure increases above that of atmospheric pressure, and air flows down the pressure gradient and out of the lungs.**

Several skeletal muscles change the size of the thoracic cavity during pulmonary ventilation. **Normal (quiet) inspiration** is an active process requiring the **contraction of the diaphragm and external intercostal muscles. The diaphragm moves from its relaxed dome shape to a flattened position, increasing the super inferior volume. The external intercostals lift the rib cage, increasing the anteroposterior and lateral dimensions.**

During **forced inspiration**, **additional muscles (the scalene, sternocleidomastoid, pectoralis major, pectoralis minor, and serratus anterior muscles) pull the ribs superiorly and laterally to further increase thoracic volume.**

Normal (quiet) expiration, however, is a passive process initiated by elastic recoil during the relaxation of the inspiratory muscles.

During forced expiration, **contraction of the internal intercostal and abdominal muscles** further reduces the volume of the lungs, thereby further increasing alveolar pressure and forcing additional air out of the lungs.

2.2 Respiratory Sounds

As air flows in and out of the respiratory tree, it **produces two characteristic sounds** that can be picked up with a **stethoscope (auscultated)**.

1-The bronchial sounds are **produced by air rushing through the large respiratory passageways** (the trachea and the bronchi).

2-Vesicular breathing sounds, apparently results from air filling the alveolar sacs and resembles the **sound of a rustling or muffled breeze.**

Air flowing smoothly through your airways creates normal (vesicular) lung sounds. Swelling, blockages or mucus in your airways can create abnormal lung sounds. These include rhonchi, wheezing, stridor, crackles (rales) and pleural rub. See the link below for lung sounds.

https://www.youtube.com/watch?v=TlgP8MzlMaw&t=18s

The stethoscope

The stethoscope is a medical device for auscultation or listening to internal sounds of an animal or human body. It typically has a small disc-shaped resonator that is placed against the skin, with either one or two tubes connected to two earpieces. **The is used bell to hear low-pitched sounds. And the diaphragm is used to hear high-pitched sounds.** The bell and diaphragm are connected by rubber tubes to earpieces that your healthcare provider places in their ears.

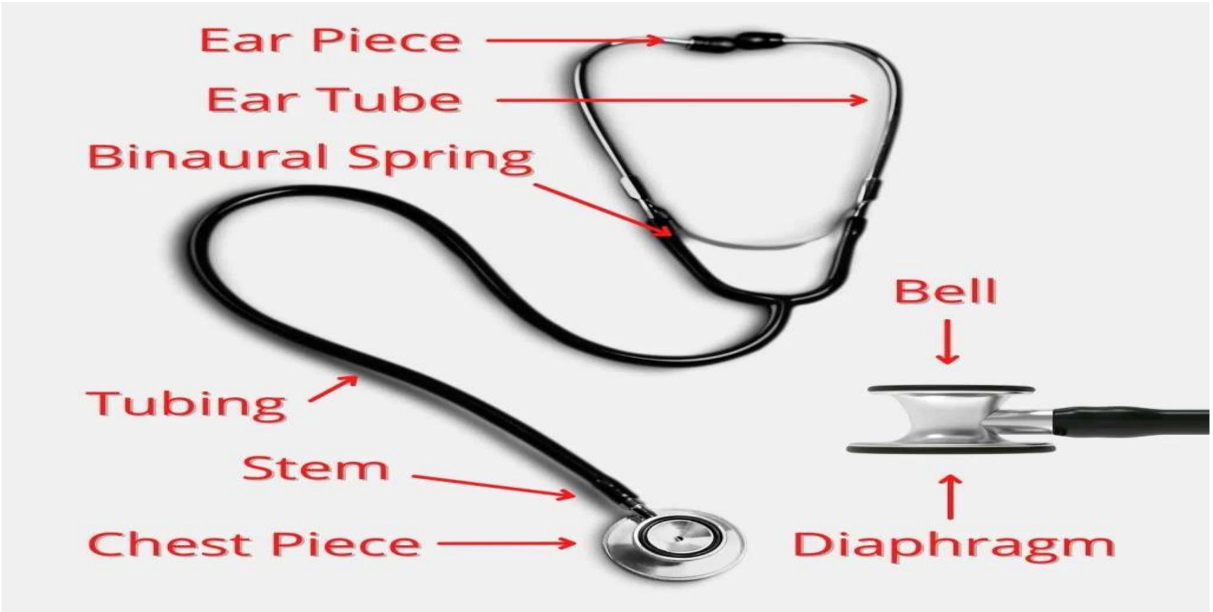
The stethoscope is used to evaluate lungs health based on.

1-Duration: Duration measures the length of your inhales and exhales.

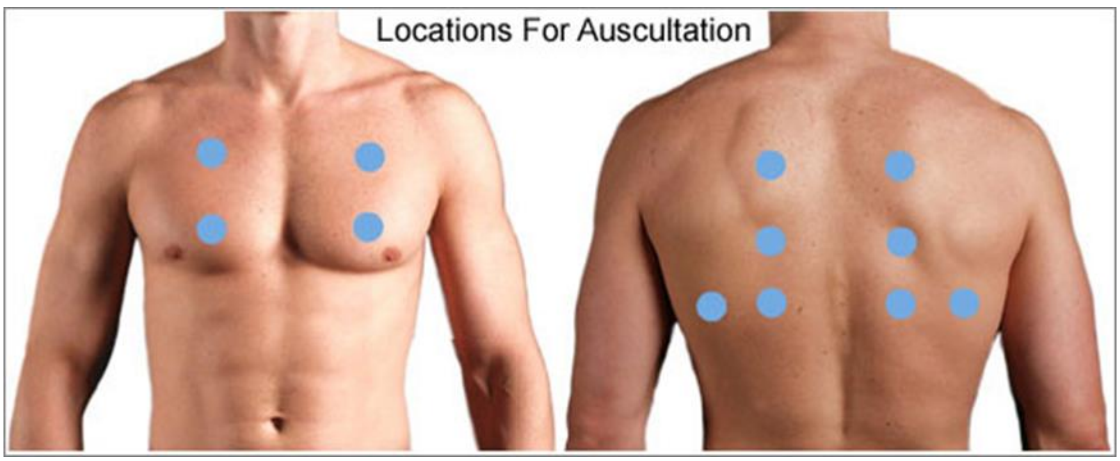
2-Frequency: Frequency, or pitch, measures sound waves and vibrations.

3-Amplitude: Amplitude is the level of loudness or intensity in your breaths.

4-Quality: Quality listens for any distinctive characteristics or abnormal sounds such as wheezing.



Lung auscultation



2.3 Spirometry

Spirometry is a type of pulmonary function test. It determines how well your lungs work by measuring how much air goes into and out of your lungs when you breathe **using a spirometer device.** Spirometry is safe, though you may feel lightheaded or dizzy from repeated deep breaths.

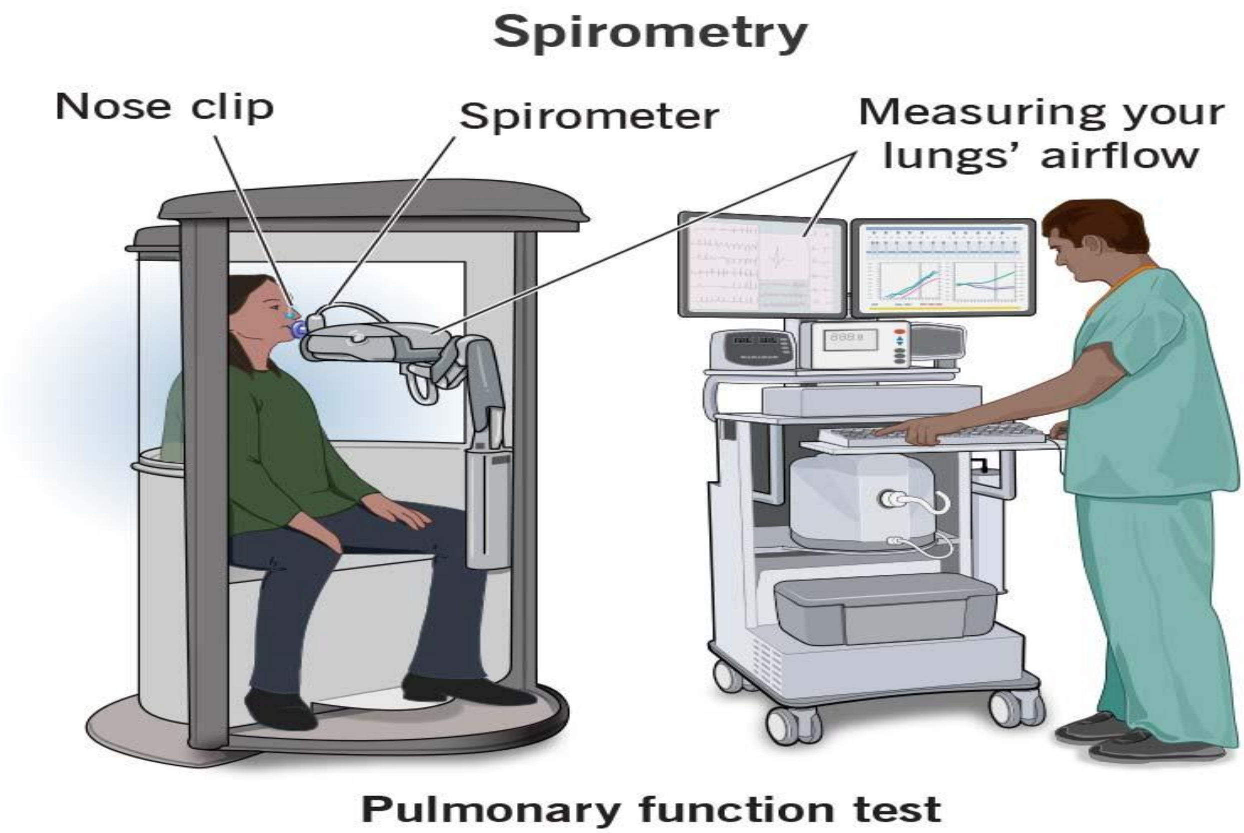
Spirometry determines if your lungs are functioning at their expected levels. It also helps to diagnose lung and airway diseases, including:

1-Asthma.

2-Chronic obstructive pulmonary disease (COPD).

3-Cystic fibrosis.

4-Pulmonary fibrosis.



Procedure

1- Make sure the spirometer is connected and calibrated.
2- With the lips closed tightly around the mouthpiece (sterile) and a nose clip on the nose. Take three normal breaths.
3- Inhale as much air as possible, then exhale and return to normal breathing.
4- Take three normal breaths.
5- Exhale as much as possible, then inhale and return to normal breathing.
6- Take three normal breaths.

Lung volumes capacities and calculations

During inhalation and exhalation, varying amounts of air move into and out of the lungs.

The different amounts of air can be classified into two types:

(1) lung volumes, which can be measured directly by use of a spirometer

(2) lungs capacities, which are combinations of different lung volumes.

Lung Volumes

at rest, a healthy adult averages **12 breaths a minute**, with each inhalation and exhalation moving about 500 mL of air into and out of the lungs.

The volume of one breath is called the tidal volume (VT=500ml).

about 70% of the tidal volume (350 mL) reaches the respiratory zone of the respiratory system.

The other 30% (150 mL) remains in the conducting airways known as **the anatomic (respiratory) dead space.**

By taking a very deep breath, you can inhale a good deal more than 500 mL. This additional inhaled air, called **the inspiratory reserve volume (IRV), is about 3100 mL in an average adult male and 1900 mL in an average adult female.**

If you inhale normally and then exhale as forcibly as possible, you should be able to push out considerably more air in addition to the 500 mL of tidal volume.

The extra 1200 mL in males and 700 mL in females is called the expiratory reserve volume (ERV).

Even after the expiratory reserve volume is exhaled, considerable air remains in the lungs. This volume, which cannot be measured by spirometry, is called the residual volume (RV) and amounts to about 1200 mL in males and 1100 mL in females

Lung Capacities

Lung capacities are combinations of specific lung volumes:

Inspiratory capacity (IC)(IC=VT+IRV) is the sum of tidal volume and inspiratory reserve volume (500 mL + 3100 mL = 3600 mL in males and 500 mL + 1900 mL = 2400 mL in females).

Functional residual capacity (FRC) (FRC=RV+ERV) is the sum of residual volume and expiratory reserve volume (1200 mL + 1200 mL = 2400 mL in males and 1100 mL + 700 mL = 1800 mL in females).

Vital capacity (VC) (VC=IRV+VT+ERV) is the sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume (4800 mL in males and 3100 mL in females).

Total lung capacity (TLC) (TLC=VC+RV) is the sum of vital capacity and residual volume (4800 mL + 1200 mL = 6000 mL in males and 3100 mL + 1100 mL = 4200 mL in females).

Minute ventilation (V) (V=VT* respiratory rate) is tidal volume multiplied by respiratory rate. In a typical adult at rest, minute ventilation is about 6000 mL/min (V = 12 breaths per minute × 500 mL = 6000 mL/min).

The alveolar ventilation (VA) is the volume of air per minute that actually reaches the respiratory zone (350 mL).

Alveolar ventilation is typically about 4200 mL/min (VA = 12 breaths per minute × 350 mL = 4200 mL/min).

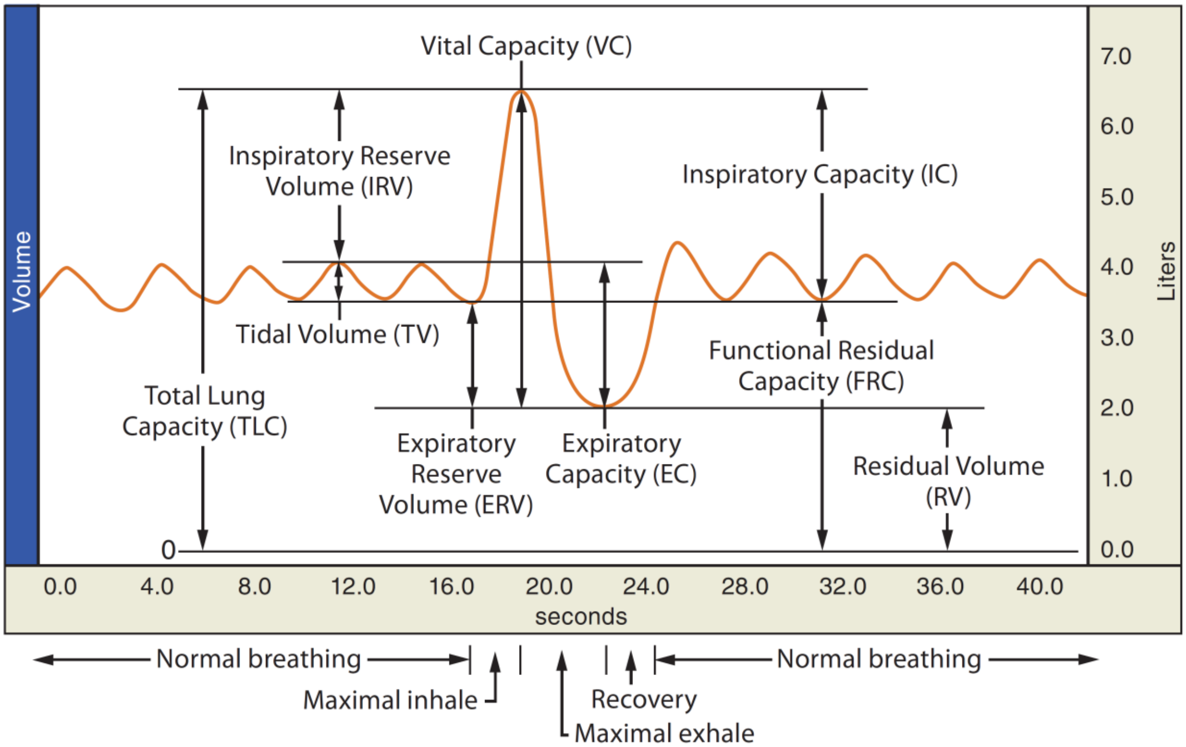


Figure 23.16 Spirogram of lung volumes and capacities

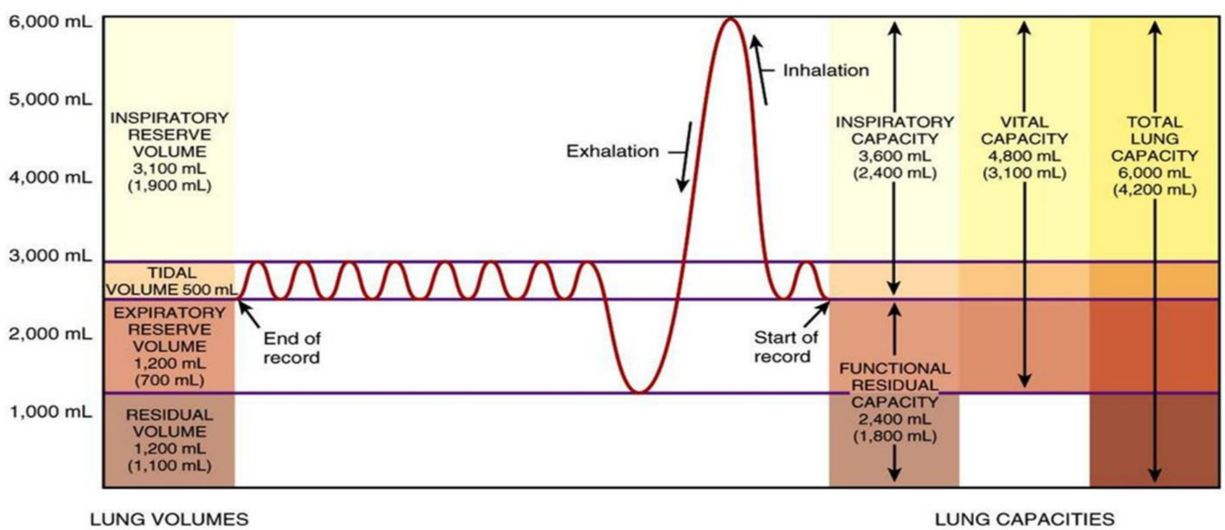


Table 27-1 Respiratory Volumes and Capacities		
Volumes and Capacities	**Definition**	**Average Values (Female, Male)**
Tidal volume (TV)	Volume of air exchanged during each normal (quiet) breath	500 ml
Inspiratory reserve volume (IRV)	Maximum volume of air that can be forcibly inspired after a tidal inspiration	1900 ml, 3100 ml
Expiratory reserve volume (ERV)	Maximum volume of air that can be forcibly expired after a tidal expiration	700 ml, 1200 ml
Residual volume (RV)	Volume of air that remains in the lungs after a forced expiration	1100 ml, 1200 ml
Inspiratory capacity	Total amount of air that can be inspired; equals tidal volume plus inspiratory reserve volume: (TV + IRV)	2400 ml, 3600 ml
Functional residual capacity	Total amount of air that normally remains in the lungs after a tidal expiration; equals residual volume plus expiratory reserve volume: (RV + ERV)	1800 ml, 2400 ml
Vital capacity	Total amount of exchangeable air; equals sum of tidal volume, expiratory reserve volume, and inspiratory reserve volume: (TV + ERV + IRV)	3100 ml, 4800 ml
Total lung capacity	Total amount of exchangeable and nonexchangeable air; equals sum of all of the pulmonary volumes: (TV + IRV + ERV + RV)	4200 ml, 6000 ml

Interpretation of spirometry readings

Forced Vital Capacity (FVC) measures the total volume of air that you were able to blow forcefully into the mouthpiece following a full inhalation. is about 4500 mL in an average adult male and 3700 mL in an average adult female.

The Forced Expiratory Volume (FEV1) in 1 Second parameter measures the volume of air that was exhaled into the mouthpiece in the first second after a full inhalation. The Measured column represents the total volume exhaled during the first second. Normal values in an average adult male from 4500 to 3500 ml, and normal values for in an average adult female 3250 to 2500 ml. The Predicted column compares the actual volume breathed out during the first second of your test to an average of the normal volume breathed out in 1 second for a person of the same gender, height, and age. This value is expressed as a percentage, with normal test values being between 80% and 120% of the average (predicted) values.

Ratio

The FEV1/FVC Ratio (FEV1%) parameter is calculated by dividing the measured FEV1 value by the measured FVC value. The Measured column shows the absolute (numerical) ratio, and the Predicted column shows the ratio expressed as a percentage. In healthy adults of the same gender, height, and age, the normal Predicted percentage should be between 70% and 85%. Percentages lower than 70% are considered abnormal. This is an important measurement because obstructive diseases such as, COPD, chronic bronchitis, and emphysema cause increased airway resistance to expiratory airflow, and may result in percentages of 45% to 60%. Restrictive diseases such as pulmonary fibrosis tend to reduce both FEV1 and FVC values, so the percentage can remain within the normal range, or even increase. See the final section below for more suggestions on assessing your result.

There are many methods of interpreting the results of spirometry tests. The following 5-step approach is commonly used to detect the presence of respiratory disease:

1-Start by looking at the FVC parameter to see if it falls within the normal range.

2-Next, look at the FEV1 parameter to see if it's within the normal range.

3-If both the FVC and FEV1 values are normal, likely the results of your spirometry test can be considered normal.

4-If either the FVC and FEV1 values are below the predicted normal value, there is a possibility of lung disease, and you should go on to step 5.

5-Look at the predicted FEV1/FVC Ratio value. If it is 69% or less, there is a strong possibility that you have some form of obstructive lung disease.

In general, your predicted percentages for FVC and FEV1 should be above 80% and your FEV1/FVC Ratio percentage should be above 70% to be considered normal.

However, the information provided in these spirometry results can be used in many additional ways. For example, when treating COPD, FEV1 is often measured after the patient has been given a bronchodilator medication to open their airways, and the resulting values are used to grade the severity of the patient's disease:

80% or more – mild COPD (able to achieve normal results after medication)

50-79% – moderate COPD

30-49% – severe COPD

less than 30% – very severe COPD

LAB 2 report

Q1 a spirometer chart showed that the following readings (VT = 400, IRV=2900, ERV 1100 and FRC= 2000)

Calculate the followings

1-IC

2-RV

3-VC

Q2 I f the spirometer chart showed Forced Vital Capacity (FVC) of 4000 ml and FEV1of 4500 ml Calculate the ratio and indicate if the findings fall within normal range. In not what is the most common cause for your findings