SPIROMETRY

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ABSTRACT

Biomedical Engineering is a field of study of bioengineering and technological concepts, which aims to develop equipment and devices for the provision of health care, where the physical, chemical, computer, mathematics and engineering principles are integrated into the study of biology, medicine, behavior, health, And transplantation of organs, which aims to prevent, diagnose and treat diseases, in order to rehabilitate the patient and improve his health, and the specialty of medical engineering is at the forefront of the medical revolution, and is achieved through multi-disciplinary activities incorporating the other sciences with engineering principles. Biomedical engineers have developed many techniques that help to facilitate all aspects of life, and contribute to the saving and preservation of life, including: prostheses, such as: artificial alternatives to human limbs, and dentures. Surgical devices and systems, such as: laser, surgery by robot. Control systems for biomarkers and blood chemistry. Organisms implanted in the body, such as: insulin pumps, pacemakers, and prostheses. Imaging, such as: ultrasound, X-ray, and MRI. Treatment equipment and devices, such as: dialysis devices, and electrical stimulation of the nerve across the skin (abbreviated: TENS). Radiotherapy using X-rays. Physiotherapy equipment. According to many magazines that is concerned in health and medicine, in addition to universities and statistics, biomedical engineering over the past years has been the best profession in the field of health care, and confirms that there is no limit to the innovations and new possibilities in terms of technology, devices, knowledge. Specializations in biomedical engineering, whether biological, neurological, orthodontic, or even stem cell engineering, that is often combine the skills of problem solving with technical knowledge, as well as focus on medicine, health care has led to a lot of development, innovation and creation of many opportunities in medical engineering. Thanks to biomedical engineering for the development and innovation that we have made to help humanity, we will give an important example in this report.

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Chapter 1 : Introduction

The human body consists of many organs and tissue that unite to perform various functions in a way that ensures the continuity of life, as the existence of a defect that would stop life gradually and then die human, and these devices are intertwined, as indispensable to one of them from the other, and the organs of the human body Nervous, periodic, polyps, digestive and respiratory systems. Respiratory system is one of the most important organs that perform the function of breathing and the transfer of oxygen to all parts of the body and the disposal of carbon dioxide, and in this article will talk about some general information about the respiratory system with some clarification. Our main idea is to design full working, functional and simple spirometer provides with all sensors needed to this purpose such as Flow meter, Differential pressure sensor and an Oximeter, and in order to program it we use an Arduino micro controller. Our point is to focus in fixing or redesign the spirometry to make it more practical, easier, more accuracy, reduce its maintenance for replaying the sensors after blockage and to make it faster in measuring the variables. There is no doubt that this subject is one of the important topics in our lives, so we will try as much as we can to spend our time and our knowledge to design and build this idea Spirometry, in this next few lines I hope that I could illustrate all the points.

Chapter 2 : Literature Review

2.1 Respiratory System

Respiratory system provides human body cells with oxygen that is necessary for their activities, and saves them from carbon dioxide (the product of oxidation process), the air of inspiration passes through the trachea and the two sticks (the two narrowest branches that branch out before entering the lungs) to the lungs, each lung contains many bronchioles, which branch into alveolar ducts and sacs till the alveoli that end up with innumerable vesicles lined with very thin membranes through which gases exchange between them because of partial pressure and the capillaries surrounding it, the intercostal muscles (between the ribs) and the diaphragm (under the lungs) activate the lungs like the bellows, drawing air into them and then pushing them out at regular intervals because of change in lungs pressure. The Figure (1) shows the Respiratory System

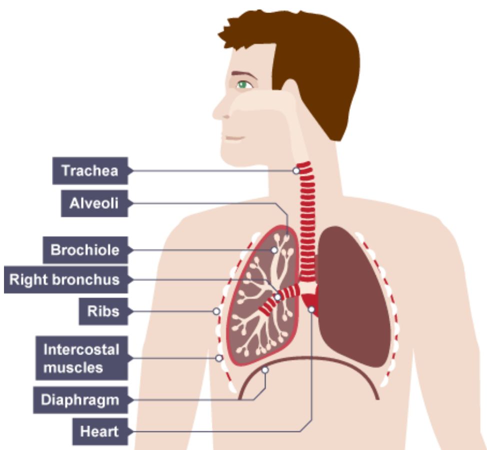

Figure (1) Respiratory System

2.2 Respiratory System Tracts

2.2.1 Lungs

Lungs are the main organs of the human respiratory system, the lungs are located in the thoracic cavity surrounded by the visceral crystalline membrane within the wall of the ribs and the diaphragm, near the spine on each side of the heart, its also include the bronchial tree that are divided into a number of bronchial vesicles that increase the capacity of the internal surface of the lungs.

We have right and left, the right lung is larger than the left because the right lung has three lobes and the left shares its area with the heart, the lungs weigh approximately 1.3 kg, and the right lung is usually heavier, the respiratory tracts begins with the nasal cavity to tracheal tubes that later branch into the bronchial tubes, the lungs together contain approximately 2,400 km of respiratory tract and contain 300 million alveoli that are thin and provide large area to support gas exchanges.

2.2.2 Nose

The nose is located in the front of the face and consists of skeleton and cartilage covered with skin, filled with a mucous material and moistens that warms and purifies the air, the nose plays a main role in the process of breathing as well as smelling, and forms the nasal cavity which is the beginning of the respiratory tracks to lungs.

2.2.3 Pharynx

The pharynx is the direct and extended pathway of the nasal passage from the back, the front part of which is lined with mucous membrane and the back part is a joint passage of food and air together, connected by the trachea and the esophagus, and passes from the pharynx through the opening of the pylorus to the throat.

2.2.4 Larynx

It is a cartilaginous organ that extends within the muscle membranes that forms the vocal cords, these ropes are vibrated by the effect of the air rising from the lungs, and the sounds are created, the throat is a member of the sound as its opens with the opening of the pimple.

2.2.5 Trachea

It is a tube consisting of semi-circular cartilage that supports the frontal area on the back of the esophagus, the function of the trachea is to prevents the expansion of the tracheal cavity above the desired, there are smooth muscles and fiber-elastic ligaments that reach the ends of the cartilage, the contraction of this muscles is to narrowing the tracheal cavity which plays a role in the cough and contributes to cleaning up the respiratory tract.

2.2.6 Bronchus

It is a passage of airway in the respiratory tract that conducts air into the lungs, that branches from the trachea into right and left, they are the widest tissue to enter the lungs at each hilum, where they branch into narrower secondary bronchi known as lobar bronchi, and these branch into narrower tertiary bronchi known as segmental bronchi and there is no gas exchange takes place in the bronchi.

2.2.7 Bronchioles

They are smaller branches of the bronchus, and are part of the conducting zone of the respiratory system forming the passageways by which air passes to the alveoli of the lungs, in which gas exchanges occur.

2.2.8 Alveolus

Alveolus is a hollow cavity found in the lung parenchyma wrapped in a fine mesh of capillaries, and its the basic unit of ventilation to form the ends of the respiratory tree, consists of the alveolar sacs and the alveolar ducts that branches into the alveoli which are the sites of gas exchange with the blood, a typical pair of human lungs contain about 700 million alveoli and area of 70m2 of surface providing gas exchanges.

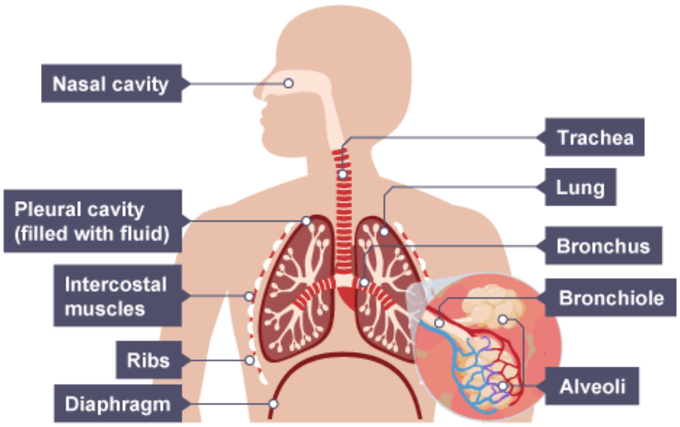

Figure (2)
Respiratory organs and air passageway and the muscles responsible for breathing

2.3 Respiratory Volumes

1. TV: Tidal Volume: The volume of air taken or subtracted in each breath (normal breathing condition) is equal to (500 ml).
2. IRV: Inspiratory Reserve Volume: The extra maximum volume of air that can be inhaled forcibly after a normal breathing and equals to (3000) ml.
3. ERV: Expiratory Reserve Volume: Expresses the maximum air volume that a person can forcibly remove after a short exhale and equals to (1100) ml.
4. RV: Residual Volume: It is the air that stays in the lungs even after forced exhalation (it can not be removed and therefore can not be measured directly) and equals to (1200) ml.

2.4 Respiratory Capacities

1. IC: Inspiratory Capacity: Expresses the volume of the maximum air that can be inhaled by forced effort and equivalent to 3500 ml (TV + IRV) (500 + 3000).
2. VS: Vital Capacity: Expresses the volume of the maximum air that can be exhaled and inhaled and is equivalent to 4600 ml (TV + IRV + ERV) (500 + 3000 + 1100).
3. FRC: Functional Residual Capacity: The remaining air volume in the lungs is expressed after a short exhale and can not be measured directly equivalent to 2300 ml (TV + ERV).
4. TLC: Total Lung Capacity: The volume of air in the lungs after greatest passion, and equivalent to 5800 ml (TV + IRV + ERV + RV) (500 + 3000 + 1100 + 1200).

2.5 Respiratory system functions

1. The function of the lungs is to capture oxygen from the atmosphere and transfer it inside the lungs into the blood stream and release carbon dioxide from the blood stream into the atmosphere in a process called gas exchange.
2. The lungs support the airflow, which causes vibration of the vocal cords, making speech possible in humans.
3. Preserving body heat as a result of combustion, demolition and construction inside the body, the body's internal temperature rises and works in several ways to get rid of excess heat.
4. Maintain the acid-pH or pH balance.

2.7 Breathing Process

During the breathing there are two main muscle that provide inhaling and exhaling, the diaphragm and the intracoastal muscles, also because of changes in air pressure and volume inside the lungs, Fig (3) and Fig (4) shows breathing process.

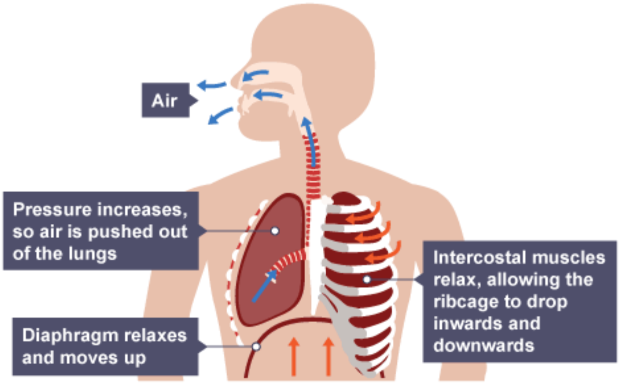

Figure (3)
The process of breathing in

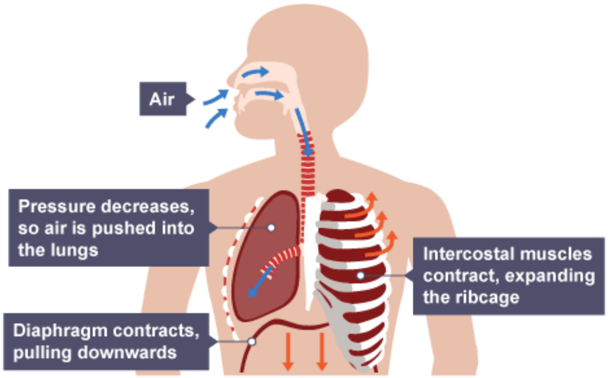

Figure (4)
The process of breathing out

2.8 Respiratory system diseases

Lung and respiratory diseases are among the most common diseases and health conditions in the world. Where tens of millions of people around the world suffer from lung and respiratory diseases. Smoking, infections, and genes are all the main culprits for most lung diseases. The lungs are part of a complex organ, which swells (or expands) and relaxes thousands of times a day to insert oxygen and expel carbon dioxide from the body. Lung disease can also result from any defect or problem in any part of this complex system. Here is a comprehensive overview of lung and respiratory diseases and symptoms.

2.8.1 Airway diseases include:

- Asthma: A common lung disease that affects the respiratory tract and may sometimes wheeze, the causing of wheezing may shortness the breath, allergies such as pollen, infection, and air pollution can be a cause of injury and asthma attacks.
- Chronic obstructive pulmonary disease (COPD): A condition that affects the respiratory tract in the lung and is characterized by the inability to exhale normally, which causes difficulty breathing.
- Chronic Bronchitis: is a form of chronic obstructive pulmonary disease (COPD) characterized by chronic mucous cough.
- Emphysema: The lung damage caused by chronic obstructive pulmonary disease (COPD) causes air to be trapped in the lungs, this disease is characterized by the difficulty of the output and blowing air outside the lungs during exhalation.
- Cystic fibrosis is a genetic condition that leads to poor cleaning of respiratory tracts of mucus, the accumulation of mucus leads to recurrent lung infections.

2.8.2 Lung disease affecting the air sacs (vesicles)

- Pneumonia: Is an infection of the alveoli, usually caused by bacteria or caused by the inhalation of a substance that hurts the lungs.
- Tuberculosis: Is a case of pneumonia which develops and spreads slowly and gradually, and is caused by Mycobacterium tuberculosis.
- Emphysema: Resulting from damage to fragile joints connecting the alveoli. Smoking is the main reason. (Also causes emphysema to reduce airflow in the lung, which affects the airways as well).
- Pulmonary Edema: In this case leakage of fluids from the small blood vessels in the lung to the alveoli and the surrounding area where the fluid collects there, one of the forms of this disease is caused by the state of heart failure and pressure that occurs within the blood vessels in the lungs.

- Lung cancer: There are many types of lung cancer, and can develop the disease in any part of the lungs and its often occurs in or around the alveoli, which are the main part of the lung.
- Severe Acute Respiratory Syndrome (ARDS): This is a severe, sudden, lung injury caused by a serious illness, this condition usually requires extensive medical attention (recovery care) accompanied by mechanical breathing means to keep the patient alive until the lungs recover and resume functioning.

2.8.3 Lung diseases affecting the interstitial tissue in the lung

- Interstitial Lung Disease (ILD): A wide range of health conditions and lung diseases that affect interstitial lung tissue, examples of these diseases include the geranium or sarcoidosis, idiopathic pulmonary fibrosis, and autoimmune diseases affecting the lung.
- Pneumonia and pulmonary edema can also affect the interstitial tissue of the lung.

2.8.4 Lung disease affecting blood vessels

The right side of the heart receives low blood oxygen from the blood veins, this blood is then pumped into the lungs through the pulmonary arteries and these blood vessels can also suffer from diseases:

- Pulmonary embolism (PE): A blood clot (usually formed in the deep vein of the leg called the deep vein clot) breaks down and moves to the heart, and then the heart pumps it into the lungs. This clot stops in the pulmonary artery, often resulting in shortness of breath and low oxygen levels in the blood.
- Pulmonary hypertension: There are many diseases and health conditions that can lead to high blood pressure in the pulmonary arteries. This can lead to shortness of breath and chest pain. When unable to determine the cause of this condition, it is called an idiopathic

2.8.5 Lung disease affecting the lining of the pleura

The pleura lining is a thin vacuum that surrounds the lungs and lining the chest wall from the inside. Having a thin layer of fluid on the surface of the lung allows the pleura lining to slide smoothly along the chest wall with all the same. Lung disease affecting the lining of the pleura includes:

- Pleural effusion: A condition in which fluid accumulates in the small pleural space between the lung and the chest wall. The main causes of this condition include pneumonia and heart failure. If the amount of fluid collected is large, the pleural effusion can weaken breathing and must be removed and discharged.
- Thoracic pneumonia: A condition caused by the presence of air in the distance between the wall of the chest and the lung, leading to shrinkage of the lung. To remove this air, the tube is usually inserted through the chest wall.
- Mesothelioma: It is a rare type of cancer that consists of the lining of the pleura. Mesothelioma tends to emerge after decades of exposure to asbestos dust or rocky asbestos.

2.8.6 Lung disease affecting the chest wall

The chest wall also plays an important role in breathing. The muscles attach the ribs to each other, helping to enlarge the chest. The diaphragm also goes down with each breath, which also leads to chest enlargement.

- Obesity Deficiency Syndrome: Excessive weight gain in the chest and abdomen makes chest expansion during breathing difficult. This can lead to serious breathing problems.
- Neuromuscular disorders: A malfunction in the nerves that control the muscles of the respiratory tract causes difficulty breathing. Acute lateral sclerosis and myasthenia gravis are examples of neuromuscular lung disease.
- Congenital heart disease in which the left and right sides of the heart connect.

- Hypoxia due to anemia: It is caused by hypoglycemia in the oxygen-carrying blood. The molecular pressure of the oxygen and its natural saturation occurs in all types of anemia or carbon monoxide poisoning, which binds to hemoglobin in the same way as oxygen, but more aggressively than the oxygen union 21 times Leading to a decrease in oxygen reaching the tissues.
- Toxic hypoxia: This is caused by oxidation of oxidized yeast in the tissues with a toxic substance such as cyanide, where the tissues themselves become disabled and unable to benefit from oxygen whose molecular pressure is normal and then rises in the veins to become higher than in the arteries.
- Rectal hypoxia: It is caused by slow blood circulation through tissue. The molecular pressure of oxygen in arterial blood is normal and the quantity of oxygen is normal, but the molecular pressure of oxygen and its amount in the venous blood is very low, if the heart is depressed. Fig (5) shows some lungs diseases.

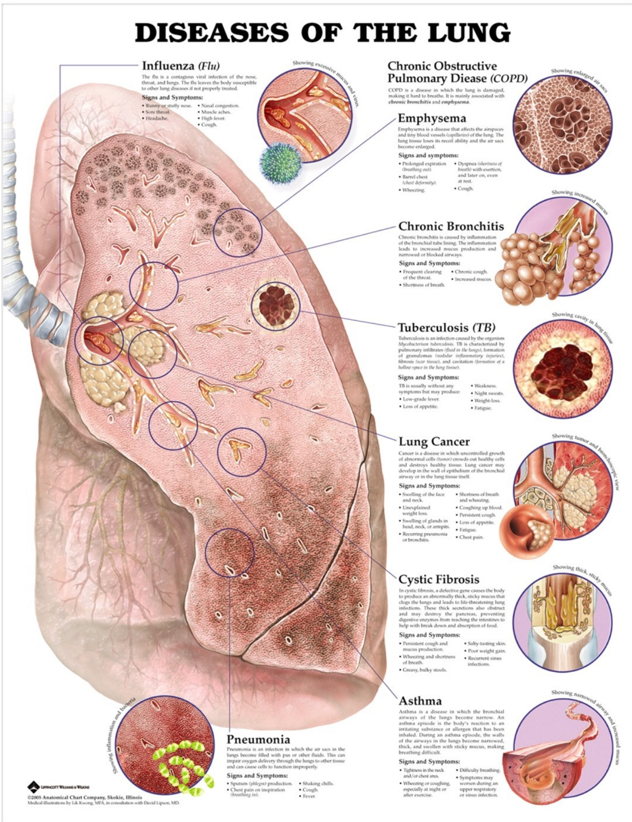

Figure (5) Lung Diseases

2.9 Test the lung functions

Lung function test is used to determine the amount (volume) and speed (flow) of the air that can be inhaled and exhale, and thus helps in detecting respiratory problems that cause shortness of breath and some lung diseases and is used before any major lung surgery to ensure that the person will not suffer from pulmonary insufficiency during or after.

To perform this examination, forceps are placed over the patient's nose to breathe only through the mouth through a tube connected to a machine known as a respirator, then ask him to breathe deeply, and then exhale in possible speed and with full force in the tube, and the duration of exhalation should not be less than six seconds to be able to machine work properly, usually the patient repeat this test three times, the best result of the three tests are considered the measurement of the function of the lungs.

Lung functions are tested by many devices such as

- Preoperative test: (to ensure that the patient is free of respiratory complications after surgery).
- Breathing measurement and maximum exhalation flow: Both exhalation volume (FEV1) and vital volume (VC) (the amount of air the patient exhales after inhaling the largest amount of air in the lung) are obtained, and the results are compared with expected values by age, sex, height and group Ethnic groups.
- Measurement of maximum pressure for exhalation and inspiration MIP & MEP: This test is used to test the strength of the patient's breathing muscles and often with patients with atrophy in the muscles. MIP: - A pressure gauge that the patient reaches while taking the inhalation from his closed tube. MEP: - A pressure gauge that reaches the patient during exhalation (with swelling of the cheeks) in a closed tube.
- Measurement of the spread of gases from lung to blood: Gas diffusion is the measure of the lung's ability to transport oxygen gas to the blood. This test uses the carbon monoxide capsule by taking the same breath from a 0.3% antenna mixture. This gas was selected as it

quickly combines with hemoglobin and provides a real assessment of the spread across the alveolar mucosa.

- Test blood oxygenation during exercise: Is a 6-minute walk test measuring the oxygen content of the blood and the distance traveled by the patient. It is a good measure for patients with chronic respiratory diseases such as chronic pulmonary embolism.
- Arterial blood gases and oxygenation: A blood sample is taken from the artery to calculate the pH of blood, oxygen and carbon dioxide to assess the degree of efficiency of the respiratory system in supplying the body with oxygen.

2.10 Spirometry

Spirometry is the most common pulmonary function test, it consists of a series of examinations of the respiratory functions, according to parameters and in precise conditions. The goal of a spirometry is to control the ventilatory function by measuring the volumes of air mobilized by respiratory movements and ventilatory flows.

These tests are designed to determine, in a relatively simple way, the parameters of different pulmonary capacities, lung volumes and airflows (inspiration, expiration) of a patient, in order to diagnose certain respiratory pathologies (asthma, COPD, among others) or to follow their evolution, providing very precise information concerning respiratory diseases, especially obstructive diseases (chronic obstructive pulmonary disease, COPD) and restrictive diseases. Fig (6) shows the Spirometry device.

Figure (6) Spirometer

2.10.1 There are tree basic types of spirometry includes:

- Laboratory spirometers: require high performance and accuracy. Desktop units must provide precise spirometry measurements and be able to perform a range of tests, such as flow volume, tidal spirometry, and maximum voluntary ventilation.
- Cabinet-size instruments: like body plethysmographs are used to perform advanced pulmonary function tests, including total lung capacity, functional residual capacity, and residual volume.
- Portable spirometers: are gaining popularity as the point of care shifts from clinical laboratories to general-practice settings and homes. General practitioners increasingly use spirometers to establish baseline measurements for their patients and to detect potential pulmonary diseases. Low cost is important to enable spirometer deployment in these new markets. Size and power consumption are also key design considerations. These devices must operate from USB and/or battery power, include charging capabilities, and offer several connectivity options. Fig (7) shows an example of portable spirometry.

Figure (7) Portable Spirometry

2.10.2 The result of Spirometers can be used to measure several parameters:

- FVC (forced vital capacity): The volume of air that can be exhaled after full inspiration.
- FEV1 (forced expiratory volume in 1s): The maximum volume of air that can be forcibly exhaled in the first second during an FVC maneuver.
- PEF (peak expiratory flow): The maximum flow (or speed) achieved during the maximally forced expiration initiated at full inspiration.
- Additional parameters such as tidal volume, maximum voluntary ventilation, flow-volume loops, and bronchial provocation can be performed, depending upon the complexity of the unit. Fig (9) explain how spirometry test results.

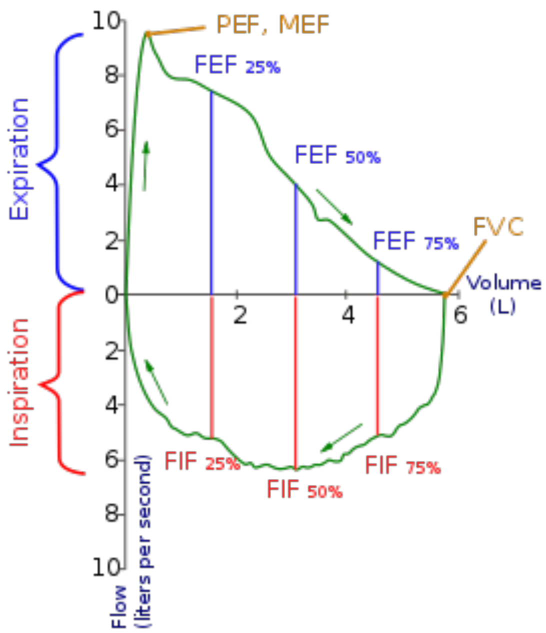

Figure (8) Spirometry Parameters

2.11 Brief history

Spirometry, from the Latin words SPIRO (to breathe) and METER (to measure). The spirometer was originally invented in the 1840's by John Hutchinson, the device (which was as tall as an adult patient) was essentially placed upside down in water, the volume of exhaled air from fully inflated lungs could accurately be measured by exhaling into a tube leading into the bucket.

Dr. Hutchinson in 1890 realized that compromise of this crucial measurement was predictive for premature mortality. Because of the strong correlation between vital capacity and mortality, Hutchinson argued that it should be utilized in actuarial predictions for life insurance policies.

The ideal changes happens around 1950 when it was determined that 90% of the predominant respiratory disorders (asthma and COPD) were obstructive (limited flow rate) in nature whereas vital capacity measured restriction. Dr. Tiffeneau of France introduced the forced measurement of air volume during a given time.

In 1960 Jones Medical determined that the classic water type spirometers of that era although adequate for measuring lung volumes were not suitable for accurately measuring flow rates, introduced the first available waterless spirometer providing an easier, more accurate and affordable spirometer.

One of the greatest opportunities in medicine is the modern Spirometry that can identify airflow obstruction before COPD symptoms present and 5-10 years before signs appear on an X-ray.

Later this year, New methods of measuring lung volume are being developed. Calculate lung volume changes by analyzing data from stereoscopic cameras. This non-contact system was originally developed for measuring lung volumes in infants. Its accuracy and utility in other applications is under investigation.

2.12 The prescription of a spirometry test may be useful for:

- Diagnosis of a respiratory condition or manage asthma.
- Assessing the impact on ventilation of a non-respiratory condition, such as myopathy.
- Screening for diseases early or before the appearance of clinical signs.
- The supervision of workers exposed to elements likely to cause variations in ventilatory function (fumes, gases, etc.).
- The differential diagnosis of a suspected disease.
- Establishment of the general condition of a subject.
- To measure response to treatment of conditions which spirometry detects.
- Preoperative examination for thoracic or upper abdominal surgery.
- The differential diagnosis of vocal cord dysfunction.

2.13 Spirometry components

- Oximetry: Pulse oximetry which is non invasively measures oxygen saturation in arterial blood used manually for diagnostic testing the asthma.
- Flow-Sensing Mechanism: Spirometers frequently use turbine transducers for flow measurement.
- Differential pressure sensors: sometimes used in place of turbine transducers. Commonly referred to as pneeumotachs, these designs can measure low flow rates with high accuracy.
- Connectivity: Desktop spirometers generally have a printer plus keyboard and include several communication. Handheld spirometers typically use USB for data transfer and battery charging; they can also include Bluetooth capabilities.
- Power Supplies: Desktop spirometers are frequently line powered, although they normally include lithium-ion (Li+) or nickel-metal-hydride (NiMH) rechargeable batteries as well.
- Displays: Spirometers typically employ a full-color, backlit LCD to display patient information, spirometry parameters and system information, such as remaining battery life.
- Modern units increasingly use a touch screen in combination with a graphical user interface (GUI) to make the programming process more intuitive.

2.14 Volume and Capacity

Volume and Capacities that measured with the Spirometry, and how it can be showed is the display screen.

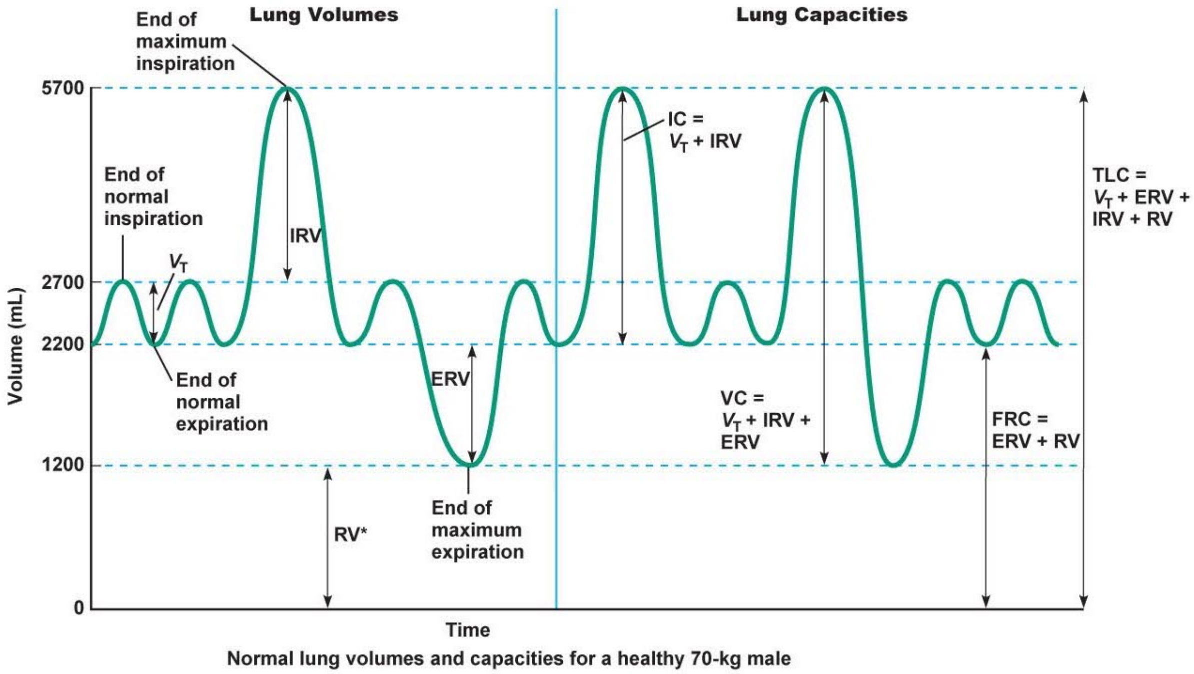

Figure (9) Volume and Capacity

Lung volumes

VT = Tidal volume = 500ml.

IRV = Inspiratory Reserve volume = 3000ml.

ERV = Expiratory Reserve volume = 1100ml.

RV = Residual volume = 1200ml.

Lung Capacities

IC = Inspiratory Capacity = 3500ml.

VS = Vital Capacity = 4600ml.

FRC = Functional Residual Capacity = 2300ml

TLC = Total Lung Capacity = 5800ml.

2.15 Working Principle

Procedure in most spirometers display the results as graphs, called “spiro-grams” a volume-time curve, showing the volume (in liters) along the Y axis and the time (in seconds) along the X axis a flow-volume loop, which graphically represents the airflow on the Y axis and the total volume inspired or exhaled on the X axis.

The patient, relaxed, is comfortably seated near the device. He puts himself at ease to breathe easily and places the spirometer transducer in the mouth. He performs a few normal breathing cycles before starting the actual exam. He must then inhale deeply and slowly, then chained by a rapid forced exhalation, in order to expel the air as much as possible from the lungs. The examination consists of three forced expirations of this type. It is best if the patient does not eat "too heavy" and does not smoke the five hours before the exam.

A spirometry test usually takes about 15 minutes and If you have evidence of a breathing disorder, your doctor might then give you an inhaled medication known as a bronchodilator to open up your lungs after the first round of tests. They’ll then ask you to wait 15 minutes before doing another set of measurements. Afterward, your doctor will compare the results of the two measurements to see whether the bronchodilator helped increase your airflow.
When used to monitor breathing disorders, a spirometry test is typically done once a year to once every two years to monitor changes in breathing in people with well-controlled COPD or asthma. Those with more severe breathing problems or breathing problems that aren’t well controlled are advised to have more frequent spirometry tests.

2.16 Failure and errors while testing

2.16.1 Limitations of the test

The procedure depends on the patient's cooperation and effort. It is normally repeated at least three times to ensure reproducibility. Since results depend on patient cooperation, FEV1 and FVC may be underestimated, but never overestimated.

Because of the importance of patient cooperation, spirometry can only be performed with patients who can understand and follow instructions. Therefore, this test is not appropriate for unconscious patients, In the same way, this test can be practiced only on children old enough to understand and follow the given instructions (from the age of 4 or 5 years). That said, there are other tests on lung function suitable for infants and unconscious.

2.16.2 Spirometry side effects

Few complications can occur during or after a spirometry test. You may feel a bit dizzy or have some shortness of breath immediately after performing the test. In very rare cases, the test may trigger severe breathing problems.
The test requires some exertion, so it isn’t recommended if you recently had a heart condition or have other heart problems.

2.16.3 Other Errors

While testing the patient blowing is the tube a coughing or sneeze in it may block the Differential pressure sensor and its compelling the doctor to redo the test again, and because the test is very difficult and require patient cooperation we are trying to help the patient too to make the test easier to him.

Chapter 3 : Material and Methods

3.1 The aim of the project

Our main idea is to design full working, functional and simple spirometer provides with all sensors needed to this purpose such as Flow meter, Differential pressure sensor and an Oximeter, and in order to program it we use an Arduino micro controller.

Our point is to focus in fixing or redesign the spirometry to make it more practical, easier, more accuracy, reduce its maintenance for replaying the sensors after blockage and to make it faster in measuring the variables.

3.2 The Working Principle

The working principle is very simple as we can describe; the power supply which is a battery feeds the microcontroller with power to generate the AC signals and to supply the component with DC current, also feeds the LCD touch screen . The microcontroller which is an Arduino Uno stores the signals in its memory, and those signals can be adjusted according to the program which is uploaded to the microcontroller and written language in C programing , the sensors that are attached to the micro controller such as the Differential pressure sensor, flow sensor, the Oximeter, and everything is displayed on the LCD screen as a single parameters values (frequency, pulse width, contraction duration, pause duration) in addition to the pre-installed settings for the particular cases. Figure (10) show the block diagram for the project

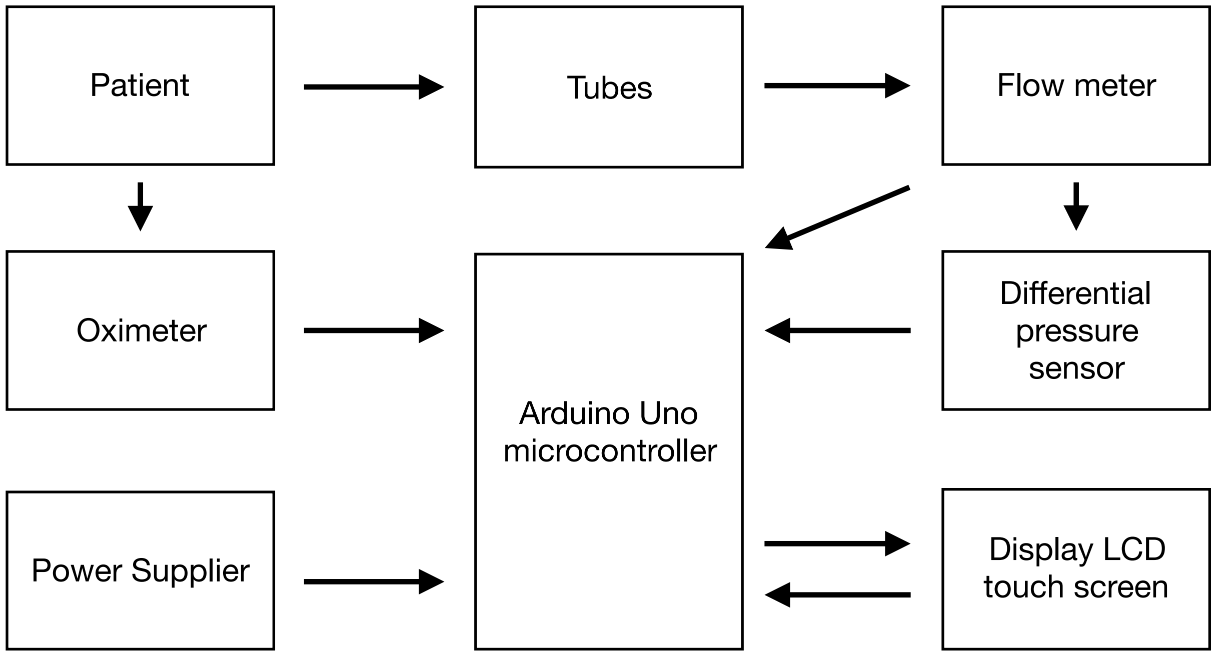

Figure (10) Working Chart

3.3 Components of the Project

3.3.1 Microcontroller / Arduino Mega

The Microcontroller is the main component of the device, because it is responsible of processing and storing the signals. Here we are using Arduino MEGA microcontroller which is an electronic development board consisting of an open source electronic circuit with a computer-controlled micro controller designed to facilitate the use of interactive electronics in multidisciplinary projects, and its mainly used in the design of interactive e-projects or projects aimed at building different environmental sensors such as temperature, wind, light, pressure, etc. Arduino can be connected to various programs on the PC. The software is based on the open source scripting language, The code for the Arduino language is similar to the C language and is one of the easiest programming languages used to write micro controller programs. Figure (11) shows the micro controller we use.

Figure (11) Arduino Mega

3.3.2 Power supply

The power supply is the main source of signal that is adjusted later. It's also important to feed the LCD and the DAC. It consists of a set of transformers, diodes, capacitors, and resistors, in addition to the main voltage source. Figure (12) shows the power supply used

Figure (12) 9V battery

3.3.3 Flow meter sensor

We use (YF-S201 Hall Effect Water Flow Meter / Sensor) this sensor contains a pinwheel sensor to measure how much liquid or air has moved through it. There's an integrated magnetic hall effect sensor that outputs an electrical pulse with every revolution. The hall effect sensor is sealed from the pipe and allows the sensor to stay safe and dry.

The sensor comes with three wires: red (5-24VDC power), black (ground) and yellow (Hall effect pulse output). By counting the pulses from the output of the sensor, you can easily calculate water flow. Each pulse is approximately 2.25 milliliters. Note this isn't a precision sensor, and the pulse rate does vary a bit depending on the flow rate.

The pulse signal is a simple square wave so its quite easy to log and convert into liters per minute using the following formulas.

Pulse frequency (Hz) / 7.5 = flow rate in L/min.

Flow rate Q = V x A

Figure (13) shows flow sensor in detail

Figure (13) Flow Meter Sensor

3.3.4 Differential pressure sensor

We use MPXV7002 Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated , its series piezoresistive transducers which are state-of-the-art monolithic silicon pressure sensors designed for a wide range of applications, but particularly those employing a microprocessor with A/D inputs. This transducer combines advanced micro machining techniques, thin- film metallization, and bipolar processing to provide an accurate, high level analog output signal that is proportional to the applied pressure.

With Features of 2.5% Typical Error over +10°C to +60°C with Auto Zero, 6.25% Maximum Error over +10°C to +60°C without Auto Zero, Ideally Suited for Microprocessor or Microcontroller-Based Systems, Temperature Compensated over +10° to +60°C and Patented Silicon Shear Stress Strain Gauge. Figure (14) is an example of the Differential pressure sensor.

Figure (14) Differential pressure sensor

3.3.5 Oximeter

The MAX30100 is an integrated pulse oximetry and heart- rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. The MAX30100 operates from 1.8V and 3.3V power sup- plies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times. Figure (15) is the Oximetry we use.

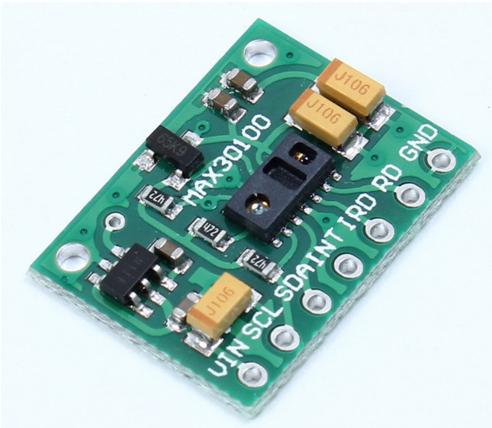

Figure (15) Oximeter

3.3.6 LCD Screen (16x2)

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. Here we use LCD 16x2 specially designed for ARDUINO micro controller.

Figure (16) LCD Screen (16x2)

3.4 What are the sensors we use / why ?

3.4.1 Pressure sensor

To select the right pressure sensor first the type of pressure measurement has to be considered.
Differential pressure is the difference between any two process pressures p1 and p2. Therefore, differential pressure sensors must offer two separate pressure ports with tube or threaded connections. Differential pressure sensors are used in medical devices to determine respiratory flow or in HVAC applications to control air flow.

So we choose the Differential pressure to support our main purpose regardless to Absolute pressure that referred to the vacuum of free space measurements or Gage pressure that measured relative to the ambient atmospheric pressure.

3.4.2 Oximetry

We use oximeter mainly to measure oxygen saturation in the blood to help us managing and detecting asthma and COPD, and monitoring heart rate and oxygen saturation during sports or high-altitude activities in order to maintain any problems in respiratory system. This we make our spirometer completable device.

3.4.3 Flow meter sensor / Air speed meter

Flow meter measure the air speed that across a radius of the tube in ml per second, the main purpose to use it in our spirometer is for two reason, first to give us more accurate results and to come up with pressure sensor blockage during the test because of coughing.

3.4.4 Pneumotachometer/ Pneumotachograph

Pulmonary function testing is a medical diagnostic procedure that measures how much air you are breathing and how fast. These parameters are measured with a device known as a pneumotach. A pneumotach is essentially a light screen that is inserted in the airflow. The pneumotach creates a known pressure drop that is directly proportional to the air velocity. A pneumotach is connected to an air tube that allows the patient to breath freely. As the air moves in and out of the patient's lungs the flow of the air creates a small drop in pressure across the pneumotach screen. A sensitive pressure transducer, like the Validyne DP45, is connected to the pressure taps of the pneumotach and produces an analog signal proportional to the flow rate. This signal is integrated to volume so that the amount of air and its flow rate into the lungs is known at each instant in the inspiration/expiration cycle. The pneumotach typically is equipped with a heater to keep condensation from forming on the pneumotach screen. A typical system is shown below.

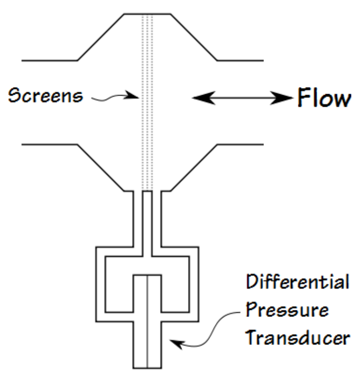

Figure (17) Pneumotach

Chapter 4 : Discussion

4.1 Improvements:

We have add flow meter sensor, providing a wide range of accurate results and reduce the blockage of pressure sensor. We've also use an Oximeter that allow us to analyze more lungs diseases, and we are trying to provide this device with pre-programmed setting for medical conditions so that the device can be used by people without an experience, also we redesign the device to use two separate tubes and the final result is combined from two signals.

4.2 Advantages :

1. The device can be used to test functional lungs and respiratory system.
2. It's portable, so the doctor can use it easily.
3. Capable to determine any interrupt that may change test result
4. Its cheap device comparing with other devices

4.3 Disadvantages:

1. Its need a lot of calibrating to accurate the results and this mean we have to do test on many patient.

2. patient most be prepared to do the test.

3. Some times due the patient illness condition he must repeat the test any times.

4.4 Errors and Challenges:

We face difficulties with the code first, the we have to replace the Nextion Screen with a normal LCD screen because we couldn’t program it as its beyond our knowledge, so we use both a computer for the graph and the LCD screen for some readable results, other problems the Differential pressure sensor must be attached to specific kind of tube called pneumotach spirometer tube which we couldn’t find in Cyprus stores or even in turkey that are able to buy.

4.5 Doctors Opinions and Suggestions

Uzm. Dr. Yağmur ALDAG :

Dr. Yağmur was very pleased with our simple achievement, he had some tips for us that spirometers in some medical cases my not work or not gives a real results, so he hoped that we can achieve the goals for the best way of examine functions of lungs.

Prof. Dr. Finn RASMUSSEN :

Dr. Finn was fascinating with our project, he said its a good step to develop real spirometer that could be rely on it in order to sell in markets, in addition he advised us to work more to solve problems to reach invention that 100% reliable.

4.5 Future aspects:

We can add an additional LCD touch screen to use a touch screen in combination with a graphical user interface (GUI) to make the programming process more intuitive and to show the exact result on time and to supply with order that restart the device and to be ready for specific test. We can also use different micro controller such as Arduino Mega to use more inputs and to provide faster processing, also we can use artificial intelligence so that it can detect the problem and output the proper currents accordingly. It's also possible to implement a Bluetooth device so it can be controlled wirelessly.

Chapter 5 : Conclusion

In the end we can only say that we have offered our opinion and we made our thoughts on this subject. From the above we can see that this subject is very important, We must make every possible effort, And to have all the available design and all the attention shown, We should take lessons and lessons that benefit society and individuals. We have presented this research to you after thinking and reasoning in the subject of the research which is Spirometer, It is a purposeful subject that everyone is interested in and who is eager to learn its details, starting with describing in detail the spirometry and its tracks, its function and the diseases that may affect our breathing system. We've also discuss the spirometer now in modern life and what inventors try to achieve. And here we are in this research and project after we were interesting in this scientific journey to raise the subject of the research so we have made a great effort to bring it out to the required level, but we can not say that it is comprehensive research and perfect, because everything is incomplete and needs more and more to reach a high level of science and knowledge. We hope and believe as a graduation student from the Biomedical Engineers Department that with this knowledge and study and after all this year of in this University and after we achieve what we do as the first project in our life, and based on this ideas and ambition we can leave a mark in this life to help the humanity one day…

Appendix : Spirometer Design Specifications

BACKGROUND AND PROBLEM: A Spirometer is used to diagnose many pulmonary diseases, including chronic respiratory diseases affecting about 300 million people. Many of these people can not reach the breath scale because the current models are expensive and require a trained technician to manage the process. The purpose of this project is to develop a low-cost spirometer that can be used without trained technical assistance. The project includes the physical design of a respirator, software development for presentation and analysis of results, and the design of a universal instrument to provide audiovisual training on tests. Among with Client requirements such as : Breathable interface interface with PC via USB cable, Portable and durable, Easy to cleanse, Reduce calibration and Display the results of the FVC maneuver graphically.

DESIGN REQUIREMENTS:

1. Physical and operational characteristics and Performance requirements.

2. Spirometer : Capable of measuring air flows continuously between 0 and 14 L/s in 15 seconds at least and record air volumes of at least 8 liters.

3. Software: volume versus time should be displayed on the laptop screen preferably in real-time, as well as numerically displayed data. The measurement display must be accurate to 0.01 L (L / s for flow). Programs must be open source and capable of working on Linux-based platforms. The patient's name, age, gender, smoking status, height and weight should be stored by computer. In addition, environmental data such as temperature, humidity, date, test location and other information.

4. Safety: The breath scale should not be a choking hazard and should not contain any components that can actually infect the user.

5. Accuracy and reliability: Spirometer - The maximum error for volume readings must be less than 3% of the read, the measurements must be sufficiently repeatable so that when

measuring steady flow patterns, all readings fall within 3% or 0.05L of the mean readings, whichever is greater.

6. Operating environment: The unit must maintain accurate function between 17 ° and 35 ° C, In relative humidity from 30% to 75%, and in the surrounding pressure from 85 to 106 kPa. The outside air is assumed to be at body temperature (37 ° C) and saturated with water vapor (100% humidity). The unit can be operated by a patient without technical training or supervision.

7. Work environment: Spirometer should be comfortable to use with either of your hands while sitting or standing. A mouthpiece should be comfortable for use during a full set of tests, at least 10 minutes. The audiovisual training tool must accommodate a range of languages and literacy.

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