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# Development of Heart Rate and Oxygen Saturation Measurement Device using MAX30100 Sensor based on Internet of Things (IoT) for Monitoring Fitness

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**ABSTRACT**

The heart is an organ that circulates blood throughout the body. Heart health can be measured through cardiac parameters such as BPM and blood oxygen saturation ($SpO_2$). Public busyness has become an obstacle in monitoring health status. This condition prompted researchers to collect data, analyze it, design the device, and conduct accuracy tests on the sensors used in the designed system. This system is designed to provide health information to users by providing real-time access to data at their fingertips during exercise. The devices used include the MAX30100 sensor which detects heart rate and the NodeMCU ESP8266 module which connects the system to the cloud (IoT), as well as a smartphone that displays data accuracy results through Blynk. The displayed data is then identified.

**Keywords:**
Heart Rate, Oxygen Saturation, MAX30100 Sensor, Blynk.

## Introduction

The development of electronic technology has rapidly advanced, extending into the field of medical electronics. Medical electronics are created for various purposes including monitoring instruments, diagnostic instruments, therapeutic instruments, and assistive devices (Wiratama et al., 2014). Diagnostic devices are used to collect patients' medical history and record data through test tubes. An example of a monitoring device is one that measures oxygen saturation point ($SpO_2$). The oxygen saturation ($SpO_2$) device is a technique that uses equipment to measure oxygen levels in a patient's blood (arterial) and assists in physical examination of patients without requiring blood analysis (Putra et al., 2006).

The normal range for $SpO_2$ is 95% to 100%, while abnormal condition values are < 95% (Handoko, 2022). The human body requires sufficient oxygen to support every cell in the body. Oxygen concentration in the blood, known as oxygen saturation, indicates the amount of oxygen available for distribution throughout the body (Fauzan et al., 2023). If oxygen saturation drops below the normal limit, the function of organs and tubular tissues can be disrupted, potentially causing organ failure and tissue damage (John, 2013).

The heart is one of the most important organs in humans due to its ability to apply strong pressure to various parts of the body (Hindarto et al., 2015). This blood contains minerals and provides nutrients needed by the body. Disruptions in heart performance can interfere with secondary organ function (Muhajirin & Ashari, 2018). Heart rate can be used as a parameter to determine health status (Anugrah, 2016).

According to the World Heart Federation in Southeast Asia, in 2014, 1,800 people died from heart disease. In Indonesia, 0.5% of the population is diagnosed with heart disease, with a mortality rate approaching 45%. This figure is equivalent to 0.5% of Indonesia's population, or approximately 1.25 million people if Indonesia's population is 250 million. Coronary heart disease is the leading cause of death in Indonesia. Fatal heart attacks are often caused by coronary artery disease, a condition in which coronary artery tissue deteriorates due to external environmental exposure. Coronary artery damage occurs due to the accumulation of protein and cholesterol from consumed food, which causes artery hardening. Heart disease does not discriminate by age and can affect anyone, especially those with a history of the disease (Kemenkes, 2017).

Pulse oximetry is a device used to measure oxygen levels in the blood without inserting any device into the body. In measurements using pulse oximetry, the oxygen level in the blood is denoted by $SpO_2$ and the measurement results are displayed as a percentage (Sunarto, 2024). However, most pulse oximetry devices currently used only display results during the measurement period. Devices used to measure oxygen levels in blood can be attached to the body. When measured with a pulse oximeter, the oxygen saturation value is given by $SpO_2$ and the results are reported as a percentage. However, most pulse oximetry techniques currently used only report results during peak performance (Davis, 2024).

Under certain conditions, oxygen levels in the blood may decrease or reduce; in such cases, a pulse oximetry device that can monitor blood oxygen levels in real-time is needed. This allows someone experiencing decreased blood oxygen levels to immediately receive appropriate assistance according to their indication. The importance of early detection of decreasing blood oxygen content is that if left untreated, even for just three minutes, it can cause brain damage and heart failure (Harianto et al., 2021). Research has been conducted on heart rate and oxygen saturation monitoring systems using the MAX30100 sensor with Node-Red application based on Internet of Things (2023), finding measurement results of the WiFi pulse oximeter device compared with an oximeter device as a comparison tool, with heart rate measurement results around 97% and $SpO_2$ around 98%. Other research using the PPG Reflectance Method on the MAX30100 sensor (2019) found results using this method with a response time of 5 seconds, achieving accuracy of 96% compared to the previously given oximeter device accuracy of 95.2, monitored using bluetooth with a maximum range of 140 meters. Other research in (2020) measuring non-invasive oxygen levels using MAX30100 in ages 20-53 years in relaxed or stationary conditions obtained varied oxygen level results between 93%-98%. Other research in (2021) using the MAX30100 sensor, Arduino interface, and processing software to display SpO2 values and IP and Red graphs obtained device deviation <10% and accuracy value >90%. Other research in (2021) on the use of MAX30100 sensor based on IoT Blynk obtained data accuracy of 96.2% for heart rate and 98.43% for $SpO_2$.

Heart rate or pulse is an important indication in the health field that serves as an effective and quick evaluation material to determine a person's body health. The pulse rate measurement method is commonly used by doctors to determine someone's heart health condition. Based on the above description, the researcher wishes to conduct research to inform heart rate data per minute and blood oxygen levels ($SpO_2$) from the MAX30100 pulse oximeter sensor based on IoT (Internet of Things) so that it can facilitate monitoring fitness or users monitoring heart rate data and blood oxygen levels from a distance. This device is designed to display pulse data in real-time and continuously to determine heart working conditions. The sensor used in this research is the MAX30100 pulse oximeter which functions to monitor heart rate frequency and oxygen levels in blood flowing through the fingertip. The distinctive feature of the device designed in this research is that we can connect this device to the Blynk Android application which will record and regularly update data for $SpO_2$ and BPM on the internet.

## Methods

*Tools and Materials*

*MAX30100 Sensor*

The MAX30100 sensor (Figure 1) is a device that integrates pulse oximetry, heart rate signal monitoring, and blood oxygen content monitoring. This device has 2 LEDs and 1 photodiode and operates with 1.8V and 3.5V power supply and can be turned off via software with negligible standby current, thus allowing the power supply to remain connected at all times. For measuring oxygen levels in the blood, the oximeter works by utilizing the natural pulse of blood flow in arteries and the property of hemoglobin that can absorb light. Infrared light will be absorbed more by hemoglobin that is richer in oxygen, while red light will be absorbed by hemoglobin that does not have oxygen. The detected values are then used to determine the amount of oxygen in the blood. Several features of the MAX30100

Pulse Oximeter Sensor are its ability to consume very low power (operating from 1.8V and 3.5V), ultra-low shutdown current (0.7µA seconds), and fast data output capability.


**Figure 1.** MAX30100 Sensor

*NodeMCU ESP8266*
NodeMCU is an Internet of Things (IoT) product development board based on eLua Firmware and ESP8266-12E System on Chip (SoC). ESP8266 itself is a WiFi chip with a complete TCP/IP protocol stack (Figure 2). The author chose NodeMCU ESP8266 because it is easy to program and has adequate I/O pins and can access the Internet network to send or retrieve data via WiFi connection (Rahadiansyah et al., 2021).

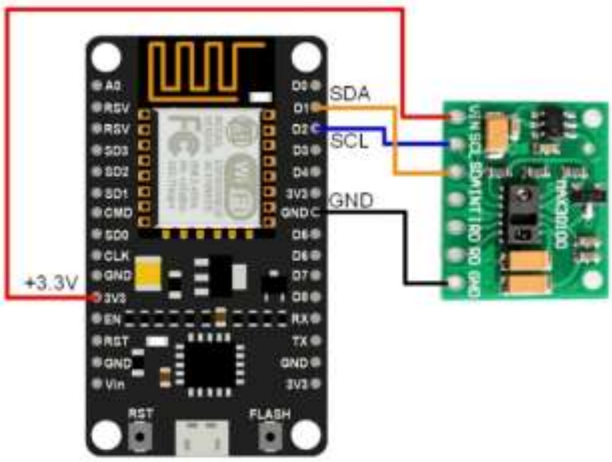



**Figure 2.** Circuit diagram of how to use MAX30100 sensor for BPM and $SpO_2$ measurement

*Arduino IDE*
IDE stands for Integrated Development Environment. Arduino IDE (Figure 3) is a programming application for Arduino and NodeMCU devices so that these devices can perform their functions as expected. Arduino uses its own programming language that resembles C language. The Arduino IDE application also has a collection of example programs located in the library so that beginners can easily program (Rahman et al., 2020).

*Blynk Application*
Blynk is an IoT application with a Mobile OS platform (iOS and Android) for controlling WEMOS D1, Raspberry Pi, ESP8266, Arduino, and similar modules via the internet. Blynk is a creative platform for creating graphical interfaces for projects to be implemented using the drag and drop widget method.

Remote control can be done using the Blynk application platform, wherever we are and at any time as long as connected to the internet with a stable connection. Blynk is not tied to specific boards or modules (Harir et al., 2019).

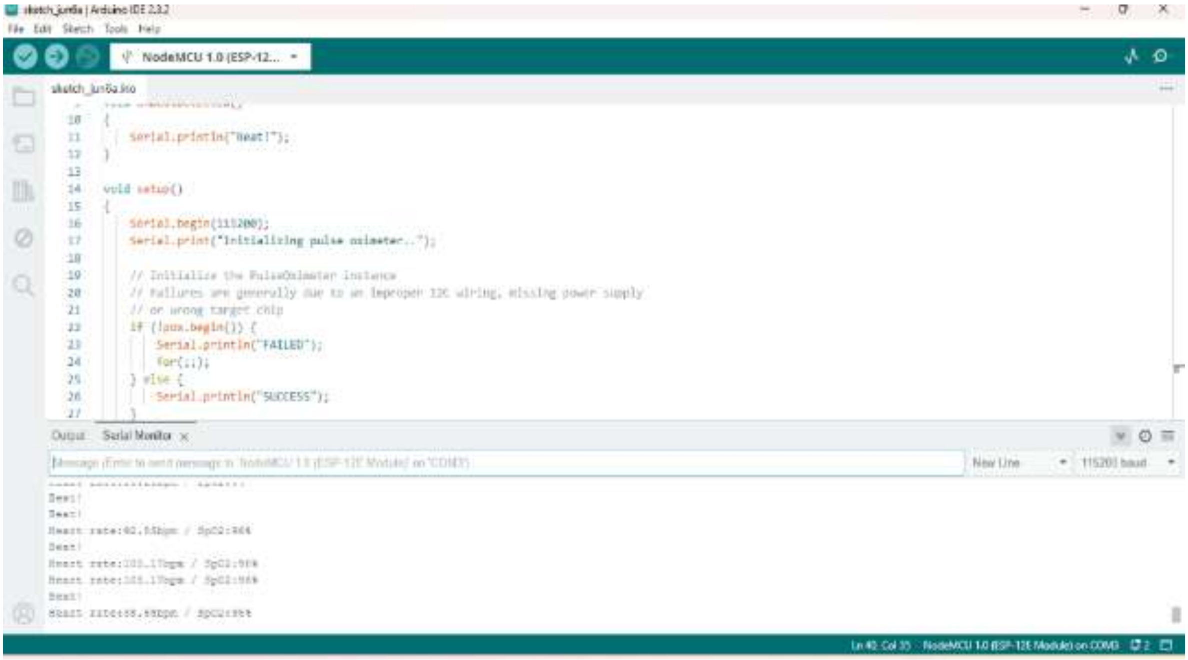



**Figure 3.** Arduino IDE Display

*Research Methodology*

The research method used in this study is the design and construction of an IoT Blynk-Based Heart Rate Detection System that begins with a literature study. The system design in this research uses two processing stages. In the initial processing, researchers design hardware, and then continue with the software design process as shown in the system block diagram shown in Figure 4. After realizing the design, the next step is testing the designed device by observing the reading results on the MAX30100 sensor used in the designed system through the user's smartphone that has been installed with the Blynk application. Heart rate measurements are also taken from Pulse Oximeter readings for reference value data collection. If the device does not work well, improvements are made; if the device already works well, data analysis is performed.

The data obtained is compared with the conventional Pulse Oximeter device with the device designed by the researcher. Next, the accuracy level of the designed system is assessed, where the system accuracy value is taken from the average value of 100% minus the percentage difference in reading values on the designed system against the Pulse Oximeter reading results (reference value). This is done for heart rate (BPM) and blood oxygen saturation ($SpO_2$) measurements. After all data results are collected and accuracy has been tested and compared, conclusions are drawn and completed.

To obtain the percentage error value using the formula as in the following equation:

$$Error = \frac{\text{BPM from researcher's device} - \text{BPM from pulse oximeter}}{\text{BPM from pulse oximeter}} \times 100\% \quad (1)$$

After that, to obtain the accuracy percentage value = 100% - error percentage.

To obtain the percentage error value using the formula as in the following equation:

$$Error = \frac{SpO_2 \text{ from researcher's device} - SpO_2 \text{ from pulse oximeter}}{SpO_2 \text{ from pulse oximeter}} \times 100\% \quad (2)$$

After that, to obtain the accuracy percentage value = 100% - error percentage.

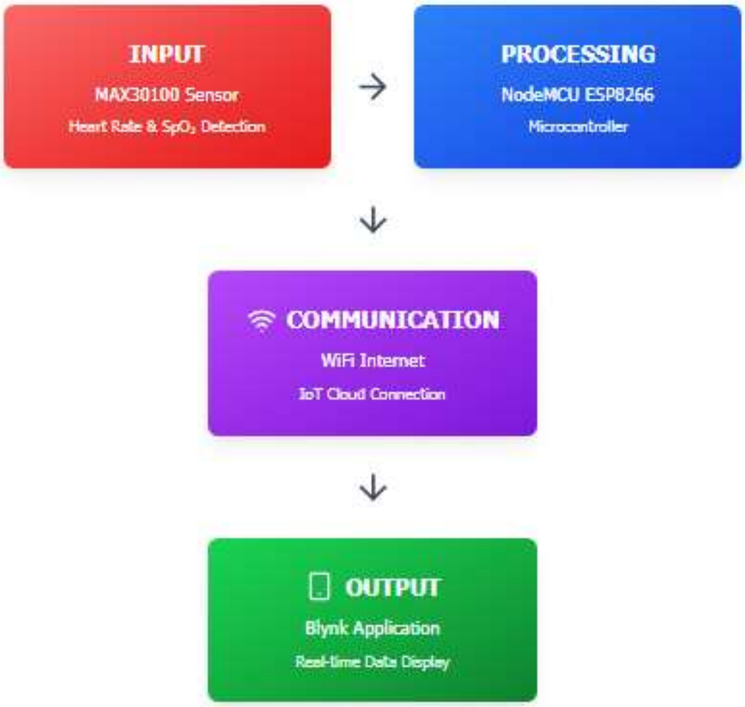



**Figure 4.** Block diagram of IoT Blynk-based heart rate detection system

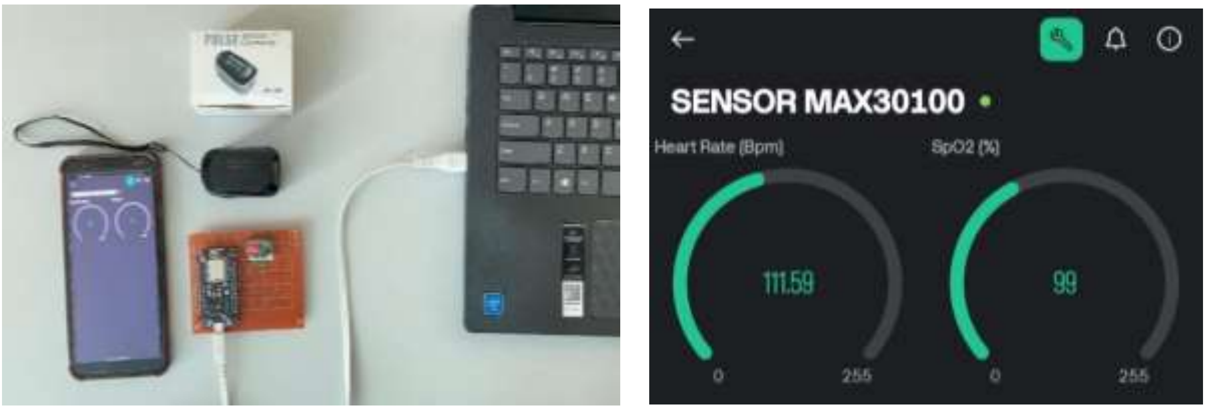
## Results and Discussions

*Research Results*

The IoT Blynk-Based Heart Rate Measurement Device that has been successfully created by the Researcher is shown in Figure 5. The equipment that has been assembled is placed on a circuit board with the layout on the left side being the ESP8266 and on the right side the MAX30100 sensor.

*Device Testing Results*

The designed IoT Blynk-Based Heart Rate Measurement Device is then tested to analyze the accuracy level of the data reading it produces. For reference values, researchers used the A2-L88 black fingertip pulse oximeter (Figure 6) as a comparison tool for measuring heart rate and oxygen saturation in human blood.




**(a)** **(b)**

**Figure 5.** IoT-based Heart Rate and SpO2 (a) Measurement device, (b) Display on Blynk


**Figure 6.** Display of A2-L88 Fingertip Pulse Oximeter

*Heart Rate and SpO2 Data Testing*

This test is conducted to determine the measurement accuracy of BPM and $SpO_2$ by the MAX30100 sensor. When testing is conducted, respondents are asked to place their finger for approximately 1 minute above the MAX30100 sensor on the research-designed device that has previously been connected to the USB port on a laptop with the aim of reading heart rate (BPM) and Blood Oxygen Level ($SpO_2$) data through the Arduino IDE serial monitor. During testing, the designed device and smartphone that has been installed with the Blynk application must be ensured to be connected to the internet network so that data can be displayed through the Blynk application.

Data from testing the MAX30100 sensor readings and the Conventional Device for Heart Rate (BPM) data reading is shown in Table 1. Table 1 shows that each respondent has 2 (value changes) for heart rate calculations performed in less than 1 minute. The average value obtained is then compared with reference data from the Conventional A2-L88 Fingertip Pulse Oximeter Device so that the accuracy level of the designed device can be determined.

**Table 1.** Testing of MAX30100 sensor reading and conventional device for heart rate (BPM) and SpO2 data reading

| Respondent | Gender | Age (years) | Heart Rate MAX30100 (BPM) | Heart Rate Oximeter (BPM) | $SpO_2$ MAX30100 (%) | $SpO_2$ Oximeter (%) |
|---|---|---|---|---|---|---|
| 1 | Female | 21 | 111.59 | 111 | 99 | 99 |
| 2 | Female | 21 | 123.49 | 122 | 97 | 97 |
| 3 | Female | 21 | 117.32 | 125 | 95 | 98 |
| 4 | Female | 22 | 108.38 | 107 | 94 | 99 |
| 5 | Female | 22 | 111.59 | 112 | 99 | 99 |
| 6 | Female | 21 | 98.74 | 92 | 95 | 99 |
| 7 | Female | 21 | 90.04 | 98 | 95 | 96 |
| 8 | Female | 21 | 135.06 | 125 | 94 | 99 |
| 9 | Female | 21 | 95.52 | 106 | 95 | 98 |
| 10 | Female | 22 | 95.52 | 95 | 95 | 99 |

Table 2 shows that the analysis results from each respondent's Heart Rate data testing are in normal condition when exercising. This is because the normal heart rate for adult humans at rest ranges between 60-100 BPM. While during fitness activities from warm-up to performing fitness exercises, it ranges between 95-152 BPM.

Data analysis results from the MAX30100 sensor for oxygen saturation ($SpO_2$) data reading are shown in Table 3. Table 3 shows that the analysis results from each respondent for oxygen saturation ($SpO_2$) data testing are in normal condition. This is because the normal arterial blood oxygen saturation level in humans is 95%-100%. If the level is below 90%, it is considered low or considered Hypoxemia, where the body condition shows a lack of oxygen flow coverage in the body and is very dangerous. If the $SpO_2$ level shows a value below 90% during fitness activities, it must be stopped immediately and rest immediately while regulating breathing.

**Table 2.** Analysis results of MAX30100 sensor for Heart Rate (BPM) data reading

| Respondent | Gender | Age (years) | Average Heart Rate MAX30100 (BPM) | Average Heart Rate Oximeter (BPM) | Normal Range (BPM) | Category |
|---|---|---|---|---|---|---|
| 1 | Female | 22 | 111.59 | 111 | 95-152 | Normal |
| 2 | Female | 22 | 123.49 | 122 | 95-152 | Normal |
| 3 | Female | 22 | 117.32 | 125 | 95-152 | Normal |
| 4 | Female | 21 | 108.38 | 107 | 95-152 | Normal |
| 5 | Female | 22 | 111.59 | 112 | 95-152 | Normal |
| 6 | Female | 22 | 98.74 | 92 | 95-152 | Normal |
| 7 | Female | 22 | 90.04 | 98 | 95-152 | Normal |
| 8 | Female | 22 | 135.06 | 125 | 95-152 | Normal |
| 9 | Female | 22 | 95.52 | 106 | 95-152 | Normal |
| 10 | Female | 21 | 95.52 | 95 | 95-152 | Normal |

**Table 3.** Analysis results of MAX30100 sensor for oxygen saturation (SpO2) data reading

| Respondent | Gender | Age (years) | Average $SpO_2$ MAX30100 (%) | Average $SpO_2$ Oximeter (%) | Normal Range (%) | Category |
|---|---|---|---|---|---|---|
| 1 | Female | 22 | 99 | 99 | 95-100 | Normal |
| 2 | Female | 22 | 97 | 97 | 95-100 | Normal |
| 3 | Female | 22 | 95 | 98 | 95-100 | Normal |
| 4 | Female | 21 | 94 | 99 | 95-100 | Normal |
| 5 | Female | 22 | 99 | 99 | 95-100 | Normal |
| 6 | Female | 22 | 95 | 99 | 95-100 | Normal |
| 7 | Female | 22 | 95 | 96 | 95-100 | Normal |
| 8 | Female | 22 | 94 | 99 | 95-100 | Normal |
| 9 | Female | 22 | 95 | 98 | 95-100 | Normal |
| 10 | Female | 21 | 95 | 99 | 95-100 | Normal |

*Accuracy Testing Results of IoT Blynk-Based Heart Rate Measurement Device*

Table 4 shows the accuracy level of the designed device for heart rate data. Each respondent will have their heart rate data measured using the comparison device (fingertip pulse oximeter), then the values obtained from the study of both devices are subtracted to get the difference value.

Thus, the accuracy result obtained from heart rate data is 95.63%.

**Table 4.** Accuracy testing of heart rate device using A2-L88 pulse oximeter with researcher's designed device

| Respondent | Gender | Age (years) | BPM Researcher's Device | BPM Pulse Oximeter | Difference | Error (%) | Accuracy (%) |
|---|---|---|---|---|---|---|---|
| 1 | Female | 22 | 111.59 | 111 | 0.59 | 0.5 | 99.5 |
| 2 | Female | 22 | 123.49 | 122 | 1.49 | 1.2 | 98.8 |
| 3 | Female | 22 | 117.32 | 125 | 7.68 | 6.1 | 93.9 |
| 4 | Female | 21 | 108.38 | 107 | 1.38 | 1.2 | 98.8 |
| 5 | Female | 22 | 111.59 | 112 | 0.41 | 0.3 | 99.7 |
| 6 | Female | 22 | 98.74 | 92 | 6.74 | 7.3 | 92.7 |
| 7 | Female | 22 | 90.04 | 98 | 7.96 | 8.8 | 91.2 |
| 8 | Female | 22 | 135.06 | 125 | 10.06 | 8.0 | 92 |
| 9 | Female | 22 | 95.52 | 106 | 10.48 | 9.8 | 90.2 |
| 10 | Female | 21 | 95.52 | 95 | 0.52 | 0.5 | 99.5 |
| **Average** | | | | | | | **95.63** |

Data from $SpO_2$ accuracy testing results using pulse oximeter device and researcher's designed device are shown in Table 5.

**Table 5.** $SpO_2$ accuracy testing using pulse oximeter device and researcher's designed device

| Respondent | Gender | Age (years) | $SpO_2$ Researcher's Device (%) | $SpO_2$ Pulse Oximeter (%) | Difference | Error (%) | Accuracy (%) |
|---|---|---|---|---|---|---|---|
| 1 | Female | 22 | 99 | 99 | 0 | 0 | 100 |
| 2 | Female | 22 | 97 | 97 | 0 | 0 | 100 |
| 3 | Female | 22 | 95 | 98 | 3 | 3 | 97 |
| 4 | Female | 21 | 94 | 99 | 5 | 5 | 95 |
| 5 | Female | 22 | 99 | 99 | 0 | 0 | 100 |
| 6 | Female | 22 | 95 | 99 | 4 | 4 | 96 |
| 7 | Female | 22 | 95 | 96 | 1 | 1 | 99 |
| 8 | Female | 22 | 94 | 99 | 5 | 5 | 95 |
| 9 | Female | 22 | 95 | 98 | 3 | 3 | 97 |
| 10 | Female | 21 | 95 | 99 | 4 | 4 | 96 |
| **Average** | | | | | | | **97.50** |

Table 5 shows the accuracy level of the designed device for blood oxygen circulation data. Each respondent's blood oxygen circulation data is measured using the comparison device (fingertip pulse oximeter), then the values from both devices are subtracted to get the difference value.
Thus, the accuracy result obtained from blood oxygen circulation ($SpO_2$) data is 97.5%.

From Table 4, it is shown that the accuracy result from heart rate data is 95.63%, and from Table 5, it is shown that the accuracy result from blood oxygen circulation ($SpO_2$) data is 97.5%. This indicates that the accuracy level of using the MAX30100 sensor is quite good. The $SpO_2$ value tends to be more stable compared to the heart rate per minute (BPM) value. The instability of the heart rate value is more caused by the heart pumping blood throughout the body continuously, thus causing blood to continue moving after exercising. Blood movement in the body is random and fast, causing infrared waves to become unstable.

## Conclusion

From the results of this research, it can be concluded that the system designed in this study has an accuracy level for heart rate measurement of 95.63% and for blood oxygen circulation ($SpO_2$) measurement of 97.5%. This proves that the accuracy level of using the MAX30100 sensor is quite good, so the sensor is suitable for use in the Development of Heart Rate and Oxygen Saturation Measurement Device Using MAX30100 Sensor Based on Internet of Things (IoT) with Blynk Application for Monitoring Fitness During Running.

## Conflicts of interest

The author declares no conflicts of interest.

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