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ELECTRONIC INCENTIVE SPIROMETER: A LITERATURE REVIEW

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ABSTRACT - Spirometry is the widely used diagnostic tool in the assessment of pulmonary function abnormality. It is a physiological test that measures individual exhalation and inhalation lung volumes as a function of time. Spirometry, although a powerful tool that plays a significant role in the early diagnosis of lung damage and its associated structures, is effort-dependent. It sometimes becomes complex to ensure co-operation and attain completion of the test in geriatric, foreign-language subjects and young children. Asthma and Chronic obstructive pulmonary disease (COPD) are both respiratory conditions that are chronic and affect a person's breathing. If asthma is not treated, it could lead to severe attacks. In this paper we are reviews various design topologies involved in spirometry implementation.

***Key Words*:** Chronic obstructive pulmonary disease; Microcontroller; Spirometer; Internet of Things.

1 INTRODUCTION

Asthma and Chronic obstructive pulmonary disease (COPD) are both respiratory conditions that are chronic and affect a person's breathing. Asthma and Chronic obstructive pulmonary disease(COPD) are both respiratory conditions that are chronic and affect a person's breathing. With many shared similarities, the two can easily be misdiagnosed for one another and that is why testing is so important to determine the exact diagnosis. Chronic Obstructive Pulmonary Disease(COPD) is the third leading cause of death globally and presents a significant burden to patients, carers and health services worldwide. More than 1.5 million adults are known to be diagnosed with COPD in England and Wales, and further 3 million adults are estimated to be living with undiagnosed COPD. Improving the care and outcomes for people with COPD is a priority for the National Health Services (NHS) in England, which aims to reduce premature mortality from respiratory disease, avoid unnecessary hospital admissions and improve the quality of life and support for patients with long-term conditions and their carers. However, several current issues remain in the diagnoses and monitoring of COPD, some of which could be resolved by technological developments or novel disease biomarkers. If asthma is not treated, it could lead to severe attacks. Many people die from asthma attacks every day in India and Worldwide. Untreated or poorly managed asthma can also cause scarring in the lungs, which can lead to COPD. Once the lungs are scarred, asthma medicines won't work as well. Pulmonary function analysers measure the performance of a patient's respiratory system, especially for outpatient or pre-surgical screening. These systems measure the ventilation, diffusion, and distribution of gases. They are used to help access patients with conditions like chronic obstructive pulmonary disorder (COPD). Spirometry helps diagnose and manage asthma. A Spirometry test can confirm whether you have asthma or another disease. And it helps your health care provider decide on your treatment. If follow-up spirometry tests shows that your asthma is well under control, your doctor may need to change your medicine or give you more medicine. Primary care spirometry services can be provided by trained primary care staff, peripatetic specialist services, or through referral to hospital-based or laboratory spirometry and is quite expensive and time consuming.

With the increasing proliferation of Internet-Connected Smartphone's across the world, low-cost smartphone-based medical devices are now attractive alternate to traditional custom-made medical equipment, especially in developing countries. So, this project encourages easy and reassuring use and is of low- cost and used for routine respiratory health checks at home. The spirometry equipment used in hospitals for pulmonary function testing costs thousands of dollars, which is beyond the means of health care facilities in many countries.

1.1 Chronic Obstructive Pulmonary Disease (COPD)

COPD is an umbrella term used to describe progressive lung diseases including emphysema, chronic bronchitis, refractory(non-reversible) asthma, and some forms of bronchiectasis. This disease is characterized by increasing breathlessness. Many people mistake their increased breathlessness and coughing as a normal part of aging. In the early stages of the disease, you may not notice the symptoms. COPD can develop for years without noticeable shortness of breath. You begin to see the symptoms in the more developed stages of the disease. Thus there is a necessity of consulting the doctor as soon as possible when you notice any of these symptoms and ask your doctor about taking a spirometry test. COPD affects an estimated 30 million individuals in the U.S., and over half of them have symptoms of COPD and do not know it. Early screening can identify COPD before major loss of lung function occurs. Figure 1 shows the Chronic Obstructive Pulmonary Disease.

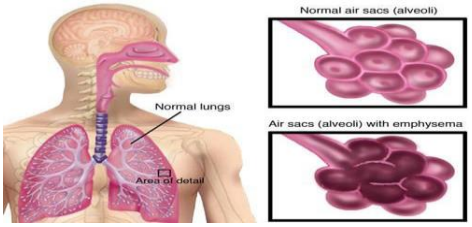

Fig-1: Chronic Obstructive Pulmonary Disease

II RELATED WORKS

Smartphone users around the globe are expanding every year. For most of all purpose people are relying on smart devices. As it is handy now researches are linking module with smart application. For the benefits patients many applications have been developed in healthcare domain but here concentrating only on the spirometry monitoring. This section depicts an outline of the past work that has been done and researches included in the spirometry monitoring. In case of embedded system microcontroller and Bluetooth technology is utilized for communication depending on the requirement.

2.1 Current Scenario

Spirometer is a form of Spiro analyzer or Ventilometer and is generally defined as an instrument for measuring the breathing capacity and other bronchial activity of the lungs. Pulmonary illness is an umbrella term that encompasses a range of conditions affecting the human respiratory system. The severity and prevalence of these illnesses continues to rise, affecting over 900 million people worldwide. Most of these pulmonary illnesses cannot be cured, but early detection can instrumental in slowing disease progression. Almost 90% of deaths from pulmonary illnesses occur in developing nations, where there is limited access to expensive diagnostic equipment. Spirometers find wide utilization in the diagnosis of lung and breathing difficulties such as asthma, Chronic Obstructive Pulmonary Disease (COPD) and emphysema. More particularly, they have found use in monitoring the progress of recipients of lung transplants. Ordinarily, spirometers involve large equipment located in laboratories or doctors' offices. The testing requires the patient to breath into the equipment with a forced expiration.

The parameters obtained through the use of spirometers are reported in well- accepted formats such as "forced vital capacity" (FVC) which is the volume of air that is exhaled following a maximum single breath regardless of the time taken; "peak expiratory flow" (PEF) which is a measure of the highest flow rate of air from the lungs during a single forced expiration; "forced expired volume during the first second" (FEV1) which represents the volume of air that can be exhaled forcibly in one second; "FEF25/75 " which is the average expiratory flow for the middle 50% of the expiration; and, other combinations of these values such as FEV1 expressed as a percentage of the FVC. Depending upon the particular malady involving the lungs, the physician or physiotherapist may choose to look at one, some, all of these parameters, or other ones. The spirometry test done in hospitals is as shown in Figure 2. When it comes to rural areas the hospitals lack sophisticated testing equipment like Spirometer, thereby requiring the patient to travel substantial distances to undergo the testing.

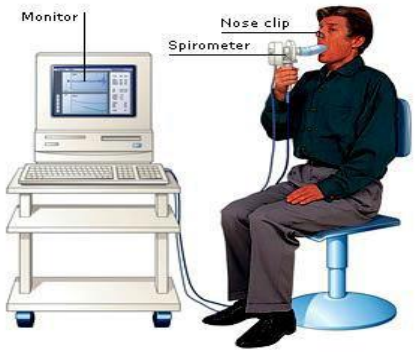

Fig-2: The Spirometry test done in hospitals

Large electronic spirometers situated in a laboratory or doctor's office are often massive and quite expensive and therefore not installed at many locations. The estimation and calculation process used for detecting lung diseases in these large spirometers are complex and time consuming. When it comes to rural areas the hospitals lack sophisticated testing equipment like Spirometer, thereby requiring the patient to travel substantial distances to undergo the testing. If a patient is found to have lung diseases such as asthma and Chronic Obstructive Pulmonary Disease (COPD), then should regularly go

through Spirometer tests in -order to get his disease diagnosed.

2.2 Types of Spirometer

Body plethysmograph, Pulmonary plethysmographs are commonly used to measure the Function Residual Capacity (FRC) of the lungs the volume in the lungs when the muscles of respiration are relaxed—and total lung capacity. In a traditional plethysmograph, the test subject is placed inside a sealed chamber the size of a the size of a small telephone booth with a single mouthpiece. At the end of expiration, the mouthpiece is closed. The patient is then asked to make an inspiratory effort. As the patient tries to inhale (a manoeuvre which looks and feels like panting), the lungs expand, decreasing pressure within the lungs and increasing lung volume. This, in turn, increases the pressure within the box since it is a closed system and the volume of the box compartment has decreased to accommodate the new volume of the subject and is shown in the Figure 3

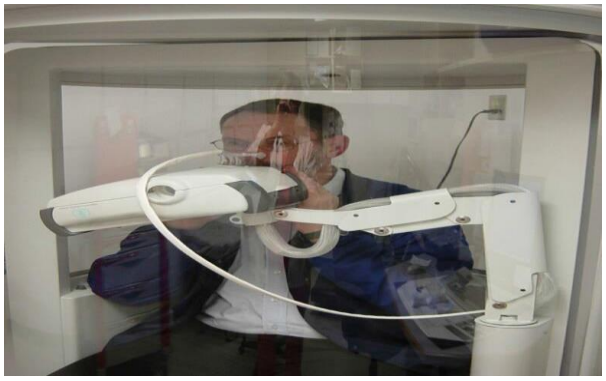

Fig-3: Body Plethysmograph

2.2.1 Pneumotachometer

Pneumotachomter measures the flow rate of gases by detecting pressure differences across the mesh. One advantage of this Spirometer is that the subject can breathe fresh air during the experiment and is shown in the Figure 4.

Fig-4: Pneumotachometer

2.2.2 Incentive Spirometer

An incentive Spirometer is a medical device used to help patients improve the functioning of their lungs. It is provided to patients who have had any surgery that might jeopardize respiratory function, particularly surgery to the lungs themselves, but also commonly to patients recovering from cardiac or other surgery involving extended time under anaesthesia and prolonged in-bed recovery. The incentive Spirometer is also issued to patients recovering from pneumonia or rib damage to help minimize the chance of fluid build-up in the lungs. It can be used as well by wind instrument players, who want to improve their air flow. The patient breathes in from the device as slowly and as deeply as possible, then holds his/her breath for 2–6 seconds. This provides back pressure which pops open alveoli. It is the same manoeuvre as in yawning. An indicator provides a gauge of how well the patient's lung or lungs are functioning, by indicating sustained inhalation vacuum. The patient is generally asked to do many repetitions a day while measuring his or her progress by way of the gauge and is shown in the Figure 5.

Fig-5: Incentive Spirometer

2.2.3 Peak Flow Meter

Peak Expiratory Flow also called peak expiratory flow rate (PEFR) is a person's maximum speed of expiration, as measured with a peak flow meter, a small, hand-held device used to monitor a person's ability to breathe out air. It measures the airflow through the bronchi and thus the degree of obstruction in the airways. Peak flow readings are higher when patients are well, and lower when the airways are constricted. From changes in recorded values, patients and doctors may determine lung functionality, the severity of asthma symptoms, and treatment. Measurement of PEFR requires training to correctly use a meter and the normal expected value depends on the patient's sex, age, and height. It is classically reduced in obstructive lung disorders such as asthma. Due to the wide range of 'normal' values and the

high degree of variability, peak flow is not the recommended test to identify asthma. However, it can be useful in some circumstances. A small portion of people with asthma may benefit from regular peak flow monitoring. When monitoring is recommended, it is usually done in addition to reviewing asthma symptoms and frequency of reliever medication use. When peak flow is being monitored regularly, the results may be recorded on a peak flow chart. It is important to use the same peak flow meter every time and is shown in Figure 6.

Fig-6: Peak Flow Meter

2.2.4 Wind Mill Spirometer

Used specially for measuring forced vital capacity without using water and has broad measurements ranging from 1000 ml to 7000 ml. It is more portable and lighter as compared to traditional water-tank type Spirometer. This Spirometer should be held horizontally while taking measurements because of the presence of rotating disc and is shown in Figure 7.

Fig-7: Wind Mill Type Spirometer

III PREVIOUS RESEARCH ON SPIROMETRY

This chapter provides knowledge of existing system with a survey of technology, components used. It provides information related to recent research views, pros and cons of previously done work. On doing survey of recent and past work gives familiarity of work and gets an opportunity to identify loopholes. This leads in gaining chance of improvising system.

3.1 A Telehealth System for Automated Diagnosis of Asthma and Chronical Obstructive Pulmonary Disease

The telehealth system proposed in this study uses a simple spirometer with a Bluetooth module, MATLAB-based ES application, and Android-based mobile application. The system utilizes Android, Java, MATLAB, and PHP technologies and consists of a spirometer, mobile application, and expert diagnostic system. To evaluate the effectiveness of the system, a prospective study was carried out in 3 remote primary healthcare institutions, Portable spirometers: used by medical professionals to acquire measurements of relative parameters needed in COPD/asthma diagnosis. The portable spirometer used in this study can be connected to a mobile phone using Bluetooth. Any commercially available portable spirometer with this communication module is applicable for this telehealth system. Android based mobile application: developed for the Android operating system and implemented in Java using Android Studio 2.0 IDE (Integrated Development Environment). It is installed on a mobile phone and used for initiating SPIR data recording, formatting, and data transmission.

3.2 Internet of things in healthcare monitoring to enhance acquisition performance of respiratory disorder sensors

IoT architectural design is based on signal acquisition through sensors and, then, processed using a programmable card. Database (DB) signals are then recorded in a Hub-IoT cloud server. Hub-IoT is a technology service for multiple programming languages DB access used in this study to acquire, save, process, and analyze by means of an application programming interface (API). Optimization capabilities for application development rely on communication channels, protocols (IoT, transport, and priorities), low resource consumption technology, among others. A performance effectiveness test application is then developed. The main acquisition module includes a high-efficiency wireless personal area network (WPAN) which is composed of low energy consumption sensors, and it also has a discontinuous control system to clinical parameters.

3.3 A Smart Phone Based Handheld Wireless Spirometer with Functions and Precision Comparable to Laboratory Spirometers

The developed spirometer was demonstrated to be able to detect flow rates ranging from 0–15 L/s with an accuracy of 4 mL/s, and can perform tests of flow volume (FV), forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), peak expiratory flow (PEF), etc. By having the functions and precision comparable to laboratory spirometers, it satisfies the American Thoracic Society and European Respiratory Society (ATS/ERS) proposed performance requirements for spirometer. At the same time, it is low cost, light and handy, low power consumption battery-powered. To be light and portable, our spirometer should be a wireless small compact handheld unit without any external connecting pipes/tubes and desktop consoles. It should have functions and precision comparable to laboratory spirometers, so as to perform a range of tests, such as flow volume (FV), forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), peak expiratory flow (PEF), maximum voluntary ventilation, and tidal spirometry, etc. It should also meet the performance index requirements for spirometer recommended by the American Thoracic Society/European Respiratory Society (ATS/ERS). Specifically, it should be able to respond flow rates ranging from 0 to 14 L/s with a resolution better than 25 mL/s, and have a precision of ≤±3% for FVC, and ±10% for PEF. Moreover, it should have the capacity to display the test results including both data and graphics immediately after the test, and at the same time transmit them to family doctors or a hospital unit.

3.4 Design and Testing of a Spirometer for Pulmonary Function Analysis

Spirometer body, Circuitry, Computer and Software. The spirometer body includes a differential pressure sensor and a pilot tube through which the patient blows. The output is transmitted to the microcontroller. The analog to digital convertor within the microcontroller is employed for the conversion. Then the pressure difference output from the pressure sensor is converted into mass flow rate which is subsequently converted into volume. The microcontroller relays this data via a Universal Serial Bus (USB) connection to a computer which transmits this to the JavaScript based graphical user interface. This interface is used to display the flow and volume data in real-time. The experimental setup is shown in Figure 2. During first phase, the age group is divided into two groups: 18-30 and 30-45. Then the proposed spirometer had experimented on both males and females in these age groups during phase 2. Then collected the forced vital capacity (FVC) and forced expiratory volume first second (FEV1) values of the subjects and compared with standard values to draw a conclusion whether the subject has any kind of disorder. FEV1 and FVC are the two important values that indicates normal lung functioning.

3.5 Breathing Monitoring and Pattern Recognition with Wearable Sensors

Spirometer device is used to conduct test to check person's lung capacities. Spirometer test helps to know the measurements of the quantity of air inhaled and exhaled by the lungs during a certain period of time to determine the pulmonary capacity. This data can be used to determine normal lung function, as well as diagnose a variety of pulmonary conditions. These measurements are useful when it comes to diagnosis pulmonary function since results are valuable in diagnosing diseases such as pulmonary fibrosis, asthma, chronic obstructive pulmonary disease (COPD), chronic bronchitis and emphysema. Presently, spirometers available in the market should be used by installing the required software and connecting it to the computer, and often times, these can be expensive and bulky making them hard to obtain in smaller hospitals across the globe. One of the unique things about this newly designed spirometer is that the results are stored in the cloud and they can be accessed at any time only by the authorized person.

3.6 A Smart Spirometry Device for Asthma Diagnosis

The device mainly subtends three modules: a flow meter, a PCB and a Smartphone. The flow meter is connected to a control system unit composed of a high pass filter, signal amplifier, stabilizer (denoted as trigger), a microcontroller and a Bluetooth module. The Bluetooth module ensures communication with the smartphone which represents the interface where data are recorded and results are displayed. It is to be noted that for children, the device will personify funny characters, images and animations in order to allow them to forget their fears whilst taking the test.

Once a test is performed, the results are transmitted to the smartphone and displayed on the screen via Bluetooth technology as shown in figure 2. It will provide spirometry parameters that will help the doctor in diagnosing the patient's case such as FEV1/6, FEF, PEF and FVC. In addition our device will ask the user to input specific characteristics of the patient that are age and gender as previously mentioned and which are to be used in a more accurate diagnosis. In fact, using equations 1, 2, 3 and 4 the device will be capable of stating whether the patient's case is "good", "moderate" or "severe". Moreover, this device is

equipped with a memory card to record previous instances and tests taken by the patient in order for doctors and patients to closely, efficiently, and easily monitor the case and thus, be able to adjust the treatment accordingly. Finally, due to today's modern life rhythm and complexities, we emphasize that such device would save precious hours or minutes in assessing and intervening in a patient's life since the proposed prototype also provides an immediate email sent to the doctor's smartphone with the results of the test right after being taken by the patient so the former can judge whether regular medication can be continued or a more severe condition has developed requiring transferring the patient to the ER of the nearest hospital.

4 CONCLUSION

There are methods employed in Hospitals to do the check-ups on Respiratory diseases like Asthma and Chronic obstructive pulmonary disease (COPD). But they are very time consuming and Costlier. When it comes to remote areas where the Doctors can't visit frequently there exists the problem for the patients like this. They may not be able to go to the hospitals at the time when they have severe effects of these illnesses. Whenever the patient needs to check or whenever the doctors suggest for the test they can make use of the simple and smart designed for the check-up they only can send the data from wherever they are irrespective of time and place. Since the device is small in size they can be carried with them. In this paper we examined the various design strategies involved in designing Smart Spirometer. This survey will be much beneficial in the upcoming COPD based researches.

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