



SMART BIOFEEDBACK EXPECTORANT SYSTEM FOR IMPROVING THE LUNG CAPACITIES

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ABSTRACT

The Biofeedback Expectorant is a device which is designed for patients suffering from various lung disorders, associated with the production and secretion of excessive quantities of mucus within the airways and help to loosen the mucous so that it tends to be hacked from the lungs. Meanwhile, the mucous in the lungs becomes thick and difficult to wash out from the air routes. When this mucous remain in the air routes, it blocks airways and becomes hard to relax. The disease is likely to be conceivable if the mucous remains permanently in the air routes. When one breathes out through this device, it bounces the ball inside to it. This action produces signals around 15 Hz and forward the vibration via the air ways. This amalgamation of enhanced intensity and vibration aids the mucous in moving into the air ways where it remains. Some patients can't blow for a longer duration, therefore a feedback system is designed in such a way that the pressure is measured using a pressure sensor. If the value goes below the certain threshold limit the beep sound is heard and a light indication is provided so that we can find whether the patient should blow effectively. The Blowing time (how much time duration the patient is blowing) was measured and display in the LCD screen. The forced expiratory flow volume (FEV1) and Peak Expiratory Flow Rate (PEFR) was calculated that gives an idea about the status of the lungs. The Mann Whitney U Test was conducted with $\alpha = 0.05$ for the sampled data, the results show that the data is statistically significant. This device is small, portable, and easy to use with no side effects.

Keywords: Forced Expiratory Flow Volume, Peak Expiratory Flow Rate

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1. INTRODUCTION

In recent years, respiratory physiotherapy has been emerged with various new techniques especially with respiratory therapy devices. One among them is flutter device which is known to mobilize and remove secretions. It is a positive expiratory pressure device which was developed in Switzerland in 1970's as an alternative to chest physiotherapy techniques.

The standard physiotherapy procedure followed for removal and mobilization of excess septum from the respiratory airway of a patient with respiratory illness like cystic fibrosis, asthma, Chronically obstruction of pneumonic infection (COPI), aspiratory fibrosis and pneumonia is bronchial drainage. Patients who have long term respiratory diseases prefer use of respiratory physiotherapy devices, as they are cost effective and easy to use independently. The most popular devices for respiratory physiotherapy are positive expiratory pressure based devices like Flutter and Acapella and more. This devices have been proven to remove mucus from bronchi and also improves pulmonary functions making them a better choice for treatment of respiration related problems.

Various studies have described that an average quantity of sputum are cleared from the lungs with flutter was four times higher than the conventional chest physiotherapy. Flutter is a positive expiratory pressure device which requires the patient to perform expiration through the device, expiratory air creates vibration by oscillating the steel ball present in between the cone and the cap. This device is made in such a way that oscillations will increase the vibration which can easily mobilize the secretions, but the patient must perform well and produce the required expiratory pressure to create oscillation and enhance the airway clearance.

The proposed system is all about developing an embedded system based biofeedback device which measures the expiatory air pressure of a patient with respiratory health issue while using a respiratory physiotherapy device called the flutter. The system mainly aims to provide a visual data of the patient's effective use of the PEP based physiotherapy device as it requires good expiratory pressure to achieve better efficiency in removal of excess respiratory secretions.

This system uses sensors to read the pressure in its electrical equivalent form and sends it to a microcontroller (Arduino) were it gets converted into digital data and uses this data to calculate some parameters like forced expiratory flow volume (FEV1) and Peak Expiratory Flow Rate (PEFR) which are displayed on a LCD display also it will have options to set the efficient threshold parameter values the system will provide a sound based alert to the physiotherapist and the patient if the calculated parameters are below the preset threshold values. This would be very useful to the physiotherapist as they can clearly view and asses the patient's performance and improve it for good treatment results. Also thus system can store the data collected on to a web database for future assessment's and diagnosis.

2. LITERATURE REVIEW

The respiratory therapy devices have emerged as an alternative as it provides a greater level of independence to the patients with chronic lung disease. Standard chest physiotherapy consumes more time for both in and patients who are disabled with air route leeway due to which patients refuse for physiotherapy treatment [1]. Flutter is a device that is very portable

to carry, cost effective, less time consuming and can be used with ease and provides with effective therapy in removing secretions.

A new flutter device with an adjustable connector among shudder vibration producer and mouthpiece to eliminate discomforts due to body position [2]. The Flutter is superior in decreasing aspiratory hyperinflation and improves the respiration mechanics among bronchiectasis; it is a device which can be easily administered [3]. The flutter device with positive inclination optimizes expiratory intensity and stream magnitude impacts and assembly of sputum comparatively higher than acapella and shaker due to its PEP variable [4]. The air route clearing methods are purposefully used to eliminate pulmonary secretion from peripheral airways to centre air routes. Flutter valve is clinically proven to benefit the patients by removing the secretions by providing PEP therapy [5].

The bronchodilator response was studied in patients with chronically obstruction of pulmonary infection using mucus clearing devices (MCDs) and sham mucus clearance device (SMCD). It shows that the FEV1 values improve significantly after bronchodilator management with MCD and SMCD [6]. The personal pocket therapeutic device was designed to treat all acute or chronic respiratory disorders. It joins safe endobronchial expiratory intensity fluctuating somewhere in the range of 10 and 20 cm of water, with the oscillation of the intrabronchial intensity and the breathed out air progression [7]. An improvement in the PEP called the Temporary Positive expiratory pressure techniques or TPEP has better efficiency as it a remove can help to remove mucus more effectively even at low expiratory pressure [8]. The use of MCD increases the bronchodilator reaction to joined ipratropium and salbutamol conveyed by metered-portion inhaler for patients with serious COPI [9].

Recurrence increment of intensifications requires anti-microbial when utilizing a swaying gadget contrasted with positive expiratory intensity and might have huge source suggestions. Frequently fueled long haul random control preliminaries are important as the results are estimated by incorporating intensifications recurrence, inclination of patients, adhere for treatment and fulfillment. Expanded adhere of treatment may prompt an enhancements in different parameters, like practice resilience and respiratory capacity [10].

The Acapella is a device similar to flutter but instead of a steel ball it utilizes a counter weighted attachment and magnet to make motions in air route. Acapella is easy to use compared to flutter as it is not gravity based and can also be used at low expiratory flows [11]. It can produce oscillation at frequencies in the range of respiratory framework's reverberation recurrence of patient with breath connected infections. This machine can deliver satisfactory average intensity that is likely to be sufficient in keeping up the alveolus open during termination process [12].

The two commonly used devices for septum secretion removal are the autogenic drainage and flutter. When we comparatively analyze the efficiency of this two the flutter has better performance in reduction of viscoelasticity of sputum this is because of the oscillatory motion of air flow [13]. A study shows the Application High-frequency oscillation through air route space or through the chest screen as the conventional chest physiotherapy had comparative enhancing results on expectorated sputum mass with no any effects on pulmonary function tests or oxygen saturation [14]. The advantages of high recurrence voice air route motion based therapy devices is its self-administrable nature which reduced treatment expenses considerably thus making them a better choice.

3. RESEARCH METHODOLOGY

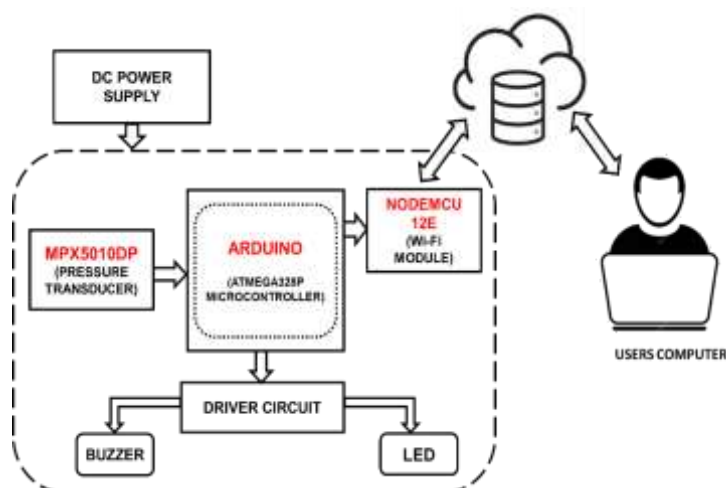


Figure 1. Proposed flow of the system

The architecture of the proposed system can be seen in figure 1. The whole unit mainly comprises of three sections which are

- Sensor section
- Microcontroller section
- Networking section
- User interface section

The sensor section comprises of an mpx5010DP which is an analog pressure sensor which produces an electrical signal in proportion to the air pressure applied on to it. This sensor is a monolithic silicon pressure sensor which makes it compact enough to be placed on a PCB. This will be placed inside the flutter device. The Analog signal produced by this sensor is fed into the microcontroller through its ADC pin where it gets converted into digital form by sampling the input signal at certain frequency. The digital data will then be used by the program fed into the arduino for the calculation of forced expiratory flow volume (FEV1) and Peak Expiratory Flow Rate (PEFR).

It also has an alerting system that has an led indicator and a buzzer. The oscillating frequency was calculated and displayed using different colored LED's (Green – 10 Hz, Orange – 16 Hz, Red – 19 Hz) and with Low, Medium and High pitch Audio. When the frequency of oscillation reached between 10 Hz to 15 Hz Green color and Low pitched, if the frequency of oscillation reached between 16 Hz to 18 Hz Orange color and Medium pitched and if the frequency of oscillation reaches above 19 Hz Red color and High pitched Unit activated. The User instructed to breathe in profoundly and breathe out gradually through the mouth piece. Two sets of 10 exhalations are performed over 15 minutes.

Then this data will be displayed on to an LCD display also the data will get transferred to a web database for storage so that the data can be used in the future whenever required. The pressure produced by the subjects while using this device and with vacuum manometer gauge were measured. The FEV1 and PEFR values for different subjects were calculated and compared with normal values using Pulmonary Function Test (Spirometry) and Peak Expiratory Flow Meter.

4. HARDWARE IMPLEMENTATION

The in-depth explanation of the various hardware components used in the hardware prototype of the proposed bio feedback system is discussed in this chapter. Here we will cover the feature and application of the arduino board, pressure sensor and other modules used in the prototype. The IoT implementation will also be elaborated here.

4.1. Arduino

Arduino is development board developed using the Atmega328p chip an 8 – bit microcontroller. The arduino board has all the necessary connections for interfacing along with power supply circuits are programming controller. This makes it very handy and preferred chose for many embedded system related prototyping projects. Microcontroller present on the arduino has 32 kilobytes of flash program memory , 2 kilobytes of SRAM it also has some peripherals like I/O ports, timers, PWM generators , ADC 's and also supports some popular communication protocols such as I2C,SPI and USART. We have made use of ADC, I/O port and USART peripherals for the hardware implementation of the proposed system.

The pressure sensor used in this work is of analog type this sensor is interfaced with the arduino by using the Analog to digital converter (ADC). Also the other parts of the system like the LCD, buzzer, LED and Wi-Fi module are also interface with the arduino. Thus the arduino acts as the master controller of the system. A firmware was written use the Arduino IDE software for performing the previously discussed tasks and was flashed on to the microcontroller.

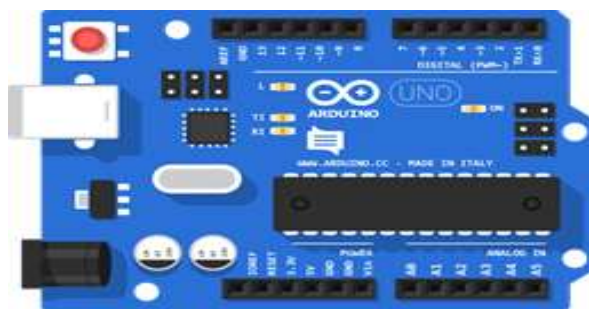


Figure 2. Arduino development board

4.2. MPX5010 - Piezoelectric Presser Sensor

The MPX5010 is a PCB mountable pressure transducer with on chip signal conditioning, it comes in a unibody package. This transducer was designed and developed using modern manufacturing techniques like slight film metallization, micro -machining and bipolar preparing. It is capable of providing precise, higher yield that is response of the given intensity. It has a body made out of durable epoxy with two tubular openings. The pressure differences between this two tubes will be used to generate a voltage signal. This varying voltage signals bets conditioned by the on chip signal conditioning circuits and send out as output. It can measure pressures in the range of 0 to 10 kpa or 1 to 1.45 psi by providing an equivalent yield potential difference in the span of 0.2 to 5.

As the output is analog in nature it can easily be interfaced with microcontroller which have ADC. Thus we have also done the same. The output of the sensor was connected to the arduino board ADC interfacing connector and the signals were read into the controller digitally. The pressure measured using this sensor will then be used to calculate forced expiratory volume and Peak expiratory flow.



Figure 3. MPX5010 - Piezoelectric Presser Sensor

This sensor operated at a voltage range of 0 to 5 V with operating temperatures of -40 to 120 °C. The sensor's accuracy is 5.0 %VFSS. The internal components of the sensor are shown in figure 3. The compact design of this transducer makes it easy to be integrated with the flutter device for expiration pressure measurement.

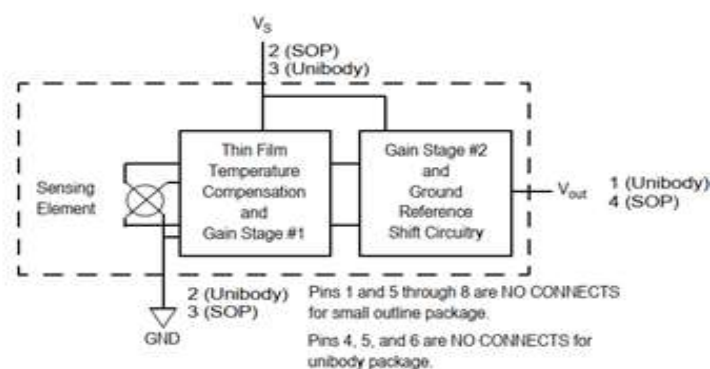


Figure 4. Schematic of Pressure Sensor internal circuitry

4.3. LCD Display

We have used a LCD display for displaying the calculated FEV and PEF. The display used is a 16 X 2 lcd display which can display 32 character 16 at top and 16 at bottom elements. It has a parallel interface in 8 bit and 4 bit configurations. 16X2 LCD is drive and controlled by HD44780U IC this IC has two registers one for command and the other for data. The module has 16 pins 8 for data interchange and others for power, register select, enable pins. The two registers can be chosen using the register select pin by providing it with 0 or 1, that is 0 for command register and 1 for data register.

The LCD driver IC has some predefined commands for initializing the LCD, clearing the screen, display on off control etc. this commands has to be written onto the command register for execution while doing this the register select pin must be at low state. Data Register can be used to display characters on to the display the character to be displayed must be send to the driver in ASCII data format the RS must be set at logical High.



Figure 5. 16 X 2 LCD Display

4.4. Wi-Fi Module: ESP8266

The ESP8266 is a cheap SOC with Wi Fi connectivity and it supports IP/TCP protocol for information interchange with the web along with microcontroller capability. The ESP8266 is a most popular chip for IOT implementations. It is sold in the market in different modular configurations the one which we have used is called Node MCU 12E which has 4MB of flash program memory in supports Wi-Fi 2.4ghz along with this it supports I2C,SPI and UART. It comes with a firmware which can accept commands from a microcontroller through UART protocol and performs tasks like establishing communication with a web server, transmitting and receiving data through the Internet.

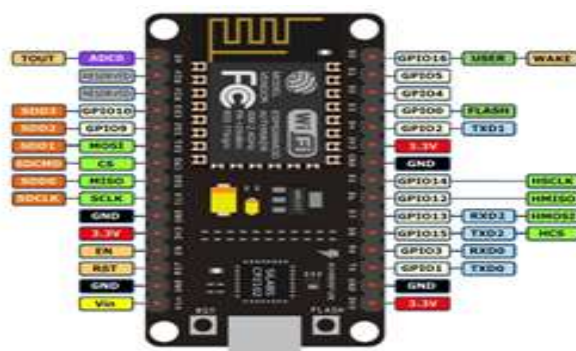


Figure 6. Node MCU 12E Wi-Fi Module

We have made use of this module for transferring the measurements taken from a patient using the proposed device on to a web server. This data will be stored on to a cloud database. The stored data will also get displayed on a webpage. The advantage of this is that that patient and the physiotherapist can keep track of the treatment data. Each time a patient uses this device this FEV and PEF will be stored with respect to time of usage. This ensures the treatments effectiveness. This data's can also be used if the patents changes his physiotherapy expert so that they can easy provide the required guidance without any uncertainty.

5. RESULTS

The pressure produced by the subjects while using this device and with vacuum manometer gauge were measured. The FEV1 and PEF values for different subjects were calculated and compared with normal values using Pulmonary Function Test (Spirometry) and Peak Expiratory Flow Meter are represented in Table 1. It was found that there is a linear relationship between the FEV1 and PEF values with the calculated FEV1 and PEF coefficients.

Table 1. FEV1 and PEF values

Sl. No.	Height of Subject	FEV1 Values (Expectorant device)	FEV1 Values (Spirometry)	PEFR Value (Expectorant device) L/min	PEFR Value (Spirometry) L/min
1	150	3.09	3.22	298	302
2	152	3.36	3.25	326	322
3	155	3.49	3.41	374	372
4	160	3.28	3.56	381	379
5	161	3.50	3.58	384	388
6	168	3.97	3.88	422	415
7	170	4.24	4.05	416	421
8	176	4.30	4.31	440	442
9	177	4.31	4.33	435	441
10	181	4.55	4.57	452	449

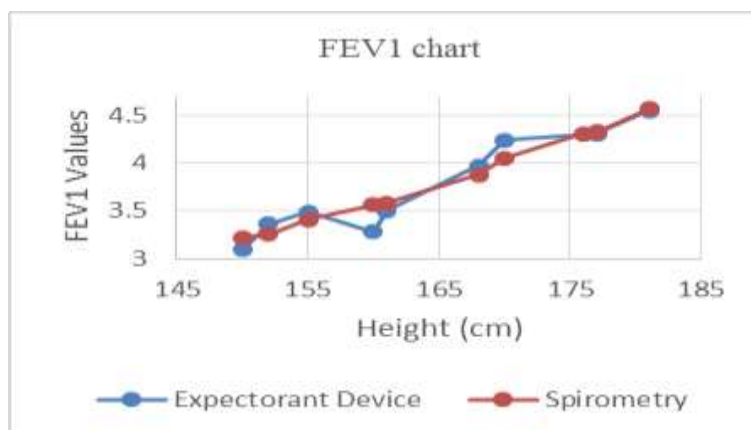


Figure 7. Comparison of FEV1 values from expectorant device with Spirometry

The percentage of error for the FEV1 values with respect to Spirometry is 2.8 % and the values are plotted in the graph shown in the Fig.7.

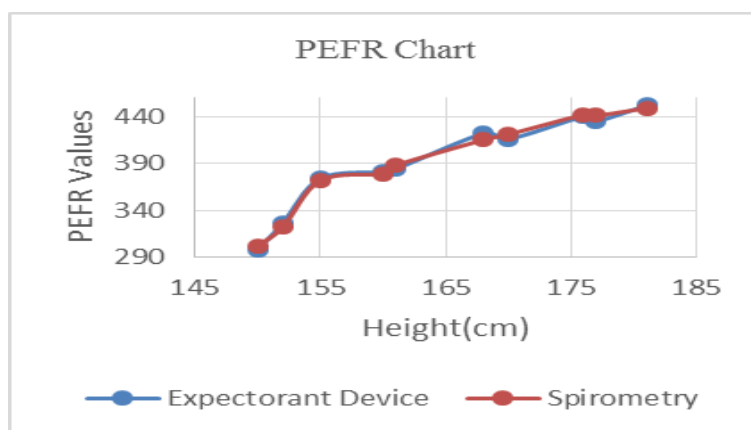


Figure 8. Comparison of PEFR values from expectorant device with spirometry

The percentage of error for the PEFR values with respect to Spirometry is 1 % and the values are plotted in the graph shown in the Fig.8.

6. CONCLUSION

A smart biofeedback expectorant device has been developed for the patients suffering from various lung disorders. The feedback system designed using a pressure sensor picks up the pressure in the mouth piece, compared with the threshold value to know the optimum pressure. The FEV1 and the PEFR values are calculated from different subjects and the results are verified with the values from spirometer and the peak expiratory flow meter. The audio and visual feedback system will increase the patient blowing time of the patient that helps in improving the lung capacities.

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