International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 09 | Sept -2020 ISSN: 2582-3930

Wearable device for real-time wheezing and pulse detection for Asthma patients

Chandrashish Roy[1], Ishanee Mazumder[1], Ankita Chakraborty[1], Adrika Saha[1], Abhijit Mukherjee[2]
[1]Department of Biotechnology, Kalinga Institute of Industrial Technology, Bhubaneshwar, India
[2]Department of Mechanical Engineering, Jalpaiguri Government Engineering College, Jalpaiguri, India

---***---

Abstract -Asthma is a chronic inflammatory disorder of the airways that causes intermittent episodes of wheezing,breathlessness, chest snugness, and cough, particularly during night and/or early in the morning or whiledoing any sort of physical activities.In this paper, awearable and wireless monitoring system for real-time wheeze detection and pulse rate detection is proposedfor asthma patients. High pulse rate(more than 100 Beats per minute) and wheezing sound will be captured through pulse rate sensor and sound sensor module respectively and will be securely uploaded to an Android smartphone via built-in Bluetooth low energy (BLE) module. The device will be a compact wireless comfortable patch-like wearable resembling a fidget spinner in shape, made up of silicon rubber.
From the experimental results, the proposed system might be a useful assisting tool for the analysis of wheezing
and pulse rate in clinical diagnosis.

***Key Words*:**Wearable Sensor, Pulse Rate, Wheezing, Bluetooth, Spectrum

1. INTRODUCTION

Chronic respiratory diseases are among the leading causes of mortality and morbidity worldwide, with chronic obstructive pulmonary disease (COPD) and asthma being the most common[1]. Among India's 1.31 billion people, about 6% of children and 2% of adults have asthma[2]. It is also the most common chronic disease in children. It is a condition in which a person's airways become inflamed, narrow and, swell and produces extra mucus, which makes it difficult to breathe[3]. Asthma is a consequence of complex gene-environment interactions, with heterogeneity in clinical presentation and the type and intensity of airway inflammation and re-modeling[3]. Early symptoms of an asthma attack include frequent cough, particularly at night, shortness of breath, feeling drained or frail when exercising, wheezing or coughing after exercise, easily annoyed or cranky, diminishes or changes in lung function as estimated on a peak flow meter, signs of a cold or allergies (sneezing, runny nose, cough, nasal congestion, sore throat, and headache) and inconvenience dozing.

Patients can keep their asthma under control at home if they can recognize asthma attacks early. To address this unmet need, a real-time healthcare device is required which can help monitor a patient's conditions. A sensor-based healthcare device is the integration of several communication technologies, people, sensors, and devices and connected applications to capture, track, store, and monitor patient information.[4]

In this paper, we present a smart sensors-based healthcare solution for asthma patients, where a high pulse rate(more than 100 beats per minute) and wheezing sound will be captured through smart sensors and will be securely uploaded to an Android smartphone via built-in Bluetooth low energy (BLE) module. The device will be a compact wireless comfortable patch-like wearable resembling a fidget spinner in shape. It can be worn by the host on the host's chest (As in Figure 1). The device will be discreet and will be worn under clothes respecting the host's privacy. The device will be able to monitor the wheezes and pulse of the host for around hours approximately. The proposed work has been authenticated by experimented results.

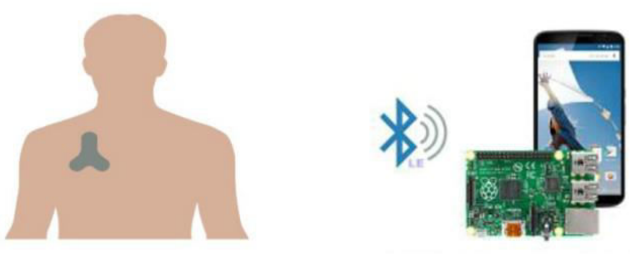

Fig -1: Architecture of the wearable sensor system.

2. MATERIALS AND METHODS

Experimented protocol

The system consists of two major components:

1. a wearable sensor device on the chest
2. a BLE-capable gateway device (smartphone)

The wearable device uses a pulse rate sensor for pulse detection and a sound sensor for detection of wheezing. It also uses a BLE-capable wireless micro-controller and flash memory for transferring the data to the smartphone application.

The wearable sensing device will be designed to resemble a fidget spinner. When powered on, the device will monitor the patients' pulse rate and wheezing sound. Data is then averaged every minute and will be stored to flash memory.
An android based application is developed on a smartphone. A BLE connection is established between the application and the wearable sensing device. Real-time measurement data will also be continuously transferred and displayed on the smartphone.

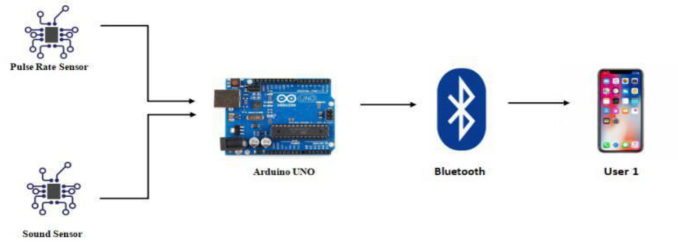

Fig -2: Overview of the Model.

Pulse Rate Sensor

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 09 | Sept -2020 ISSN: 2582-3930

Pulse rate measuring sensor is a well-designed plug heart-rate sensor for Arduino. It carries an open-source monitoring app to display heart rate via diagrams in real-time. It has specifications of 3.3 V- 5 V operating voltage, 4 mA current, and an indicator LED.[5]

Working of Pulse Rate Sensor in our proposed idea :

In the proposed system we have connected the pulse sensor into 3.3 volts or 5 volts Arduino pin (Arduino UNO). The sensor contains a LED light and an ambient light sensor. When the sensor is clipped on the chest, the LED shines light into the capillary tissue, and the sensor reads the light that bounces back. Since our main aim is for detecting early asthma condition in a patient or a normal person. So, with the help of a Bluetooth module, we have connected the Arduino UNO to the application of smartphone to obtain the required data which will give a warning notification to the user when the pulse rate exceeds 100 beats per minute.

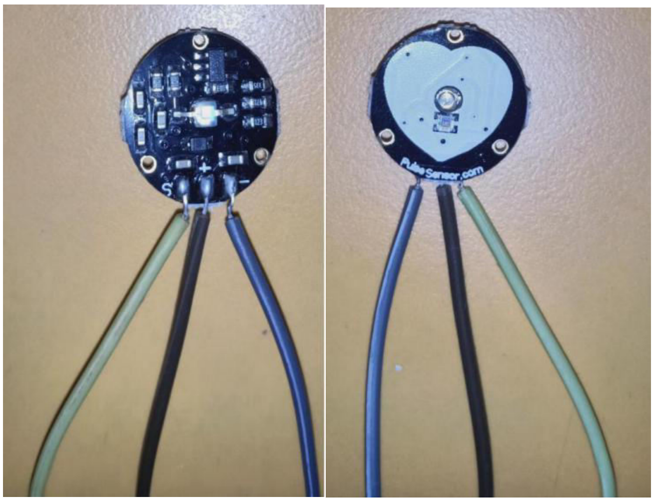

Fig -3: Pulse Rate Measuring Sensor.

Sound Sensor Module

The sound sensor used in our proposed product is a LM393 Sound Sensor Module for Arduino. The sound sensor module is devised from PCB material. It utilizes a LM393 main chip and has an electric condenser microphone. The two outputs in this sensor are analog output and real-time microphone voltage signal output. A potentiometer is used to regulate the sensitivity of the sound sensor.

The working voltage of the LM393 sound sensor is 3.3-5V.

Method of use of the sound sensor in our proposed model :

Before extracting the features of breathing sounds, the received breathing sound has to be first processed by a band-pass filter (frequency band: 150 Hz–1000 Hz) to reserve meaningful components of breathing sounds and also remove heart sound, muscle interference sound and blood sound [6].The raw wheezing sound will be split into 250-ms sound segments with 200-ms overlapping, and then the power spectrum of these segments will be calculated by using Fast Fourier Transform with a Hanning window. After obtaining the power spectrum of wheezing sounds, the features of these sounds in the frequency domain can be calculated. Here, the ratios of the spectral integration (SI) features SI 0 Hz–250 Hz (from 0 Hz to 250 Hz), SI 250 Hz–500 Hz (from 250 Hz to 500 Hz), and SI 500 Hz–1000 Hz (from 500 Hz to 1000 Hz) to SI 0 Hz–1000 Hz (from 0 Hz to 1000 Hz) are defined as the normalized spectral integration (NSI) features NSI 0 Hz–250 Hz, NSI 250 Hz–500 Hz, and NSI 500 Hz–1000 Hz, respectively.

In this algorithm, Fisher linear discriminant analysis (LDA) will be used to separate wheezing and normal breathing sounds. After the experiment, the normalized spectral integration NSI 0 Hz–250 Hz, NSI 250 Hz–500 Hz, and NSI 500 Hz–1000 Hz were used as the frequency-domain features to detect the wheezing sounds, and they have better recognizing patterns than other features. The feature of breathing sound fits the given criteria[7]:

(i)Type A = –230.54489 + 402.72499 × NSI 0 Hz−250 Hz + 500.32269 × NSI 250 Hz−500 Hz + 677.28994 × NSI 500 Hz−1000 Hz.

(ii) Type B = –266.87228 + 418.88239 × NSI 0 Hz−250 Hz + 554.36286 × NSI 250 Hz−500 Hz + 699.35894 × NSI 500 Hz−1000 Hz.

If Type A < Type B, then this segment will be recognized as an abnormal breathing sound. (ii) If the duration of abnormal breathing sound > 250 ms [8]. Then, it will be recognized as a wheezing sound.

The frequency resembling as the highest peak in the power spectrum of the wheezing sound is the peak frequency. The frequency which is at the center of the power spectrum of the wheezing sounds is the median frequency. The bandwidth is defined as the frequency range between the frequencies which are 25% and 75% of the total integration area in the power spectrum of the wheezing sounds. The peak and median frequency are most commonly used to describe the feature of breathing sounds. Hence we have used peak and median frequencies to best describe our algorithm. The alterations in the peak frequency and the bandwidth will be the cause of the changes in the spectral integration of wheezing sound directly. Besides, the peak frequency usually shifts within a breathing cycle. Therefore, we have tried to incorporate the spectral integration of breathing sounds in our algorithm to detect wheezing sounds.

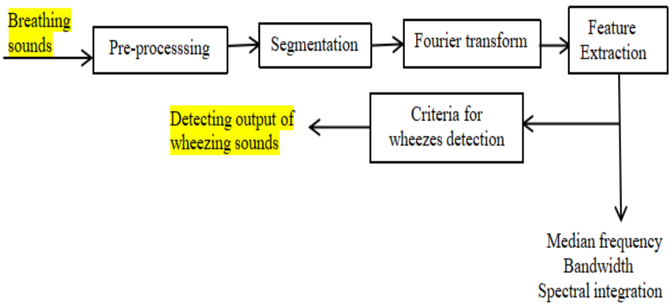

Fig -4: Flowchart of breathing sound analysis algorithm.

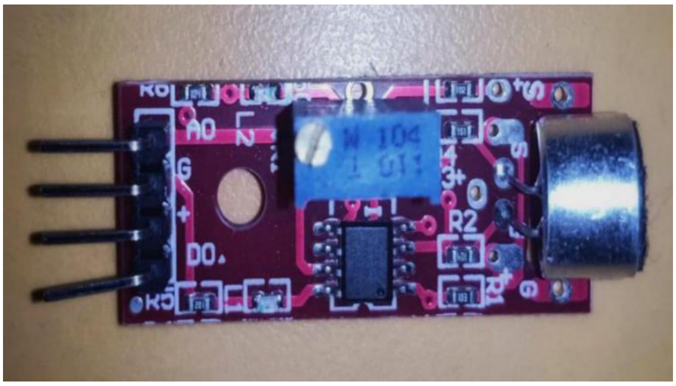

Fig -5: Sound Sensor Module

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 09 | Sept -2020 ISSN: 2582-3930

Bluetooth Low-Energy (BLE) Microprocessor Module

It is a low-power wireless data transmission technology widely adopted by smartphones and IoT devices[9]. With the help of a custom smartphone application, end-users will be able to view sensor data in real-time and contribute to research by sharing their data[9]. A low-power BLE-enabled, small-footprint micro-controller was selected for our wearable sensor platform.

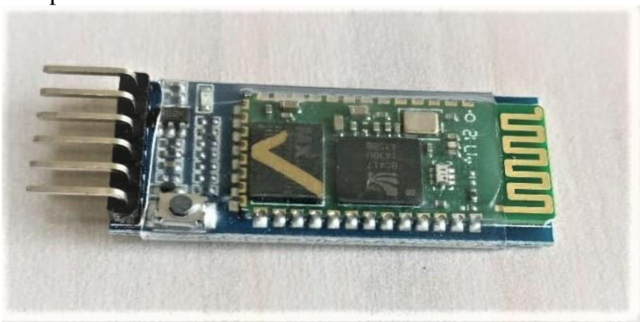

Fig -6: Bluetooth Low Energy Microprocessor Module

Arduino UNO

The Arduino UNO is the most popular one among other Arduino development boards[10]. It is based on the microcontroller ATmega328 [11]. The factor which makes Arduino UNO differ from others is that it does not use FTDI USB-to-serial driver chip[11]. Instead, it uses a micro-controller Atmega16U2 (Atmega8U2 up to version R2) which is programmed as a USB-to-serial converter[11].

We can power Arduino UNO in 2 different ways, either by a USB connection or by using an external power supply. AC-DC adaptor and battery will come under the category of external power supply.

The role of Arduino UNO in our proposed product :
In the proposed system we have connected the pulse sensor, the bluetooth module, and the sound sensor to the Arduino UNO. Since we are focusing on the early detection of asthma in a patient or a normal person, so, we have to code the sensors in such a way that it helps in giving a warning to the user. This process of coding the sensors is done with the help of Arduino UNO R3. Programs can be loaded on to it from the easy-to-use Arduino computer program[11]. The Arduino has an extensive support community, which makes it a very easy way to get started working with embedded electronics[11].

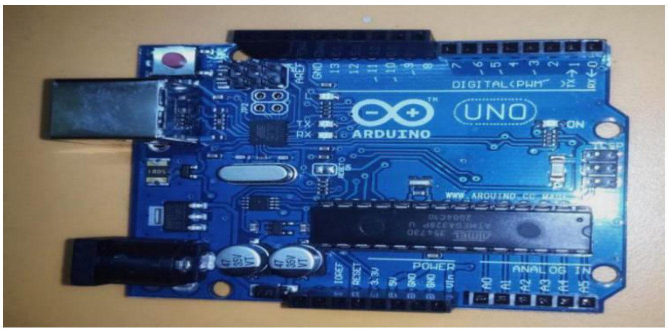

Fig -7: Arduino UNO

3. RESULTS

We performed validity testing, comparing results of wheezes and pulse among some selected individuals, both healthy and suffering from Asthma. We equated the data from both the set of individuals and measured the asthma condition, including Forced Expiratory Volume in 1 second, Asthma Control Test, daily symptom diaries, visual analog scale, and asthma-related quality of life. The pulse beat was measured using a medical-grade pulse oximeter.

Features of Wheezing and Healthy Breathing Sounds:
For our proposed experiment, the spectral features of wheezing and healthy breathing sounds were investigated. Figure 8 shows the two varieties of the spectrum of wheezing and healthy breathing sounds. The distribution of the wheezing sound was mainly from 250 Hz to 500 Hz and is relatively narrower than the normal breathing distribution. Also, the intensity of the wheezing distribution is higher than that of the normal breathing distribution. Wheezing sounds can be easily distinguished from the normal breathing sounds from the difference of different patterns.

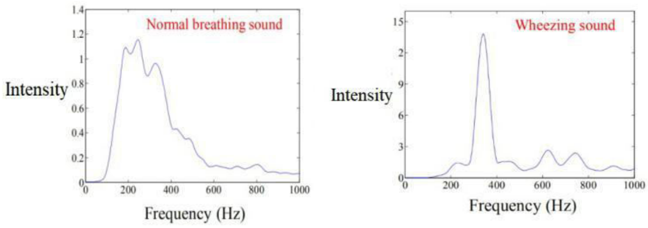

Fig -8: Shows the two varieties of spectrum of wheezing and healthy breathing sounds.

Precision rate of wheezing detection :

We provided 50 data of around 10 seconds long to train our algorithm and we tested it on 30 individuals. The proposed algorithm is then evaluated to determine the percentage of accuracy in the detection of wheezing sound. The accuracy and loss of wheezing detection are depicted in the graphs below(Figure9). The different possibilities during the evaluation can be: the depiction of real wheezing sound correctly, depiction of non-wheezing sound as wheezing sound, depiction of non-wheezing sound correctly, and the depiction of real wheezing sound as non-wheezing sound. The false detections may have occurred due to the interference of environmental noise, such as the speech sound of the staff or families.

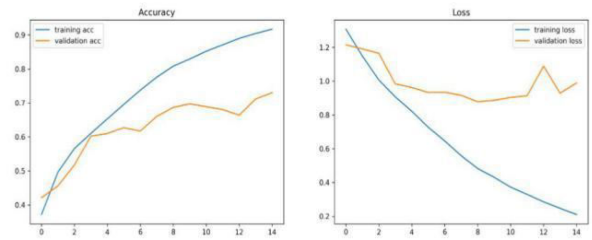

Fig -9: The accuracy and loss of wheezing detection.

Data from pulse rate sensor:

Figure 10 (a) shows the data of an asthma patient in normal condition. Figure 10 (b) shows the data of the patient before having an attack.

The data which is collected is then averaged every minute and stored in the flash memory and then transferred to the smartphone application via the BLE microprocessor module. The average pulse rate of a person just before an asthma attack rises to more than 100 bpm.

In cardiac asthma, the reduced pumping efficiency of the left side of the heart leads to a build-up of fluid in the lungs (pulmonary edema) [12]. This fluid build-up lead to increase in the pulse rate. [12]

After comparing our experimented data with a medical-grade pulse oximeter, we evaluated our accuracy as 97.2%.

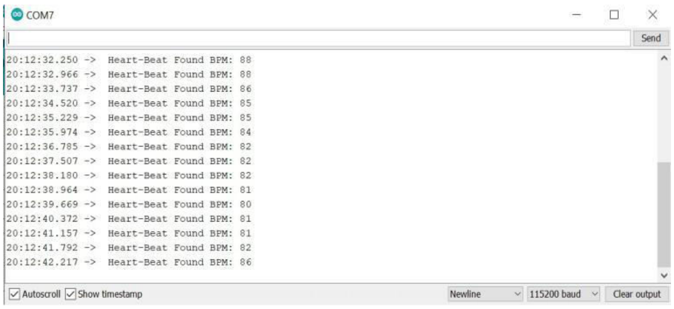

Fig -10(a): Data of an asthma patient in normal condition.

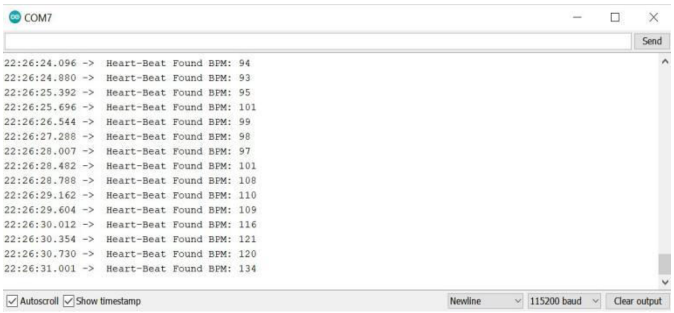

Fig -10(b): Data of the patient before having an attack.

Proposed plan on detection of asthma attack using smartphone :

After collecting the data from the pulse sensor and sound sensor, it is transmitted to the proposed application of the smartphone.This proposed android-based smartphone application will have four major functions:

1.discover and list nearby BLE-enabled devices
2.display and plot incoming BLE data in real-time when connected to a wearable device
3.collect historical data from the wearable device and
4. show notification and provide an alarm when the conditions of the asthma attack are fulfilled.

The conditions for detecting early asthma attacks are pulse rate exceeding 100 bpm and wheezing sound detection.

The fulfillment of the conditions will give an alarm to the host's smartphone.

4. DISCUSSION

For the normal breathing sounds, the value of normalized spectral integration (NSI)0 Hz–250 Hz was similar to NSI 250 Hz–500 Hz and larger than NSI 500 Hz–1000 Hz. Therefore, the spectral feature of healthy breathing sounds was exhibited as the characteristic of the low-pass filter due to the chest surface [13-15]. After running the experiment for 24 hours for 4 days, we have found that the value of NSI 250 Hz-500 Hz for wheezing sounds was much larger than that of NSI 0 Hz–250 Hz and NSI 500 Hz–1000 Hz. This proved that the spectral distribution of wheezing sound is mainly crowded at a frequency range from 250 Hz to 500 Hz during bronchoconstriction. This fits the experimental data. By using the method of time-frequency analysis and the technique of supervised learning classifier, it provides fairly accurate detection wheezing sounds, but it requires more computational multifaceted nature. To solve this above problem, we acquired shorter breathing sounds that were used to analyze the time-frequency feature of breathing sounds in this study.

Pulse beats are identified by estimating the adjustment in volume utilizing an optical sensor and a green LED. Adopting an optical filter optimized for beat wave discovery in the sensor and limits the impacts of surrounding light, for example, red and infrared beams. This empowers the best beat signs to be gained.

5. CONCLUSION

We proposed a wearable and wireless wheezing and pulse detection system for early monitoring of an asthma attack. The device comprises of a pulse rate sensor and a sound sensor which helps in detecting wheezing sound and pulse rate. The breathing sounds are analyzed using our proposed algorithm which only requires short term breathing sound data to train it for the detection of the wheezing sound. The pulse rate is averaged and stored in the flash memory. A dedicated android application is proposed which serves as a gateway to wirelessly retrieve sensor data and gives an alarm when the conditions show the probability of an asthma attack.

Therefore, the proposed system contains the potential for being developed as a useful monitoring system for early detection of an asthma attack. We envision this wearable device will be used by the asthma patients so that they can be conscious beforehand.

ACKNOWLEDGEMENT

The authors would like to thank the faculties of KIIT (Kalinga Institute of Industrial Technology) School Of Biotechnology, Bhubaneshwar, and Jalpaiguri Government Engineering College, Jalpaiguri for their support and cooperation. They would also to thank anonymous reviewers for their suggestions that greatly helped in improving the quality of the paper.

REFERENCES

1. Parvaiz A Koul and Raja Dhar. Economic burden of asthma in India. 2018 Jul-Aug; 35(4): 281–283.
2. The Global Asthma Report 2018. Available at: http://www.globalasthmareport.org/, accessed August 2020.
3. Prof Alberto Papi, Prof Cristopher Brightling, Prof Soren E Pedersen, Prof Helen K Reddel. Asthma. February 2018, p. 783-800. https://doi.org/10.1016/S0140-6736(17)33311-1.
4. Syed Tauhid Ullah Shah, Faizan Badshah, Faheem Dad, Nouman Amin, Mian Ahmad Jan. Cloud-Assisted IoT-Based Smart Respiratory Monitoring System for Asthma Patients. 2019, p. 77-86.
5. Pulse Rate Sensor. Available at: https://wiki.eprolabs.com/index.php?title=Pulse_rate_Sensor, accessed August 2020.

6. Morillo, D.S.; Moreno, S.A.; Granero, M.A.F.; Jimenez, A.L. Computerized analysis of respiratory sounds during COPD exacerbations. Comput. Biol. Med. 2013, 43, 914–921.

7.Shih-Hong Li, Bor-Shing Lin, Chen-Han Tsai, Cheng-Ta Yang and Bor-Shyh Lin. Design of Wearable Breathing Sound Monitoring System for Real-Time Wheeze Detection. 2017 Jan; 17(1): 171.

8. Sovijarvi, A.R.A.; Vanderschoot, J.; Malmerg, L.P.; Righini, G.; Stoneman, S.A.T. Defifinition of terms for applications of respiratory sounds. Eur. Respir. Rev. 2000, 10, 597–610.

9. Baichen Li, Quan Dong, R. Scott Downen, Nam Tran, J. Hunter Jackson, Dinesh Pillai, Mona Zaghloul, Zhenyu Li. A Wearable IoT Aldehyde Sensor for Pediatric Asthma Research and Management. 2019 May 15;287:584-594. doi: 10.1016/j.snb.2019.02.077.

10. Arduino UNO. Available at: https://electrosome.com/arduino-uno/

11. Arduino UNO R3. Available at: https://www.pololu.com/product/2191

12. Bronchial asthma and cardiac asthma. Available at: https://www.mydr.com.au/asthma/bronchial-asthma-and-cardiac-asthma

13. Felton, T.R.; Pasterkamp, H.; Tal, A.; Chernick, V. Automated spectral characterization of wheezing in asthmatic children. IEEE Trans. Biomed. Eng. 1985, 32, 50–55.

14. Sovijarvi, A.R.A.; Malmberg, L.P.; Charbonneau, G.; Vanderschoot, J.; Dalmasso, F.; Sacco, C.; Rossi, M.; Earis, J.E. Characteristics of breath sounds and adventitious respiratory sounds. Eur. Respir. Rev. 2000, 10, 591–596.

15. Wodicka, G.R.; Stevens, K.N.; Golub, H.L.; Cravalho, E.G.; Shannon, D.C. A model of acoustic transmission in the respiratory system. IEEE Trans. Biomed. Eng. 1989, 36, 925–934.