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Design of a device for the assessment of dyspnea patients

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K E Y W O R D S

Incentive spirometer (IS)

Dyspnea

Hypertensive

Smoking

Alcohol detection

A B S T R A C T

Dyspnea is a disorder that occurs because of shortness of breath and may lead to multiple complications. Intoxicated dyspnea patients are those who are addicted to alcohol, as well as have breathing problems. Mostly, problems faced by dyspnea patients are inhalation, when they take alcohol with severe concentration. For intoxicated dyspnea patients, there is a continuous need for alcohol breath testing along with breath indicators, since, an individual is prone to alcohol addiction, and faces problems of breathing such as asthma, hypertension, etc. The severe outbreak of dyspnea in these individuals may be deadly. To handle this condition, an alcoholic meter along with an incentive spirometer is designed that helps in the assessment of breathing problems by measuring the alcohol concentration and inhaled air. Several parameters have opted for both inhalation detection and alcohol concentration which include the severity of health problems encompassing asthma, hypertension for the detection of inhaled air, and normal, moderate, severe alcohol concentration. The working of the proposed device is validated through the analysis of these parameters. The results are obtained on the graph as well as on display, which shows a variation in the range among every individual with respect to selected parameters either in incentive spirometer (inhalation detection) or alcoholic meter, and these ranges are also displayed in a numeric form on LCD. The idea is to design an economical and portable device for intoxicated dyspnea patients for emergency conditions which is a combination of an alcoholic meter with an incentive spirometer (IS) for the measurement of alcohol concentration along with breathing problems by making use of sensors. This unique idea of combining an alcoholic meter with an incentive spirometer will aid intoxicated dyspnea patients in case of emergency.

1. Introduction

Dyspnea has been known for shortness of breath and discomfort breathing sensation, which in practice is annoying and irresistible simultaneously [1]. The intensity of dyspnea varies subjectively since it has symptoms of different diseases rather than a disease itself. The etiology and origination of dyspnea are respiratory and cardiac systems. However, it was found that it occurs in such patients who would have experienced respiratory and cardiovascular diseases [2].

Dyspnea can be acute and chronic depending upon the span of disease. Consequences of chronic dyspnea may result in asthma, chronic obstructive pulmonary disease, heart failure [3]. Therefore, examination of the patient is necessary which can be done either physically or by taking a history of the patient by the clinician [4].

Assessment of breathlessness plays an important role in guiding respiratory problems, which may also lead to other complications [5]. Thus, resolving breathing issues is critical which can be healed and stabilized to some extent by an Incentive spirometer [6]. Moreover, practice by clinicians with multiple exercises for breathing can also improve the patient's condition. Incentive spirometer (IS) is one of the types of spirometer which is used to facilitate slow deep breathing and monitor the performance of the lungs. It utilizes balls in different chambers and mouthpieces through which an individual will blow some air so the lung's performance could be evaluated by the movements of balls in the chambers [7]. The usefulness of IS is evident, as it is suggested for lungs recovery after surgery and also for lungs illness, along with that it is widely prescribed to prevent Postoperative Pulmonary Complications [8], Primary spontaneous pneumothorax (PSP) [9], improve Ortho motors and pulmonary functions in children with Down’s syndrome [10], etc.

However, alcohol intoxication causes a transition in the human body and indicates multiple problems. Intoxication is of various types including mild, moderate, and severe. Each type recognizes according to their effects on the body, however, severe intoxication may lead to adverse consequences such as asthma and breathing exertion [11], when they immerse into the bloodstream [12]. Therefore, this emphasized the fact that alcohol concentration should be determined along with breath level.

Alcohol Intoxication levels within the blood can be determined through blood alcohol concentration (BAC) through a breathalyzer [12], [13]. Measurement of Breath Alcohol Concentration (BAC) is possible either by invasive or non-invasive procedures. Whereas, invasive measures involve drawing a blood sample, and non-invasive strategy via breath, salvia, or urine samples [12]. Mostly, non-invasive procedures are preferred for breath testing. These approaches include semiconductor Models (breathalyzer), Fuel-Cell Models, Infrared (IR) intoxilyzer, gas intoximeter [14] and are mend only for alcohol level detection in an individual [12]. Thus, the concept of alcohol concentration level measurement and incentive spirometer for breathing issues emerges in introducing a device that helps to monitor the breathing issue of dyspnea patients along with the alcohol intoxication of a user. This device has been specially designed for dyspnea patient who is associated with hypertension and smoking issues too [8].

2. Literature Survey

2.1 Incentive Spirometry

Decades ago, the concept of intermittent positive-pressure breathing (IPPB) proposes to inhibit the complications of postoperative pulmonary complexities [15], later, it was found to be not as supportive and as useful [16]. At that time, the concept of incentive spirometer (IS) was introduced by Bartlett et al., with the conclusion that yawning might generate pulmonary benefits for postoperative patients [17-18].

Accentuating this relation, a group establishes a device to coach the patient to follow a yawning-like sustained maximal inspiration in an effort to inhibit atelectasis. The inventor's early data, from postoperative patients performing sustained maximal inspiration, proved progress in ventilation/perfusion mismatch and alveolar gradient, the latter suggestive of alveolar inflation and subsequent reduction in the intrapulmonary shunt. When sustained maximal inspirations were repeated each hour, PaO2 levels remained near normal. These preliminary findings came to define the anticipated physiologic effects of IS [4].

In 1973, the Bartlett-Edwards IS device was presented to incentivize deep breathing by providing visual light feedback when patients achieved their inspiratory target volume. In 1975, the Spirocare device further bettered the electronic IS visual feedback by positioning the display lights on a scale indicating an elevation in inspiratory volume. These electronic IS devices were in use for many years but have been replaced by less expensive, disposable units now [5].

2.2 Alcohol Detector

2.2.1 History of breath alcohol determination

Blood Alcohol concentration studies were achieved in the 1930s when Erik Widmark established a concentration-time profile of ethanol [19]**.**

A high correlation between blood and breath ethanol concentration was reported by Liljestrand and Linde and also determine blood: breath ratio depending on ratio after drinking. This relation shows that the presence of alcohol in the breath is an indication of its existence in the blood, thus, illustrating the significance of its recognition level in breath [20].

The first breath alcohol measurement device was designed by Robert Borkenstein at Indiana University in 1954. He utilized wet chemistry and makes a reaction between alcohol and potassium dichromate for estimation of the absorption difference with UV spectroscopy [21-22].

The National Highway Traffic Safety Administration and the Automotive Coalition for Traffic Safety together have undertaken the task to encourage new technology research to eliminate drunk driving on American roads, which is recognized as the 'Driver Alcohol Detection System for Safety program' [23].

2.2.2 Alcohol impairment in the body

Mainly all organs in the human body get affected by alcohol consumption. There are marked effects when performing a complex task, *e.g.* driving, that are related to the central nervous system. Alcohol damages numerous important physiological functions, including vision and reaction time. Alcohol also hinders the ability to see objects at a greater distance, reduces peripheral vision, and weakens feature extraction in low light conditions [19].

2.2.3 Absorption of ethanol

Alcohol gets into the body through the mouth, then, it reaches to stomach, absorption starts slowly through the wall of the stomach and the major part of the ingested alcohol will however be absorbed after gastric draining, in the duodenum and the small intestine. The immersion of alcohol into the body follows a pharmacokinetic profile with great variation with intensity, duration, and onset of the drug. The variation is caused by many factors, including age, gender, liver status, stomach content, the concentration of the devoured liquid, *etc*. The absorbed alcohol moves from the intestinal tract with venous blood through the hepatic vein and its extensions throughout the entire body. Just because of the solubility of alcohol in water, the small size of the molecule itself, and the sheer amount of water in the human body, approximately 50-60% of the total body weight, alcohol makes its way into almost all sections of the body [19].

2.2.4 Measuring alcohol intoxication

Alcohol is found to be present in an intoxicated person's entire body. Examination of blood or breath samples are the two most frequently used measures among the species. Possible pathways for analysis of the ethanol concentration in several human samples are urine, saliva, or even directly in tissue. Mostly, blood alcohol analysis is performed on venous blood, which is not a good estimator of CNS impairment as arterial blood is, especially in the absorptive phase. The techniques for sample examination are invasive by nature and require penetration of the subjects' skin. The risk associated with an arterial puncture is relatively high and therefore venous blood is more regularly used [19].

Breath alcohol analysis is favorable because of its non-invasive sampling nature. The techniques also allow for on-site testing with a readout within seconds. The analyzed breath is, however, never in direct contact with the brain, but instead with various parts of the respiratory system. Blood is the transporter of alcohol to all parts of the body. As past stated studies have shown a correlation between blood and breath alcohol with physiological variations present [19].

It is also more accurate to compare breathing to arterial blood alcohol levels instead of venous blood alcohol and is a good indicator for CNS impairment [24]. Urine alcohol analysis has also confirmed itself as a feasible method for alcohol intoxication testing. Analyses of urine samples are not as disturbing as blood analysis is. On another side, the correlation to blood alcohol levels shows huge variation [25].

The changes that occur also show a reliance on time after consumption of alcohol. Common testing requires a two-test methodology, such as a second test being performed around 20 to 30 minutes after the first one [19]. Saliva is another possibility of analysis. Testing can be done relatively non-intrusively mainly as one go single-use screening test and is accessible based on a colorimetric method, with test results available within minutes [19].

For high accuracy measurements, laboratory methods, and equipment are required. A new technique based on NIR spectroscopy is introduced, which measures the amount of alcohol throughout the body non-invasively. Here light penetrates through the skin to a depth of several millimeters and confirms measurement with the dermal layer of the skin. The reflected light is collected and analyzed using an interferometer [26], [27].

2.2.5 Breath alcohol sensors

Human body intoxication can be determined through numerous technological access. Among them, most systems rely on three main technologies which are fuel cell sensors, semiconductor sensors, and infrared spectrometry. The majority system uses a mouthpiece to evaluate breathing [28-29].

2.2.5.1 Fuel cell sensor: When alcohol interacts with the sensor, it produces a small amount of electricity, that electricity is measured and converted into the breathalyzer reading. The current produces through reaction is relative to the ethanol concentration of the sample and is used for analytical purposes [30].

Fuel cell-based sensors are considered to be accurate and precise. Fuel cells rely on catalytic surfaces [20], prone to sensitivity variation upon use. It is used in a variety of different applications including alcohol interlocks, screening devices as well as evidential equipment.

2.2.5.2 Semi-conductor element: Another type of sensor used for breath alcohol measurement is the semiconductor element. The leverage of this type of sensor is that it is of low cost and high sensitivity [31].

When a semiconductor sensor comes in contact with ethanol, it adsorbs to the sensor surface, the conductivity of the sensor element is changed in quantity to the concentration of the gas. The conductivity alteration can be converted into an understandable output voltage [30].

2.2.5.3 Infrared spectrometry: Infrared Spectrometry breath is an analyzer commonly found at police stations. Spectrometers work by perceiving molecules based on the way they absorb infrared light. The level of ethanol in a sample is regulated and an individual alcohol level can then be determined [32].

3. Methodology

The design of the proposed device (Fig. 1) for dyspnea patients is related to the working of the MQ-3 sensor and Arduino Uno. The basic components of the device are Mouthpiece, Arduino Uno, and MQ-3 sensor. The mouthpiece is constructed through a cylindrical pipe. In the design, Arduino Uno is used as the main processing unit which is interfaced with an MQ-3 sensor for the detection of Alcohol, Ethanol, and the outcome result is displayed on LCD 16x2.

3.1 MQ-3 Sensor

MQ-3 is a semiconductor-type alcohol sensor that is able to detect concentrations of alcohol between 0.05 mg/L to 10 mg/L. It has direct relation between its electrical conduction and alcohol level or concentration. It gives an output signal result in form of graphs on Arduino's serial plotter and digital value on the LCD screen.

MQ-3 comprises of some specified pins that are VCC pin that powers the module (sensor), typically the operating voltage is +5V. GND (ground) pin used to connect the module to system ground. Then for a digital result, the sensor can also utilize from its pin digital out (DO) by changing threshold value with the help of a potentiometer. Analog Out (AO) T pin outputs 0-5V analog voltage based on the intensity of the gas.

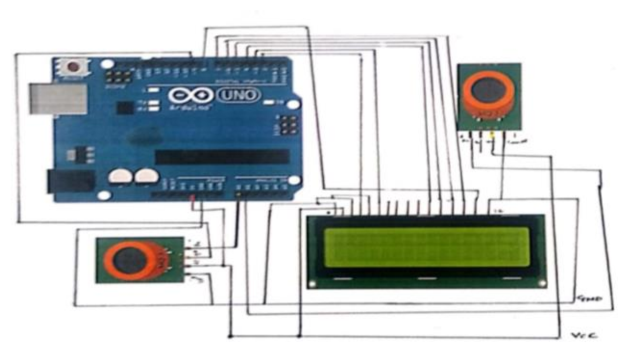

Fig. 1. Schematic diagram of the proposed prototype

For the inceptive part, the signal is initiated by blowing off the patient using a cylindrical pipe into the MQ-3 sensor which is considered as an input signal (Analogue signal) to Arduino. Its analog pin then analyzes the data and generates an output on screen through LCD. Similar conditions are followed for the alcohol detector but instead of a cylindrical pipe patient breath normally towards the second sensor. This is how these two sensors will work.

3.2 Working

The proposed device consists of two sensors, sensor I and sensor II respectively, which receive analog signals as input to create an output that is shown on LCD 16x2 with the help of Arduino Uno. The outcome of the sensor relies on alcohol and breathe level detection. The Block diagram of the suggested device is shown in Fig 2.

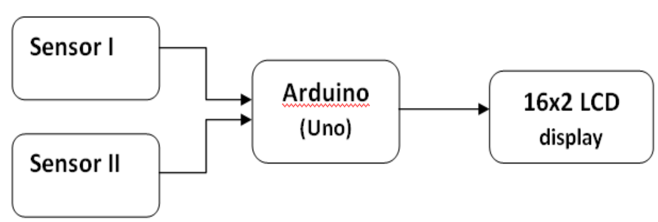

Fig. 2. Block diagram of the proposed prototype.

For the detection of alcohol level in blood and rate of respiration, an MQ-3 sensor is used. MQ-3 sensor is highly sensitive to vapors of organic solvent. This sensor is of low cost, reliable, long-lasting, and easily interfaced with an Arduino Uno microcontroller. For the measurement of alcohol in the breath, the patient blows in the mouthpiece, after which alcohol is absorbed by bead which increases the electrical conduction of sensor, as the relation between conduction and alcohol level or concentration in-breath is proportional, it is estimated electronically and changed into voltage current. The same procedure occurs in the measurements for the rate of respiration. Now as mentioned in Fig 2, both of these sensors are interfaced with a microcontroller. For the display of data digitally, an LCD (TLC1602A) is used which is controlled and operated by the microcontroller of Arduino Uno to display the level of breathing and concentration of alcohol. Fig.3. shows the working flow of the device for analysis of data graphically by plotting a graph between the volume of breath or alcohol level on the y-axis and time on the x-axis by using C program language and graph plotting on software.

4. Results and Discussion

The suggested device is examined for both dyspnea patients and healthy individuals by using the MQ-3 sensor. Here breathing level and alcohol consumption of dyspnea patients is determined to examine the strength and diseases of the lungs. It may also vary from age to age, condition to condition, and body to body capability but the high consumption of Alcohol is not beneficial for human health as it has a lot of disadvantages over the human body for example unconsciousness, slurred speech, liver disorder, and also death in some cases. Table 1 represents the testing results of breathing levels of healthy and dyspnea patients which include asthmatic, hypertensive, smokers, and chain smokers, and Table 2 shows the testing results of the level of alcohol consumption of healthy individuals and dyspnea patients. It is clear from the results that massive alcohol consumption by dyspnea patients is harmful to their breathing level such as distortions in their breathing pattern due to the massive consumption of alcohol.

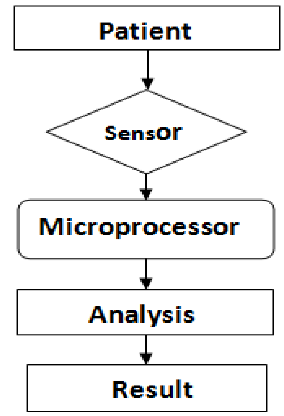

Fig. 3. Working flow of proposed prototype

Table 1

Healthy Participants (L)	Asthmatic Patients (L)	Hypertensive Patients (L)	Smokers (L)	Chain Smokers (L)
-142	-144	-150	-154	-160
-145	-144	-146	-147	-157
-141	-141	-155	-153	-149
-142	-142	-148	-145	-162
-145	-141	-156	-150	-151

Table 2

Participants	Sober (mg/dL)	Drunk (mg/dL)	Moderately Drunk (mg/dL)	Severely Drunk (mg/dL)
Healthy	40	67	179	381
Asthmatic Patient	31	74	213	354
Hypertensive Patient	28	55	143	400
Smoker	37	92	215	539
Chain Smoker	42	59	289	464

4.1 Graphical Representation of Selected Parameters

4.1.1 Variation in breathing level of Healthy individuals with time

Fig. 4 shows the alteration in breath or inhalation level of 4 healthy participants with respect to time, which ranges from -142 to -146 liters. The negative sign is an indication that the reading shows the inhaled air volume to demonstrate the performance of lungs unlike the commercially available spirometer which shows the exhaled air volume.

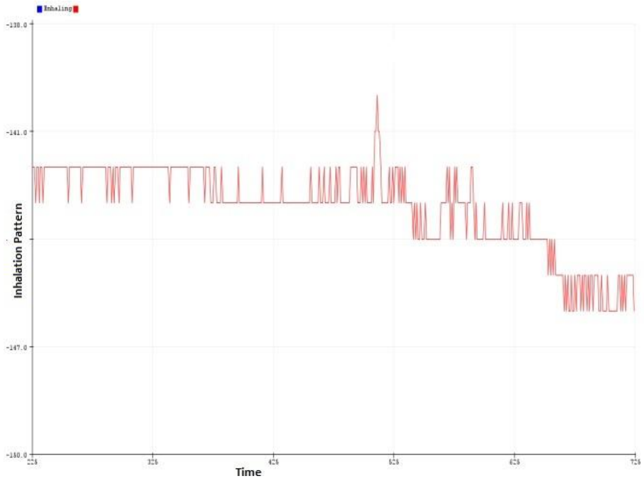

Fig. 4a. Subject 1

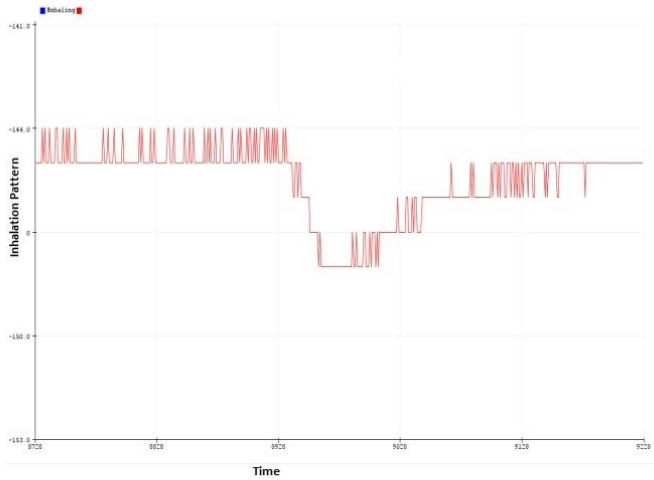

Fig. 4b. Subject 2

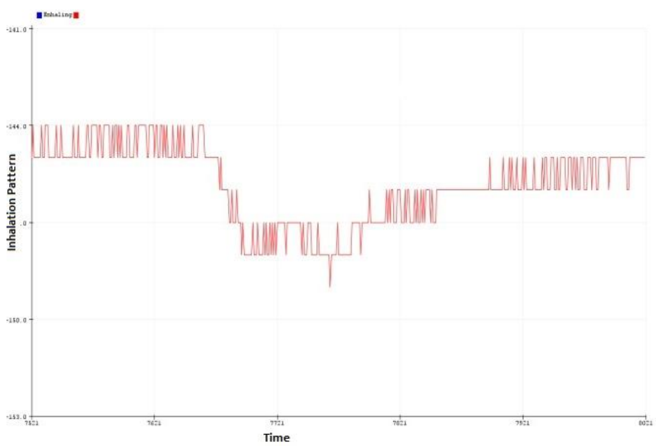

Fig. 4c. Subject 3

4.1.2 Variation in breathing level of Hypertensive patients with time

Fig. 5 shows the variation in breath or inhalation level of hypertensive patients with respect to time, which ranges from -144 liters to -157 liters. By comparing the range of values of breathing pattern of healthy participants Fig. 4. with Hypertensive patints Fig. 5 it is evident that the inhalation capacity of healthy participants is more than the hypertensive individuals.

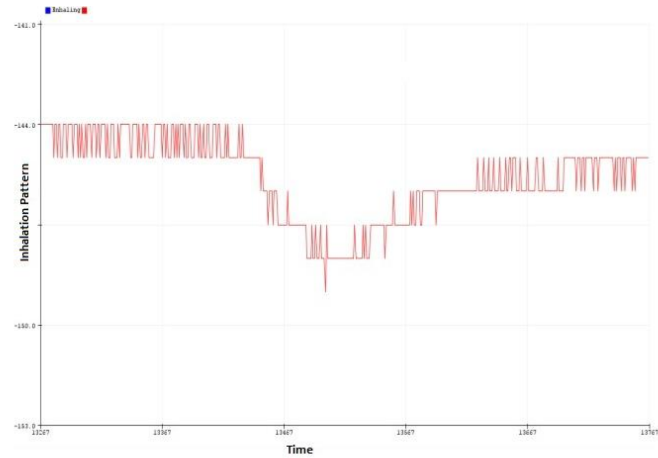

Fig. 4d. Subject 4

Fig. 4. Variation in breath or inhalation level of a normal person with respect to time, which ranges from -142 liters to -146 liters

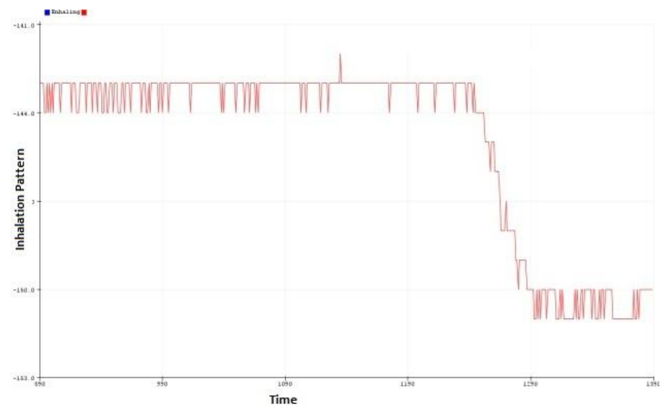

Fig. 5a. Subject 1

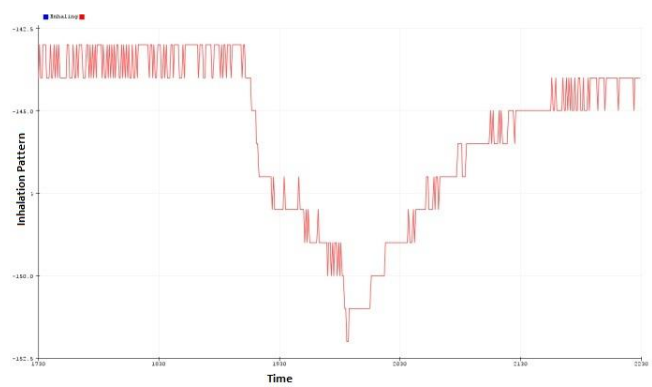

Fig. 5b. Subject 2

4.1.3 Variation in breathing level of Asthmatic patients with time

Fig. 6 shows the variation in breath or inhalation level of asthamatic patients with respect to time, which ranges from -140 liters to -156 liters. The co-relation of Fig. 6. with Fig. 4. (healthy participants) expose that the asthmatic patients can not inhale much because of the hindrance in the respiration due to asthma.

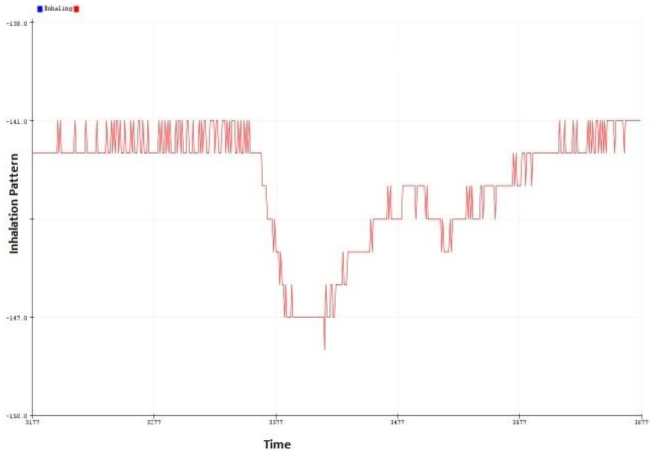

Fig. 5c. Subject 3

Fig. 5. Variation in breath or inhalation level of hypertensive patients with respect to time, which ranges from -144 liters to -157 liters

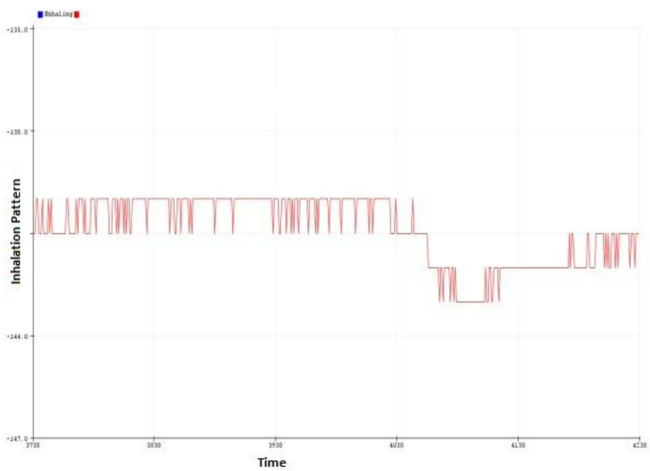

Fig. 6a. Subject 1

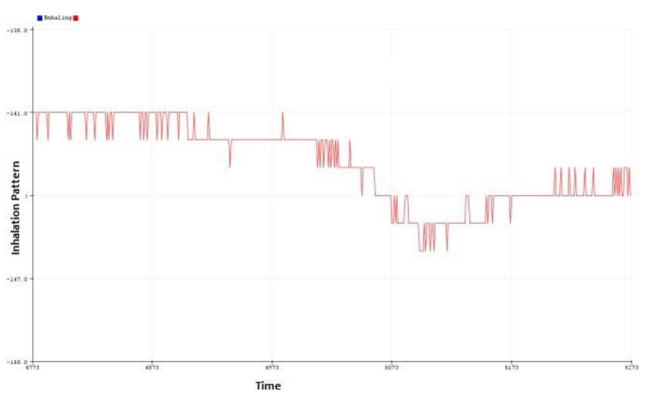

Fig. 6b. Subject 2

4.1.4 Variation in breathing level of Smokers with time

Fig. 7 shows the variation in breath or inhalation level of smokerswith respect to time, which ranges from -144 liters to -156 liters. It shows that the smoking directly has an impact on the lung performance thats why an obvious change is observed from the output of healthy participants breathing pattern Fig. 4.

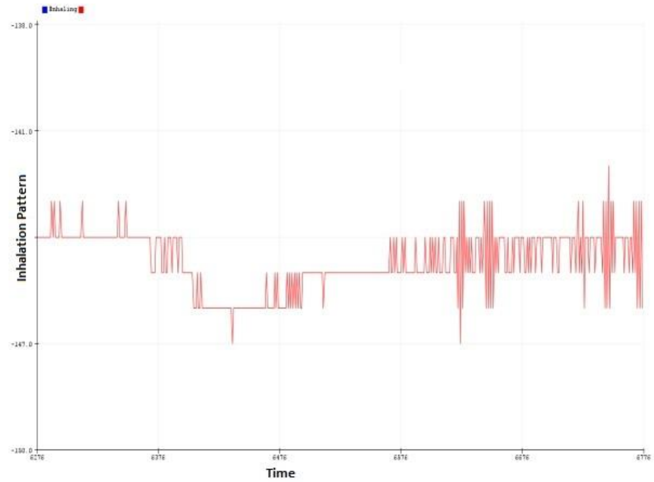

Fig. 6c. Subject 3

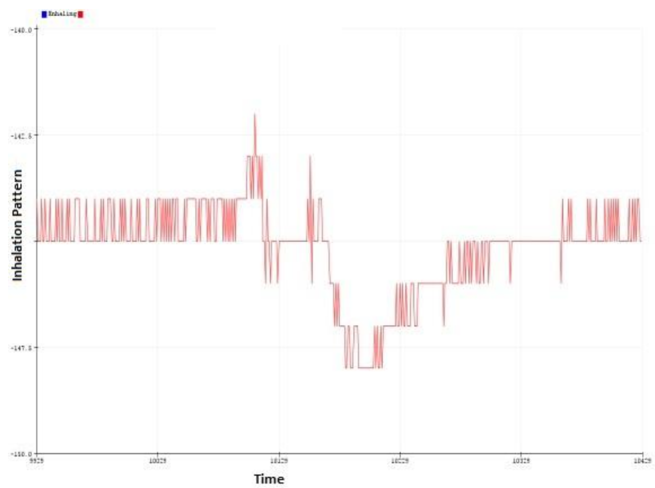

Fig. 6d. Subject 4

Fig. 6. Variation in breath or inhalation level of asthamatic patients with respect to time, which ranges from -140 liters to -156 liters

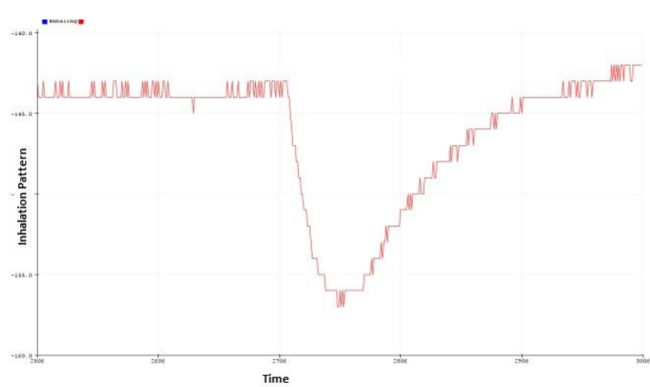

Fig. 7a. Subject 1

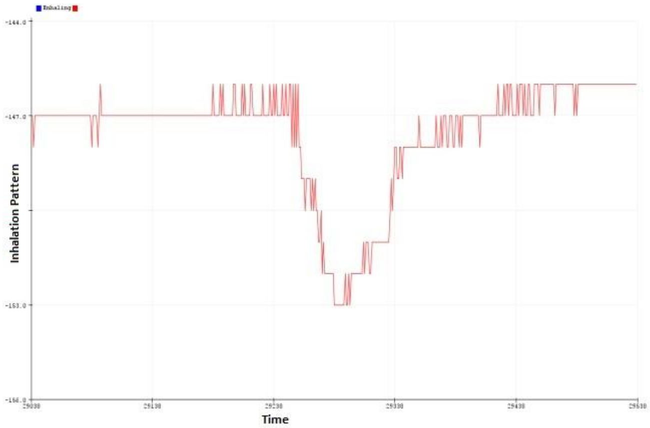

Fig. 7b. Subject 2

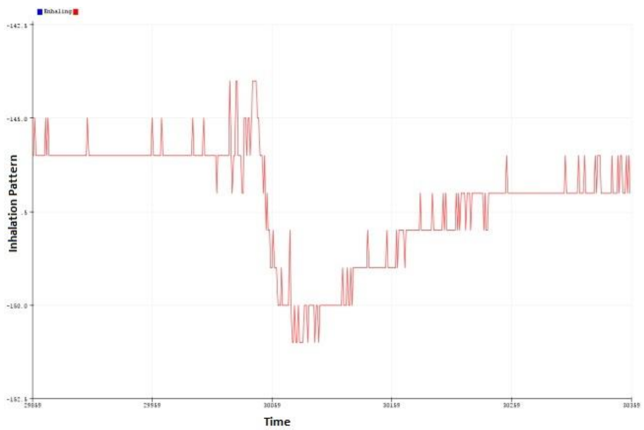

Fig. 7c. Subject 3

Fig. 7 shows the variation in breath or inhalation level of smokerswith respect to time, which ranges from -144 liters to -156 liters

4.1.5 Variation in breathing level of Chain Smokers with time

Fig. 8 shows the variation in-breath or inhalation level of chain smoker to time, which ranges from -140 liters to -162 liters is an indication that the increasedsmoking rate further lower down the inhalation capacity Fig. 7. It is due to this reason the habitual smokers can inhaled to a minimum of -162 liter Fig. 8. while smokers can inhaled to a minimum of -156 liter.

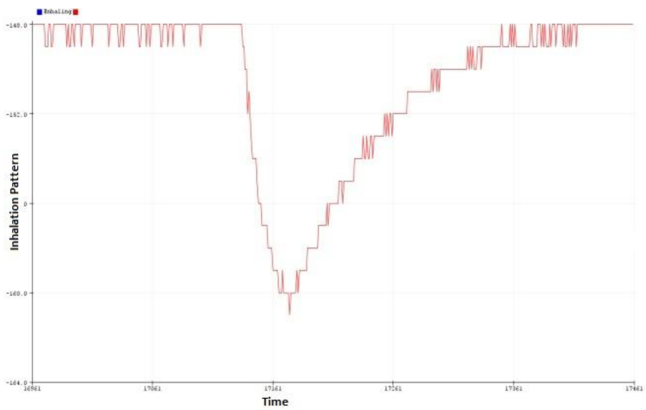

Fig. 8a. Subject 1

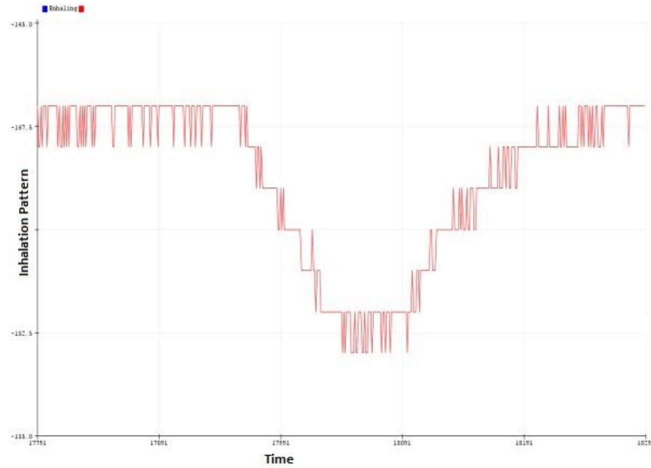

Fig. 8b. Subject 2

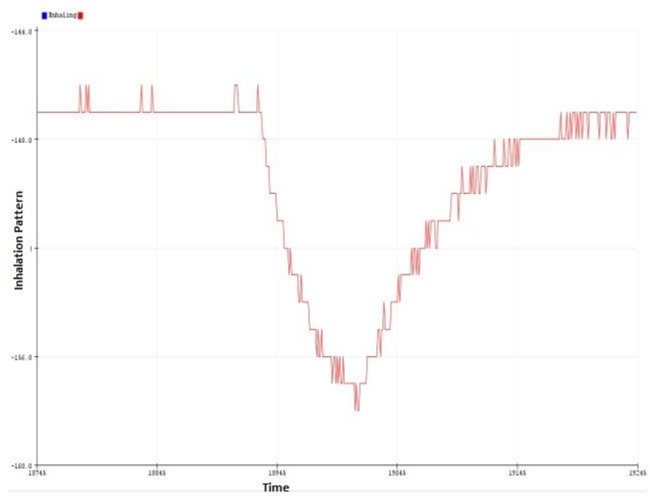

Fig. 8c. Subject 3

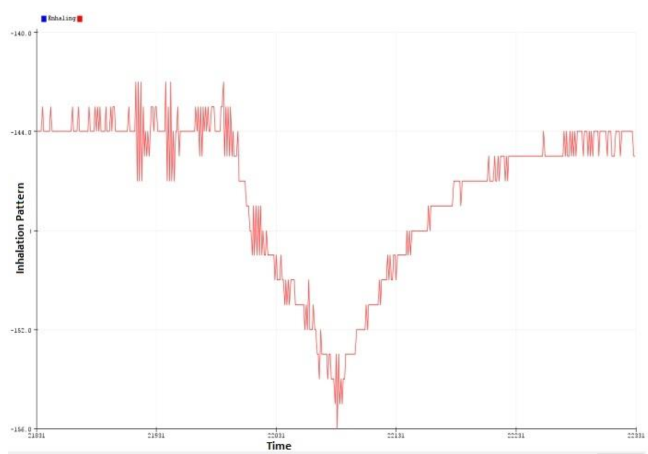

Fig. 8d. Subject 4

Fig. 8. Variation in-breath or inhalation level of chain smoker to time, which ranges from -140 liters to -162 liters

The Fig. 9 shows the variation in inhalation patterns of different conditions including asthmatic participants, hypertensive individuals, smokers, and non-smokers with normal individuals. It is evident that chain smokers have adverse breathing patterns than smokers and hypertensive patients. Moreover, it is also evident from the bar chart that the inhalation pattern of normal and asthmatic patients have a closer value but from figure 4 (normal individuals) & figure 6 (asthmatic patients) has a difference in the timings of a downward dip in the graph indicating that the asthmatic patients cannot hold their breath for a longer duration of time for inhalation, that is why the dip in asthmatic patients occur priorly than normal individuals.

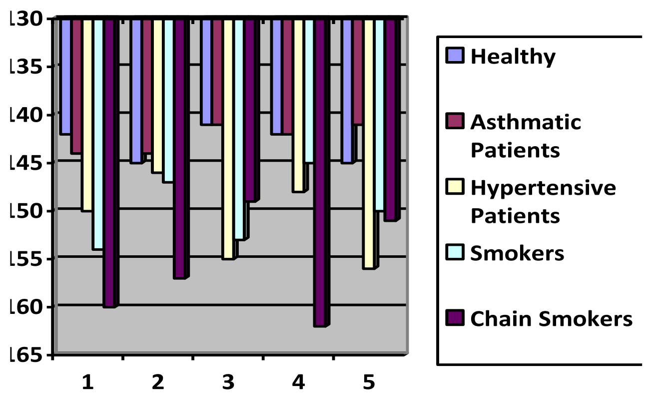

Fig. 9. Comparison bar chart for inhalation

5. Conclusion

In this paper development of a device for intoxicated dyspnea patients has been introduced. As dyspnea patients are found to be sensitive with exposure to the environment and medication, they continuously needed to be monitored when they become prone to alcohol addiction. Several patients are tested with certain parameters through this device and it is found that intoxication varies from patient to patient, addiction capacity, and breath to breath. But continuous intoxication leads to the death of an individual since dyspnea patients are already sensitive to breathiness. Therefore, this portable device could be at home in case of emergency.

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