A Comparative Study of Asthmatic and Normal Subjects for Feasible Device Development to Predict Asthma Attack

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ISLAMABAD

AUGUST 2021

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A thesis submitted in partial fulfillment of the requirements for the degree of

Masters of Science

Biomedical Engineering

Thesis Supervisor:

Dr. Umar Ansari

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Declaration

I certify that this research work titled "*A Comparative Study of Asthmatic and Normal Subjects for Feasible Device Development to Predict Asthma Attack*" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which He setup in my mind to improve it. Indeed, I could have done nothing without His priceless help and guidance.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout at every step of my life.

I would also like to express special thanks to my supervisor Dr.Umar Ansari for his help throughout my thesis. His continuous support and guidance has allowed me to fulfill the requirement of my studies. His continuous support and effort has been fruitful so that I have completed my work effortlessly and with ease. I am thankful for his encouragement, guidance and support. Each time I got stuck in something, he came up with the solution. Without his help I wouldn't have been able to complete my thesis. I appreciate his patience and guidance throughout the whole thesis.

I would also like to thank my GEC members, Dr. Omer Gilani, Dr. Asim Waris and Dr. Saima Zafar for being on my thesis guidance and evaluation committee. I am also grateful to the members for their support, cooperation, and critically evaluating my thesis

Finally, I would like to express my deep gratitude to my sister Engineer Ayesha Sarwar who has rendered valuable assistance to my study. I am also thankful to my brothers Engineer Numan Bin Sarwar, Engineer Usama Bin Sarwar and Dr. Huraira Bin Sarwar for being there and cooperation.

All my appreciation to my fellows Hassan Nawazish, Fatima Amin, Maria Qibtia , Anisa Tahir, Bakhtawar Sahar and Maria Rashid and all lab members for their support and help whenever needed.

Dedicated to my exceptional parents and adored siblings whose tremendous support and cooperation led me to this wonderful accomplishment, and, of course, myself ;)

Abstract

In this study we have proposed a method to make wearable device for Asthma attack prediction by using four basic parameters associated with asthma disease. Asthma is a lung disease that interferes with breathing. The main symptoms are chest tightness, breathlessness, cough, wheezing and high mucus production. If we can make a device that should not only be wearable but also be simple and easy to use then it will be great addition in medical services for patients. In this study we used simple sensor system to obtain four basic parameters that includes EBT, Heart rate, Respiration rate and Oxygen concentration in the blood. On the basis of these four parameters, we can make a device to detect exacerbations in asthma conditions. The system was consisted of a sensor placed inside the oxygen mask that was further connected to capacitor and Arduino. Power of 5V was given through Laptop or PC. Pulse oximeter was used to calculate heart rate and O_2 concentration in blood. 40 subjects were taken from which 20 were normal healthy subjects and 20 were asthma patients. For data collection and display Arduino software was used. For data analysis Mat Lab software was used. The results obtained showed the clear difference between the four parameters values for normal and healthy subjects. Using these four parameters we can make a wearable device for asthma patients to detect asthma attack.

Key Words: *Exhaled breath temperature (EBT), Respiration Rate (RR), Heart Rate (HR), Wearable device, Pulse Oximeter,* O_2 *Concentration.*

Table of Contents

Contents

List of Figures

List of Tables

Chapter 1: Introduction

Asthma is a chronic disease of airways in the lungs. These air passages allow air to come in and out of the lungs. When a person develops an asthma disease the air ways become swollen and the muscles around the airways becomes tightened and the person feels chest tightness. Asthma is generally considered due to allergens like pollens or sometimes exposure to air pollutants can trigger the asthma attack but asthma due to allergens occur in half of the people who have asthma and the remaining half have non allergic inflammation of bronchial tubes[1].The main symptoms of the disease are wheezing, chest tightness, cough ,high mucus production and breathlessness[2]. Asthma affects nearly 339 million people around the world. Although it has low fatality rate but it affects the quality of life very much in various ways.

World Health Organization estimates almost 417918 deaths around the world due to asthma disease and disability adjusted life years to asthma were 24.8 million in 2016. In Pakistan the numbers of reported asthma have much variation that range from 31.5 to 4.3% in various regions. Increased number of patients in hospitals is due to high poverty rate, poor management of asthma and high pollution rate. Due to high urbanization rate, changes in life style the prevalence of asthma in Pakistan has increased in previous few years and this number is expected to increase in the coming year[3].

Although in the past few years much work is being done on asthma management and still work is going on wearable devices for asthma control and its early detection. But still no device is available commercially and on reasonable prices for early detection of asthma attack which will be a great success in the ongoing efforts to manage this disease. Those devices have either not gained the clear results because of low efficiency and accuracy or they have got them on very controlled conditions which are not possible in normal life of patients. Those devices are also very difficult in use or they are not user friendly.

In this study the development of early predictor of asthma will not only be simple, accurate and cost effective but will also be easy to use which will be a great help for asthma patients. This device will help to reduce burden on hospital emergencies. Because when asthma attacks on asthma patient they suffer a lot like severe shortness of breath, so they are shifted to hospital emergencies if condition becomes worse and load on hospital emergencies increase so this device will help to reduce this burden. It will also reduce the mortality rate due to this disease. It will help the people to take early precautionary measures to deal with worsening of asthma disease or its attack.

1.1 Background

For the very first time in history the Chinese good book and ancient Greek described the symptoms of shortness of breath and respiratory discomfort. Until then asthma had not its name. Then in Greece the Hippocrates mentions it about 2000 years later. He for the very first time described the connection between the asthma and the environmental irritants and workplace atmosphere like exposure to chemicals and metalwork. Aretaeus a physician in Greece first time described the definition of asthma that is much similar to modern definition and the triggers of this disease.

Pliny for the first time described the link between the breathing difficulties and exposure to pollens and he also suggested the medicine for quick relief named epinephrine. Henry Hyde Salter in the nineteenth century claimed that he has prepared the drawings of inside airways of lungs on what happens when asthma attacked on patient.

Asthma is a long-term disease in the airways of a person's lungs that is thought to be caused by genetics or due to environmental allergens like pollens, cold air, air pollutants or some kind of medications like aspirin etc. although exact causes of the disease are not known still and they usually vary from person to person. It is an inflammation disease of air passages that cause air flow obstruction or hyper responsiveness of bronchial tubes. Its symptoms usually include chest tightness, wheeze sound in breathing and breathlessness and these symptoms usually worsen at night time or when a person does an exercise. These symptoms occur on regular basis few times in a day or in a week. About 334 million people in the world have been affected by asthma and by year 2025 this number will reach to 100 million. About 26 million people in the America have been affected. Worldwide death rate due to asthma is nearly 180,000 per year. This is a common disease in children and its chronic disease of airways.

Normally whenever we get some infection our immune system immediately response to that by making some antibody and inflammation is caused as a result of this response by our immune system. When someone breaths in air and inhale some irritants like pollens then immune system give response and strongly react and inflammation is caused as a result in the airways and more mucus is produced. The air passages then become narrow and muscles in surrounding of airways also becomes tight. The person faces difficulty in breathing, while some people do not affect by these allergens. Other factors that can cause asthma disease are your workplace atmosphere, smoke, exposure to chemicals, your family history or race can trigger the symptoms and develop asthma disease. There is no cure for asthma but your doctor asks you to avoid triggers and irritants so that to avoid worsening of disease. If you diagnose with asthma disease then your physician makes a planner of treatment to avoid exacerbation or possible asthma attack. Treatment also depends on your individual conditions, your age and your body's response to the medicine used.

In future there is a possibility that doctors and researchers might try to find out and to change the genes that are responsible of changes in the tissues of lungs. They will try to identify and changes the ways these genes do communications with cells of immune system that caused the inflammation such as T-cells.

1.2 Problem Statement

An automated wearable system is required for the monitoring of asthma patients' conditions. The aim of this study is to determine the changes in the EBT of patients, to find Breaths per minute or respiration rate, heart rate and to determine the concentration of O_2 in the blood for the early prediction of exacerbation in asthma symptoms or possible asthma attack.

1.3 Objectives of the study

- To conduct study on asthmatic and normal subjects to find clinically significant basic parameters for asthma attack detection.
- To find out the breath per minute or respiration rate, exhaled breath temperature EBT, heart rate and concentration O_2 in the blood for accurate detection of changes in asthma conditions.
- To compare the results of measured parameters in Asthma patients with non-asthmatics.
- To make the device relatively accurate, simple, easy to use by person himself and low price.

- To compare the results and displays with the results of already done studies available in the literature.

1.4 Significance of study

The main idea is to suggest a method for feasible device design to construct a wearable simple device for asthma patients for continuous monitoring of their physical conditions. This will be very valuable for them as:

- The wearable biosensors are small, easy to handle and accurate.
- The device will help asthma patients in selfcare and asthma management.
- It will reduce burden on hospital emergencies.
- It will help people with asthma to avoid worsening of their conditions and to take early precautionary measures.

1.5 Areas of Application

- Health care and research
- Hospitals
- Indoor usage by asthma patients for selfcare and medication
- Rehabilitation center

1.6 Thesis Overview

In this thesis chapter 1 consists of the introduction and background of the work done. The chapter 2 includes all the relevant work done so far by previous researchers or literature review and theory. The chapter 3 consists of the methodology adopted to design the asthma detection device and the experimental protocol and workflow. The chapter 4 includes the results obtained through experimentation and after data collection and its processing all results are displayed. The chapter 5 consists of discussion and the conclusion and the future work and limitations have been discussed in chapter 6 of the thesis.

Chapter 2: Literature Review/ Previous Work

2.1 Previous Work

Fenton et al. (1985) first developed a technique for wheeze detection. He did computer aided analysis of wheezing sounds of children by placement of sensor on trachea and lungs. Sensor recorded the continuous data of wheezing breath sounds and Fast Fourier Transform was done to extract feature like power spectrum. He concluded that trachea is better place to record wheezing sound and asthma attack prediction [4].Christensen et al. (2014) presented the smart phone-based sensor system for monitoring of functions of lungs by recording the breath sounds of trachea. They extracted the flow parameters like PEF and FEV1 from the recorded sounds to monitor the asthma or worsening of asthma conditions [5].

Dieffenderfer et al. (2016) presented the multimodal wearable sensor array system for asthma patients that continuously monitored the patient health and environmental conditions also for asthma management. Their device was consisting of three parts chest patch, wrist band and spirometer. The basic purpose was to monitor the impact of low-level ozone and volatile organic components (VOC) on exacerbating the asthma conditions. Yuasa et al. (2017) proposed a wearable system which he named HARS and the purpose was to acquire respiratory sounds and chest movement to differentiate between respiratory phases and to acquire measuring parameters to differentiate between asthma sounds and normal sounds [6].

Paredi et al. (2002) proposed a system to measure exhaled breath temperature and concentration of exhaled NO (nitric oxide) to differentiate between asthmatic and normal people. They showed that exhaled breath temperature is higher in asthmatic compared to normal person and this higher exhaled temperature is an indicative of inflammation in the airways or bronchial tubes [7]. Honkoop et al. (2017) proposed use of home monitoring and mobile application system to continuously monitor the health of asthma patients and the changes in the asthma conditions like exacerbating or deterioration of conditions of asthma. This study was basically an observational study in which they provided the patients with mobile application health system and home monitoring to record the daily, weekly and monthly data to check the relationship between physiological, environmental and behavioral parameters and the loss of control over asthma or worsening of conditions [8].

Popov et al. (2010) also proposed the handheld device for measuring the temperature of exhaled air and on the basis of results they predicted the swelling in the airway passage of lungs. They collected the thermal energy of EBA in the insulated chamber and temperature sensor in that chamber then measured the EBT [9]. Emrani et al. (2014) proposed a method to detect wheezing in the breath sounds as a marker of asthma disease. They used topological methods to identify the periodicity in the breath signals and wheeze signals. For this purpose, they used embedding system of delay-coordinate as a tool. They used autocorrelation function to find out the proper delay and applied the topological approach for the analysis of breath sounds to find out the wheezing in those sounds [10].

A new portable device was introduced by Siemens which they claimed was easy to use and the person by himself would be able to monitor his asthma conditions before they get worsen. The device measured the NO in the airways to detect inflammation in them. In this way a person would be able to get an early warning of worsening of asthma and to take precautionary

measures for himself [11]. Chu et al. and Nguyen et al. (2019) proposed a method to measure respiration rate and volume of chest by placing strain sensor on the ribcage and also on abdomen. They basically measured the change in strain of both of these parts (ribcage and abdomen) during a person breaths and compared the results with the results of spirometer to monitor the asthma conditions [12].

Schmidt et al. (1998) proposed a system containing RC model to explain the respiratory system. They basically studied the effects of development of lungs and measurements tools or equipment on the impedance of respiratory system specially in infants. They said that respiratory path is similar to electrical resistor and the alveoli tubes are just like electrical capacitor [13]. Uwaoma et al. (2015) presented a Smartphone based embedded system to identify the early signs of attack of asthma while a person doing exercise and this activity triggered that attack. They used embedded microphone in cell phone, gyroscope or accelerometer as motion sensors to measure the intensity of body movement changes and position changes. In this way the long term monitoring of asthma patients conditions could be possible [14].

Star et al. (2007) developed a handheld device for early detection of asthma attack. This device was consisted of Carbon nano tube for the measurement of Nitric Oxide in the EB.

Patients required to blow out in the handheld device and the sensor inside it measured the level of NO in the exhaled air. In this way patient himself and physicians can keep eye on the conditions of the asthma of their patients to take early measures [15]. Rhee et al. and Belyea et al. (2014) presented an automated device for teenagers which he named ADAM for continuously monitoring the symptoms of asthma disease and they also assessed the adaptability of the device by patients. The device collected the audio data of the patients and then extracted the required features from the sound signals to identify the worsening of asthma symptoms [16].

Chatterjee et al. (2019) presented a method to detect wheezing in respiratory sounds to differentiate between asthmatic and normal people. They devised a method using convolution neural network to identify the respiratory phases then to identify the wheezing in that data. In this way they said the long term monitoring of asthma conditions or exacerbation in them is possible [17]. Olson et al. (1958) presented an electrical system that was similar to human ventilatory system [18]. Taplidou et al. (2007) proposed a method containing spectral analysis to detect wheeze or for monitoring of asthma conditions. They did TF analysis of recorded breath sounds for wheeze detection and for continuous monitoring of asthma conditions [19].

Macagnano et al. and Bearzotti et al. (2014) introduced a device that was portable and this was for measurement and monitoring of nitric oxide in exhaled breath air. They named the device NEOSIS. They used the conductive polymer that was doped with electro spun metal oxide nanofibers. They said that their device was low powered and has high sensitivity [20].Kikidis et al. (2016) presents the study on future of inhaler type system for health monitoring devices[21]. Maalauf et al. (2018) proposed a system to detect asthma irritants. He named the device AIM. They made the device using sensors for environmental irritants detection. The purpose was also to inform the patients about the conditions of their surrounding that whether environment is good for them or not. The device was also for sending data of patient to his physician for record and plan. But the device was bulky and difficult to use [22].

In the present study we have suggested a method for feasible device development to predict asthma attack that will not only be simple, cheap but also easy to handle or use. This will be with high performance characterization. It will consist of a simple sensor and pulse oximeter that will measure EBT, respiration rate, heart rate and concentration of O_2 in the blood and on the basis of these four parameters values it will predict exacerbations in the asthma conditions. In this way the accuracy and specificity of the automated asthma attack predictor will be ensured.

2.2 Theory

Our body's normal temperature is considered to be 37℃ or 98.6°F on an average but it can be anywhere between 36.1℃ to 37.2℃. Body's internal organs like heart, brain, lungs etc. have different temperatures. Multiple ,affordable devices are used for measuring temperature of body like thermometer as standard and the reason behind is our all body organs try to maintain a certain temperature because enzymes work at specific temperature and if temperature goes beyond a certain range it means there is some pathological processes or conditions [23].

Thermometry first used only for measuring fever temperature and for infectious diseases but now it is used in broader sense. It is now used as indicator of inflammation processes in body or in controlled hypothermia requirements [24]. Exhaled breath temperature is one of many other characteristics of air that we exhale. Its analysis is done as noninvasive method to look for any respiratory disease or malfunction[25][26].

Normal oxygen level in body is considered to be between range 95 to 100%. But when someone develops asthma disease the oxygen concentration level decrease from normal level. When someone has severe acute asthma the saturation of oxygen in his blood is below 92%. And if this level is below 90% it means person is suffering from severe asthma or going to have asthma attack. All asthmatic patients have low oxygen in body, so they breathe fast again and again to take more oxygen from air and that is why their respiration rate or breaths per minute are also very high as compared to normal subjects. They face severe chest tightness or shortness of breath and breaths per minute are more than 30 or 40 in case of severe asthma. And when a person has moderate asthma the oxygen saturation in his blood is between 92 to 95% and the respiratory rate is above 25 breaths per minute[27].

2.2.1 LM35 Temperature Sensor

LM35 is a sensor for measurement of temperature. Its output is analog voltage that are proportional to measuring temperature. It gives output in degree centigrade temperature and there is no need to calibrate the results. Its sensitivity is 10mV/℃. With increase in temperature the output voltage also increases. Its results or accuracy in more than thermistor and its range is from -55℃ to 150℃. It has very low self-heating so actual results are not affected by sensor's self-heating process.

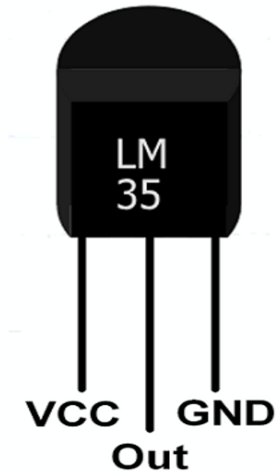

Figure 1.1: LM35 Sensor Pin Configuration

Its interfacing with Arduino is very easy its output pin is connected to any analog pin of Arduino and data of lm35 is transferred to Arduino for further processing. Its accuracy is 0.5℃ at 25℃ and its operating voltage is from 4V to 30V. Its application setup is like as follows[28].

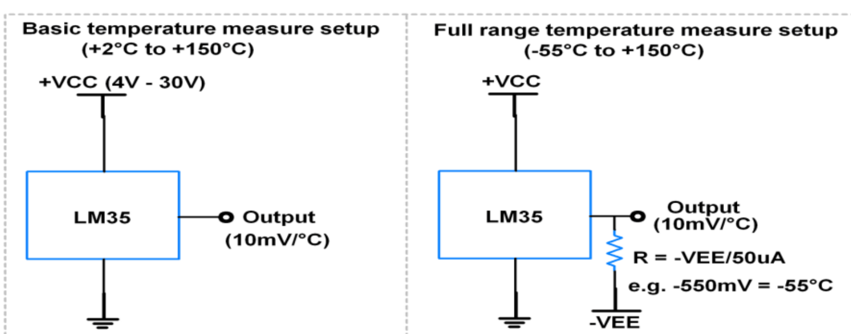

Figure 2.2: Application Setup

2.2.2 22pF Capacitor

It is a ceramic capacitor and it is used for power decoupling. It is useful and good if we place this sensor next to power pins of microcontroller. These ceramic capacitors are used in number of applications in various kinds of circuits. We use them for smoothing, filtering, coupling and decoupling purposes. They work efficiently in bread board also.

Figure 2.3: 22pF capacitor

2.2.3 Pulse Oximeter

Pulse oximeter is a medical device that is used to check oxygen concentration in blood and also to find heart rate noninvasively. It can detect very small changes in heart rate and oxygen concentration in body accurately and with efficiency. It is small clip like device that is normally put on finger but can also be placed on earlobe or toes etc. In asthma disease we use it to check how well heart is working and supplying oxygen to body and it also used to check If someone wants help in breathing etc[29].

Figure 2.4: Pulse oximeter

2.2.4 Oxygen Mask

These masks are used in hospitals or in homes to provide relief if you have respiratory disorders or feeling difficulty in breathing. It is used to provide oxygen to patients with respiratory diseases. In asthma disease when someone faces difficulty in breathing or having asthma attack, then oxygen is supplied to them through oxygen mask.

Figure 2.5: Oxygen Mask

Chapter 3: Research Methodology

3.1 Project Work Flow

The research methodology of my thesis focusses on main objectives as already described in chapter 1, section 1.3. Following is shown the work flow of my thesis

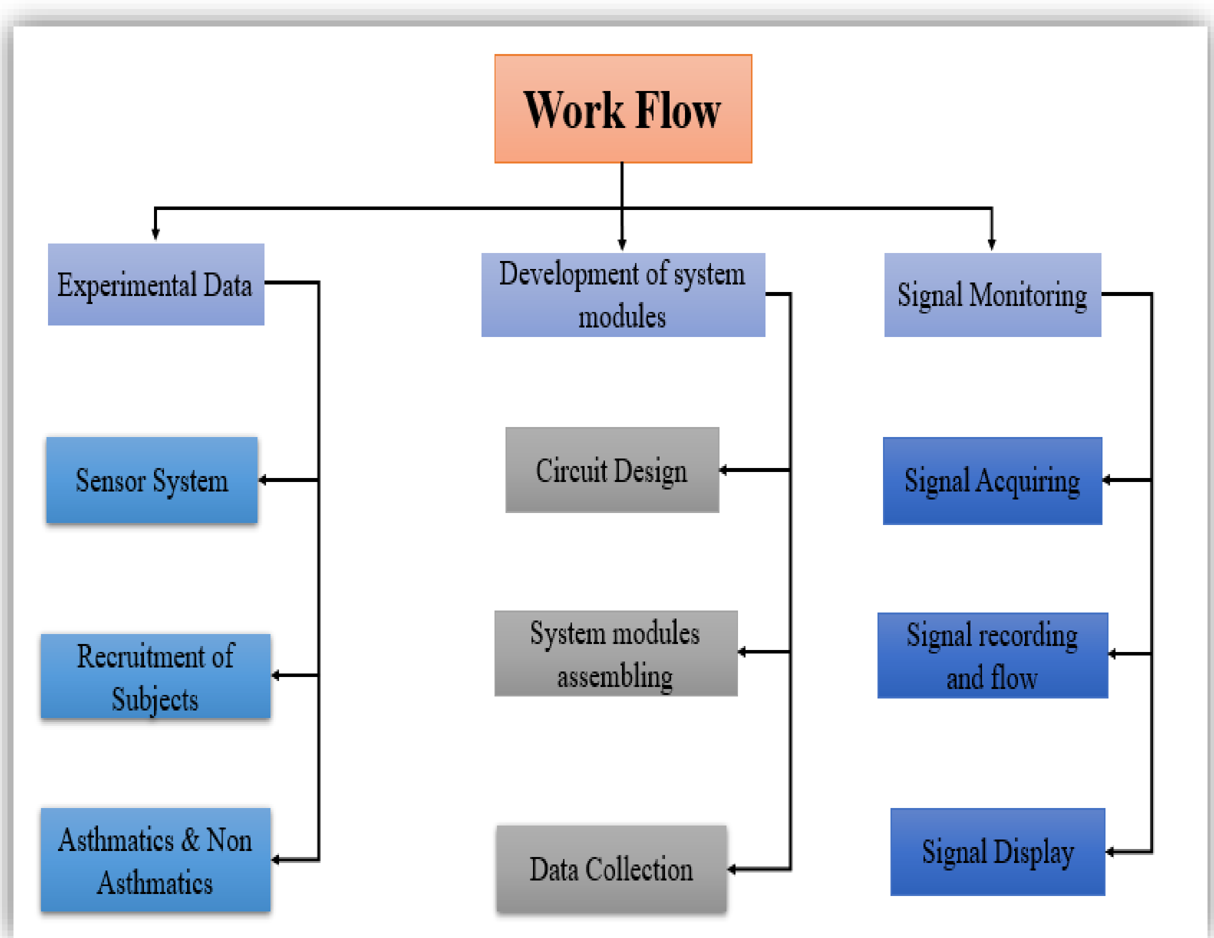

Figure3.1: Overview of research methodology

Here is another simple block representation of work flow of thesis. It consists of three basic parts including device design, Data acquisition and Data Analysis. Device design includes sensor placement inside surgical mask and connections with capacitor and Arduino and pulse oximeter usage while data acquisition was done through Arduino software and data analysis done in Mat lab.

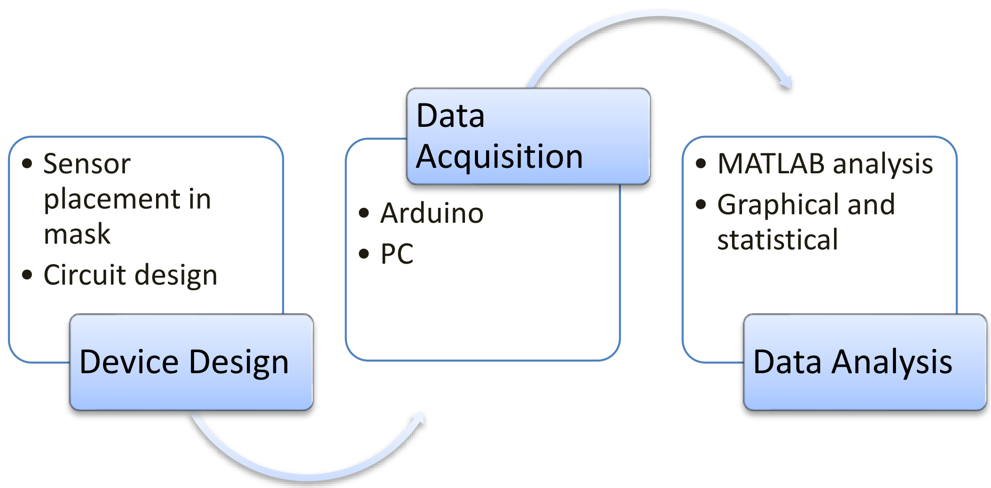

Figure 3.2: Thesis Work flow

3.2 Modules of System Design

The hardware of the system consists of microcontroller Arduino mega 2560 connected with circuit components including temperature sensor LM35 (for the measurement of EBT) and 22pF ceramic capacitor for filtering and smoothing purposes. Pulse Oximeter is used separately but parallel to circuit to record heart rate and to find O_2 concentration in blood. Respiration rate is calculated from the EBT data through an algorithm execution in Mat lab software. Serial monitor is used for data display and values display and power is supplied to circuit of 5 volts through laptop connection with Arduino.

3.2.1 Circuit Design

The circuit is made using software named Fritzing. All electronic components (LM35, Capacitor) are placed by picking from library of fritzing software and connected with Arduino mega as shown in following diagram, power supply of 5Volts is provided to circuit through Arduino connected to laptop.

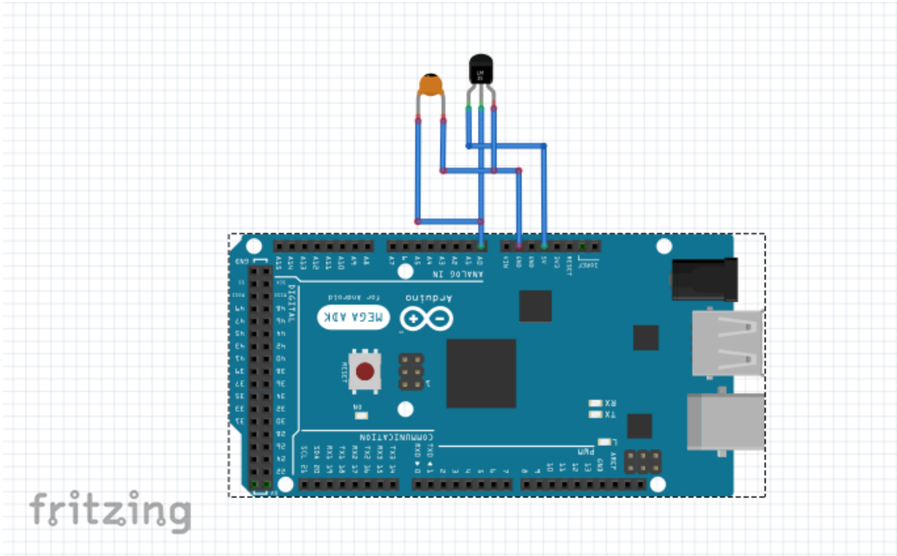

Figure3.3: Circuit design on fritzing

3.2.2 Working Principle

The working principle is simple we know that temperature of exhaled air is higher than that of inhaled air. In asthma patients the exhaled breath temperature is significantly higher than normal subjects. Exhaled breath temperature (EBT) is a potential biomarker for airway inflammation. The temperature sensor measures the temperature of exhaled air.

3.2.3 Device Design

The device design includes LM35 temperature sensor that is places or pasted inside the oxygen mask and this sensor is connected to capacitor and Arduino mega through wires. Arduino is further connected with laptop in which an algorithm is executed to collect the data from the normal and asthma patients for 40 seconds. The specifications of this sensor are as follows:

LM 35 temperature Sensor

- Easy to use
- Very cheap
- Linear response
- Calibrated directly in Celsius

- Low self-heating /Accurate

Oxygen Mask

- Easy to wear
- Cheap

Not allergic for skin

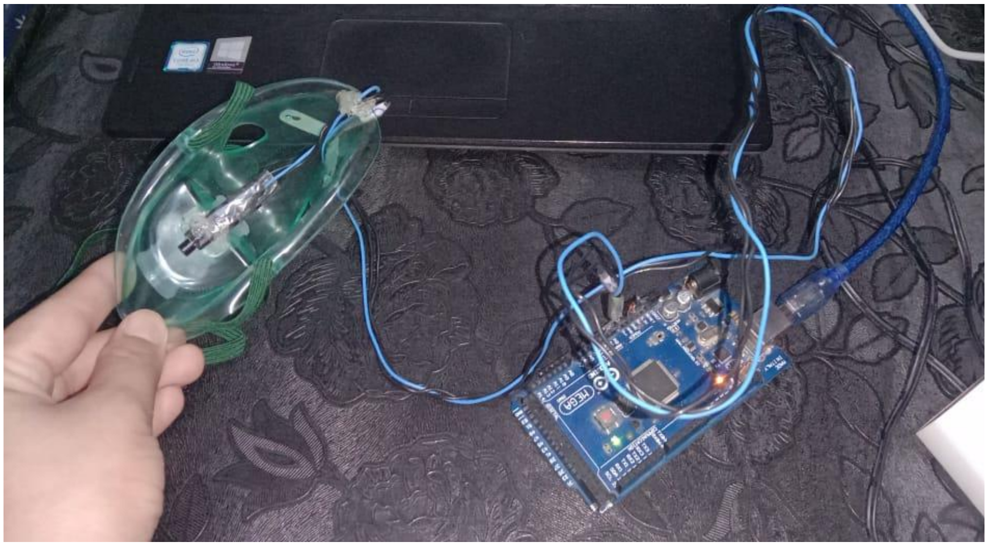

Figure 3.4: Device Design or Prototype design

3.3 Data Acquisition

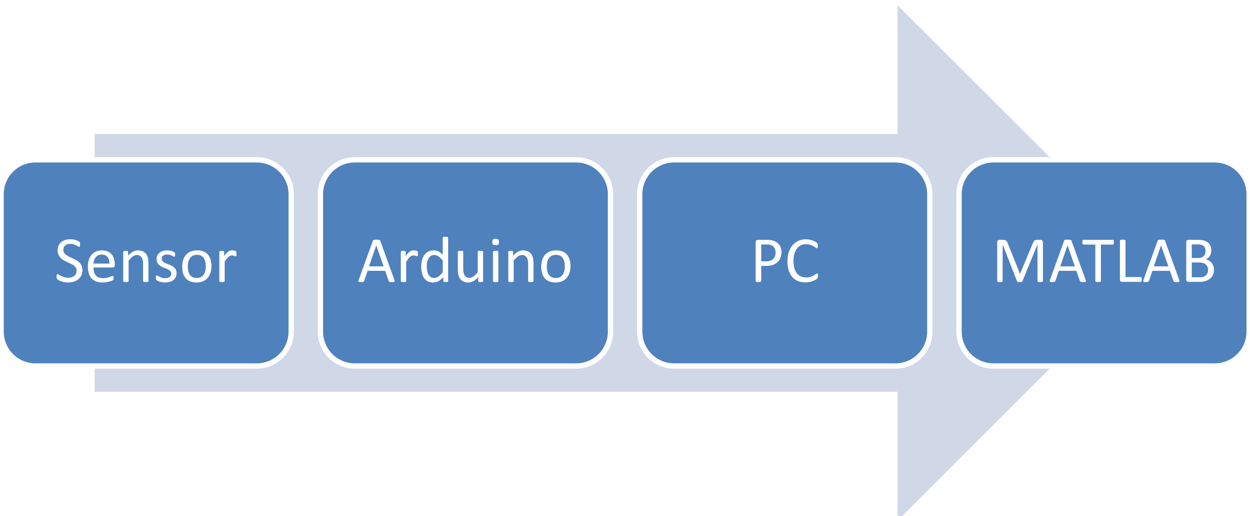

Figure 3.5: Data Acquisition steps

3.3.1 Data Collection

For data collection total 40 subjects were taken, 20 of them were healthy subjects with no disease history while 20 were asthma Patients. All the participants' age was in range 25 to 35 years. All the data was collected in normal resting state. The participants were first asked to fill a consent form and questionnaire and the purpose was to know about their consent for taking part in this study and to know about their family history of any respiratory disease and to know about all the factors that participate in their disease in any way and effects their daily life.

3.3.2 Experimental Data

All the subjects were asked to sit and relax both physically and mentally on comfortable benches. Then they were asked to fill questionnaire and after that they wore oxygen mask having LM35 temperature sensor placed inside it on their faces and they breathed in it for 40 sec as long as the algorithm was running on Arduino software to collect EBT data with respect to time. Also, when I was collecting their data, they were asked to place their index finger inside the pulse oximeter to collect their oxygen concentration values in blood and also heart rate.

3.3.3 Signal Acquisition and Signal Processing

Signals coming as a result of data collection was acquired and displayed in Arduino software in serial monitor. All the data was collected one by one and saved in excel file. This file was imported in Mat lab software and signals were filtered through coding and then displayed on graphs for calculation of Asthma specific parameters, EBT and RR.

Figure 3.6: Data Collection

Chapter 4: Results

The following tables show the values of all the four parameters taken into account for prediction of asthma attack. Here tables show the values of five normal and five asthma patients because we cannot represent data of all the 40 subjects here. From these tables we can see clear differences between all the parameters values for normal and asthma patients.

4.1 Exhaled Breath Temperature

The first table shows the values of EBT of normal and asthma patients and their age. From this table it can be seen that the temperature values for all the normal subjects' lies in the range 27.31±0.79 degree Celsius that satisfies the theoretical criteria of EBT of normal subjects being in the range 27.47±0.24 degree Celsius [30]. The exhaled breath temperature for asthma patients lies in the range 30.01±0.71 degree Celsius and this also satisfies the theoretical criteria of exhaled breath temperature of asthma patients being in the range 30.18±0.14 degree Celsius [30].

Table 4.1: Healthy and Asthma temperature difference table

Age (Years)		**Exhaled Breath temperature (EBT) C^o**	
Healthy	**Asthma**	**Healthy**	**Asthma**
30	35	28.10	30.01
26	29	27.31	31.82
25	30	27.49	30.67
25	26	27.55	30.65
25	33	27.74	30.37

The following graph shows the average temperature of normal subjects shown with the blue color plot and average temperature of asthma patients shown with the color red. There is significant difference between normal and asthma patient's EBT. The level of exhaled temperature was significantly higher in asthmatics than in controls, being 30.01+/-0.71 degrees C vs. 27.31+/-0.79 degrees C.

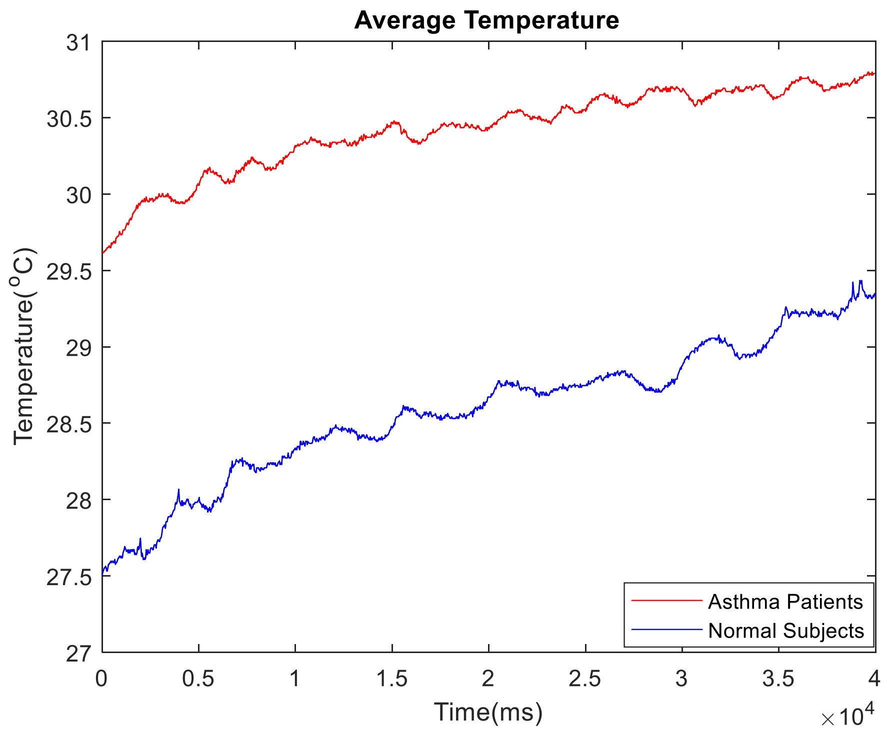

Figure 4.1: Average temperature of normal and asthma subjects

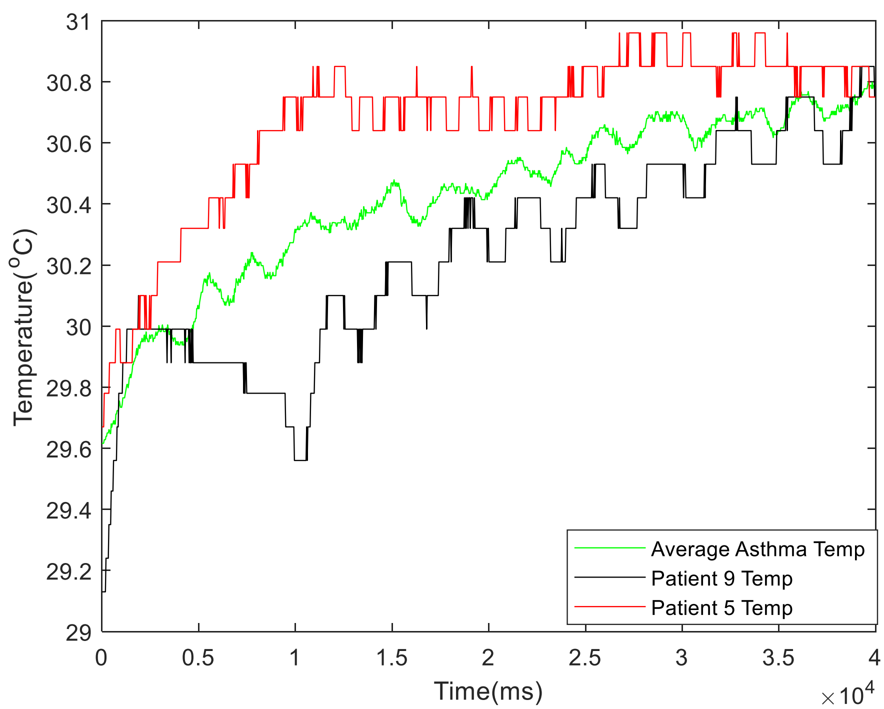

Figure 4.2: Average temp of asthma patients and temp of random 2 patients

The above plots shown with the color green shows the average temp of asthma patients with respect to time, while other two plots are of two patient's temperatures. The deviation of these two plots from the average temp plot can be seen from this graph.

4.2 Oxygen Concentration in blood

The table shows the Oxygen concentration in the blood of normal and asthma patients and it can be seen very clearly from this table that there is a significant difference in O_2 concentration in blood of healthy and asthma patients. Asthma patients have high mucus production in airways and face severe inflammation in their airways due to which they feel chest tightness and breathe again and again to take more oxygen from air to meet the requirement. According to literature the normal O_2 level in blood is between range 95 to 100%. And in asthma patients if the oxygen level is 92% or below it means they have severe asthma according to[31].

Table 4.2: Healthy and Asthma O_2 concentration difference table

Age (Years)		**O_2 Concentration in the blood (%)**	
Healthy	**Asthma**	**Healthy**	**Asthma**
30	35	97	90
26	29	98	90
25	30	97	92
25	26	97	84
25	33	97	80

4.3 Heart Rate

Heart rate is another parameter taken to determine the asthma patient's condition and to differentiate between normal and asthma patients. Normal heart rate in humans is 71 beats per minute. But this can fluctuate due to some factors including age, running, some injury, trauma and emotions etc. According to literature if someone has asthma the heart rate increases from normal values. And if an asthma patient has heart rate more than 100 till 120 beats per minute along with other asthma conditions it means he is going to have asthma attack or exacerbations in asthma conditions. The Following table shows the values of heart rate of normal subjects and asthma patients in resting state and we can see the clear difference between the values.

Table4.3: Healthy and Asthma Heart Rate table

Age (Years)		**Heart Rate (beats per minute)**	
Healthy	**Asthma**	**Healthy**	**Asthma**
30	35	71	80
26	29	70	82
25	30	80	88
25	26	73	105
25	33	75	147

4.4 Respiration Rate (Breaths per minute)

In normal healthy adults at rest the respiration rate or breaths per minute lies in range 12 to 25, and if the breaths per minute are below 12 or above 25 it means there is some abnormality in breathing system of human. The following table shows the values of breaths per minute of normal subjects and asthma patients. The breath rates obtained were all in the range of (25–33) breaths per minute for asthma patients. And this satisfies the theoretical criteria of respiration rate for asthma patients that respiration rate should be above than 25 for asthma patients [33]. The breath rates obtained were all in the range of (12–18) breaths per minute for normal subjects and according to literature the respiration rate for normal subjects should be in range 12 to 25 [33].

Table 4.4: Healthy and Asthma Respiration rate table

Age (Years)		**Respiration Rate (Breaths per minute)**	
Healthy	**Asthma**	**Healthy**	**Asthma**
30	35	14	31
26	29	12	26

25	30	18	33
25	26	16	30
25	33	12	25

The following graph shows the number of peaks in some Asthma Patients temperature graphs. From these peaks the breaths per minute or respiration rate was calculated through formula

Breaths per minute=(No. of peaks/30 sec) *60

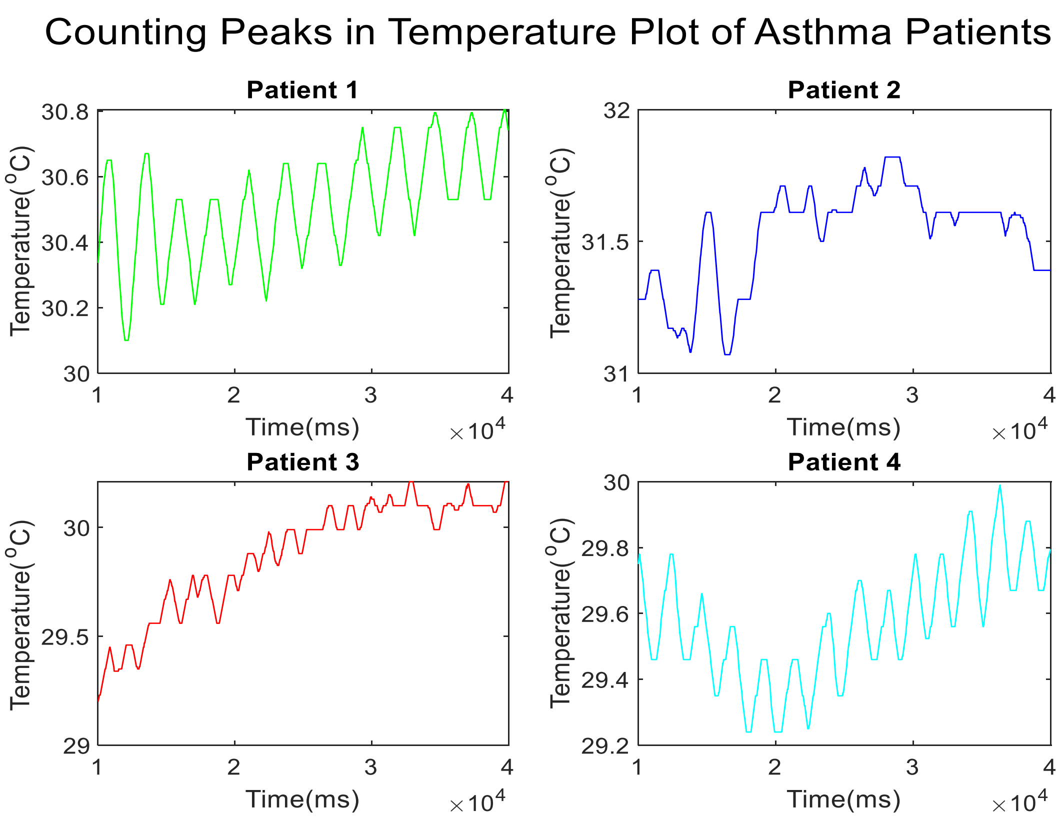

Figure 4.3: Respiration Rate calculation for Asthma patients

The following graph shows the number of peaks in Normal subject's temperature graphs. From these peaks the breaths per minute or respiration rate was calculated through formula

Breaths per minute=(No. of peaks/30 sec)*60

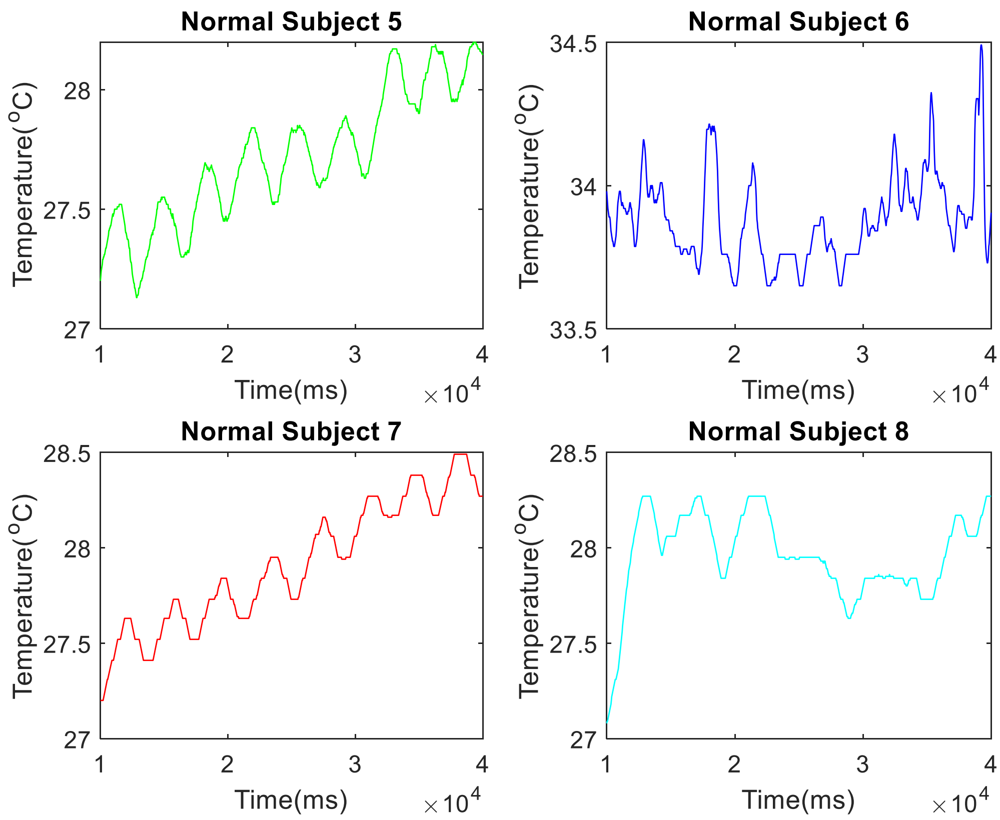

Figure 4.4: Number of peaks in temp graphs of normal subjects for RR calculation

The following graph shows a threshold value for respiration rate to differentiate normal and asthma patients. Here in the following graph the breaths per minute of some random patients have been shown and the horizontal straight line shows the threshold value to differentiate between normal and asthma patients. All the patients have values more than 25 indicating they are asthma patients.

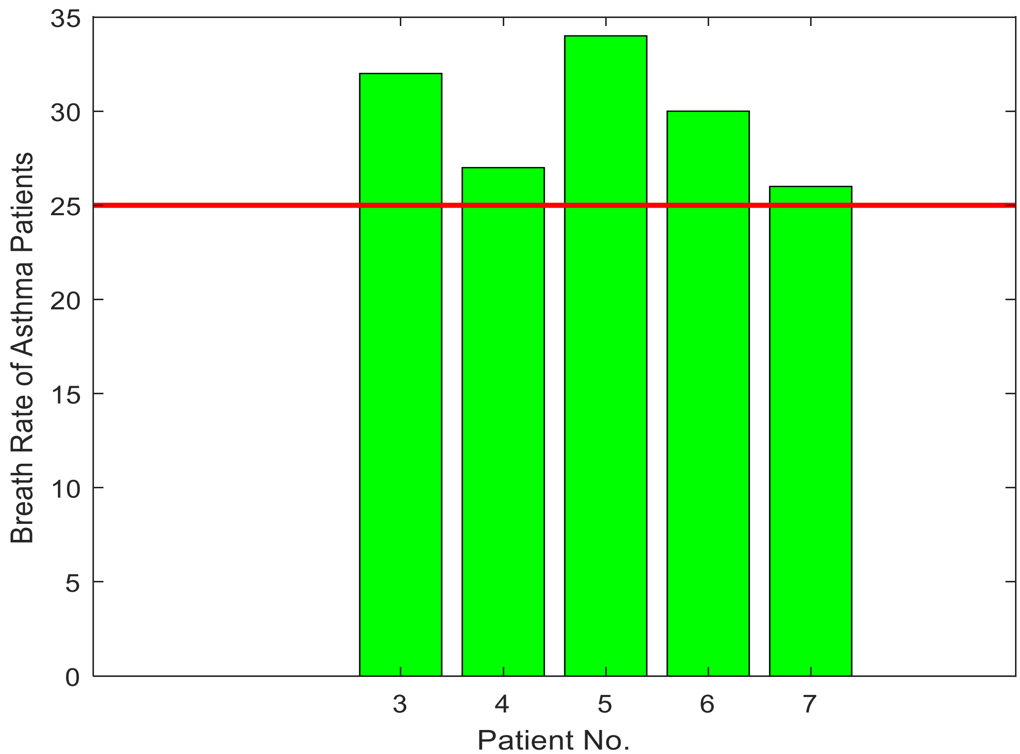

Figure 4.5: Threshold value to differentiate between normal and asthma patients

Chapter 5: Discussion and Conclusions

5.1 Discussion

Asthma is a chronic disease of lungs and respiratory volume decreases in this disease and patient suffers from hypercapnia. The patients have low oxygen level in their blood, high respiration rate, increased heart rate and high EBT. In this study the proposed method is able to find out all these four parameters' values to predict asthma attack. The system is simple and easy to use and able to differentiate between normal and asthma patients clearly. It includes uses of LM35 temperature sensor placed inside oxygen mask and pulse oximeter sensor system. For data acquisition and display Arduino software was used. MAT LAB software was used for processing of data to get clinically significant basic parameters to predict asthma attack.

The comparison of results with already available studies shows that this system is better than those because in previous studies the results were not so clear or the systems were bulky, complex and expensive. Or they have used multiple sensing systems and a layman is reluctant to use them. The current study proposed a method to make a simple wearable device based on the above calculated four parameters. It will not only be simple, easy to use and cheap but it will also work efficiently.

5.2 Conclusion

In the study the proposed method to find out the basic parameter to identify the asthma conditions is good enough that it cannot only be used to differentiate the normal and asthma patients but it can also be used to make a wearable device for asthma patients to predict exacerbations in asthma conditions or to predict asthma attack. It can be seen clearly that this system is better than already done studies because it is not only simple and cheap but also it is easy to use by the person himself at home.

Chapter 6: Future Work and Limitations

6.1 Future work

As discussed in this study, it is quite clear that there is room for more accurate results because this present system still needs lots of improvement not only in calculated parameters but also in system design. We can see clearly that we are still far from the exact parameters that can detect asthma attack accurately and with high efficiency. The increasing trend of research in wearable devices field and on asthma disease to predict asthma attack is establishing a right path to get better and accurate results. There are some issues and areas the improvement in them or solving them will be a great success to achieve a method for feasible device development to predict exacerbations in asthma conditions.

First one is that including more parameters that are strongly associated with asthma disease will increase the efficiency of asthma attack predicting system for example wheeze detection and calculation for high mucus production can be made and added in this system for more accurate and early prediction for asthma attack. Secondly the data collection can be made using controlled conditions to get better values or improvement in the system or for reduced error.

6.2 Limitations

In this study the sample size was 40 young male and female. By increasing this sample size, the data can be increases which in turn will improve the results obtained. Also, this system cannot be used in hospitals because more efficiency is required to use it commercially. One or two more asthma specific parameters should be included to enhance the accuracy of results so that it can be used commercially. Also, we cannot use the system in water.

7 Appendix I

```
float temp_val,c;
int time1,pre_time;
unsigned int temp_time;
void setup() {
analogReference(INTERNAL1V1);
  // put your setup code here, to run once:
Serial.begin(9600);
}

void loop() {
temp_time=millis();
pre_time=temp_time/1000;
  while((time1-pre_time)<40){
temp_val=TempIN(40);
temp_val=float(temp_val*1.075);
    c=float(temp_val/10);
Serial.print(c);
Serial.print(",");
Serial.println(temp_time);

//    Serial.print("...........");
//    Serial.print(temp_time);
//    Serial.println("temp_time");
delay(25);
temp_time=millis();
    time1=temp_time/1000;
  }
while(1);
}

float TempIN(int point) {
  unsigned int val = 0;
  float Rval;
  int temp;
  int j;
  for (j = 0; j < point; j++) {
    temp = analogRead(A0);
val = val + temp;
  }
Rval = float(val / point);
  return Rval;
}
```

8 Appendix II

```
load M.mat
load Timee
P1_asthma = sgolayfilt(P1_temp,1,11)
P2_asthma = sgolayfilt(P2_temp,1,11)
P3_asthma = sgolayfilt(P3_temp,1,11)
P4_asthma = sgolayfilt(P4_temp,1,11)
P5_asthma = sgolayfilt(P5_temp,1,11)
P6_asthma = sgolayfilt(P6_temp,1,11)
P7_asthma = sgolayfilt(P7_temp,1,11)
P8_asthma = sgolayfilt(P8_temp,1,11)
P9_asthma = sgolayfilt(P9_temp,1,11)
P10_asthma= sgolayfilt(P10_temp,1,11)

tt=Timee(334:1329);
p1=P1_asthma(334:1329);
p2=P2_asthma(334:1329);
p3=P3_asthma(334:1329);
p4=P4_asthma(334:1329);
p5=P5_asthma(334:1329);
p6=P6_asthma(334:1329);
p7=P7_asthma(334:1329);
p8=P8_asthma(334:1329);
p9=P9_asthma(334:1329);
p10=P10_asthma(334:1329);

figure(1);
subplot(2,2,1);
plot(tt, p1,'g')
title('Patient 1')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,2);
plot(tt, p2,'b')
title('Patient 2')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,3);
plot(tt, p3,'r')
title('Patient 3')
xlabel('Time(ms)');
```

```
ylabel('Temperature(^oC)')

subplot(2,2,4);
plot(tt, p4,'c')
title('Patient 4')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')


suptitle('Counting Peaks in Temperature Plot of Asthma Patients');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

figure(2);
subplot(2,2,1);
plot(tt, p5,'g')
title('Patient 5')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,2);
plot(tt, p6,'b')
title('Patient 6')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,3);
plot(tt, p7,'r')
title('Patient 7')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,4);
plot(tt, p8,'c')
title('Patient 8')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

figure(3);
subplot(2,1,1);
plot(tt, p9,'g')
title('Patient 9')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,1,2);
```

```
plot(tt, p10,'b')
title('Patient 10')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')
suptitle('Counting Peaks in Temperature Plot of Asthma Patients');
figure(4);
Count = [32 27 34 30 26];
PatientNo = [3 4 5 6 7];
bar(PatientNo,Count,'g')
hold on;
xlimm=[0 9]
ylimm=[25 25]
plot(xlimm,ylimm,'r','linewidth',2)
xlabel('Patient No.');
ylabel('Breath Rate of Asthma Patients');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

load M_N.mat
load Timee
N1_normal = sgolayfilt(N1_temp,1,11)
N2_normal = sgolayfilt(N2_temp,1,11)
N3_normal = sgolayfilt(N3_temp,1,11)
N4_normal = sgolayfilt(N4_temp,1,11)
N5_normal = sgolayfilt(N5_temp,1,11)
N6_normal = sgolayfilt(N6_temp,1,11)
N7_normal = sgolayfilt(N7_temp,1,11)
N8_normal = sgolayfilt(N8_temp,1,11)
N9_normal = sgolayfilt(N9_temp,1,11)
N10_normal = sgolayfilt(N10_temp,1,11)

tt=Timee(334:1329);
n1=N1_normal(334:1329);
n2=N2_normal(334:1329);
n3=N3_normal(334:1329);
n4=N4_normal(334:1329);
n5=N5_normal(334:1329);
n6=N6_normal(334:1329);
n7=N7_normal(334:1329);
n8=N8_normal(334:1329);
n9=N9_normal(334:1329);
n10=N10_normal(334:1329);

figure(5);
subplot(2,2,1);
plot(tt, n1,'g')
```

```
title('Normal Subject 1')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,2);
plot(tt, n2,'b')
title('Normal Subject 2')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,3);
plot(tt, n3,'r')
title('Normal Subject 3')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,4);
plot(tt, n4,'c')
title('Normal Subject 4')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')


suptitle('Counting Peaks in Temperature Plot of Normal Subjects');

figure(6);
subplot(2,2,1);
plot(tt, n5,'g')
title('Normal Subject 5')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,2);
plot(tt, n6,'b')
title('Normal Subject 6')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,3);
plot(tt, n7,'r')
title('Normal Subject 7')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,2,4);
plot(tt, n8,'c')
```

```
title('Normal Subject 8')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

figure(7);
subplot(2,1,1);
plot(tt, n9,'g')
title('Normal Subject 9')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')

subplot(2,1,2);
plot(tt, n10,'b')
title('Normal Subject 10')
xlabel('Time(ms)');
ylabel('Temperature(^oC)')


suptitle('Counting Peaks in Temperature Plot of Normal Subjects');
```

9 Appendix III

```
load M
load M_N
figure(1);
plot(TT,M,'r')
title('Average Temperature');
xlabel('Time(ms)');
ylabel('Temperature(^oC)');

hold on;
plot(TT,M_N,'b')

legend('Asthma Patients','Normal Subjects');

figure(2);
plot(TT,D,'m')
title('Standard Deviation Plot');
xlabel('Time(ms)');
ylabel('Standard Deviation');

hold on;
plot(TT,D_N,'k')

legend('Asthma Patients','Normal Subjects');


figure(3);
plot(TT,M,'g')
hold on;
plot(TT,P9_temp,'k');
hold on;
plot(TT,P5_temp,'r');
xlabel('Time(ms)');
ylabel('Temperature(^oC)');
legend('Average Asthma Temp','Patient 9 Temp','Patient 5 Temp')
```

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