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***Short Paper**

An MCU-Based Peak Expiratory Flow Rate Device and Mobile-App Interface for Asthma Attack Prevention

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Special Issue on International Research Conference on Computer Engineering and Technology Education 2023 (IRCCETE 2023). Guest Associate Editors:* **Dr. Nelson C. Rodelas, PCpE (*Computer Engineering Department, College of Engineering, University of the East-Caloocan City; nelson.rodelas@ue.edu.ph*) and **Engr. Ana Antoniette C. Illahi**, PCpE (*Asst. Professor & Vice Chair, Department of Computer and Electronics Engineering, Gokongwei College of Engineering, De La Salle University, Taft Ave., Manila; ana.illahi@dlsu.edu.ph*).

Abstract

Purpose – Monitoring of the peak expiratory flow rate (PEFR) and its corresponding asthma management plan is one of the ways to prevent an asthma attack. The study introduces an MCU-Based Monitoring and Control Prototype with mobile application that prompts the person of the scheduled time to take the PEFR and automatically records the rate and displays the asthma management plan corresponding to it. When the reading hits a critical level, it sends an alert to the immediate family and doctor of the patient.

Method –The prototype was tested with asthmatic and non-asthmatic patients to evaluate its accuracy and timeliness. Data were also taken using the commercially available peak flow meters and all information were recorded manually. T-test and variability measures were used for all the samples of both devices.

Results – The results show that the values measured by the prototype compared with the commercially available meter have no significant difference. Moreover, the on-time data-logged monitoring has shown the trend on the PEFR of a patient relative to his personal best reading. The data showed the decline of the PEFR measured for days. When the medical intervention was done, the PEFR readings improved.

Conclusion – The prototype reading has high degree of accuracy and consistency as seen from the results of the testing. The system has shown critical values with the continuous decline of the PEFR measured. This has served as an important information for immediate control and intervention of an impending asthma attack.

Recommendations – Future works must include mobile application that works for all platforms. Also, communication between the hardware and the mobile device must not be limited to Bluetooth technology.

Research Implications – The study will serve as a reference for other research or technological breakthroughs that can aid not only in the field of technology but also in other professional fields.

Keywords – Asthma, Peak flow meter, Microcontroller, MCU-Based, PEFR

INTRODUCTION

Asthma is a heterogeneous disease usually characterized by airway inflammation (Global Initiative for Asthma, 2017). Asthma cannot be cured but can be controlled by appropriate management (Cleveland Clinic, 2017; World Health Organization, 2017; Asthma and Allergy Foundation of America, 2017; American Academy of Allergy Asthma & Immunology, 2017; Centers for Disease Control and Prevention, 2017). The study of Ahmed et al (2014) identified factors that showed insufficient asthma control of patients that led them seeking management in emergency departments. The severity of an asthma attack escalates fast; thus, the asthma symptoms must be immediately treated once these symptoms are recognized. Medical doctors use the lung function test to analyze the presence of asthma and monitor if the condition of the person is in control or worsening.

Lung function test includes spirometry, challenge test, and peak flow meter test. These are used to diagnose and monitor asthma. Spirometry, as seen in Figure 1, is the most common function test for asthma done by trained professionals where the person takes a deep breath and exhale into a hose attached to a device called a spirometer. The data will record lower if the airways are swollen or constricted. The challenge test is used to help confirm the diagnosis of asthma. The person inhales a small amount of a substance such as histamine or methacholine known to trigger the asthma symptoms. After inhaling the substance, the person undergoes the lung function test. He must be assisted by a medical practitioner since the test can trigger an asthma attack. The peak flow meter test using a peak flow meter seen in Figure 2, is done to measure how well the person's lungs push out air. This test is a good way to regularly test the patient's lung function at home. The test is done using a peak flow meter. The peak flow meter is a handheld device with a mouthpiece on one end where the person breathes into after inhaling a deep breath. The peak expiratory flow rate (PEFR) or peak flow rate is monitored on a regular basis. The PEFR is recorded manually in an asthma diary. The information in the diary which will either be an increased or a decreased in the peak flow rate is a very useful information to the control of asthma and the necessary asthma action plan the doctor and the person need to work out. Reshmarani et al (2017) presented a comparative study on measurement of PEFR which showed that readings of spirometer and peak flow meter vary, however, peak flow meter gives consistent readings and are more portable and convenient to use.

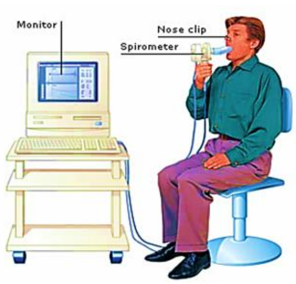


Figure 1. Spirometer (www.pccma.net)

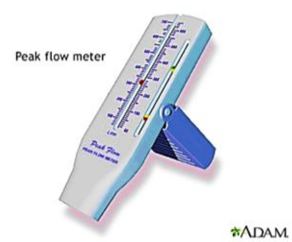


Figure 2. Peak Flow Meter

The study aimed to develop an MCU-based monitoring and control prototype with mobile application interface that will aid in the prevention of an asthma attack. Specifically, it aspires to

a. Measure the personal best of individuals with asthma history;

b. Measure and compare the PEFR of individuals with asthma and no-asthma history using both the commercially available and the MCU-based prototype devices;

c. Analyze the readings from the commercially available and the MCU-based prototype devices in terms of accuracy and consistency.

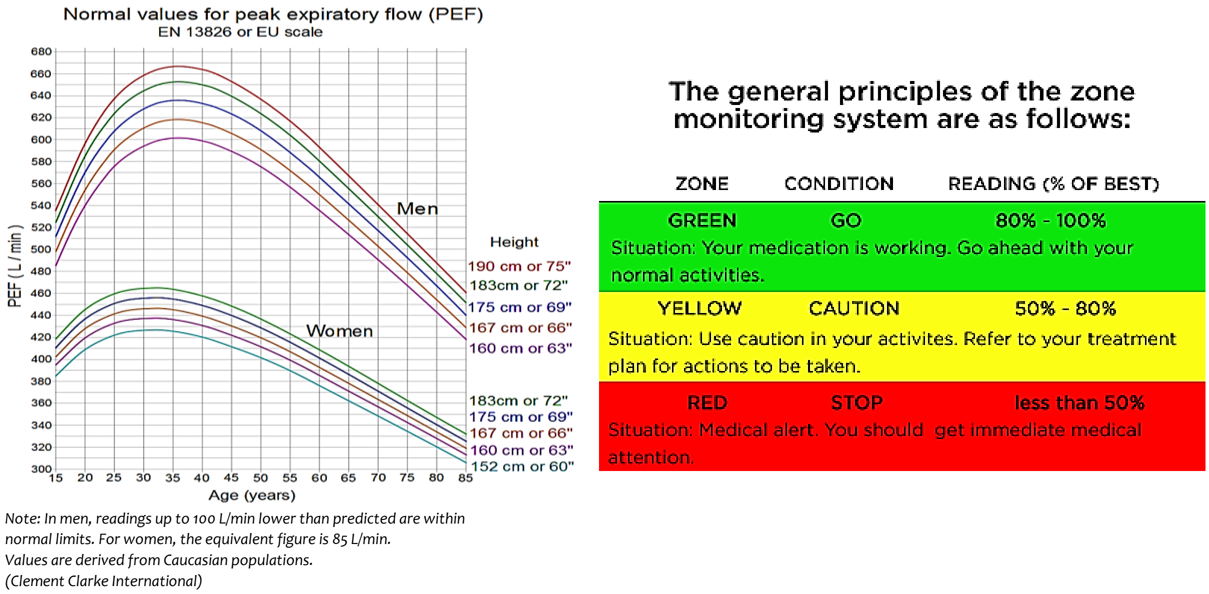
LITERATURE REVIEW

In the peak flow measurement, the baseline or personal best is established first. According to medical resources and medical professional, each time Peak Flow (PF) is measured the best of 3 is recorded, and the highest over a period is considered the Personal Best (PB) - this will be the basis of severity measures during attacks - percentage of PB. This baseline is necessary to determine the peak flow value that is normal to a patient. This is established first because a normal peak flow of an individual varies from another individual. The normal peak flow is determined when the person has no asthma symptoms. He has to perform three measurements with the same peak flow meter two to four times a day for two to three weeks (WebMD, 2017; PeaceHealth, 2017). This is also indicated in the study of Reddel et al (2004) that the personal best PF is necessary for asthma management that is determined as the highest over the two weeks. The highest amongst the readings is noted and is the individual's personal best. This number is used to determine if the peak flow measurements in the future are normal or low. The measurement is considered normal if it falls between 80 to 100 percent of the personal best peak flow measurement of the person. Measurements which will fall below the normal range indicate a sign of a narrowing of the airways. This measurement can occur before the asthma symptoms developed. The determination and measurement of the personal best is done yearly to account for growing children and/or changes in the asthma for both children and the adults. The normal peak flow values for pediatrics and adults were shown in the table (Table 1) and chart (Figure 3a) that followed.

Table 1. Pediatric Normal Values: Peak Expiratory Flow Rate

Height (m)	Height (ft)	Predicted EU PEFR (L/min)	Height (m)	Height (ft)	Predicted EU PEFR (L/min)
0.85	2'9"	87	1.3	4'3"	212
0.9	2'11"	95	1.35	4'5"	233
0.95	3'1"	104	1.4	4'7"	254
1	3'3"	115	1.45	4'9"	276
1.05	3'5"	127	1.5	4'11"	299
1.1	3'7"	141	1.55	5'1"	323
1.15	3'9"	157	1.6	5'3"	346
1.2	3'11"	174	1.65	5'5"	370
1.25	4'1"	192	1.7	5'7"	393

Note: (For use with EU/EN13826 scale PEF meters only) *Normal PEF values in children correlate best with height; with increasing age, larger differences occur between the sexes. These predicted values are based on the formulae given in Lung Function by J.E.Cotes (Fourth Edition), adapted for EU scale Mini-Wright peak flow meters by Clement Clarke. Date of preparation – 7th October 2004 (from the www.peakflow.com)*



(a) (b)

Figure 3. (a) Normal Values for Peak Expiratory Flow (www.slideshare.net); (b) Peak Expiratory Flow Rate Zones (https://www.semedicalsupply.com/)

The values presented on the table and on the chart are used for comparison for the peak flow rates being measured by the person in monitoring his asthma condition. His asthma condition may fall into any of the three zones presented in Figure 3b. Each of these zones has each own asthma management plan or an asthma action plan (Kouri et al., 2017) as discussed between the patient and his health professional. These three zones can easily be identified using the colors of the traffic light: green, yellow, and red. Green zone means the patient does not experience any asthma symptoms; the yellow zone indicates caution because the patient experiences symptoms like coughs, wheezes, and had difficulty in doing his usual responsibilities. The red zone indicates danger.

Different studies focused on the utilization of electronic devices and microcontrollers in the measurement of peak flow and its data recording. Natarajan et al (2014) proposed a portable and smartphone compatible peak flow meter design that connects via audio jack. Meanwhile, the study of Vinuraja et al (2017) presented the use of mobile communication module that sends to a specialist the recorded data from an interfaced designed device. Triviño et al (2020) proposed a low-cost design of a PEF estimation using turbine sensor and comparison with commercially available resulted to an error of under 0.57%. Sallyfan et al, in 2020, designed a peak flow meter equipped with inspection results indicator, and values were sent to a PC. Result showed that errors were less than 5%. In the same year, Anisa et al (2020) designed and tested their peak flow meter with measurement analysis with a data storage facility, an SD card. Range of error rate was 0.42% to 4.41% compared to the original device. The study of Azzahra et al (2022) presented the design and implementation of microcontroller based peak flow meter that showed an error rate was between 0.50 % and 4.21 % compared with the mechanical-based peak flow meter. From the previous studies presented, there was no determination and recording of the personal best of the individual. The designed prototype in this study addressed this with the initial recording of the personal best of the individuals and consequently determining the green, the yellow, and the red zones of these individuals and outputs corresponding asthma management as advised by the medical professional. This is in addition to the wireless communication between the micro-controlled peak flow meter and the android device for data gathering, recording and analysis.

METHODOLOGY

The study used experimental type of research. The researcher developed an MCU-based peak flow meter interfaced with a mobile application that measures and logs the peak expiratory flow rate of a person. Figure 4 shows the block diagram of the overall system.

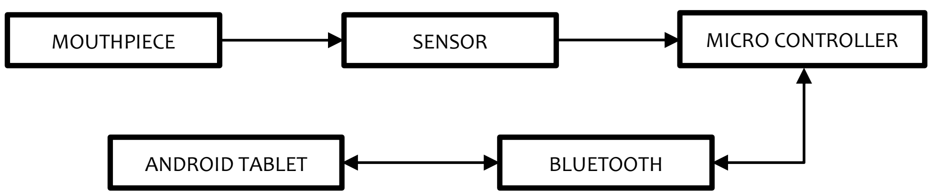


Figure 4. Block Diagram of the System

The constructed prototype and the overall design consist of the mouthpiece, pressure sensor, microcontroller, Bluetooth, and the android device. The patient blows into the mouthpiece as hard as he can for three times. Each of these blows is measured by the microcontroller thru the pressure sensor and transmits the data to the android device wirelessly using the Bluetooth technology. The device through the installed system analyses the data received and records the information. A message is sent to the doctor through the mobile application immediately when the measured and recorded information reaches the critical values.

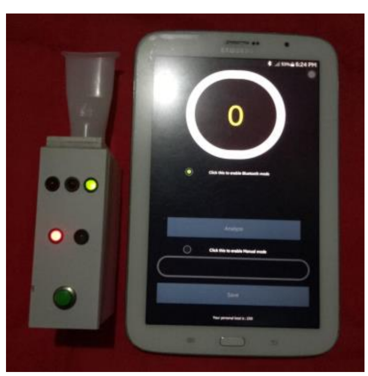


Figure 5. System Integration and Testing

Both devices are paired via Bluetooth for communication, the MCU-based prototype and the mobile Android device with the mobile application installed (Figure 5). The patient blows into the mouthpiece by pressing initially the green button that signifies the microcontroller is sending information to the Android device and releases it when the blow is already through. The Android device waits for the second and the third blows and then analyses the values and displays and records the highest value. A corresponding management plan is shown simultaneously with the highest rate so that the patient is reminded of his medication if the case calls for it.

The measured values are sent to and recorded in an Android device through Bluetooth technology which receive the data and automatically record the highest amongst the values. This value is compared to the individual's personal best which served as the vital information in order to generate the asthma action plan. When critical value is measured, a message is sent to the medical doctor and to the relative of the person. The respondents of the design are the individuals who have asthma history. Individuals with no asthma history are also requested to use the device.

To measure the accuracy of the results for both devices, this study employed the *t*-test for independent samples. The prototype is accurate if it satisfies the condition that there is no significant difference on the average peak flow rates between the prototype and the commercially available meter. This is manifested when the *p*-value obtained using the independent sample *t*-test (Equation 1) is at least 0.05. The data points for x_1 and x_2 correspond to the control device and the MCU-based prototype, respectively. The variance of error was measured as well, using the mean-square error (MSE) and root-mean-square (RMSE) error formulas (Equation 2) to measure the consistency and variability of one device against the other. Ideally, the smaller the value of variability, the more consistent the readings of both devices when compared against each other.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$ Equation 1

$$MSE = \frac{\sum_i (x_{1i} - x_{2i})^2}{n}, \qquad RMSE = \sqrt{\frac{\sum_i (x_{1i} - x_{2i})^2}{n}}$$ Equation 2

RESULTS

Prior to the monitoring of the PEFR daily, the personal best (PB) of the person must be recorded first. This PB or baseline is taken three weeks without any asthma symptoms. The measurement is done thrice in the morning and thrice in the evening at the same time each day. The highest among the three values in the morning and in the evening is recorded. For the three weeks, the highest amongst all the values recorded is the personal best. The PBs for all three asthmatic persons are measured and recorded based on the commercially available (controlled) meter and the MCU-based meter. For a total of 21 days, the measurement of the peak flow rate of all individuals was done twice a day. It should be noted that these measurements were done to these individuals experiencing no asthma symptoms or had no asthma attack.

The following figures displayed the personal best of everyone as compared to the PEFR given by the prototype (MCU-based meter).

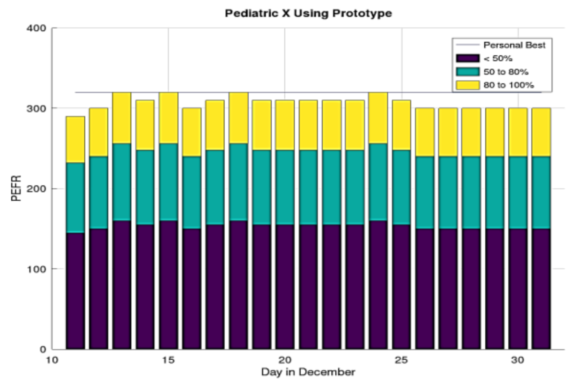


Figure 6. Pediatric X Peak Expiratory Flow Rate

Figure 6 showed the graph of the PEFR of Pediatric X. The graph showed the personal best of the person which was 320 L/min from Day 11 to Day 31. The x-axis showed the days while the vertical axis showed the daily peak expiratory flow rate. Figure 7 and Figure 8 showed the personal bests of Adult Y and Adult Z with 320 L/min and 450 L/min respectively.

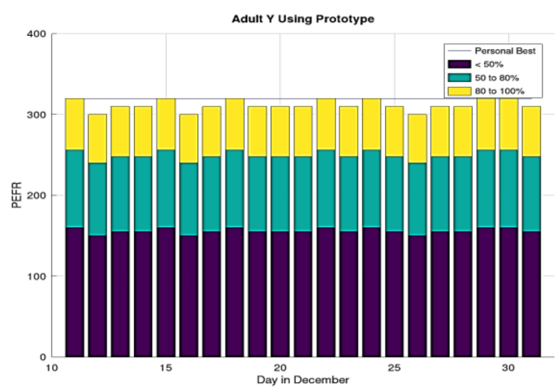


Figure 7. Adult Y Peak Expiratory Flow Rate

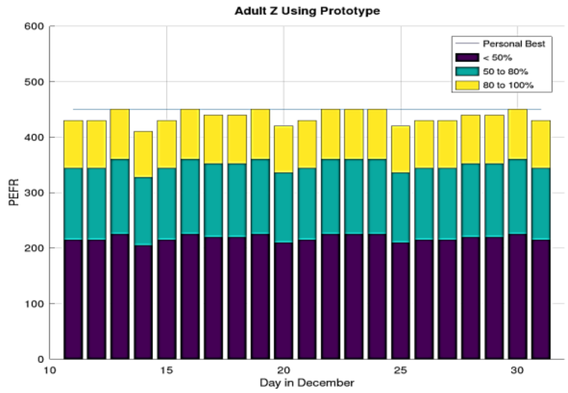


Figure 8. Adult Z Peak Expiratory Flow Rate

Table 2 shows the summary of the personal bests of the 3 individuals with asthma history. The baselines were 320L/min for Pediatric X, 320L/min for Adult Y, and 450L/min for Adult Z. These baselines were important information in the succeeding measurements because these values served as the reference for the peak expiratory flow rate measurement of the three individuals. Values measured daily would be compared to the baseline and these would indicate the condition of the individual whether improving or worsening based on the percentage as compared to the baseline. The PEFR measured would fall in any of the ranges in the different zones. The minimum value in each of these zones corresponds to the threshold level as shown in Table 3. When the PEFR fell within the green zone, the patient did not experience any asthma symptoms; the yellow zone indicated caution because the patient experienced symptoms like coughs, wheezes, and had difficulty in doing his usual responsibilities. The red zone indicated danger.

Table 2. Personal Best (Baseline)

Patient and Peak Flow Meter Used	Pediatric X		Adult Y		Adult Z	
	Control Device	MCU-based Prototype	Control Device	MCU-based Prototype	Control Device	MCU-based Prototype
Highest Peak Flow Rate	320L/min	320L/min	320L/min	320L/min	450L/min	450L/min

Note: *L/min- liters per min*

Individuals with asthma history were requested to take their peak expiratory flow rate for ten (10) days. The personal best or the baseline was entered into the system (android tablet) so that the data would serve as the reference value for all the measured and recorded values. Measurements were done using both the commercially available (controlled meter) and the MCU-based peak flow meters. Full report of data results of the measurements was tabulated in Appendix A-2.

Table 3. Threshold Values

Asthmatic Zones	Pediatric X PB = 320 L/min	Adult Y PB = 320 L/min	Adult Z PB = 450 L/min
Green Zone (80% – 100%)	256 - 320	256 - 320	360 - 450
Yellow Zone (50% – 80%)	160 - 256	160 - 256	225 - 360
Red Zone (< 50%)	< 160	< 160	< 225

Note: PB - personal best (baseline)

For the accuracy of the prototype, referring from the data tabulated in Table A-2, T-test for independent samples is shown in Table 4. Table 4 shows that the *p*-values of more than 0.05 for individuals X, Y, and Z. These implied that the average peak flow rates given by the prototype (MCU-based meter) had no significant difference on the average peak flow rates given by the commercially available (controlled) meter. Likewise, the overall result showed a *p*-value = 0.956, then it could be said straightforward that the MCU-based peak flow meter was accurate. Similarly, the accuracy test of the prototype was conducted for individuals with no asthma history both for the commercially available (controlled meter) and the MCU-based peak flow meters. Results of the measurements were tabulated on Table A-3 in Appendix A.

Table 4. T-test Results of Peak Flow Rates of Individuals with Asthma History

Individual	Average Peak Flow Rate		Standard Deviation	t-value	Degrees of freedom	P-value
X	Controlled Meter	301.00	12.867	0.326	18	0.748
	MCU-Based Meter	299.00	14.491			
Y	Controlled Meter	305.00	8.498	-0.264	18	0.795
	MCU-Based Meter	306.00	8.433			
Z	Controlled Meter	447.00	4.830	0.885	18	0.3888
	MCU-Based Meter	445.00	5.270			
Overall	Controlled Meter	351.00	69.647	0.056	58	0.956
	MCU-Based Meter	350.00	69.083			

For the accuracy of the prototype used by individuals with no asthma history, T-test for independent samples showed the following results. Table 5 showed *p*-values of more than 0.05 for individuals A, B, and C. These signified that the average peak flow rates given by the prototype (MCU-based meter) had no significant difference on the average peak flow rates given by the commercially available (controlled) meter for individuals with no asthma history. Moreover, the overall result showed a *p*-value = 1.000, thus it could be said that the MCU-based peak flow meter was accurate.

Table 5. T-test Results of Peak Flow Rates of Individuals with No Asthma History

Individual	Average Peak Flow Rate		Standard Deviation	*t*-value	Degrees of freedom	*P*-value
A	Controlled Meter	204.00	6.992	-1.116	18	0.279
	MCU-Based Meter	207.00	4.830			
B	Controlled Meter	456.00	5.164	0.429	18	0.673
	MCU-Based Meter	455.00	5.270			
C	Controlled Meter	490.00	0.000	1.500	18	0.168
	MCU-Based Meter	488.00	4.216			
Overall	Controlled Meter	383.33	129.836	0.000	58	1.000
	MCU-Based Meter	383.33	127.640			

Table 6. Test of Variability for Asthmatic and Non-asthmatic Test Subjects

Variance of Error	With Asthma History			Without Asthma History		
	Pediatric X	Adult Y	Adult Z	Pediatric A	Pediatric B	Adult C
Mean-Square Error (MSE)	20	20	20	30	10	20
Root-Mean-Square Error (RMSE)	4.4721	3.1623	4.4721	5.4772	3.1623	4.4721

The variability test of computing the mean-square error (MSE or variance) and root-mean-square error (RMSE or standard deviation) for tables in Appendix A-2 and Appendix A-3 have yielded very small values (Table 6). This implies that the consistencies in readings between the commercially available device and the MCU-based prototype are the same and empirically stable. The timeliness of the device was observed from the period when the MCU-based meter was used by individuals with asthma history. The data shown in the following figures were taken for a total of 38 days. Results of the measurement were tabulated in Table A-4 in Appendix A. The figures showed the recorded information.

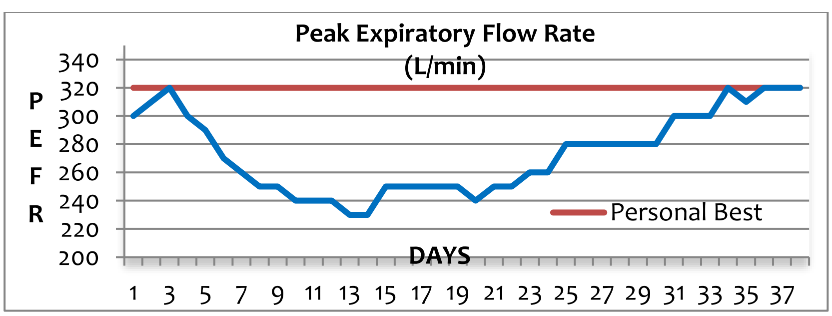


Figure 9. Pediatric X Peak Expiratory Flow Rate

From Figure 9, it was observed that for the consecutive days of the first two weeks, the PEFR of the person continued to decline. It was also in this period that the person started to show asthma symptoms like coughing and sneezing. The PEFR for the succeeding days of the weeks were regularly taken and observed with medical interventions already given to the person. This intervention included the nebulization. This affected the PEFR of Pediatric X. It started to rise and eventually went back to its personal best.

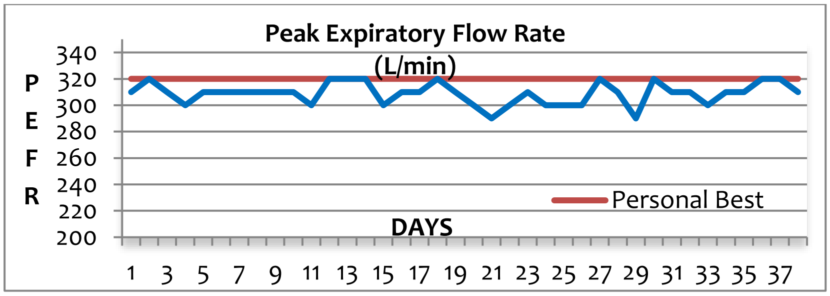


Figure 10. Adult Y Peak Expiratory Flow Rate

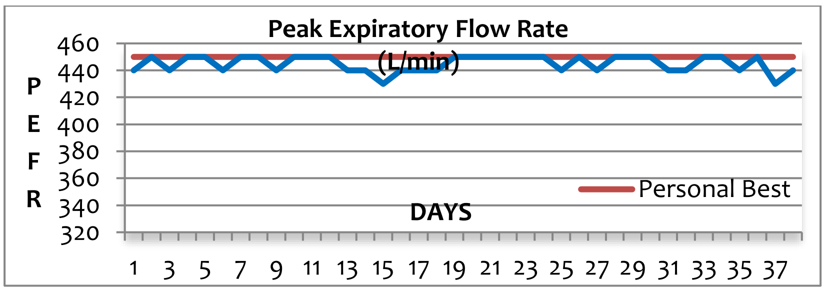


Figure 11. Adult Z Peak Expiratory Flow Rate

Both charts in Figures 10 and 11 showed personal bests and the daily peak expiratory flow rates of Adult Y and Adult Z, respectively. For the 38 days data gathering and recording, the MCU-based PEFRs of both patients mostly overlapped with their personal bests. As indicated in Table 3, the table of threshold values for all the individuals with asthma, the data of Adult Y and Adult Z fell within the range of green zone or no asthma symptoms.

DISCUSSION

The researcher measured and recorded the baseline for the asthmatic patients for 21 days using the prototype and the commercially available. The baseline was used as reference for the asthmatic patients when recording their daily PEFR. The accuracy test for both asthmatic individuals (with asthma history) and for those non-asthmatic individuals (no asthma history) was also conducted. The accuracy was done using the commercially available meter and the MCU-based meter. Ten (10) tests were done to all individuals. From the utilized t-test from all the samples (asthmatic and non-asthmatic), it showed the overall p-values of 0.956 and 1.000 respectively which meant that the values from the prototype and the commercial meters have no significant difference; thus, the prototype reading had high degree of accuracy. Moreover, the timeliness of the device was also seen through the figures that showed how the PEFR of Pediatric X continued to decline overtime and how it was also affected with the necessary medical intervention. This showed that the device reflected the condition of the PEFR of the patient prior to the onset of the symptoms and showed how the medical intervention influenced the decreasing PEFR.

CONCLUSIONS AND RECOMMENDATIONS

The research showed that the MCU-based peak flow meter measured and recorded the personal best (baseline) of the 3 individuals with asthma history. This value was used as reference for the daily PEFR measurement. The PEFRs of both asthmatic and non-asthmatic persons were measured and recorded for 10 days and the values were assessed for their accuracy. It was seen that the measured value using the prototype gave high degree of accuracy as compared to the commercially available peak flow meter. It also demonstrated how the prototype worked on certain conditions like the individual that showed the decline of the PEFR values and exhibited eventually asthma symptoms. The information that the system recorded and reflected thru the charts showed the onset of the asthma symptoms which were immediately addressed with the corresponding management plan. Improving asthma control could have dramatic effects on patients' health and utilization of healthcare resources (Gold et al, 2014). The result of this study also supports Mehta et al (2016) that vital role of PEFR in the changes in the airflow can result in the early identification of children with airway obstruction. Also, the utilization of mobile device, in this study, the android tablet, also supported the study of Cleland et al (2007) the acceptability of the use of mobile technology in clinical trials and immediate communication to healthcare professionals without the need of face-to-face consultation. Future works must include mobile application that works for all platforms. Also, communication between the hardware and the mobile device must not be limited to Bluetooth technology.

ACKNOWLEDGEMENT

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DECLARATIONS

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

All data acquired are public data.

Ethics Approval

No ethics approval due to nonexistence of the issuing body; however, all participants consented on the data gathering and testing.

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Appendix A.

Raw Data Tables

Table A-1. Actual Daily Measurement to Determine Personal Best

Day in December	Time of Day	Pediatric X		Adult Y		Adult Z	
		Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)
11	AM	280	280	310	310	420	420
	PM	280	290	320	320	430	430
12	AM	300	300	300	300	430	430
	PM	310	300	310	300	440	430
13	AM	320	320	310	310	440	440
	PM	320	320	310	310	450	450
14	AM	310	300	310	310	410	410
	PM	310	310	300	300	410	410
15	AM	320	320	320	320	430	430
	PM	320	320	320	320	430	430
16	AM	300	300	300	300	440	440
	PM	300	300	300	300	450	450
17	AM	310	310	300	300	440	440
	PM	310	310	320	310	440	440
18	AM	320	310	320	320	440	440
	PM	320	320	320	320	440	440
19	AM	310	310	310	310	440	450
	PM	310	310	310	310	450	450
20	AM	310	310	310	310	420	420
	PM	310	310	310	310	430	420
21	AM	310	310	300	300	430	430
	PM	310	300	310	310	430	430
22	AM	310	310	320	320	450	450
	PM	310	310	320	320	440	440
23	AM	310	310	310	310	450	450
	PM	320	310	320	310	450	450
24	AM	310	310	320	320	440	450
	PM	320	320	320	320	450	450
25	AM	310	310	300	300	420	420
	PM	310	310	310	310	430	420
26	AM	300	300	300	300	420	420
	PM	300	300	310	300	430	430
27	AM	290	290	310	310	430	430
	PM	300	300	310	310	430	430
28	AM	300	300	300	310	430	440
	PM	310	300	310	310	440	440
29	AM	300	300	310	310	430	430
	PM	300	300	320	320	440	440
30	AM	300	300	320	320	440	450
	PM	300	300	320	320	450	450
31	AM	300	300	310	310	420	430
	PM	310	300	310	310	430	430

Table A-2. Peak Flow Rates of Individuals with Asthma History

Day	Pediatric X*		Adult Y*		Adult Z**	
	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)
1	310	310	300	300	450	450
2	300	300	320	320	450	440
3	320	320	300	300	450	450
4	320	320	310	310	450	450
5	300	290	300	300	450	450
6	290	290	320	320	440	440
7	300	300	300	300	440	440
8	300	300	300	300	450	450
9	290	280	300	300	450	440
10	280	280	300	310	440	440

*Note: * Personal best is 320 L/min ; ** Personal best is 450 L/min.*

Table A-3. Peak Flow Rates of Patients with No Asthma History

Day	Pediatric A		Pediatric B		Adult C	
	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)	Peak Flow Meter (control)	Peak Flow Meter (MCU-based)
1	210	210	460	460	490	480
2	210	210	460	450	490	490
3	200	210	450	450	490	490
4	210	210	450	450	490	490
5	190	200	450	450	490	490
6	200	200	450	450	490	490
7	210	210	460	460	490	490
8	200	210	460	460	490	480
9	210	210	460	460	490	490
10	200	200	460	460	490	490

Table A-4. Peak Expiratory Flow Rates Monitoring for Individuals with Asthma History

	Pediatric X		Adult Y		Adult Z	
Day	MCU-Based PEFR	Personal Best	MCU-Based PEFR	Personal Best	MCU-Based PEFR	Personal Best
1	300	320	310	320	440	450
2	310	320	320	320	450	450
3	320	320	310	320	440	450
4	300	320	300	320	450	450
5	290	320	310	320	450	450
6	270	320	310	320	440	450
7	260	320	310	320	450	450
8	250	320	310	320	450	450
9	250	320	310	320	440	450
10	240	320	310	320	450	450
11	240	320	300	320	450	450
12	240	320	320	320	450	450
13	230	320	320	320	440	450
14	230	320	320	320	440	450
15	250	320	300	320	430	450
16	250	320	310	320	440	450
17	250	320	310	320	440	450
18	250	320	320	320	440	450
19	250	320	310	320	450	450
20	240	320	300	320	450	450
21	250	320	290	320	450	450
22	250	320	300	320	450	450
23	260	320	310	320	450	450
24	260	320	300	320	450	450
25	280	320	300	320	440	450
26	280	320	300	320	450	450
27	280	320	320	320	440	450
28	280	320	310	320	450	450
29	280	320	290	320	450	450
30	280	320	320	320	450	450
31	300	320	310	320	440	450
32	300	320	310	320	440	450
33	300	320	300	320	450	450
34	320	320	310	320	450	450
35	310	320	310	320	440	450
36	320	320	320	320	450	450
37	320	320	320	320	430	450
38	320	320	310	320	440	450