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Design and Development of an IoT-based Pulmonary Function Monitoring Device of FVC and FEV1 for Children with Bronchial Asthma

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ABSTRACT Health information technology plays a crucial role in managing the healthcare of patients and their families during illness. One of the frequently encountered diseases is Asthma, a chronic inflammatory disorder of the respiratory tract that is reversible and fluctuating, capable of causing exacerbations with mild to severe symptoms and even death. The objective of this research is to develop a device to facilitate the monitoring and input of data regarding pulmonary volume measurements (spirometry). The sensors used for measuring pulmonary volume are the flow turbine sensor, while the SpO2 sensor used is the MAX30102. The data obtained from the sensor measurements will be processed on the ESP32. A health monitoring application is created using Kodular software, which incorporates a MySQL database for data storage. Furthermore, the examination results can be accessed through an Android application on a tablet or smartphone. The results obtained from this research indicate an error value of 8.78% for FVC, 14% for FEV1, and a FEV1/FVC ratio of 4.6%, with zero data loss. It is expected that the spirometer with Internet of Things (IoT) capabilities will be implemented, as monitoring can be easily conducted anywhere. The portable design will facilitate future examinations. The implications of this study are that it obtains information about individual variability in lung function measurement, the public can better understand the importance of respiratory health monitoring, as well as support the development of better medical technology to improve lung disease diagnosis and management and improve spirometer technology.

INDEX TERMS Spirometry, Pulmonary Function, FVC, FEV1, ESP32, Application, Kodular

I. INTRODUCTION

Respiratory disorders are diseases that affect approximately 18% of the population in various countries[1]. One common example of respiratory disorders is bronchial asthma. In Indonesia, bronchial asthma is one of the top 10 diseases with the highest morbidity and mortality rates. According to the 2013 Riskesdas data, based on population projections, more than 11 million Indonesians suffer from bronchial asthma. The number of people with bronchial asthma continued to increase by 0.5% in 2018. This disease causes narrowing of the airways due to hyperactivity, which leads to disrupted breathing patterns and decreased oxygen levels [2][3]. Individuals with asthma experience increased resistance in the smaller airways to expiratory airflow, thus requiring more time to exhale their entire vital capacity (FVC) [4][5]. In measuring FVC, forced expiratory volume in 1 second (FEV1) data is also obtained, which indicates abnormalities such as restriction and obstruction[6]. In detecting the presence of bronchial asthma, health workers usually use a spirometer by measuring the volume in the FVC and FEV1 examinations [7][8]. However,

In providing services to patients with bronchial asthma not only requires this measurement alone as the only diagnostic tool, but health care providers need time to access to unsuitable for use as standard measurement references. In addition, there are obstacles associated with inadequate data transfer, which impede the effectiveness of the devices. In

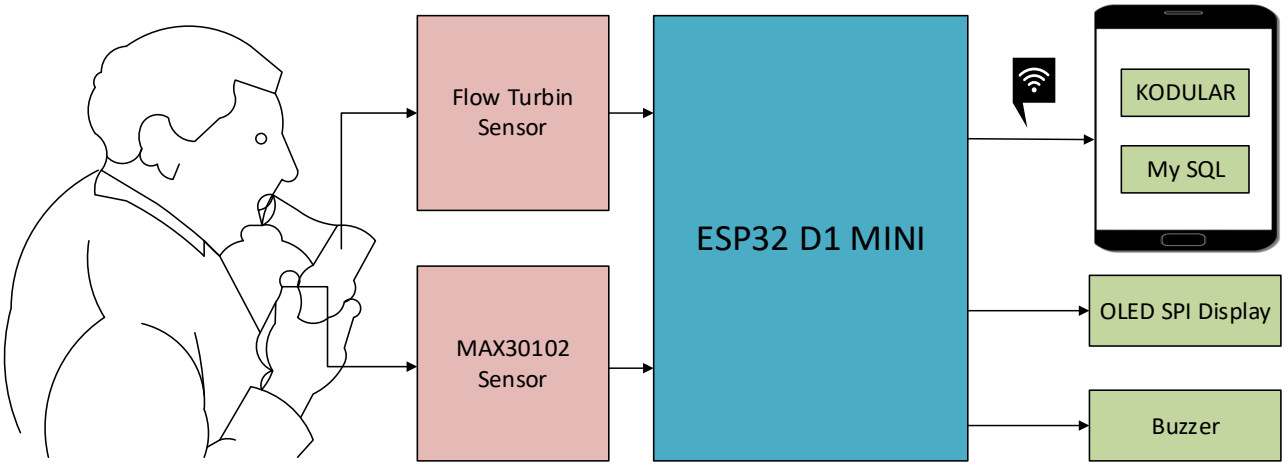

FIGURE 1. System Block Diagram in Research spirometry with Flow Turbine sensor and MAX30102 sensor

spirometer data and then follow up on symptoms and treatment schedules[9][10].

In 2018, Kemalasari did a study on a non-invasive piezoelectric spirometer that can diagnose illnesses by measuring lung volume and capacity. Nevertheless, the duration of utilization was insufficient, resulting in inefficiency. Akbar Novel effectively designed a spirometer utilizing the MPX5500DP air pressure sensor. The results indicated deficiencies in the display and a requirement for a more precise sensor. Lia Andriani modified the sensor model by incorporating the MPX5100DP and experienced erroneous readings in the mouthpiece[11]. Kharis conducted a research project on a portable spirometer utilizing the MPXV7002DP. However, the study encountered an error margin of 1.58% and unresolved parameters [12]. Purwanto designed a spirometer that incorporated an additional sensor, the MPX5100DP. However, there was still a tolerance value of 10% present. Ibrahim conducted a portable investigation using the Ni sbRIO 963 microcontroller. While the experimental curve closely approximated the expected results, there were discrepancies in the values [13]. Amir conducted a study on a cost-effective piezoelectric spirometer, but, the sensor's functionality was compromised by temperature variations, leading to imprecise measurements [14]. Gupta did a study using a mobile spirometer equipped with the MPXV7002 sensor, however, the measurement only achieved a maximum of 95%. Sokol effectively developed a turbine spirometer by utilizing a measuring turbine, which demonstrated measurement errors that did not surpass 3%[15].

The aforementioned research has identified multiple unresolved concerns. An issue of significant concern is that certain instruments exhibit elevated error rates, rendering them addition, the devices have inadequate designs, being too big and needing computer usage, which makes them inefficient as assessment instruments for patients. These concerns necessitate additional enhancements in spirometer technology. The objective is to create a spirometer apparatus that effectively tackles these obstacles and delivers dependable and precise measurements. In order to establish the device as a standard reference, it is crucial to decrease the error rates and enhance the precision of the measurements. Furthermore, the ability to transmit data efficiently is essential for smooth and efficient operation. The results of this study will enhance the field of respiratory health monitoring and offer healthcare professionals a dependable instrument for detecting and treating respiratory diseases.

The author's research study seeks to tackle the stated concerns by concentrating on lung health evaluation utilizing a spirometer which is equipped with an oximeter. The main goal is to increase the examination results by integrating additional factors and employing sensors with improved precision. Through this approach, the research aims to offer more thorough and precise assessments of pulmonary function. To guarantee convenient access to the measurement results, we will employ an Internet of Things (IoT) approach [16]. This entails the creation of a mobile application that allows users to download and retrieve their findings on their personal smartphones. This technique is specifically developed to provide advantages to both consumers and healthcare professionals by simplifying the process of monitoring indications and symptoms, minimizing errors in service, and eventually decreasing healthcare expenses. The study specifically aims to analyze three crucial pulmonary function measurements: Forced Vital Capacity (FVC), Forced

Expiratory Volume in one second (FEV1), and the FEV1/FVC ratio. The objective of this research is to create an innovative and easy-to-use spirometer device that delivers precise measurements and comprehensive analysis of pulmonary function. The primary goal of this research is to enhance healthcare services and enhance patient outcomes in the field of lung health. The results of this study have the potential to enhance the progress of creating cutting-edge spirometer devices, enhancing their precision and user-friendliness for pulmonary function tests. The integration of IoT technology can profoundly transform the area and improve the accessibility of healthcare for breathing-related conditions. This research intends to utilize these breakthroughs with the goal to bring about beneficial improvements in the management and treatment of lung health, ultimately benefiting both patients and healthcare systems as a whole.

This work greatly contributes to the monitoring and diagnosis of lung health, particularly in the context of bronchial asthma disease. The primary innovation is the creation of a sophisticated spirometer device that includes an oximeter. This device enhances the accuracy of measuring important lung function indicators, such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1). Consequently, it offers a more comprehensive diagnostic device. Furthermore, the incorporation of Internet of Things (IoT) strategies, such as the creation of intelligent mobile applications for easy access to results, can enable immediate monitoring of lung health. This can also streamline communication between patients and healthcare providers, potentially minimizing mistakes in service and lowering healthcare expenses. In summary, the results of this study are anticipated to foster the progress of spirometer devices, enhancing their precision, user-friendliness, and availability for pulmonary function screening. This, in turn, aims to improve patient outcomes and facilitate healthcare in the field of respiratory health.

II. MATERIALS AND METHOD

This research was carried out as an empirical investigation. In this study, the author recommends using a spirometer to assess pulmonary function measures. The subsequent section provides a detailed description of the materials and methods used.

A. EXPERIMENTAL SETUP

The research was conducted at the Biomedical Engineering Department and the Integrated Laboratory of Poltekkes Kemenkes Surabaya. The module development utilized a pre-experimental design, specifically employing an after-only design method. The data collection technique featured a cohort of 20 participants, consisting of 13 males and 7 females. All participants were in good health, with heights ranging from 140cm to 180cm, and ages between 19 and 22 years. Every participant went through three measurement sessions. The study utilized the Cardinal Health FlowScreen brand as a spirometer for comparison purposes. The FlowScreen spirometer is renowned for its precision and dependability in assessing lung function measures. The effectiveness and performance of the experimental spirometer can be assessed by comparing its measurement findings with those acquired from the Cardinal Health FlowScreen. This comparison will yield vital data regarding the dependability and accuracy of the recently designed spirometer module.

B. DATA ACQUISITION

The variables examined in this investigation are lung function, with the primary measurements being forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and the ratio between the two (FEV1/FVC). The measurement findings will be compared to projected values, which are affected by characteristics such as age, gender, height, and race [17][18]. The identification of respiratory disorders can be established by assessing the magnitude of the first-second volume, specifically by examining the ratio of FEV1/FVC rather than relying on absolute values. An FEV1/FVC ratio below 75% shows an anomaly. In obstructive disorders such chronic bronchitis or emphysema, there is a more significant decrease in FEV1 compared to vital capacity, leading to a FEV1/FVC ratio below 75% [19].

C. DATA COLLECTION

This study involves the utilization of spirometer and oximeter devices to perform measurements. Refer to **FIGURE 1**, during the measuring process, the patient inserts their finger on the flow turbine sensor to quantify Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and the ratio of FEV1 to FVC. The sensor values are transmitted to the microcontroller, especially the ESP32 D1 Mini, and exhibited on an OLED SPI LCD screen [20][21][22]. In order to facilitate convenient access and surveillance, the data is delivered wirelessly over a WiFi connection to an Internet of Things (IoT) display. This display is a smartphone application that has been constructed using Kodular software[23]. Moreover, the data is kept securely in a MySQL database to facilitate future reference and analysis. The device is fitted with a buzzer that signifies the data collecting process, allowing for feedback to be provided. The flowchart diagram in **FIGURE 2** shows the order in which the module operates. When the device is powered on, it undergoes an initialization process. After the breathing procedure is started, the device then proceeds to monitor the flow turbine sensor. Once the FVC measurement is finished, the buzzer emits a signal to indicate its completion. At the same time, the measurement results are shown on the OLED module and sent to the application. Users can choose to store the FVC test data by pushing the specified button, which will activate a second buzzer signal. Afterwards, the device proceeds to do the second breathing process to assess FEV1. After the FEV1 measurement is

finished, the buzzer will sound again to prompt the user to store the results and show them on the OLED module. Additionally, the results will be sent to the application. The program provides the calculated ratio that is determined from the obtained measurements. Users can save the final test results to the database by clicking the "Save Final Test" button. Consult **FIGURE 3** When the application is launched, a startup procedure occurs in the initial state. The application establishes a Wi-Fi connection with the module that ensures security. Upon establishing a connection, users are immediately brought to the login screen in order to guarantee the confidentiality of their data. Users can gain access to the biodata display and data entry form by inputting the accurate login and password. In this form, they can supply their name, gender, age, and height. The "New" button permits respondents to input their data, facilitating the computation of the anticipated lung function value. Once users have finished entering the data, they can press the

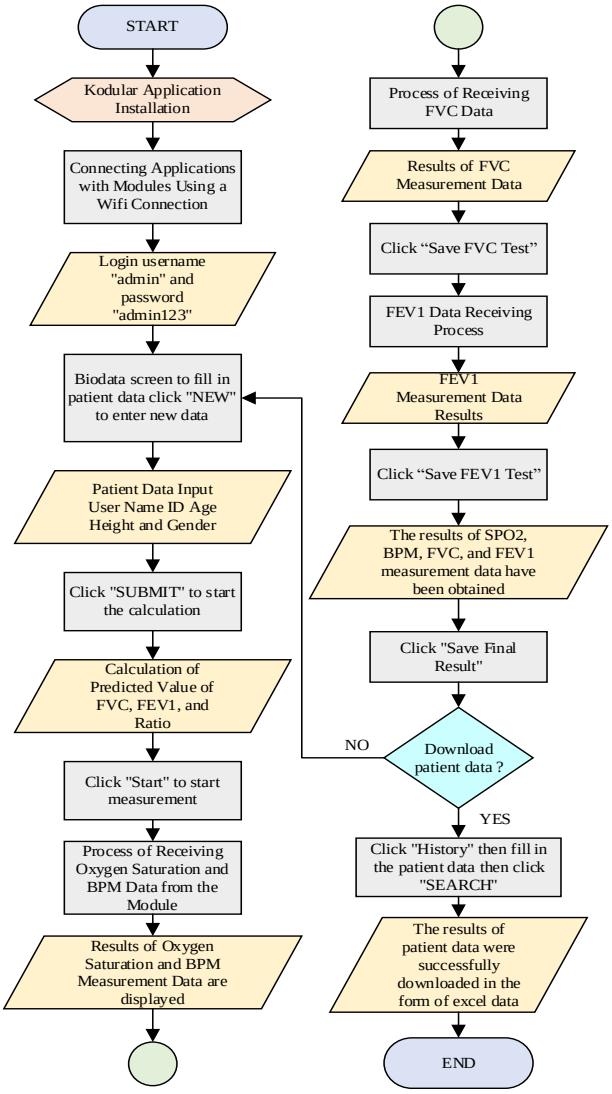

FIGURE 3. The system flowchart of android application

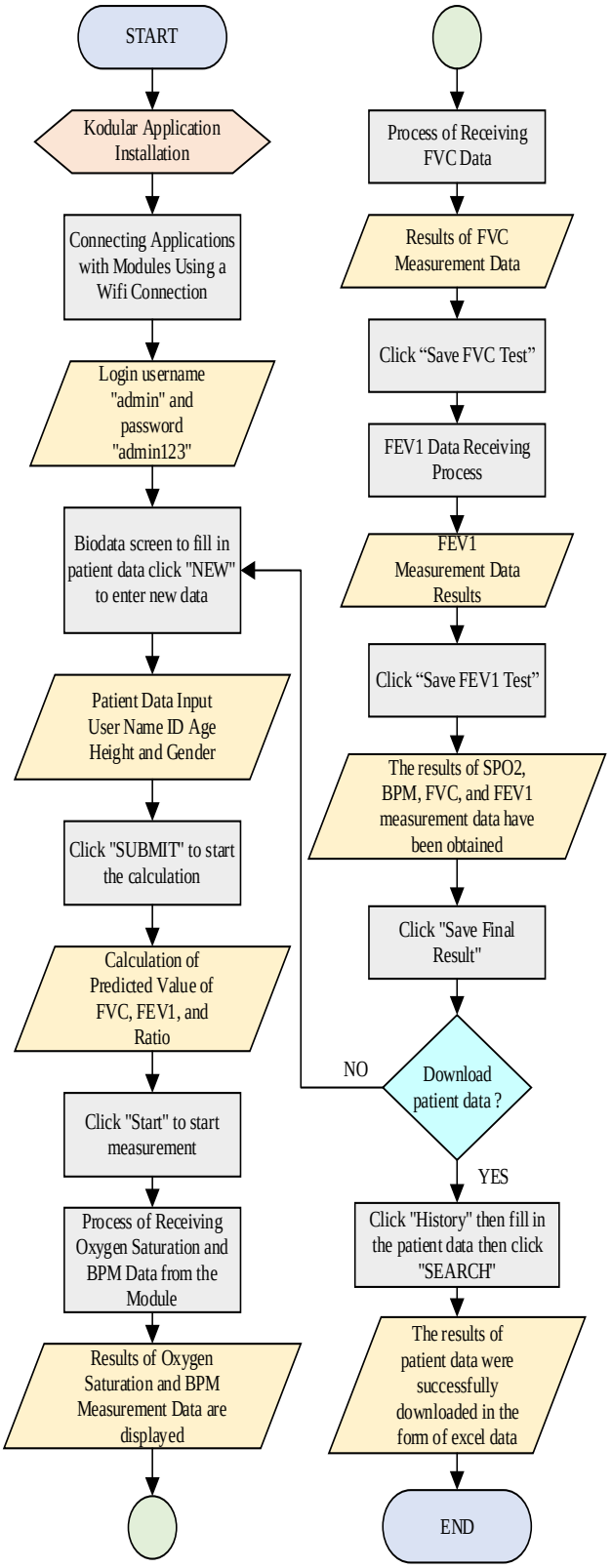

FIGURE 2. The system flowchart of box module

"Submit" button to calculate the anticipated result. Initiating the parameter measurement process begins by pressing the "Start" button. This process begins with measuring oxygen saturation, and then proceeds to gather Forced Vital Capacity (FVC) data. Users have the ability to preserve the FVC measurement findings by simply pressing the "Save FVC Test" button. Next, the application proceeds to collect data on the Forced Expiratory Volume in one second (FEV1). After finishing, users have the option to save the FEV1 results by clicking the "Save FEV1 Test" button. By clicking the "Save Final Results" button, all the measurements are stored in the database. Users can download their data by selecting the "History" button, inputting their user ID acquired during data entry, and accessing their measurement results. By clicking on the "Download" button, users can initiate the process of acquiring the measurement file. In the absence of a user ID, the application will redirect back to the data entry screen.

D. DATA ANALYSIS

Three measurements are taken for each parameter: FVC, FEV1, and Ratio. By utilizing equation (1), we may determine the mean or average measurement value. The average is determined by dividing the sum of all data points by the total count of values. The formula (1) calculates the average value of a set of numbers by summing them up and dividing the sum by the total number of values.

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$$\overline{x} = \frac{x1+x2\ldots+xn}{n} \quad (1)$$

Let x denote the average value for a set of n measurements. The measurements in this set are represented as x1, x2, and xn, where x1 refers to the first measurement, x2 to the second, and xn to the nth measurement. The standard deviation is a statistical measure that quantifies the spread of a dataset or predicts the spread of the average value. The formula used to compute the standard deviation (SD) is as follows: (2).

$$\mathrm{SD} = \sqrt{\frac{\sum(xi-\overline{x})^2}{(n-1)}} \quad (2)$$

Within this particular framework, the symbol "xi" denotes the quantity of desired values, "x" signifies the average of the measurement results, and "n" represents the total number of measurements. An "error" refers to a malfunction or failure occurring within a system. The lower error value indicates the average difference between each data point. Mistakes can function as evidence of disparities between the standard and the idea or archetype. The error formula is represented by equation (3).

$$\%\mathrm{ERROR} = \frac{(x_n-\mathrm{x})}{x_n} \times 100\% \quad (3)$$

The variable xn denotes the calibrated measurement value of the machine. The monetary value of the design, represented as X. The Lost Data function is intended to assess the module's capacity to communicate data to the application. The formula for the lost data is represented by equation (4).

$$\%\mathrm{LOST\ DATA} = \frac{\mathrm{x}}{x_n} \times 100\% \quad (4)$$

Let xn denote the measured value of the module box. X represents the numerical value that quantifies the android application.

III. RESULT

In this study, the module has been tested using a Cardinal Health FlowScreen brand as a comparative standart spirometer. Consult **FIGURE 4** The graphic depicts the results of the implemented module. The front exterior is equipped with an OLED LCD panel and a specifically designed space for the MAX30102 sensor, which is utilized for the measurement of SPO2 (blood oxygen saturation) and BPM (heart rate in beats per minute). Located at the rear, there is a cover that encloses the battery. Furthermore, there are two apertures or conduits available for the purpose of measuring the flow turbine sensor. The left side functions as the inlet for air, located in close proximity to the patient's or respondent's mouth, while the right side functions as the outlet for air. The input funnel will be fitted with a disposable mouthpiece to ensure precise measurements. The module comprises the Arduino Pro Mini and D1 Mini ESP32 microcontroller circuits internally[24]. The device also includes the flow turbine sensor for measuring lung function, the MAX30102 sensor for measuring SPO2 and BPM, a Buzzer circuit for indicating, and a battery circuit for power supply. **FIGURE 5** showcases the utilization of the Kodular website for developing this application. The website provides a user-friendly interface that allows the creation of Android applications using a drag-and-drop block programming concept [25]. The application utilizes a resilient MySQL database and is appropriately dubbed Smart SpirOxi. xxx

According to the data in **TABLE 1**, the entire computation indicates an error value of around ± 8.7% between the module and the reference device. This suggests that the FVC readings from the module are quite accurate in comparison to the reference device. In addition, the evaluation of data loss between the module and the data transmitted to the Android application shows an extremely low value of around ± 0.00%, indicating the very dependable transmission of FVC measurement data from the module to the application. **FIGURE 6** displays the FVC measurements obtained from 20 participants utilizing the module, the reference device, and the data shown in the application. Through the analysis of the mean data, we may detect discrepancies in the measured

values collected from the module, the reference device, and the data sent to the application. Xxx

FIGURE 5. Final Design of Android Application Spirometry with Oximeter IoT

TABLE 1
Overall Average Result of FVC

RESPONDENT	AVERAGE FVC (L/S				
	STANDARD COMPARISON	BOX MODULE	ANDROID APPLICATION	ERROR	LOST DATA
1	2.9±0.04l/s	2.4±0.14 l/s	2.4±0.14 l/s	19.3 %	0.0 %
2	2.0±0.23l/s	2.0±0.41 l/s	2.0±0.41 l/s	-1.0 %	0.0 %
3	2.1±0.30l/s	2.0±0.28 l/s	2.0±0.28 l/s	6.0 %	0.0 %
4	2.5±0.35 l/s	2.4±0.34 l/s	2.4±0.34 l/s	3.6 %	0.0 %
5	2.8±0.33 l/s	2.1±0.14 l/s	2.1±0.14 l/s	25.2 %	0.0 %
6	2.6±0.28 l/s	1.9±0.17 l/s	1.9±0.17 l/s	27.4 %	0.0 %
7	2.9±0.44 l/s	2.0±0.30 l/s	2.0±0.30 l/s	30.5 %	0.0 %
8	2.4±0.36 l/s	2.3±0.07 l/s	2.3±0.07 l/s	4.6 %	0.0 %
9	2.5±0.31 l/s	1.7±0.37 l/s	1.7±0.37 l/s	30.2 %	0.0 %
10	2.3±0.15 l/s	1.4±0.23 l/s	1.4±0.23 l/s	39.1 %	0.0 %
11	3.2±0.38 l/s	1.9±0.32 l/s	1.9±0.32 l/s	42.2 %	0.0 %
12	1.5±0.44 l/s	1.6±0.11 l/s	1.6±0.11 l/s	-12.8 %	0.0 %
13	1.6±0.16 l/s	1.9±0.49 l/s	1.9±0.49 l/s	-13.3 %	0.0 %
14	1.7±0.01 l/s	1.8±0.44 l/s	1.8±0.44 l/s	-3.8 %	0.0 %
15	1.6±0.08 l/s	2.2±0.11 l/s	2.2±0.11 l/s	-40.3 %	0.0 %
16	2.3±0.30 l/s	1.9±0.13 l/s	1.9±0.13 l/s	18.7 %	0.0 %
17	3.1±0.85 l/s	2.5±0.51 l/s	2.5±0.51 l/s	19.1 %	0.0 %
18	1.6±0.13 l/s	1.2±0.26 l/s	1.2±0.26 l/s	21.6 %	0.0 %
19	1.4±0.10 l/s	2.1±0.28 l/s	2.1±0.28 l/s	-47.3 %	0.0 %
20	2.0±0.20 l/s	1.9±0.29 l/s	1.9±0.29 l/s	5.6 %	0.0 %
OVERALL DATA				**±8.7 %**	**±0.0 %**

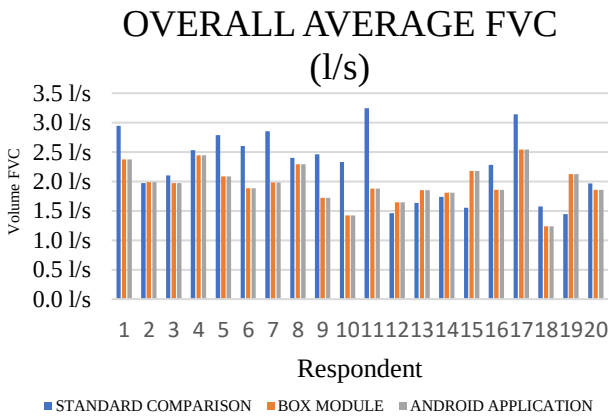

FIGURE 6. The Graph of the Overall Average Result FVC

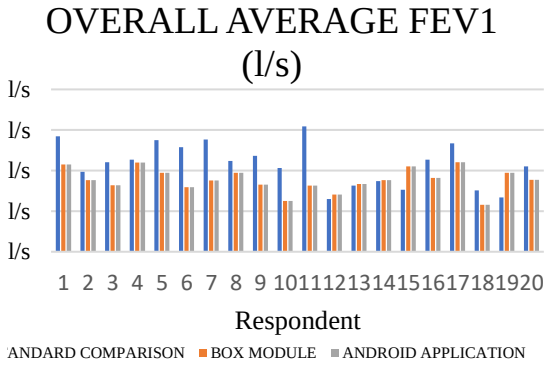

FIGURE 7. The Graph of the Overall Average Result FEV1

FIGURE 4. Final Design of Module Spirometry with Oximeter IoT

TABLE 2 shows that the error value between the module and the reference device is around ± 14.0%. This indicates that the FEV1 measurement from the module is less accurate compared to the reference device. However, the computation of the data loss between the module and the transferred data to the Android application reveals a value of around ± 0.00%, suggesting that the transmission of FEV1 measurement data from the module to the application is extremely trustworthy. According to **FIGURE 7**, the FEV1 measurements were collected from 20 participants utilizing the module, the reference device, and the data shown in the application. Through the analysis of the mean data, we can detect discrepancies in the measured values acquired from the module, the reference device, and the data sent to the application.

TABLE 3 shows the error value between the module and the reference device, which is around ± 4.6%. This indicates that the FEV1/FVC measurement from the module is reasonably accurate compared to the reference device. Furthermore, the computation of the data loss rate between the module and the data sent to the Android application results in a value of roughly ± 0.00%, suggesting that the transmission of FEV1/FVC measurement data from the module to the application is quite dependable.

TABLE 2
Overall Average Result of FEV1

RESPONDENT	AVERAGE FEV1 (L/S)				
	STANDARD COMPARISON	BOX MODULE	ANDROID APPLICATION	ERROR	LOSS DATA
1	2.8±0.06 l/s	2.1±0.08 l/s	2.1±0.08 l/s	±24.5 %	±0.0 %
2	1.9±0.23 l/s	1.7±0.36 l/s	1.7±0.36 l/s	±10.3 %	±0.0 %
3	2.2±0.40 l/s	1.6±0.39 l/s	1.6±0.39 l/s	±25.7 %	±0.0 %
4	2.2±0.40 l/s	2.1±0.39 l/s	2.1±0.39 l/s	±3.1 %	±0.0 %
5	2.7±031 l/s	1.9±0.12 l/s	1.9±0.12 l/s	±29.3 %	±0.0 %
6	2.5±0.26 l/s	1.5±0.26 l/s	1.5±0.26 l/s	±38.2 %	±0.0 %
7	2.7±0.42 l/s	1.7±0.48 l/s	1.7±0.48 l/s	±36.5 %	±0.0 %
8	2.2±0.32 l/s	1.9±0.26 l/s	1.9±0.26 l/s	±12.8 %	±0.0 %
9	2.3±0.40 l/s	1.6±0.31 l/s	1.6±0.31 l/s	±30.1 %	±0.0 %
10	2.0±0.21 l/s	1.2±0.13 l/s	1.2±0.13 l/s	±39.4 %	±0.0 %
11	3.0±0.45 l/s	1.6±0.33 l/s	1.6±0.33 l/s	±47.3 %	±0.0 %
12	1.3±0.38 l/s	1.4±0.27 l/s	1.4±0.27 l/s	±8.2 %	±0.0 %
13	1.6±0.16 l/s	1.6±0.27 l/s	1.6±0.27 l/s	±2.2 %	±0.0 %
14	1.7±0.01 l/s	1.7±0.36 l/s	1.7±0.36 l/s	±1.1 %	±0.0 %
15	1.5±0.08 l/s	2.1 ±0.22 l/s	2.1 ±0.22l/s	±37.3 %	±0.0 %
16	2.2±0.29 l/s	1.8±0.44 l/s	1.8±0.44 l/s	±19.8 %	±0.0 %
17	2.6±0.91 l/s	2.2±0.60 l/s	2.2±0.60 l/s	±17.5 %	±0.0 %
18	1.5±0.10 l/s	1.1±0.16 l/s	1.1±0.16 l/s	±23.2 %	±0.0 %
19	1.3±0.04 l/s	1.9±0.23 l/s	1.9±0.23 l/s	±45.0 %	±0.0 %
20	2.1±0.23 l/s	1.7±0.32 l/s	1.7±0.32 l/s	±15.7 %	±0.0 %
OVERALL DATA				**±14.0 %**	**±0.0%**

TABLE 3
Overall Average Result of Ratio FEV1/FVC

RESPONDENT	AVERAGE FEV1 / FVC				
	STANDARD COMPARISON	BOX MODULE	ANDROID APPLICATION	ERROR	LOST DATA
1	96.3±2.52 %	89.7±7.79 %	89.7±7.79 %	±6.8 %	±0.0 %
2	100±0.00 %	89.1±10.27 %	89.1±10.27 %	±10.9 %	±0.0 %
3	97±4.36 %	81.9±11.69 %	81.9±11.69 %	±15.5 %	±0.0 %
4	88.6±4.73 %	89.5±4.11 %	89.5±4.11 %	±1.0 %	±0.0 %
5	99.6±0.58 %	94.5±1.43 %	94.5±1.43 %	±5.2 %	±0.0 %
6	99.3±0.58 %	84.5±13.81 %	84.5±13.81 %	±14.9 %	±0.0 %
7	96.4±3.08 %	87.6±9.98 %	87.6±9.98 %	±9.1 %	±0.0 %
8	89±4.36 %	92.7±25.49 %	92.7±25.49%	±4.3 %	±0.0 %
9	96.5±2.29 %	88±2.08 %	88±2.08 %	±8.8 %	±0.0 %
10	90.6±4.04 %	88.8±6.16 %	88.8±6.1 %	±2.0 %	±0.0 %
11	93.2±5.84 %	86.4±5.54 %	86.4±5.54 %	±7.2 %	±0.0 %
12	91.3±8.41 %	85±14.48 %	85±14.48 %	±6.9 %	±0.0 %
13	100±0.00 %	95.5±36.51 %	95.5±36.51 %	±4.5 %	±0.0 %
14	100±0.00 %	97.6±2.07 %	97.6±2.07 %	±2.3 %	±0.0 %
15	98.6±0.15 %	97.5±1.23 %	97.5±1.23 %	±1.1 %	±0.0 %
16	99.3±1.10 %	99.2±30.24 %	99.2±30.24 %	±0.1 %	±0.0 %
17	83.7±7.42 %	86.7±7.17 %	86.7±7.17 %	±3.5 %	±0.0 %
18	96±1.65 %	95±4.86 %	95±4.86 %	±1.0 %	±0.0 %
19	93.0±4.01 %	91.7±2.19 %	91.7±2.19 %	±1.5 %	±0.0 %
20	96.8±3.48 %	94.7±2.49 %	94.7±2.49 %	±2.2 %	±0.0 %
OVERALL DATA				**±4.6 %**	**±0.0 %**

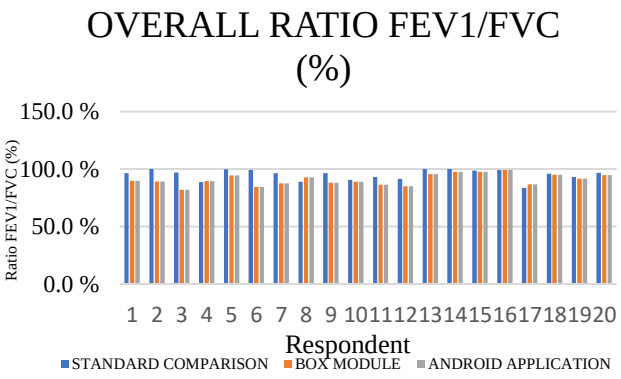

FIGURE 8. The Graph of the Overall Average Result Ratio FEV1/FVC

In **FIGURE 8** The FEV1/FVC ratio was measured in 20 participants using the module, the reference device, and the data was shown in the application. Through the analysis of the mean data, we can detect discrepancies in the measured values acquired from the module, the reference device, and the data sent to the application.

IV. DISCUSSION

The FVC measurements were performed three times on each of the 20 respondents, resulting in an average data value of 2.01 L/s from the module. When compared to the average data obtained from the reference device, which was 2.31 L/s, the average error value was approximately ±8.7%. This difference could be attributed to variations in individuals' breath exhalation or a decline in exhalation quality due to repeated measurements. Ineffective data collection methods and less precise sensor readings could also have an impact. As for the comparison between the data sent by the module, averaging 2.01 L/s, and the data received by the application, averaging 2.01 L/s, there was no data loss during transmission, as indicated by an average lost data value of ±0.0%. However, the error value exceeds the tolerance level suggests that the flow turbine sensor is currently unable to reliably measure FVC. The FEV1 measurements were performed three times on each of the 20 participants. The

mean data value acquired from the module was 1.85 liters per second, whereas the mean data value from the reference device was 2.26 liters per second. The comparison yielded an average error value of around ±14.0%. The discrepancy observed in the FVC measurements can be ascribed to inter-individual variability in breath exhalation and a deterioration in exhalation quality resulting from repeated observations. It may also be affected by less precise sensor readings and incorrect data collection methods. Regarding the comparison of the data transmitted by the module, which has an average rate of 1.85 L/s, and the data received by the application, which also has an average rate of 1.85 L/s, there was no loss of data throughout the transmission. This is evidenced by an average value of lost data of ±0.0%. Nevertheless, if the error value beyond the tolerance threshold, it suggests that the flow turbine sensor is still incapable of precisely detecting FEV1. Regarding the FEV1/FVC ratio measurements made on the 20 respondents, three times for each respondent, the average data value acquired from the module was 90.9%. The average error value, roughly ±4.6%, was derived by comparing it to the average data value of 95.3% from the reference device. Like the previous observations, differences in individuals' exhaled breath, a decrease in the quality of exhalation caused by repeated tests, less precise sensor readings, and poor methodology for collecting data could all contribute to this discrepancy. Regarding the comparison of data supplied by the module, which has an average of 90.9%, and the data received by the application, which also has an average of 90.9%, there was no loss of data during transmission. This is indicated by an average lost data value of ±0.0%. Nevertheless, the error figure, which remains within the acceptable level of less than 5%, suggests that the flow turbine sensor is capable of reliably measuring FEV1/FVC. This pertains to the analysis of lung function using the accurately measured FEV1/FVC ratio.

Compared to previous research, this method offers distinct benefits in the precise distribution of applications. Prior research has indicated that numerous studies encountered inaccuracies in the measuring process, namely in the transmission of error values from modules to applications. Consequently, these inaccuracies compromised the effectiveness of obtaining error readings for the results. Furthermore, the tools produced are equipped with comprehensive parameters for measuring lung function, including FVC, FEV1, and Ratio, ensuring a thorough and precise assessment for examination purposes. The tool is meant to be portable and cordless, making it convenient and easily transportable. Furthermore, this device is equipped with an integrated oxygen level check, which serves as an extra parameter to enhance the diagnostic evaluation. This module is limited in terms of its device display. The device's screen exclusively displays numerical results, without incorporating graphs, so limiting the capacity for conducting additional analysis. Another constraint is the connectivity of the device, as a reliable connection is important for precise readings. Furthermore, the sensor demonstrates reduced precision when sensing exhalations of breath.

The findings of this study reveal several notable weaknesses that could impact the validity and reliability of its conclusions. Firstly, the inadequacy of the sample size, with only 20 participants, poses a significant limitation. Increasing the sample size would enhance the generalizability of the findings to a larger population. Additionally, the diversity among respondents introduces another challenge, potentially diminishing the relevance and applicability of the results to a broader demographic. Homogenizing the respondent pool could yield more dependable outcomes. Moreover, the repetition of measurements on the same individuals raises concerns about the reliability of the data, as factors like fatigue or changes in breathing patterns may have influenced the results. Furthermore, while data transmission between modules and applications remained intact, discrepancies between measured values and reference devices suggest potential issues with data accuracy or interpretation. Methodological shortcomings, particularly in data collection techniques, also undermine the study's robustness. Overall, while this study endeavors to evaluate lung function using flow turbine sensors, these limitations underscore the need for further refinement in methodology and consideration of potential sources of error to strengthen the reliability and accuracy of its conclusions. Subsequent research efforts could focus on refining techniques and addressing these limitations to bolster the validity of findings. However, it is important to acknowledge that the module developed in this study has certain limitations and imperfections. These limitations encompass aspects such as planning, manufacturing, and the overall functionality of the module. In order to overcome these shortcomings, several improvements have been identified. Firstly, incorporating graphical or signal displays would greatly enhance the visualization of data, allowing for better analysis and interpretation. Secondly, utilizing more accurate sensors would improve the measurement accuracy and reduce error rates, leading to more reliable results. Finally, enhancing the design of the device would focus on improving usability and overall performance. By addressing these areas of improvement, it is expected that the module's limitations can be mitigated, and the accuracy and usability of the system can be significantly enhanced. Future iterations of the module should aim to implement these improvements in order to achieve more accurate and reliable measurements of lung function parameters through IoT technology.

There are many strengths of this study compared to previous studies that have the same purpose in monitoring/measuring lung function using flow turbine sensors. The study carried out a comprehensive measurement where FVC and FEV1 measurements were performed three times in each of the 20 respondents, thus providing a strong set of data for analysis. Furthermore, the accuracy of this study increases the reliability of the findings where in the transmission of data between modules and

applications, no data is missing, indicating a reliable data transfer process. This ensures the completeness of data sets and minimizes potential bias. Furthermore, this study has a detailed error analysis, namely this study carefully examines the error values, giving insight into the accuracy and limitations of the flow turbine sensor. The depth of this analysis allows researchers to identify areas for improvement and refinement of measurement techniques. In addition to the tolerance threshold for error values, this study establishes a clear benchmark for evaluating sensor performance. It helps researchers assess the reliability of measurements and interpret the significance of differences. The following is the reliability of the FEV1/FVC ratio: this study found that the flow turbine sensor reliably measured the ratio of FEV1/VVC within an acceptable error margin. It underscores the ability of sensors to evaluate lung function accurately, in determining air flow obstruction. Furthermore, accurate measurement of the FEV1/FVC ratio has clinical significance in diagnosing respiratory conditions such as chronic obstructive pulmonary disease (COPD) and bronchial asthma. The findings of this research provide valuable insights for healthcare professionals, helping in accurate diagnosis and treatment planning. Flow turbine sensors in assessing lung function, enhance our understanding of respiratory health and inform future research as well as clinical practice. The module's technology is designed to analyze FVC, FEV1, and the FEV1/FVC ratio, offering a thorough evaluation of lung function. The expected result of this research is the gradual integration of spirometers that are equipped with Internet of Things (IoT) capabilities. This will allow for easy monitoring and measuring from various places. In addition, the module's portable form provides an extra level of convenience, making it easier to conduct future examinations and improving access to pulmonary assessments.

This research has some relevant implications for the public, including that the results highlight the importance of monitoring respiratory health, especially in detecting lung diseases such as asthma or chronic obstructive lung disease. (PPOK). This study shows that there is a challenge in ensuring the accuracy of the measurement. The results of this research could encourage further researchers to continue to improve and improve the technology of spirometers. By improving the accuracy of sensors and data collection methods, we can ensure that these medical devices deliver more reliable results for patients and health professionals. Another implication of this study is that it obtained information about individual variability in the measurement of lung function. Everyone has a unique breathing pattern, and awareness of these differences can help in interpreting test results and ensuring appropriate treatment. Implications of this study provide knowledge and information to patients and the public about the importance of lung function tests and how to prepare yourself before tests can help improve the quality of measurements. More informed patients are more likely to collaborate with medical personnel in obtaining accurate test results. And most importantly, the public can better understand the importance of monitoring respiratory health, as well as supporting the development of better medical technology to improve lung disease diagnosis and management.

V. CONCLUSION

The objective of this study was to examine various lung function parameters, specifically the FVC, FEV1, and the FEV1/FVC ratio, using Internet of Things (IoT) technology. Research has been successfully made and tested with standard calibrators, performance and delivery test results are quite good. The average error values obtained for these measurements were found to be approximately ±8.7% for FVC, ±14.0% for FEV1, and ±4.6% for the FEV1/FVC ratio. Similarly, the average values of lost data for these measurements were approximately ±0.0%. This indicates that there was minimal data loss during the measurements of FVC, FEV1, and the FEV1/FVC ratio. Future research could improve techniques and take into account possible causes of error to strengthen the research conclusions.

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