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Smart, Portable, and Affordable ECG Testing Kit

Uzma Tabassum [a,*], U B Mahadevaswamy [b]

[a] *Sri Jaya Chamarajendra College of Engineering, JSS Science and Technology University, Mysuru, India*
[b] *Department of Electronics and Communication Engineering, JSS Science and Technology University, Mysuru, India*
*Corresponding author: *tuzma103@gmail.com*

***Abstract*—The electrical activity of the heart is measured and recorded using an electrocardiogram, often known as an EKG or ECG, which is a basic diagnostic tool in cardiology. Electrodes are applied to the patient's skin during this non-invasive process in order to record the electrical impulses generated during the cardiac cycle. Cardiac arrhythmia signifies an abnormal heart rate or rhythm. When the heart beats too rapidly or irregularly, its pumping efficiency decreases, potentially reducing blood flow to the brain. This can lead to fainting, dizziness, or even death if not promptly addressed. The proposed health monitoring system is a comprehensive, portable solution designed to monitor key cardiovascular indicators—specifically, heart rate and blood oxygen saturation (SpO2)—in real-time. The system integrates two microcontrollers: an Arduino Mega and a NodeMCU. The Arduino Mega is responsible for displaying ECG waveforms on a TFT screen, as well as calculating and displaying the heart rate. This is achieved through an ECG sensor connected to the Arduino, which plots the heart's electrical activity on the display. A potentiometer allows users to set a customizable threshold line on the ECG waveform, which is used to count heartbeats. The heart rate is calculated based on the number of beats detected per second. If the heart rate falls below or rises above the normal range, the system alerts the user by displaying "Bradycardia" or "Tachycardia," respectively. Meanwhile, the NodeMCU module is connected to a MAX30100 sensor, which measures SpO2 levels. The sensor data is wirelessly transmitted to the Arduino Mega, where it is displayed on the TFT screen alongside the ECG data. This dual-functionality system not only provides continuous monitoring of vital signs but also offers immediate feedback on potential heart conditions, making it an essential tool for proactive health management.**

***Keywords*—Electrocardiogram; MAX30100; AD8232; ESP8266; arrhythmias; bradycardia; tachycardia.**

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I. Introduction

An electrocardiogram, often known as an ECG, is a crucial diagnostic tool used in cardiology that tracks and evaluates the heart's electrical activity over time [1], [2], [3]. Cardiovascular disorders are a major global cause of morbidity and mortality [1], [4], [5], [6], [7]. These conditions include arrhythmias, heart attacks, and stroke. Vital indicators, including blood oxygen saturation (SpO2) and heart rate, must be continuously monitored and detected early to effectively treat and prevent these illnesses. However, traditional monitoring techniques are often limited to clinical settings because they require advanced technology and professional supervision, making them less accessible for routine at-home use. Microcontroller technology has advanced quickly, opening the door to creative solutions that can put healthcare monitoring in people's hands and enable continuous, real-time monitoring of vital health data [8], [9]. This project aims to create a portable, user-friendly gadget that can measure SpO2 levels and heart rate by integrating modern microcontroller technology into a health monitoring system. The system employs the Arduino Mega and NodeMCU microcontrollers to provide users with immediate feedback on their cardiovascular health. This enables users to take proactive steps to maintain their overall well-being.

The ECG sensor and the MAX30100 SpO2 sensor are the two main sensors that are crucial to the system's operation [10], [11]. The ECG sensor records the heart's electrical activity and plots the waveform on a TFT display when it is linked to an Arduino Mega [10], [12], [13]. Users may track their heart rate and identify any anomalies with this real-time heart function visualization [14], [15], [16], [17], [18]. To precisely count heartbeats, users must be able to establish a threshold line on the ECG waveform, which is made possible by the potentiometer built into the system. After calculating heart rate as beats per second, the device is designed to identify and notify users if the heart rate deviates from the typical range, signaling conditions such as bradycardia (abnormally slow heartbeat).

The aim of this project is to close the accessibility gap between clinical-grade health monitoring and everyday use by providing a small, affordable device that people may use in the comfort of their own homes. Anyone wishing to proactively manage their cardiovascular health would find the system to be a useful resource due to its user-friendly design and real-time feedback.

The motivation for this project is the alarming statistic that approximately 19.7 million people worldwide are dying each year due to the late detection of arrhythmias [10]. The rise in the incidence of arrhythmias and high blood pressure among a larger portion of the youth population has led to an increase in related deaths. This concerning trend reflects significant changes in lifestyle, stress levels, and other health factors affecting younger individuals. Our product would identify a rise in cardiac activity before damage has been caused, hence being a prediction system for minor heart attacks and disturbances that would end up as major conditions leading to fatality or death.

The project approach consists of multiple important steps. First, the AD8232 sensor was used to record ECG signals. Preprocessing was applied to these raw signals to remove noise and extract pertinent information, and other vital parameters like SpO2 and BPM would be taken from the patient. Then, sophisticated algorithms were used to calculate heart rate and detect arrhythmia patterns. A study by [19] developed an ECG-based arrhythmia detector that sounded alarms, sent SMS alerts, and displayed vital signs. It aimed to prevent adverse outcomes by early detection, especially during sleep. A study by [20] employed machine learning to classify arrhythmias using ECG data. Noise reduction, feature extraction (R-R interval, BPM, P wave to QRS peak), and SVM classification achieved 91% accuracy, demonstrating the potential of machine learning in arrhythmia detection.

A study used an AD8232, MCP3008, and Raspberry Pi to demonstrate real-time ECG monitoring, where Python and Plotly were used to record, digitize, process, and display ECG signals [10]. This low-cost method demonstrated the possibility of easily accessible and effective ECG analysis. Lastly, Owis et al [21] used an Android software developed by [22] enables automated arrhythmia detection by evaluating ECG parameters and real-time electrocardiogram (ECG)monitoring.

Autoregressive modeling was employed by [23], [24], [25] to classify and identify the kind of arrhythmia and other heart illnesses. The ECG was then utilized to confirm the diagnosis of the heart problem. To expand the capabilities, a study by [26] developed a single-lead ECG detector that could identify ventricular tachycardia. This work presents a comprehensive solution that includes real-time wireless warnings to healthcare practitioners, enabling timely intervention in case of arrhythmic episodes, while prior models largely focus on ECG data processing and arrhythmia diagnosis.

II. Materials and Method

An electrocardiogram, often known as an EKG or ECG, is performed using a methodical technique that guarantees precise recording of the heart's electrical activity [10]. Preparing the patient, placing the electrodes, recording, and interpreting the results are all part of this process.

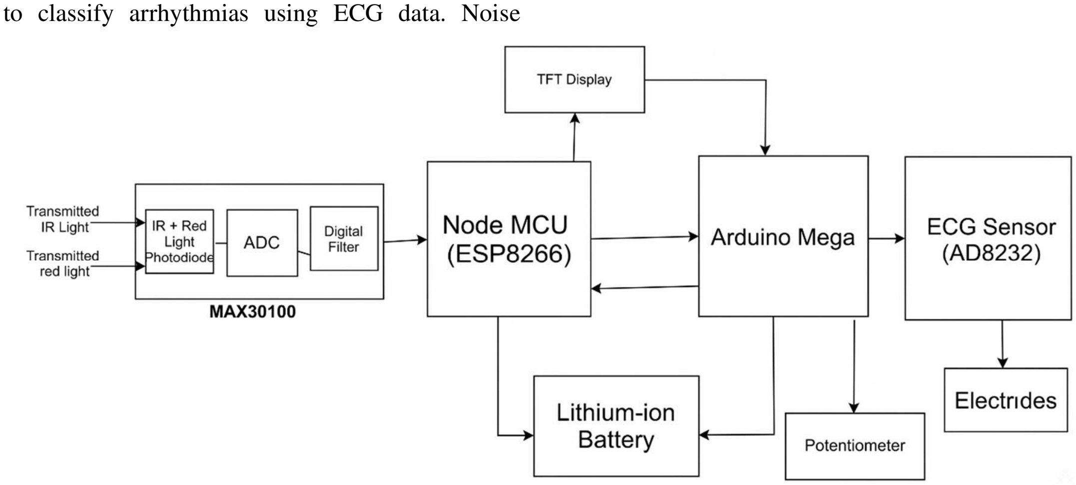

Fig. 1 Block Diagram

An electrocardiogram (ECG) signal analysis and monitoring system is depicted in the block diagram. The provided block diagram, Figure 1, illustrates a system designed to monitor and analyze electrocardiogram (ECG) signals. It utilizes an Arduino UNO microcontroller and a NodeMCU (ESP8266) to capture, process, and transmit ECG data to a TFT display**.** The Arduino Mega is a potent microcontroller that functions as the system's central processing unit [27]. It receives and processes data from various sensors, manages the information, and regulates the system's general operation.

NodeMCU encompasses a microcontroller with wireless communication as its main focus, equipped with Wi-Fi. Data from the MAX30100 sensor is received and then sent to the Arduino Mega for additional processing and display. The TFT Display is a visual output device that shows the processed data in an easily comprehensible format. Together with the estimated heart rate and SpO2 values, it shows the ECG waveform.

An ECG sensor is a medical gadget used to measure the heart's electrical activity. It records and transforms the faint electrical impulses produced by the heart into a digital representation. The MAX30100 sensor is a non-invasive tool that uses light absorption analysis in blood to determine heart rate and blood oxygen saturation (SpO2). A potentiometer functions as a variable resistor that enables the user to modify the ECG signal detection threshold level, guaranteeing precise heart rate readings.

The suggested health monitoring system's design approach centers on integrating multiple sensors and microcontrollers to produce a portable, real-time monitoring tool that can measure blood oxygen saturation (SpO2) and heart rate. The main parts of the system are an Arduino Mega microcontroller, a NodeMCU microcontroller, a TFT display, an ECG sensor, a MAX30100 sensor, and a potentiometer. To guarantee dependable data collection and smooth operation, these carefully chosen and connected parts are used.

The main microcontroller is an Arduino Mega, selected for its high processing power and wide range of I/O capabilities, which are required to interface with several sensors and drive the TFT display. The ECG waveform, estimated heart rate, SpO2 levels, and other data are displayed on the TFT display to give the user a visual interface. The TFT display, which gives patients rapid access to their cardiovascular health parameters, is crucial for real-time monitoring.

One essential part that records the electrical activity of the heart is the ECG sensor. It recognizes the small electrical impulses that the heart produces with every beat and transforms them into a waveform visible on the TFT display. The waveform offers significant insights into the functioning of the heart, particularly in identifying irregular heart rhythms such as tachycardia (rapid heart rate) and bradycardia (slow heart rate)

The Arduino Mega receives a direct connection from the ECG sensor, interprets the signal, and plots it on the display. To set a threshold line on the ECG waveform, a potentiometer is also attached to the Arduino Mega. To detect heartbeats accurately, this threshold is essential. The ECG waveform signals a heartbeat when it reaches this threshold, and the machine counts these heartbeats to determine the heart rate. Next, a real-time display of the heart rate is seen on the TFT screen. With this feature, users can precisely and individually monitor their heart rate by adjusting the threshold to suit their needs. The microcontroller NodeMCU is used to monitor SpO2. It is selected because of its integrated Wi-Fi capabilities, which make wireless data transfer easier.

The NodeMCU microcontroller is used to monitor SpO2. It is selected because of its integrated Wi-Fi capabilities, which make wireless data transfer easier. The Node MCU is linked to the MAX30100 sensor, a small and extremely precise sensor that uses the user's fingertip to absorb red and infrared light to detect pulse rate and SpO2 levels. The SpO2 data is collected by the MAX30100 sensor and processed by the NodeMCU. The processed data is sent wirelessly to the Arduino Mega, where it is shown next to the ECG data on the TFT screen. The system's ability to manage several data streams effectively is ensured by the integration of the Arduino Mega and NodeMCU, giving consumers a thorough picture of their cardiovascular health.

The NodeMCU with Arduino Mega's wireless connectivity enables variable sensor placement, improving user convenience. The system is designed to be easy to use. The MAX30100 sensor is hooked onto the fingertip, and the ECG sensor is positioned on the user's chest. The Arduino Mega and NodeMCU start gathering data from their respective sensors as soon as the system is powered on. The Arduino Mega uses the potentiometer-set threshold to process the ECG data, plot the waveform on the TFT display, and count heartbeats. Concurrently, the NodeMCU processes the SpO2 data and wirelessly transfers it to the Arduino Mega, where it is shown next to the ECG waveform.

In conclusion, integrating essential parts such as the Arduino Mega, NodeMCU, ECG sensor, MAX30100 sensor, potentiometer, and TFT display ensure an effective, real-time monitoring solution throughout the design process of this health monitoring system. With this hardware combination, customers can monitor their heart health in great detail and have a dependable, easily accessible tool to help them manage their health.

III. RESULTS AND DISCUSSION

The results of the smart, portable, and affordable ECG testing kit are shown in Fig. 2, depicting the whole configuration of the prototype model used to identify arrhythmia problems.

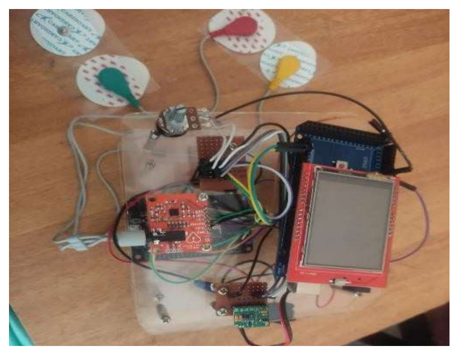

Fig. 2 Prototyping model

Initial ECG readings were captured from a healthy individual using the ECG sensor connected to the microcontroller. The ECG waveform obtained from the patient is visually represented in the following graph, Fig. 3, with the serial monitor.

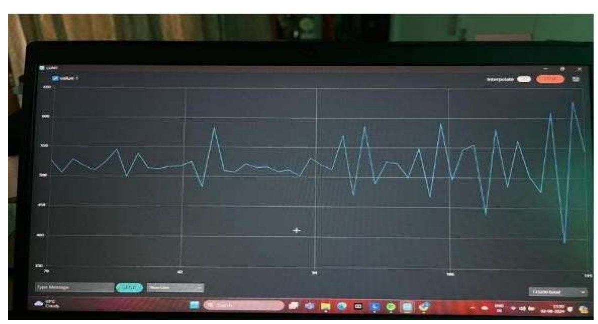

Fig. 3 ECG reading with serial monitor

An essential part of the pulse oximeter system is the red light that is emitted in the upper right corner. The MAX30100 sensor uses this light, which is frequently in the infrared spectrum. This sophisticated sensor is intended especially for measuring physiological factors like blood oxygen saturation (SpO2) and heart rate (bpm). Through light emission and analysis of reflected light, the MAX30100 can identify minute variations in blood volume that are connected to each heartbeat, as shown in Fig. 4 below. The bpm is then precisely calculated by processing these modifications. SpO2 can also be calculated since the sensor can distinguish between oxygenated and deoxygenated hemoglobin depending on how each absorbs light.

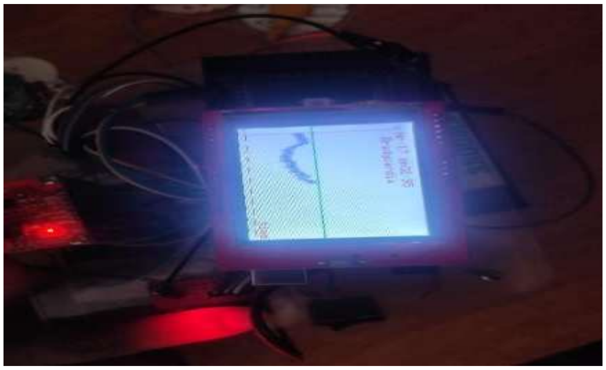

Fig. 4 Bpm and spo2 values

In addition to the local display on the serial monitor, the processed ECG data is simultaneously transmitted and visualized on a TFT display. Figure 5 below shows the ECG reading of a patient.

Fig. 5 ECG Reading with TFT display

The ECG graph is analyzed to determine if the heart rate falls below the bradycardia threshold of 60 beats per minute or exceeds the tachycardia threshold of 120 beats per minute. This analysis enables the identification of potential bradycardia or tachycardia conditions. Figure 6 illustrates the system's response to a heart rate above 60 beats per minute (bpm). In this scenario, the system diagnoses tachycardia, displays the graph on the TFT, and calculates the patient's heart rate.

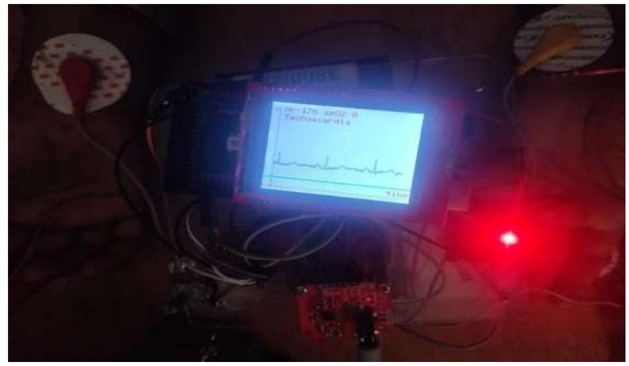

Fig. 6 Tachycardia detection

Figure 7 illustrates the system's response to a heart rate below 60 beats per minute (bpm). In this scenario, the system diagnoses bradycardia, displays the graph on the TFT, and calculates the patient's heart rate.

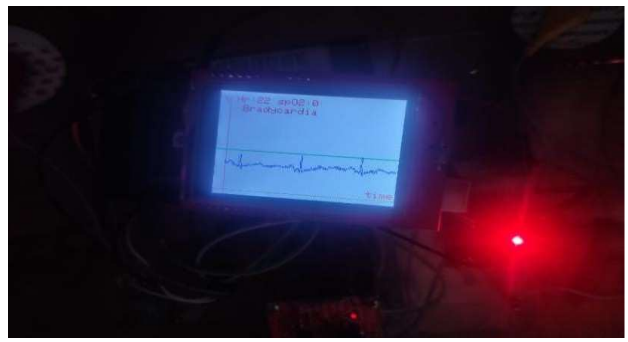

Fig. 7 Bradycardia condition

The below Fig 8 shows that the blood oxygen saturation (SpO2) values for men in three age groups—10–20, 20–35, and 35–60—are displayed on the graph. The age group of 10 to 20 had the highest average SpO2 levels, followed by the group of 20 to 35. The 35–60 age group had the lowest average SpO2 levels.

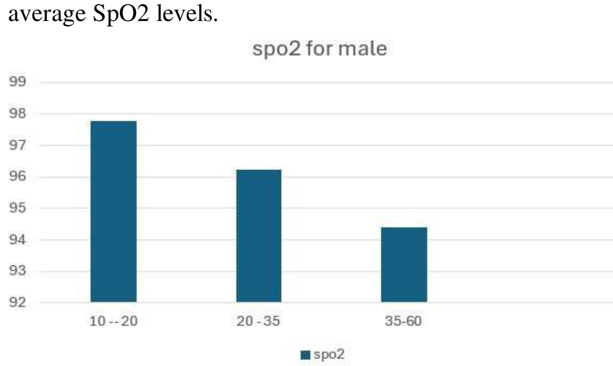

Fig. 8 Spo2 graph for males

Fig 9 displays the female blood oxygen saturation (SpO2) levels for the ages of 10–20, 20–35, and 35–60. The age group of 10 to 20 had the highest average SpO2 levels, followed by the group of 20 to 35. The 35–60 age group had the lowest average SpO2 levels.

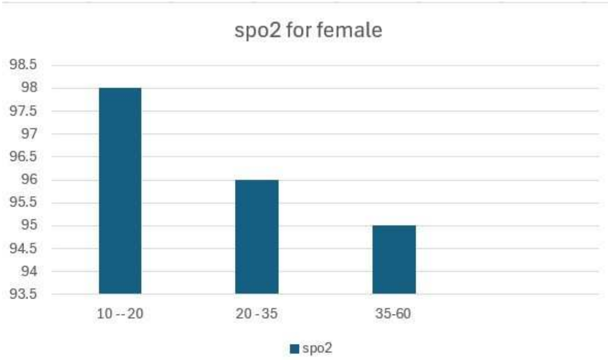

Fig. 9 Spo2 graph for females

Figure 10 below shows a bar graph that shows the ranges of BPMs (beats per minute) for various age groups for males. For each age group, the maximum BPM is indicated by blue bars, while the minimum BPM is indicated by green bars. Three age groups—11–20, 20–35, and 36–60—have their maximum and minimum heart rate ranges (BPM) displayed on the graph. Both maximal and minimum heart rates often decline with aging.

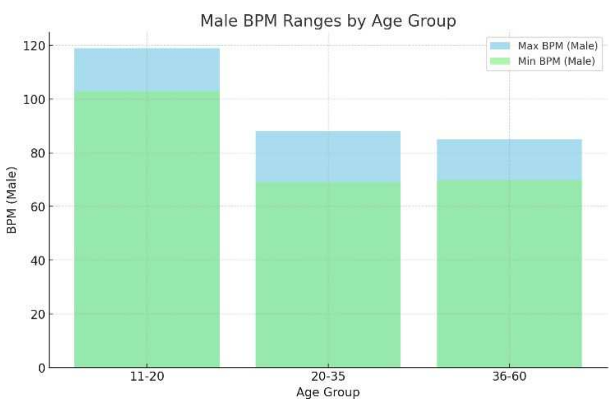

Fig. 10 BPM graph for males

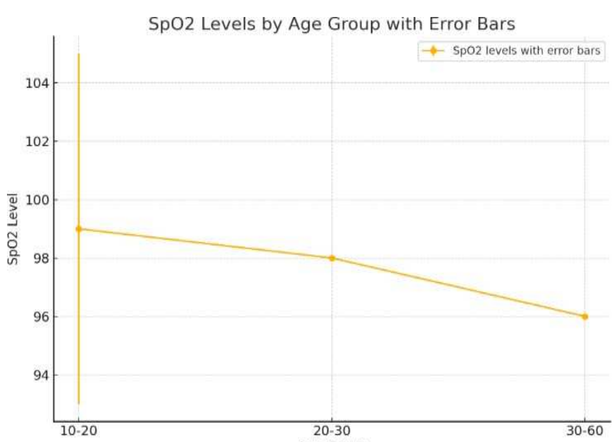

Fig. 11 line plot with error bars for Spo2

Figure 11 shows a bar graph of BPM (beats per minute) ranges for various age groups for females. For each age group, the maximum BPM is indicated by blue bars, while the minimum BPM is indicated by green bars. Three age groups—11–20, 20–35, and 36–60—have their maximum and minimum heart rate ranges (BPM) displayed on the graph. Both maximal and minimum heart rates often decline with aging.

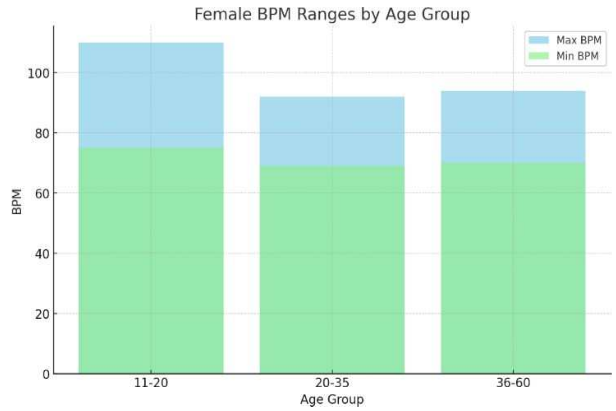

Fig. 12 BPM graph for females

The mean beats per minute (BPM) for men and women in three age groups—11–20, 20–35, and 36–60—are displayed on the graph as shown in fig 12. The variability in the data is shown by error bars.

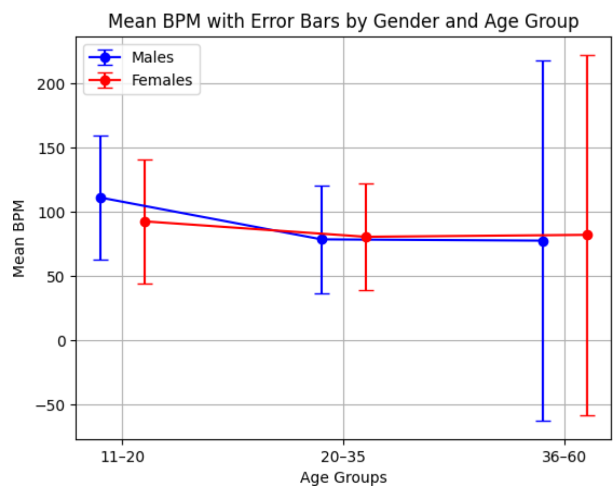

Fig. 13 Line plot with error bars for BPM

Overall, the graph indicates that, although there are a few small gender-specific variances, the mean BPM for both males and girls usually decreases with age. Within each age group, there is individual diversity in BPM, as indicated by the error bars. The blood oxygen saturation (SpO2) for three age groups—10–20, 20–30, and 30–60—is depicted in the accompanying graph. The data's standard deviation is shown by error bars. SpO2 readings often show a mild declining tendency as people age. The error bars, however, show substantial individual variability within each age group, which is crucial to highlight.

IV. Conclusion

The incorporation of IoT in ECG data reading and collection represents a transformative approach in the field of healthcare. It enables continuous, real-time monitoring of cardiac health, leading to early detection and timely intervention for cardiac events. Technological advancements have led to the development of innovative solutions for various challenges. In the realm of healthcare, the integration of smart and portable devices has the potential to revolutionize patient monitoring and diagnosis. One such development is the ECG monitoring system, which has been designed to be both affordable and accessible. This system holds immense promise for individuals residing in rural and remote areas, where access to quality healthcare facilities may be limited. By utilizing advanced algorithms and sensors, the ECG monitoring system can accurately capture and analyze electrocardiogram data. This data can then be used to generate comprehensive reports that include morphological values. These reports can serve as invaluable tools for healthcare providers, aiding them in making more accurate and timely diagnoses.

The future scope of this technology is vast, with potential advancements in data analytics, sensor technology, real-time monitoring, and integration with other health metrics. Moreover, cloud computing and big data can significantly enhance the capabilities and scalability of ECG monitoring systems. As technology evolves, it would be crucial to address challenges related to data security, privacy, and regulatory compliance. With ongoing research and development, IoT-based ECG systems have the potential to revolutionize cardiac care, making it more accessible, efficient, and effective. This would not only improve patient outcomes but also reduce the overall burden on healthcare systems worldwide

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