University of Diyala/ College of Medicine
Department of Physiology
Physiology Lab

Pulmonary Function Tests

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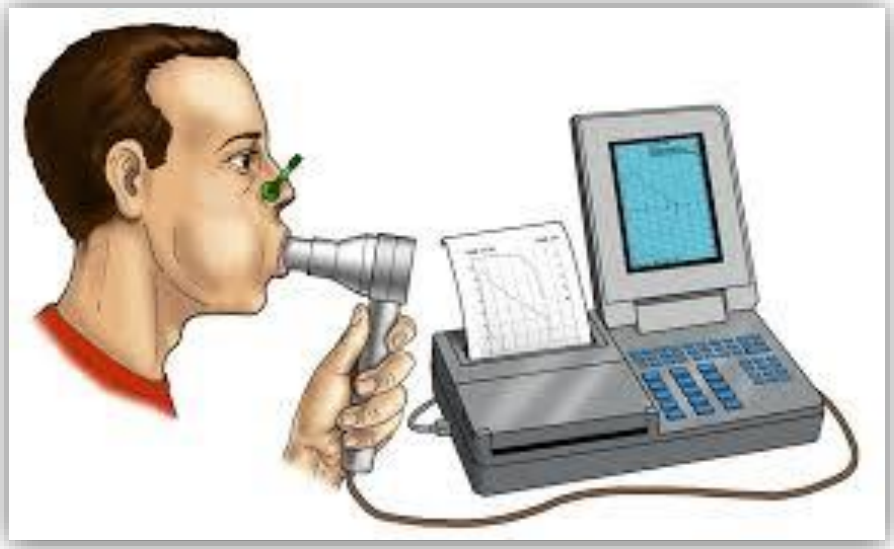


June 2021

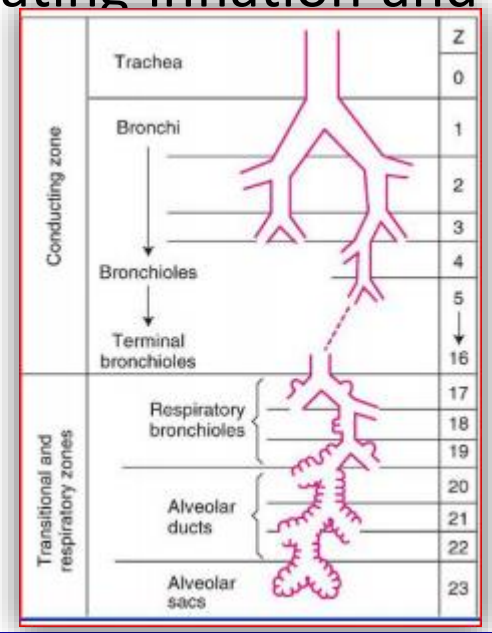
Objectives

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

1. Know different lung volumes and capacities.
2. Perform and interpret the spirometry test.
3. Obtain some of the significant spirometric parameters and compare them with those of a typical person of the same gender, height and age.
4. Differentiate between normal, obstructive, and restrictive pattern spirograms.

Introduction

- ✓ Lungs comprised of the : **airways** and **alveoli**. The **airways** consists of the : **Conducting zone:** no gas exchange occurs , **Transitional zone**: alveoli appear, but are not great in number, and **Respiratory zone:** contains the alveolar sacs. Regarding the **alveoli**, there are Approximately 300 million alveoli , 1/3 mm diameter , and the total surface area if they were complete spheres 80 sq. meters (size of a tennis court) .
- ✓ 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 the : airways , alveoli, thoracic cage(bones and muscles), and respiratory control mechanisms.



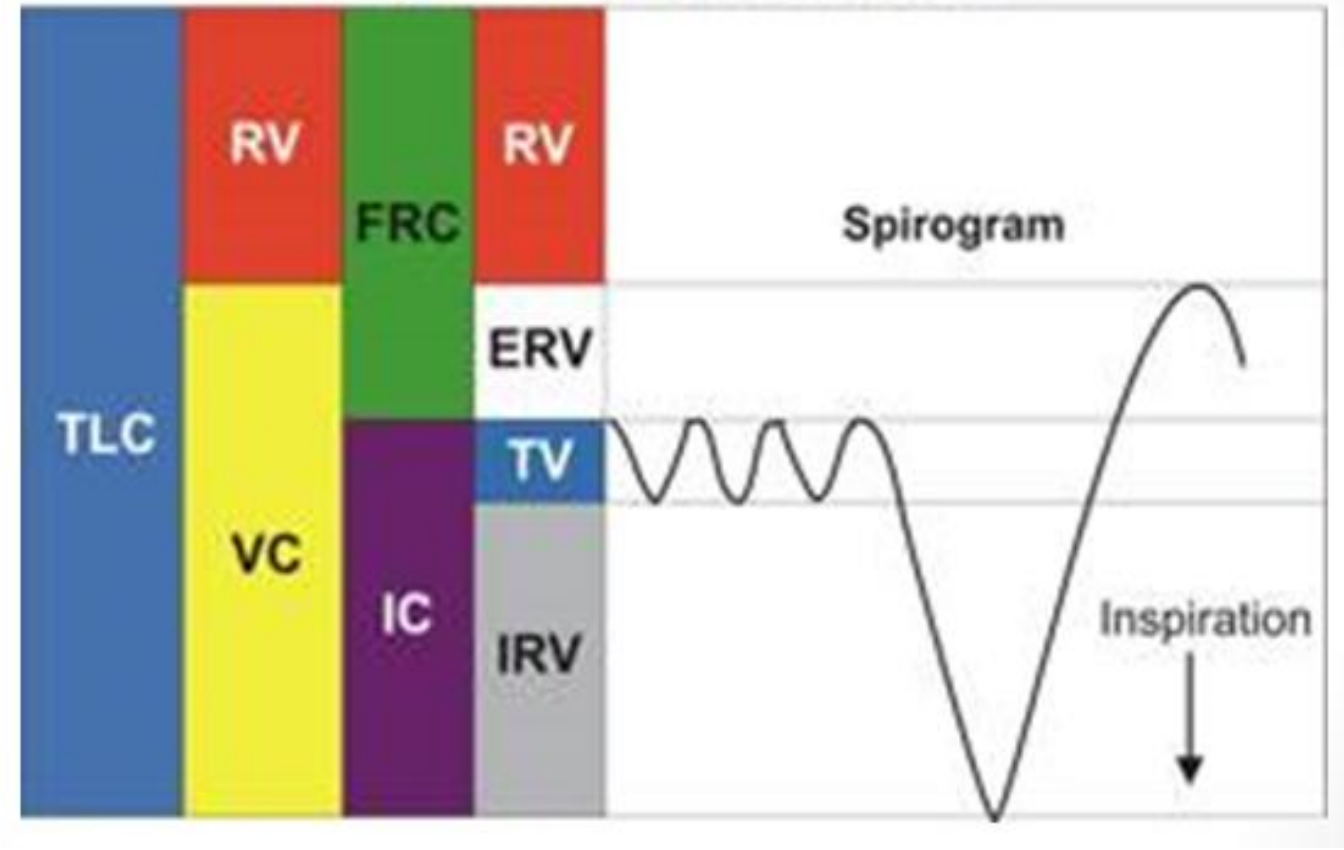
Pulmonary Function Tests (PFTs)

- ✓ The term of PFTs encompasses a wide variety of objective tests to assess lung function. PFTs provide objective and standardized measurements for assessing the presence and severity of respiratory dysfunction.
- ✓ PFTs help in diagnosis and differentiation of many respiratory diseases (**restrictive** and **obstructive** lung disorders, diagnose **exercise induced asthma**, differentiate **chronic bronchitis** from **Bronchial Asthma (BA)**).
- ✓ PFTs explain the cause of symptoms in patients who are diseased and clinically normal (as early detection of **small airways disease**)
- ✓ Assessing **the course of the disease** and **effect of therapy**(as steroids with bronchial asthma and radiotherapy with cancer).
- ✓ Objective quantitative measurements of lung damage due to **occupational injury**.
- ✓ **Pre-operative assessment.**

Lung Volumes and Capacities

Pulmonary Function Test (PFT) tracings have:

- ***Four Lung volumes:*** tidal volume, inspiratory reserve volume, expiratory reserve volume, and residual volume
- ***Five capacities:*** inspiratory capacity, expiratory capacity, vital capacity, functional residual capacity, and total lung capacity.



Lung Volumes

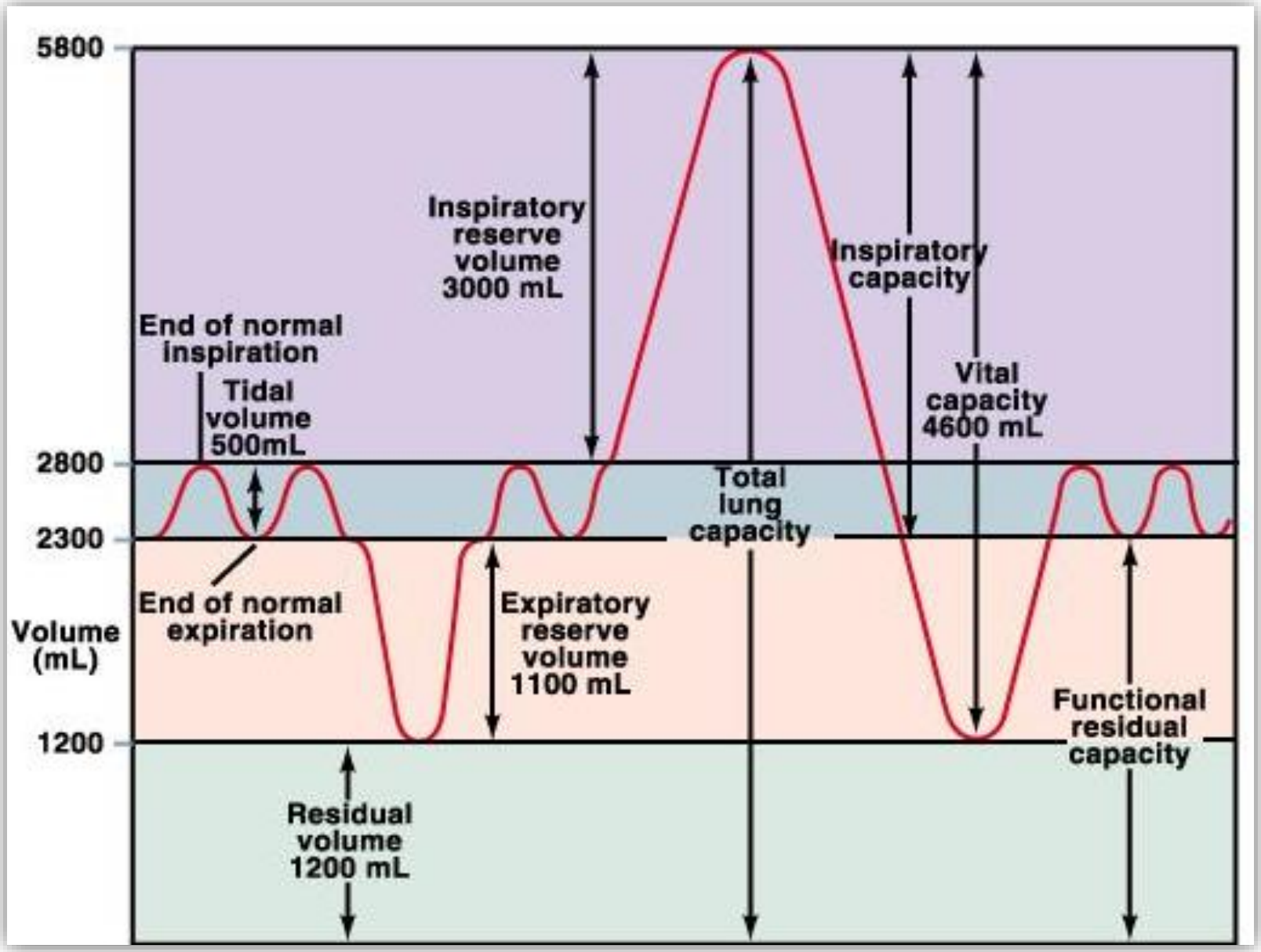
- **Tidal Volume (TV):** volume of air inhaled or exhaled with each breath during quiet breathing. It is about 500 ml in an adult male.
- **Inspiratory Reserve Volume (IRV):** maximum volume of air inhaled from the end-inspiratory tidal position (3000 ml).
- **Expiratory Reserve Volume (ERV):** maximum volume of air that can be exhaled from resting end-expiratory tidal position(1100 ml).
- **Residual Volume (RV):** Volume of air remaining in lungs after maximum exhalation (1200 ml). It is indirectly measured (FRC-ERV) , i.e. It can not be measured by spirometry.

Lung Capacities

Lung capacity is defined as the combination of two more lung volumes.

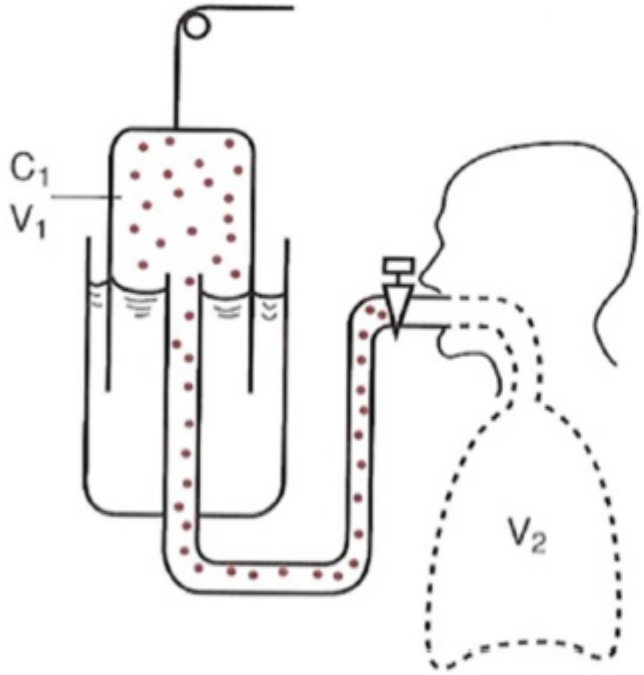
1. ***Inspiratory Capacity (I.C):*** the volume of air that can be inspired by maximal inspiration following a normal expiration. It equals to TV+IRV and has average of 3500ml in an adult male.
2. ***Expiratory Capacity (E.C):*** the volume of air that can be expired by maximal expiration following a normal inspiration. It equals to TV+ERV and has average of 1600ml in an adult male.
3. ***Functional Residual Capacity (F.R.C):*** the volume of air remaining in the chest at the end of normal expiration. It equals to ERV+RV and has average of 2300ml in an adult male.
4. ***Vital Capacity (V.C):*** the volume of air that can be expired by a maximal expiration following a maximal inspiration. It equals to IRV+TV+ERV with average of 4600ml in an adult male.
5. ***Total Lung Capacity (T.L.C):*** the volume of air presents in the chest at the end of the maximal or deepest inspiration. It equals to IRV+RV+ERV with average of 5800ml in an adult male.

Lung Volumes and Capacities

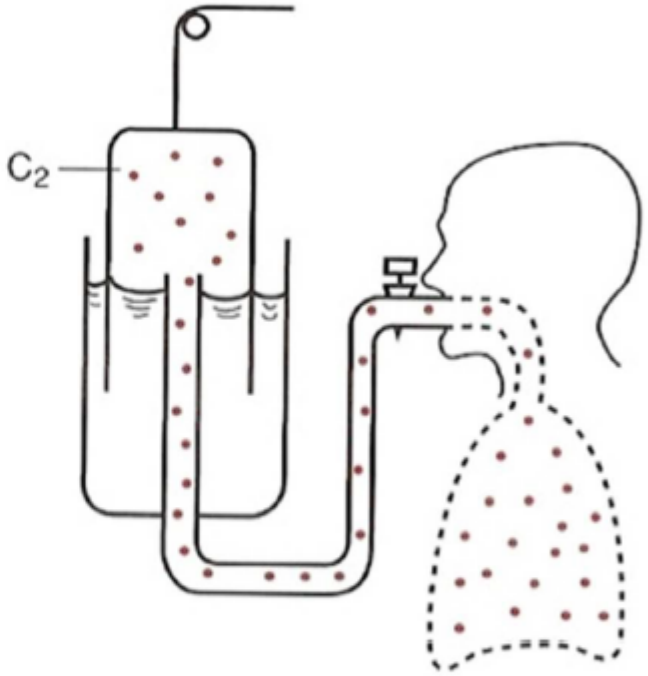


Lung Volumes and Capacities

Measuring FRC with Helium Dilution



Before equilibration



After equilibration

INITIAL FINAL

$C1 \times V1 = C2 \times (V1 + FRC)$

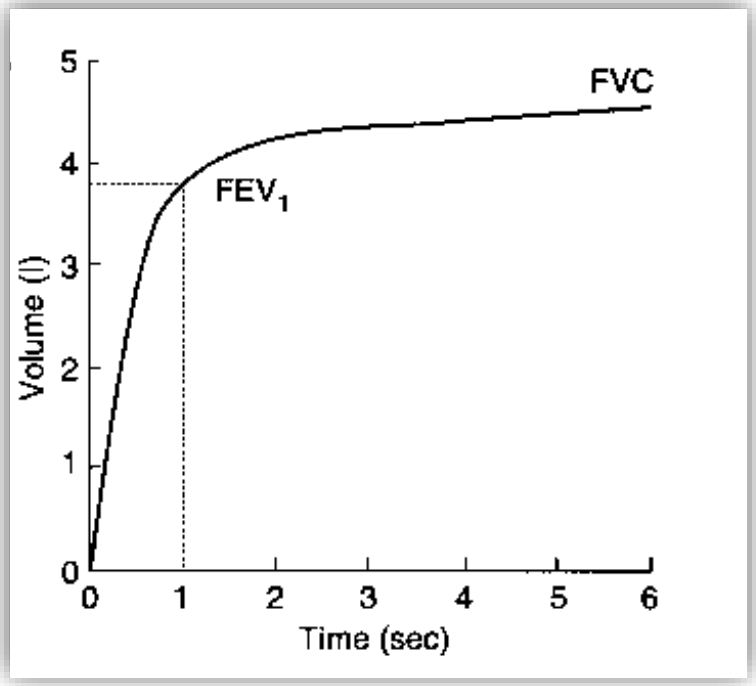
Factors Affecting Lung Volumes & Capacities

1. **Age:** T.L.C and RV increase with age.
2. **Gender:** Males have greater lung volumes and capacities than females (greater by about 20-25%).
3. **Body building:** V.C increases in athletes.
4. **Diseases of the respiratory system.**
5. **Height:** Tall people have a higher lung volumes as compared to short people.
6. **Race:** White people generally have greater lung volume than dark people.

Forced vital capacity (FVC)

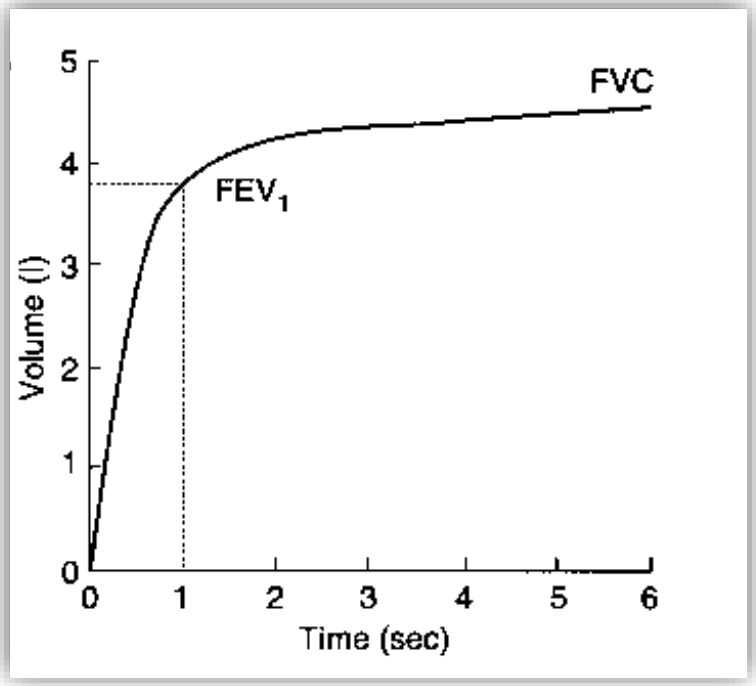
- ✓ **Forced Vital Capacity (FVC):** Total volume of air that can be exhaled forcefully from TLC.
- ✓ The majority of FVC can be exhaled in <3 seconds in normal people, but often is much more prolonged in obstructive diseases. It is measured in liters (L).
- ✓ **Interpretation of % predicted:**

– 80-120% Normal
– 70-79% Mild reduction
– 50%-69% Moderate reduction
– <50% Severe reduction



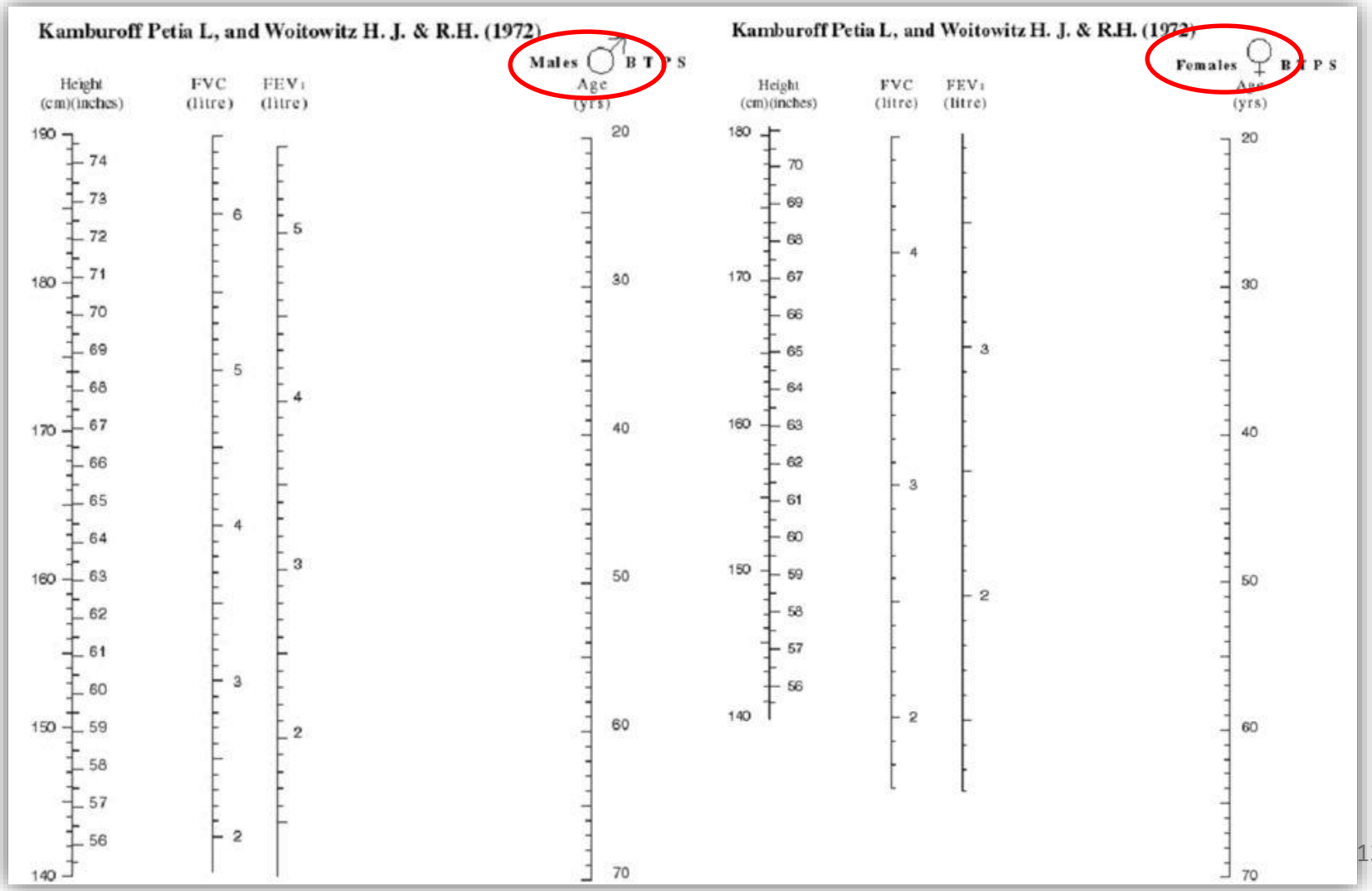
Forced Expiratory Volume in 1 Second (FEV1)

- ✓ **Forced expiratory volume in 1 second (FEV1):** Volume of air forcefully expired from full inflation (TLC) in the first second. Measured in liters (L)
- ✓ Normal people can exhale more than 75-80% of their FVC in the first second; thus the FEV1/FVC can be utilized to characterize lung diseases.
- ✓ **Interpretation of % predicted:**
  - >75% Normal
  - 60%-75% Mild obstruction
  - 50-59% Moderate obstruction
  - <49% Severe obstruction



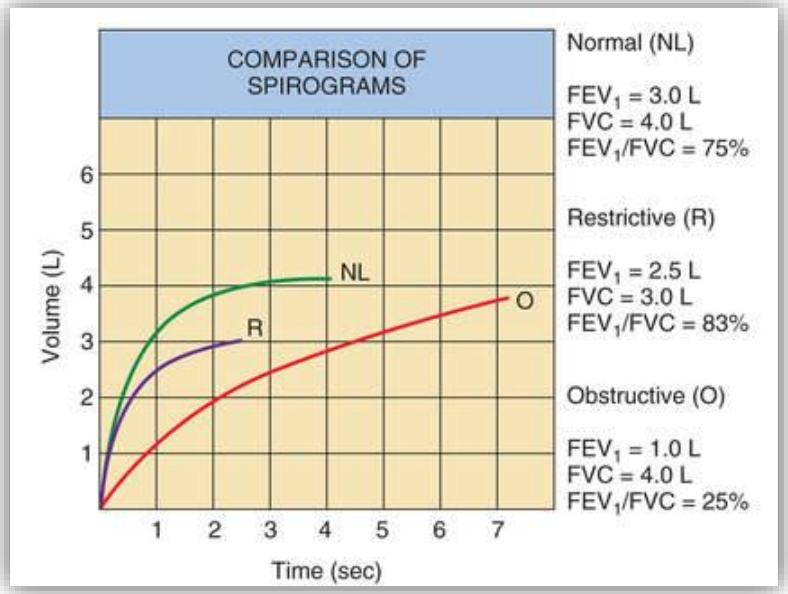
FVC and FEV1

- ✓ The predicted FVC and FEV can be measured using a special table that based on the age, gender, and height. This is done by plotting a line between the age and height columns, then read the value at the intersection of the line.



Standard Spirometric Indices

- ✓ ***FEV1 (Forced expiratory volume in one second):*** The volume of air expired in the first second of the blow.
- ✓ ***FVC (Forced vital capacity):*** The total volume of air that can be forcibly exhaled in one breath.
- ✓ ***(FEV1/FVC)*100:*** The percentage of volume of air exhaled in the first second of forceful expiration to the forced vital capacity. Normally 75-80% of FVC is expired in the first second of the forceful expiration. This ratio is used to differentiate between two groups of respiratory diseases : obstructive and restrictive diseases. In obstructive diseases, (FEV1/FVC)*100 decreases, but it is normal in restrictive diseases.



FEV1/FVC in Obstructive Lung Diseases

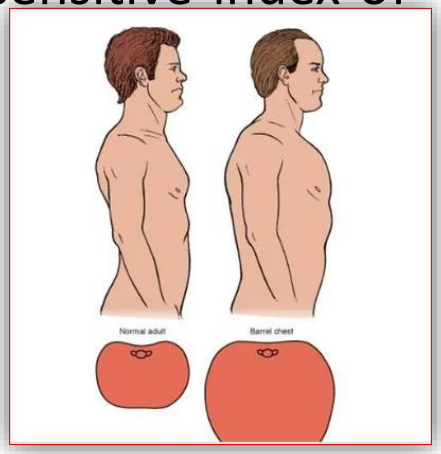
✓ **Obstructive Respiratory Diseases:** They mainly affect the airway passages causing a certain degree of obstruction. Air enters lungs with difficulty inspiration and got entrapped in the lungs during expiration, as a result the total lung capacity increases and the anteroposterior diameter of the chest approaches the transverse diameter and finally the chest becomes barrel-shaped (see figure below).

✓ **Obstructive lung diseases affect lung volumes and capacities:**

- TLC increases
- RV increases
- VC is either normal or decreases in sever cases
- FEV1 decreases
- (FEV1/FVC)*100 always decreases and considered as a sensitive index of obstruction.

✓ **Types of obstructive lung disease include:**

- Chronic obstructive pulmonary disease (COPD)
- Emphysema
- Asthma
- Cystic fibrosis



FEV1/FVC in Restrictive Lung Diseases

✓ **Restrictive Respiratory Diseases:** They cause a restriction or limitation of the lung/chest expansion. ***Causes include:***

A. Respiratory Muscle Paralysis:

- Diseases of the central nuclei such as poliomyelitis that affects the anterior horn cells.
- Peripheral nerve injuries or diseases affecting the phrenic nerve and intercostal nerves.
- Neuromuscular junction diseases such as myasthenia gravis in which there is a deficiency in Ach.
- Myopathies (Muscle Diseases).

B. Thoracic wall diseases or deformities as :fracture ribs, scoliosis, kyphosis, pigeon chest, funnel chest, ….etc.

C. Pleural diseases such as pleurisy, pneumothorax, hydrothorax, pleural fibrosis.

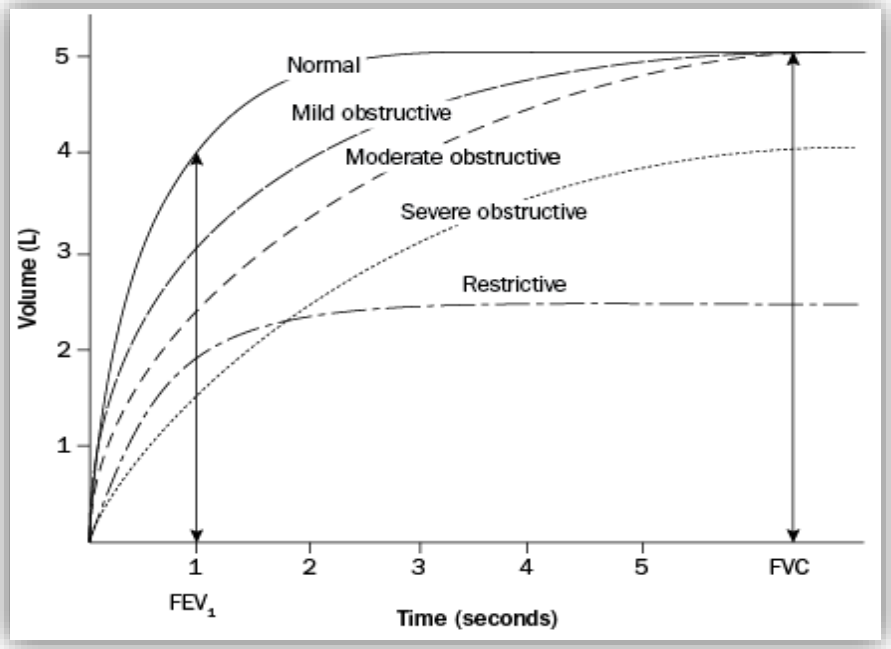
D. Lung diseases such as pulmonary fibrosis, pulmonary edema, pneumonia,…etc.

FEV1/FVC in Restrictive Lung Diseases

✓ **Restrictive lung diseases affect lung volumes and capacities:**

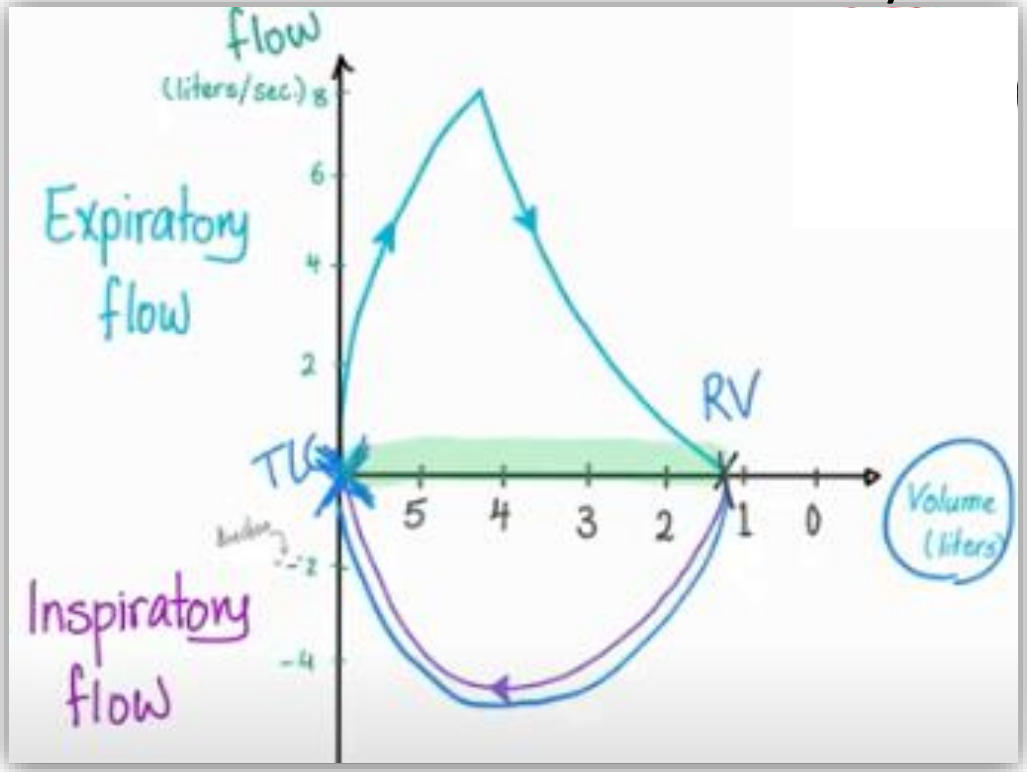
- TLC decreases
- RV decreases
- VC decreases
- FEV1 decreases
- (FEV1/FVC)*100 is normal.

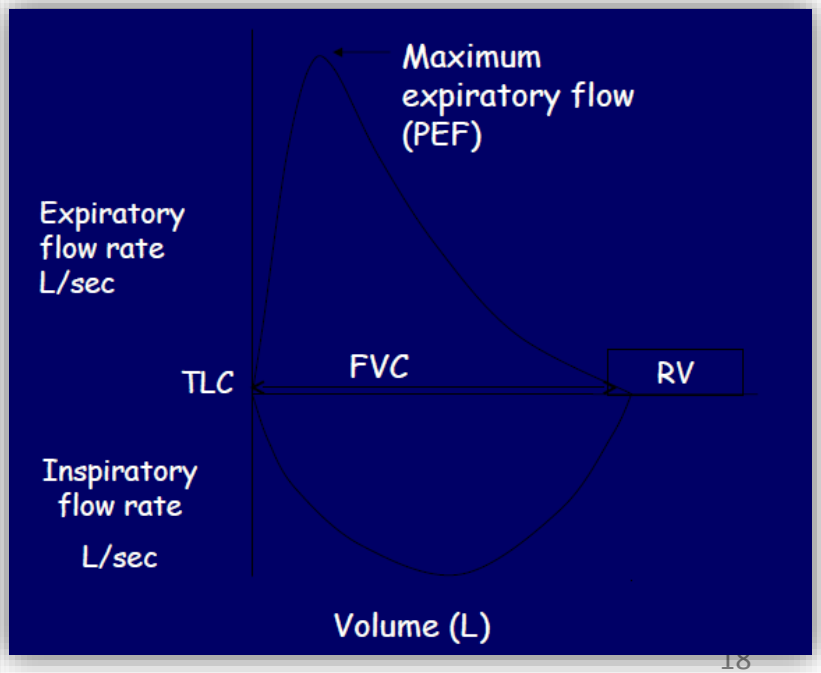
Thus, measuring the (FEV1/FVC)*100 can differentiate between obstructive and restrictive lung diseases .



Flow Volume Curve

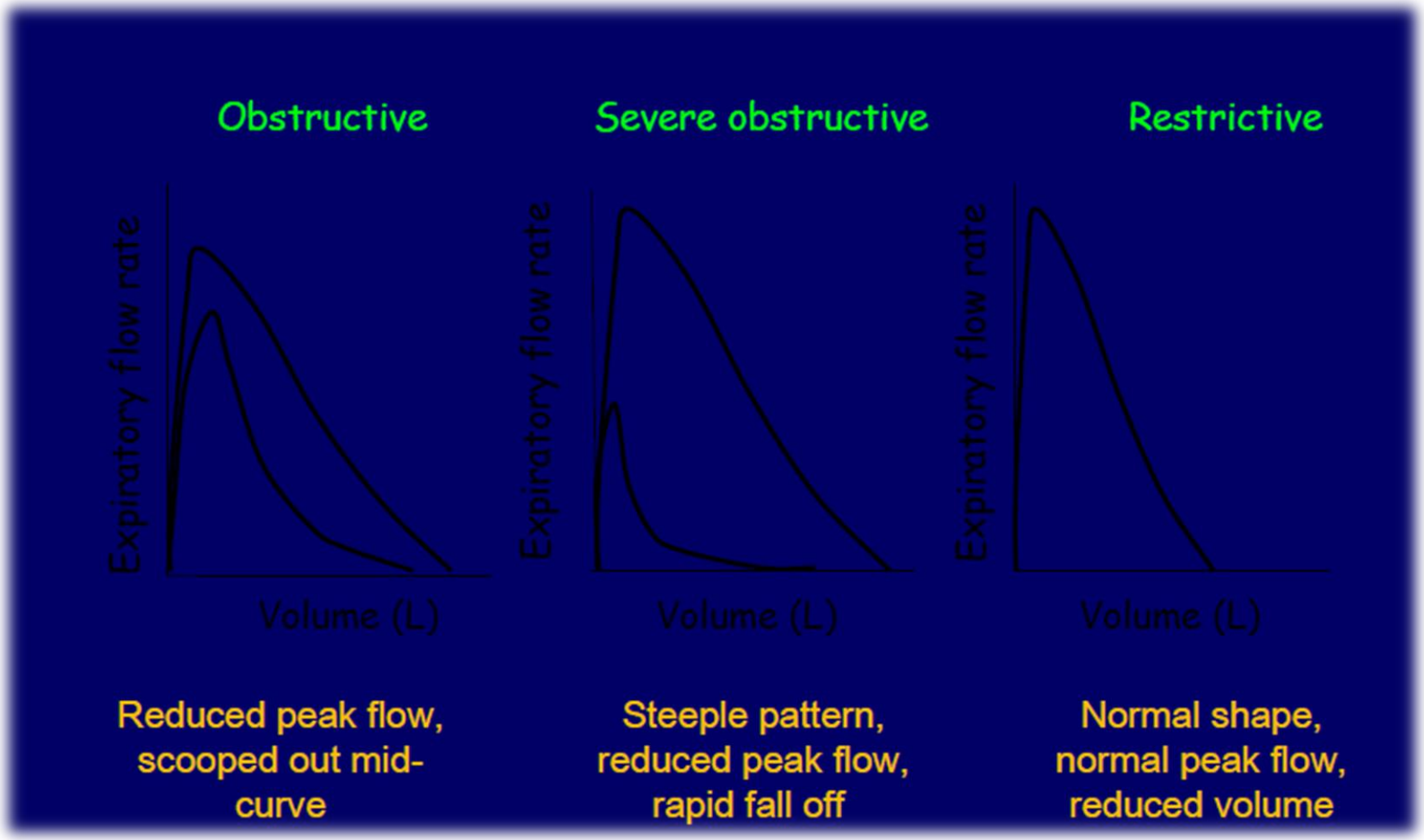
- ✓ Adds more information than volume time curve.
- ✓ Less understood but not too difficult to interpret
- ✓ Better at demonstrating mild airflow obstruction.
- ✓ Illustrates maximum expiratory and inspiratory flow volume curves.
- ✓ ***Peak Expiratory Flow (PEF):*** The highest instantaneous airflow rate measured during the FVC maneuver. PEF is measured in liters per second and will be used mainly to assess participant effort.





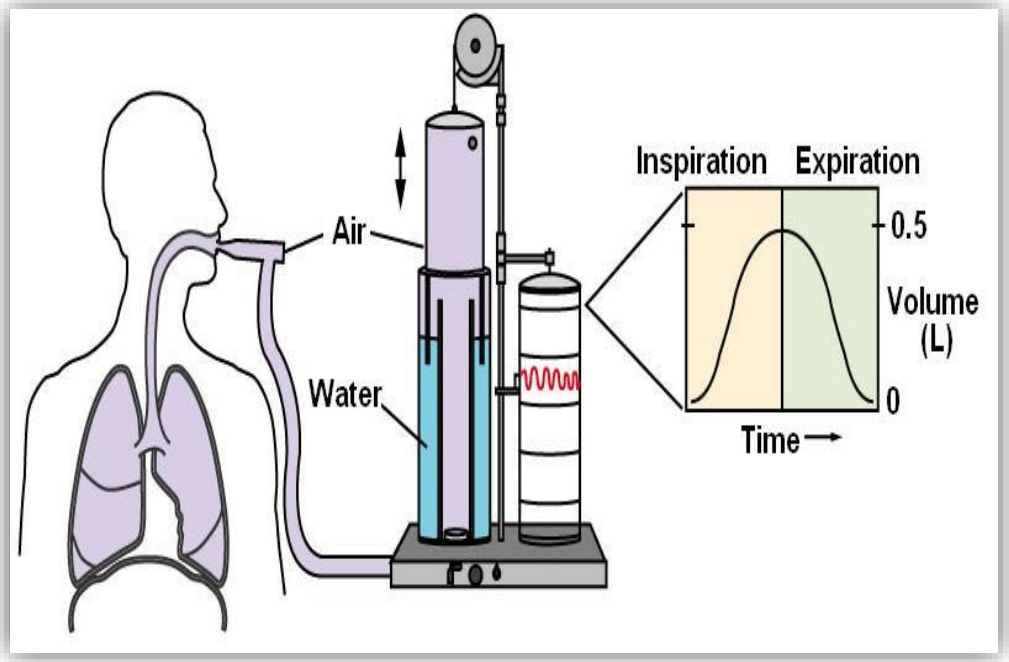
Flow Volume Curve

- ✓ Useful to help characterize disease states (e.g. obstructive vs. restrictive).



Spirometry

- ✓ Spirometry, which means “the measuring of breath,” is a routinely used pulmonary function test (PFT) that measures the amount and speed of air that a person can inhale and exhale. Results from the test can be used to estimate lung function and aid in the diagnosis of certain respiratory disorders.
- ✓ **Spirometer** is ***an instrument that measures the volume of air moved into or out of the lungs*.**



Indications for Spirometry

Diagnostic

1. To establish baseline lung function.
2. To evaluate symptoms like dyspnea, signs or abnormal laboratory tests.
3. To detect or screen individuals at the risk of pulmonary diseases.
4. To measure the effect of disease on pulmonary function.
5. To assess pre-operative risk.

Monitoring

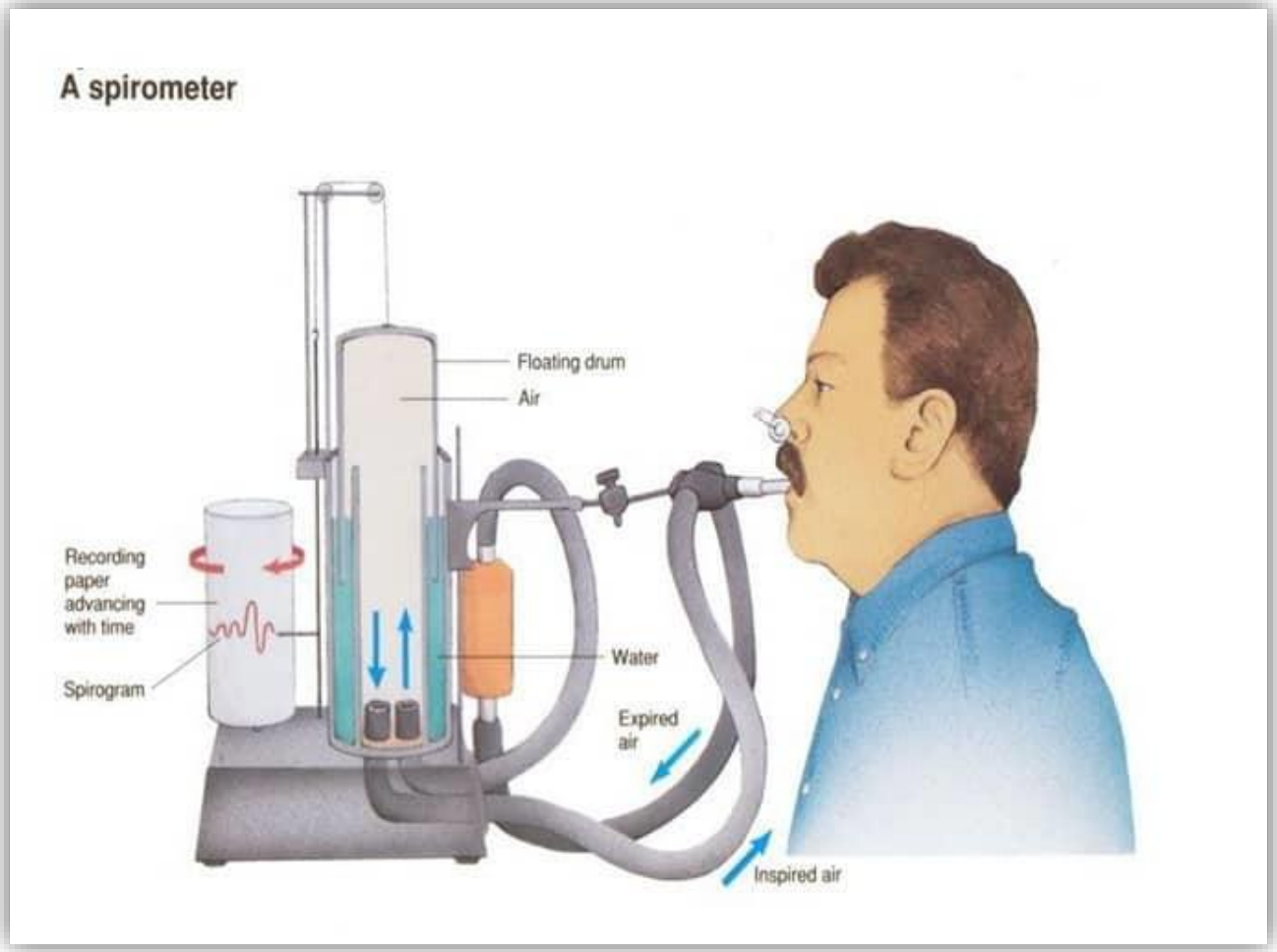
1. To assess therapeutic intervention.
2. To describe the course of diseases that affect lung functions.
3. To monitor people exposed to injurious agents and surveillance of occupation related lung disease.
4. To monitor for adverse reactions to drugs with known pulmonary toxicity.
5. To assess patients as part of a rehabilitation program.

Water Sealed Spirometer

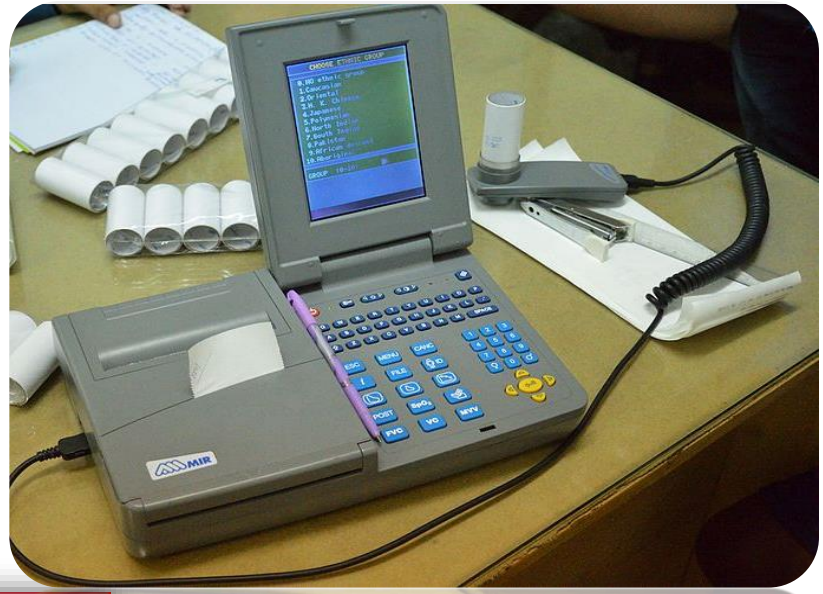
The multipurpose spirometer consists essentially of:

1. Water tank that is filled with tap water.
2. Afloat or gas holder that is inverted over the water tank so that the air in entrapped inside the float.
3. Corrugated hoses or tubes that connect the mouth piece to either the inside of the float or atmosphere.
4. Valve or a tap interposed between the hoses and the spirometer. It has 2 positions: atmosphere (indicates that the subject is connected to the atmosphere) and spirometer (means that the mouth of the subject is connected t the spirometer and is breathing the air that is inside it).
5. Soda lime canister: interposed within the hose that conveys the expired air to the spirometer. It contains a granular mixture of NaOH and Ca(OH)2, it is green when fresh and changes to pink after several uses.
6. Mouthpiece: this must be sterilized with antiseptic solution.
7. Nose clip to occlude the nasal passages so that the monitoring of pulmonary functions occurs through mouth only.
8. A recording drum on which the pen is recording. It rotates at different speeds. The spirogram is drawn on a special paper. Each 1 mm deflection of the pen represent 30 ml of air volume.

Water Sealed Spirometer



Computer Based Spirometer



1. MiniFlowmeter sensor
2. Thermal paper container
3. Flow sensor compartment
4. Display
5. Keyboard
6. Oximeter sensor

SpiroLab III is available in our lab

What to Do Before the Test?

1. **Exclude contraindications:**

- Hemoptysis of unknown origin.
- Current chest infection or within in last 6 weeks.
- Pneumothorax.
- Recent myocardial infarction.
- Unstable angina in last 24 hours.
- Recent surgery (eye, chest, abdomen) (< 3m).
- Recent CVA (< 3m).

2. **Stop Asthma Medications:** Medications may be continued if the test aims to assess the patient condition on treatment.

3. **Other Precautions:**

- Physical and mental rest.
- No coffee or smoking for 30 mins.
- Empty the bladder in females or those with history of urinary incontinence.

What to Do During the Test?

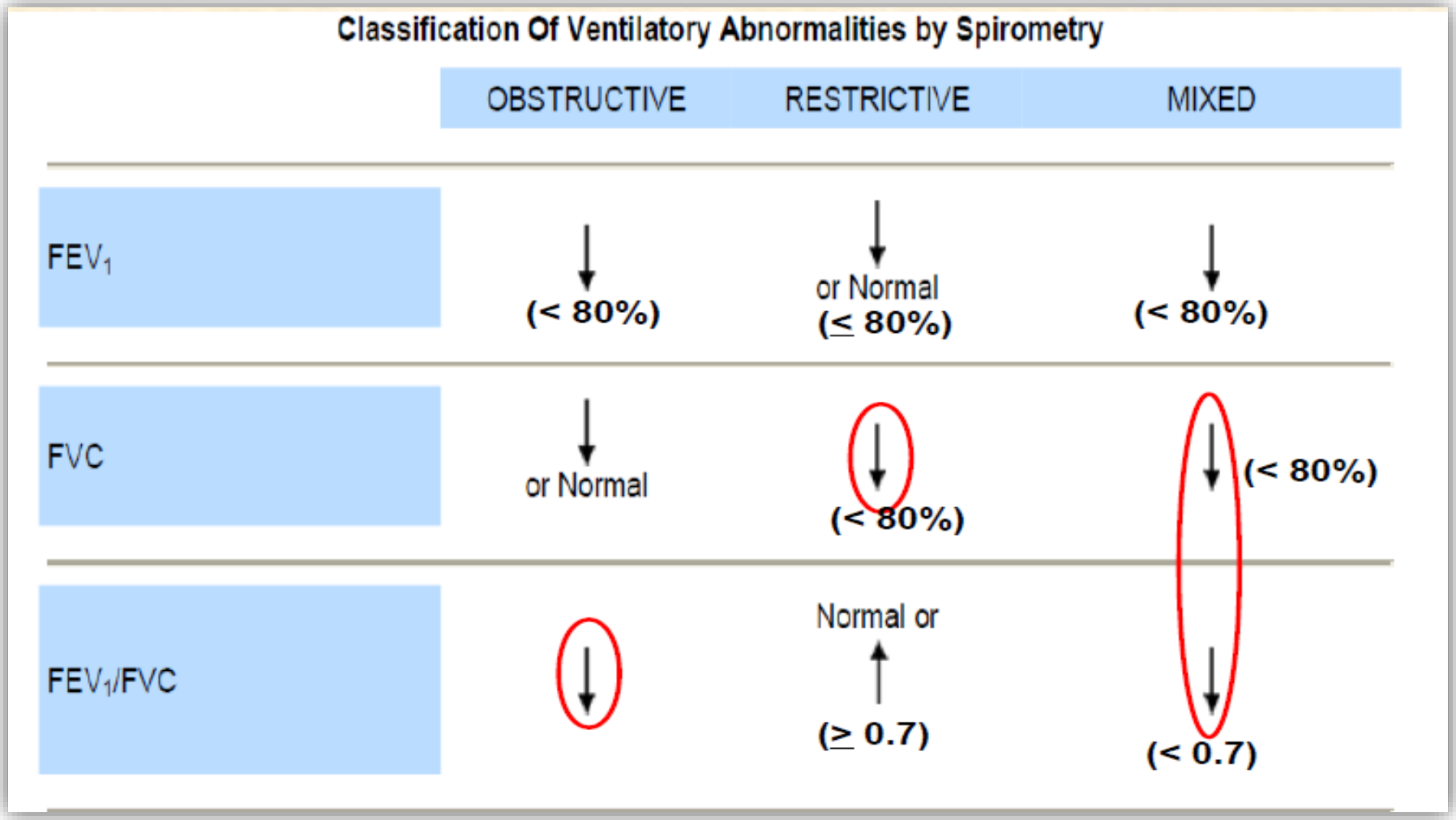
- ✓ Patient is sitting comfortably, not leaning forwards, legs not crossed, feet firm on floor.
- ✓ No tight clothes or collars.
- ✓ Explain the procedure to the patient.
- ✓ Nasal clip is optional.
- ✓ Ask the patient to do a Forced Expiratory Maneuver (FEM):
- Take a maximal inspiration.
- Hold the breath and seal your lips tightly around the mouth piece.
- Blow as fast as possible (blast expiration) until the lungs feel completely empty (at least 6 sec., up to 12 sec in obstructive disease)
- Repeat the test 3 times and record the highest reading.
- Continue watching, explanation and encouragement throughout the procedure.

https://www.youtube.com/watch?v=6uamAQ10CrQ

Spirometry includes:

- Lung volumes (most simple).
- Lung capacities (composite of > 2 volumes).
- Volume per time: as FEV1,2,3,4,5,6.
- Volume / Time Curve.
- Flow / Volume Loop.

Classification of Ventilatory Abnormalities by Spirometry

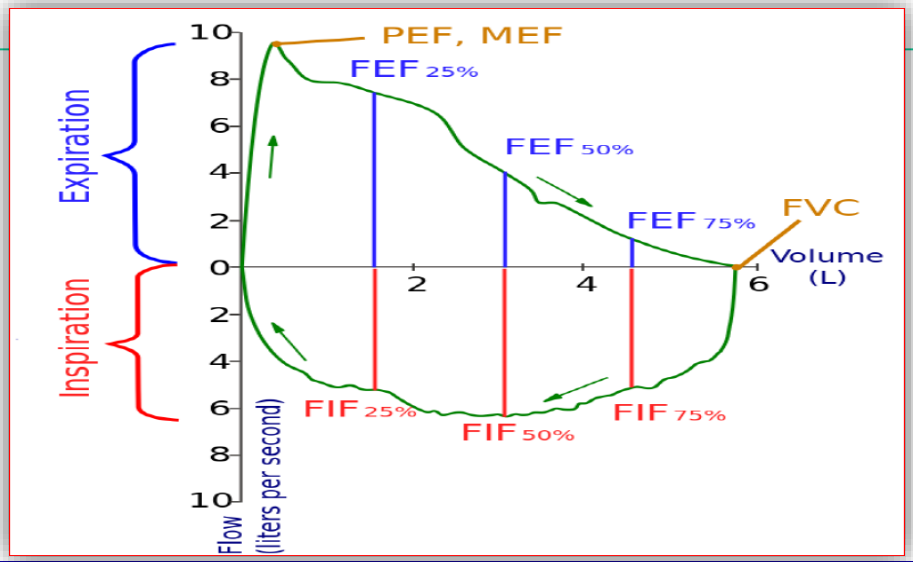


Forced Expiratory Flow

Forced expiratory flow (FEF) is the flow of air coming out of the lung during the middle portion of a forced expiration. It can also be given as a mean of the flow during an interval, usually 25– 75% (FEF25–75%).

FEF25–75% - Forced expiratory flow over the middle one half of the FVC; the average flow from the point at which 25 percent of the FVC has been exhaled to the point at which 75 percent of the FVC has been exhaled.

FEF25-75% is a more sensitive parameter than FEV1 in the detection of obstructive small airway disease.

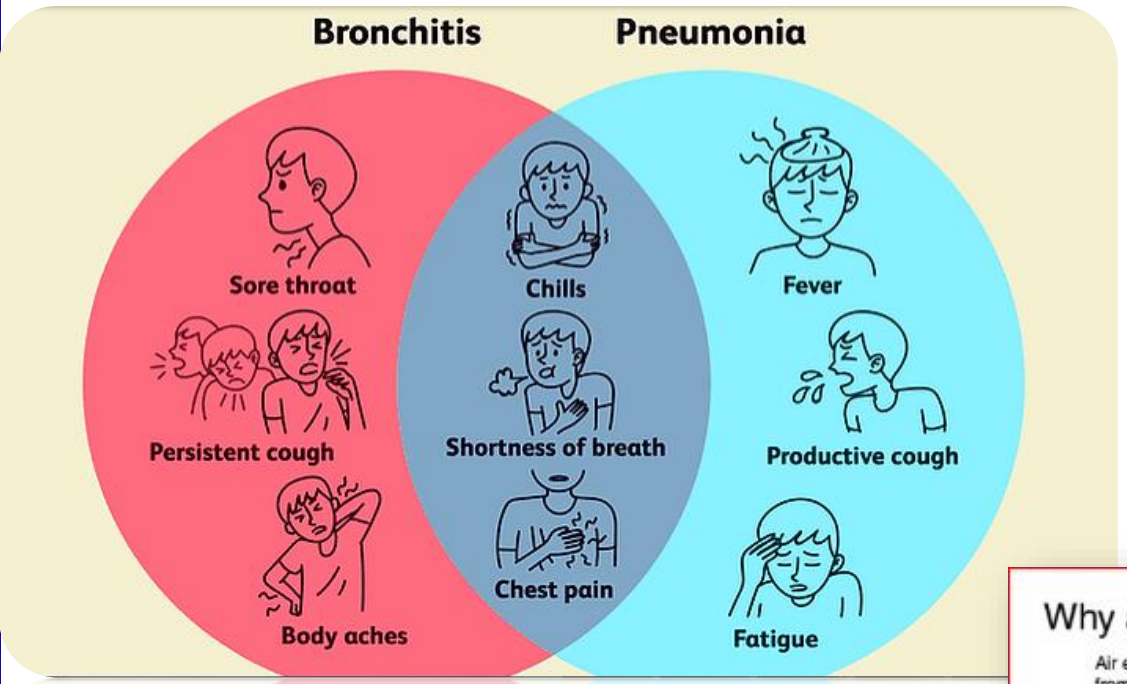


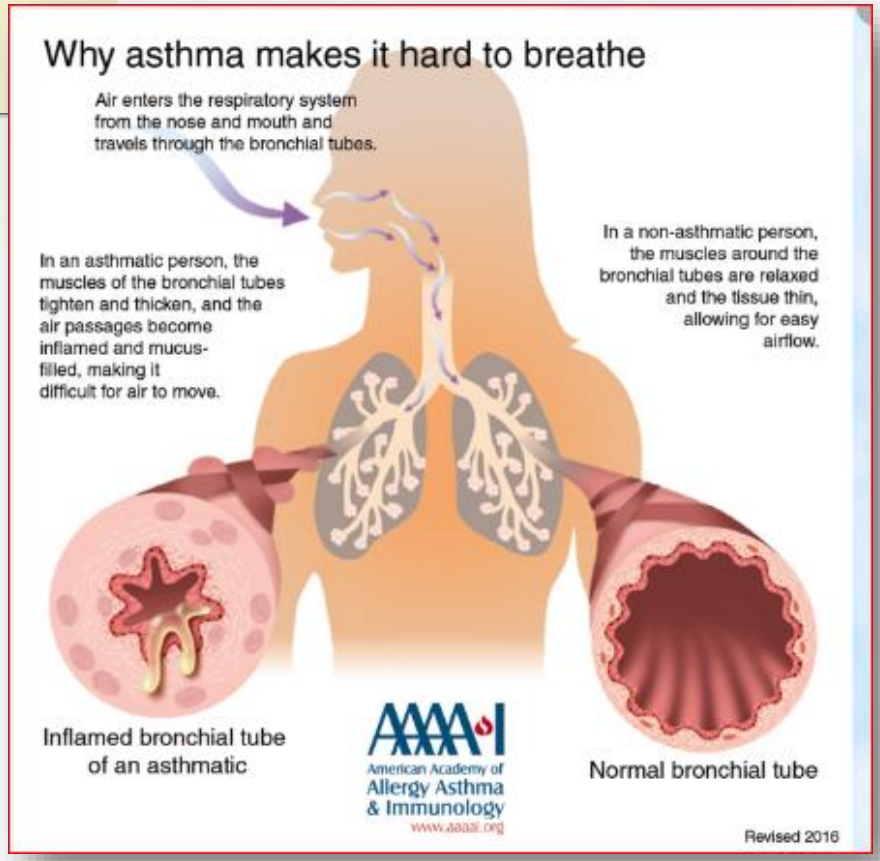
Maximum Voluntary Ventilation

- ✓ **Maximum voluntary ventilation (MVV)** is a measure of the maximum amount of air that can be inhaled and exhaled within one minute. For the comfort of the patient this is done over a 15-second time period before being extrapolated to a value for one minute expressed as liters/minute. Average values for males and females are 140–180 and 80–120 liters per minute respectively.

- ✓ **Technique:** subject is directed to breathe rapidly and deeply for 12 to 15 seconds; the total volume inspired or expired is measured; the volume is extrapolated to one minute.

- ✓ **MVV Decreased in:** Patients with moderate to severe obstructive lung disease, patients who are weak or have decreased endurance, and **patients** with neurological deficits.


Bronchitis
Pneumonia
Sore throat
Chills
Fever
Persistent cough
Shortness of breath
Productive cough
Chest pain
Body aches
Fatigue


Why asthma makes it hard to breathe
Air enters the respiratory system from the nose and mouth and travels through the bronchial tubes.
In an asthmatic person, the muscles of the bronchial tubes tighten and thicken, and the air passages become inflamed and mucus-filled, making it difficult for air to move.
In a non-asthmatic person, the muscles around the bronchial tubes are relaxed and the tissue thin, allowing for easy airflow.
Inflamed bronchial tube of an asthmatic
Normal bronchial tube
American Academy of Allergy Asthma & Immunology
www.aaaai.org
Revised 2016