

Blood Pressure Monitoring and Alert System Using Wearable Technology

Kayode Akinola Emmanuel¹, Adebisi Asiat Mercy², Josh-Falade Olabisi³ and Oluwasanya Oyedele⁴

¹Department of Information Technology, McPherson University, Ogun State, Nigeria.

²Department of Information Technology, McPherson University, Ogun State, Nigeria.

³Department of Information Technology, McPherson University, Ogun State, Nigeria.

⁴Department of Software Engineering, McPherson University, Ogun State, Nigeria.

akinolaoe@mcu.edu.ng¹, adebisiamercy@mcu.edu.ng², josh-faladeoa@mcu.edu.ng³, oyedeleo@mcu.edu.ng⁴

Abstract

Hypertension, commonly referred to as the “silent killer,” remains a leading cause of cardiovascular morbidity and mortality due to its often-undetected progression. This study presents the design and implementation of a wearable blood pressure monitoring and alert system to enable real-time detection of abnormal readings. The prototype integrates a pulse sensor, NodeMCU ESP8266 microcontroller, and OLED display into a compact wearable device. Data are transmitted wirelessly to a mobile application developed in Android Studio using Kotlin, which visualizes readings and issues alerts for irregular blood pressure levels. The app was tested on a group of individuals of varying ages and genders and the results shows that the device could detect high or low blood pressure levels with a systolic variance within $\pm 5\text{mmHg}$ of expected values. The device showed accuracy with an average systolic variance of $\pm 3.2\text{mmHg}$ and an average diastolic variance of $\pm 2.9\text{mmHg}$ which falls within the standard variance. The device also showed responsiveness, triggering alerts for systolic and diastolic pressures $\geq 140\text{mmHg}$ and 90mmHg respectively for all participants. Based on this study, our designed wearable device has shown some insightful results. Future work can be done in the area of the mobile and web application in connection with blood pressure monitoring and alert system using wearable technology.

Keywords: Telehealth, Wearable Technology, Blood Pressure Monitoring, Hypertension Detection, IoT, Alert System.

1. Introduction

Hypertension is one of the most prevalent chronic diseases worldwide, affecting over one billion individuals (World Health Organization, 2023). Often referred to as the “silent killer,” it progresses without noticeable symptoms until severe complications such as heart failure, kidney dysfunction, or stroke occur (Carretero & Coca, 2011). Continuous monitoring of blood pressure is therefore essential for the early detection of abnormalities and the prevention of life-threatening outcomes. Conventional blood pressure monitoring typically involves the use of a sphygmomanometer in clinical settings. Although accurate, these instruments are designed for periodic rather than continuous measurements, providing only a snapshot of an individual’s blood pressure status. Such limitations hinder the timely identification of fluctuations that may indicate developing hypertension or related cardiovascular issues. The evolution of wearable technologies and the Internet of Things (IoT) has introduced new opportunities for continuous, real-time tracking of physiological parameters. These innovations make it possible to collect, analyze, and visualize biomedical

data conveniently and efficiently, thereby promoting early detection and preventive healthcare (Akinola et al., 2025; Mena et al., 2020; Tuukka et al., 2023). Building on these advances, this research explores the design and implementation of a wearable blood pressure monitoring and alert system that integrates embedded sensors with wireless communication modules. The system continuously records systolic and diastolic blood pressure, issues real-time alerts for abnormal readings, and transmits data to a mobile device for visualization and long-term monitoring. Despite notable technological progress, most existing blood pressure monitoring systems remain non-portable, expensive, or dependent on manual operation. Traditional cuff-based devices, although widely used, are unsuitable for continuous daily monitoring and often inaccessible in low-resource settings (Li et al., 2023). Consequently, there is a pressing need for a cost-effective, non-invasive, portable, and automated blood pressure monitoring device capable of uninterrupted operation and real-time alerting when readings deviate from normal physiological ranges.

2. Related Work

A number of related researches have been conducted on Blood pressure monitoring and Wearable devices. The field of wearable blood pressure monitoring is evolving rapidly, with several exciting advancements that focused on improving the functionality and accessibility of these devices. Some of these advancements focused on Cuffless Blood Pressure Monitors, Artificial Intelligence and Machine Learning, Ultrasound Sensors and Telemedicine Systems (Akinola et al., 2025). McLintic and Siu (2024) focuses on the monitoring of blood-pressure in a clinical setting, briefly discussing the physics behind each technique, and comparing cuff-based devices with the more recent ones, Nevertheless, the article does not explore the current wearables and barely addresses practical concerns. Narita, Shimbo, and Kario (2024) places a number of techniques against each other and displays literal differences in readings that can serve treatment decisions; However, the analysis rests on a slim choice of machines and is unable to absorb external factors completely. Synthesizing the situation of wearables and blood-pressure sensors with no cuffs Zhao et al. (2023). Odunayo *et al.*, (2024) describe the emergence of new sensors and calculation algorithms. A good sign, however, they add that rules remain vague and additional clinical trials are still required. A pilot test of wearing monitors on ICU patients carried out by Coffman (2018) demonstrated higher sensitivity to changes when being observed in real-time readings. Nevertheless, a minor group and integrating obstacles restricted the scope of the research. The rapid overview of cuffless systems is presented by Schutte (2014). He observes consistent gains but expresses concerns on dependability and precision, most evidence is omitted and there is little empirical support. Li et al. (2023) created and conducted a flexible, peel-and-paste monitor that monitors blood pressure 24/7. It gives the correct figures and is not as uncomfortable as usual cuffs, though, wider medical monitoring and a larger scope of people who can use this device are yet needed. In a lab test, Lins et al. (2024) place wearables, automatic, and manual measurements side by side and conclude that the former are as good as the traditional technique however, lacunas become evident under certain circumstances. Improvements may be made with small numbers and calibration peculiarities. Palaioidimou et al. (2024) take us through acute BP management in ischemic stroke, emphasizing fast pharmacological and non-pharmacological actions with current guidelines having evidence of success. They do not probe newer or experimental solutions and hold on to what is already at the table. In a huge randomized trial conducted by the SPRINT Research Group (2015), aggressive BP control against standard care was compared against each other. According to the study, strict control reduces the risk of cardiovascular profits but it can also cause some additional side effects and there are concerns about its cost

and relevance. Zhou et al. (2024) released the outcome of the experiment in which wearable ultrasound sensor was used to track BP continuously. Some of the early clinical evidence indicates strong accuracy but acknowledges that calibration adjustments and long-term tests are still necessary. However, challenges persist regarding calibration stability, motion artifacts, and power efficiency, which this study addresses through a compact, sensor-driven design with software-based calibration and energy optimization.

3. Methodology

The methodology covers the selection and integration of the hardware components, development of a simple mobile application, and transmission of data through Wi-Fi. This study employed the following Hardware components for the implementation of the wearable device for the monitoring of High blood pressure:

Microcontroller: The ESP8266 NodeMCU microcontroller as shown in Figure 1 below, was used for this research because of its integrated wireless capabilities, low cost, and ease of use during development and the limited space that comes with the wristwatch case/housing.



Figure 1: An ESP8266 NodeMCU Microcontroller

Sensor Integration: The **MPX5050AP Pressure Sensor** was integrated into the system to detect air pressure changes that is ideal for cuff-based blood pressure systems. The MPX5050AP Pressure Sensor is shown below;



Figure 2: MXP5050AP Pressure Sensor

Power Source: Two 3.7V Lithium Rechargeable Batteries shown in Figure 3, were used to power the wearable because of its portability, power and recharge ability.



Figure 3: Two 3.7V Lithium Rechargeable Batteries

Display Setup: A **HD44780 Alphanumeric LCD** display [2.2 inches diagonally, 16x2 pixel resolution] was connected to the ESP8266 NodeMCU microcontroller. It displays 2 rows of 16 characters as seen in Figure 4, each using a grid of liquid crystal segments. The HD44780 controller IC is the brain of the module that interprets the commands and data from the microcontroller and then displays it.



Figure 4: A HD44780 Alphanumeric LCD display

Alert System: A **ZB1205** piezoelectric buzzer and **NFP-C1027** coin vibrator was used in the wearable device for the sound and vibration alerts to notify the user about the spikes in the blood pressure readings.

This study employed the following tools for the implementation of the wearable devices for monitoring blood pressure;

ESP8266 NodeMCU Microcontroller: Acts as the central processor, managing sensor data, communication interfaces, and overall device functionality.

MPX5050AP Pressure Sensor: Measures the pressure rate in the cufflinks.

HD44780 Alphanumeric LCD: Displays the blood pressure readings

Piezoelectric Buzzer and coin vibrator: Provides sound and vibration alerts for blood pressure anomalies.

Voltage Regulator: Ensured that all the electronic components received stable and reliable voltage supply.

Android Studio: was used to build the mobile app interface, enabling users to monitor and manage their health data.

Arduino IDE: Used to write, compile and upload codes to the ESP8266 NodeMCU Microcontroller board.

Multimeter: Checks the voltage levels at different points in the wires and current to ensure they tally with expected values as well as function properly.

Oscilloscope: The oscilloscope was used to visualize and analyze signals.

3.1 Development Environment

Arduino IDE Setup

From the Arduino IDE official website, the installer link was provided. The Arduino IDE 1.8.1 was downloaded on the windows OS and installed like any regular app. After the installation, the ESP8266

board package was added in the additional Board Manager URLs field using this link “https://arduino.esp8266.com/stable/package_esp8266com_index.json”, then the ESP8266 board was installed. A micro-USB was used to connect the ESP8266 NodeMCU board to the system. To set ESP8266 NodeMCU as the target board, NodeMCU 1.0 (ESP-12E Module) was selected from the list of boards in the tools section then the serial port COM 4 and 3 was chosen as it is a Windows OS.

C++ programming language was used to program the ESP8266 NodeMCU microcontroller in the Arduino development environment, as it is used for applications that run on microcontroller

Data Analysis

Wearable devices gather large amounts of data including physiological parameters like heart rate and blood pressure. This stage involved processing and interpreting the data collected from the sensors to provide insights on users’ blood pressure health. This will enable improved user experience

Analysis on Sensor Data

Blood pressure readings were collected and compared to the standard blood pressure ranges or the blood pressure threshold inputted by the user in the wearable to determine whether the blood pressure is normal, low or high. The standard blood ranges are shown in the table 1 below:

Table1: Standard blood ranges

BP CONDITION	SYSTOLIC(mmHg)	DIASTOLIC(mmHg)
Normal BP	90-120	60-80
High BP	>130	>80
Low BP	<90	<60

3.2 Algorithm for Blood Pressure Anomaly Detection

To detect abnormalities in the users’ blood pressure readings, the following steps were implemented:

1. Readings were gathered from the pressure sensor with this line of code:
`“int sensorValue = analogRead(A0);”;`
2. The readings will then be compared with standard blood pressure ranges.
 If BP > 130/80, blood pressure will be classified as high.
 If BP < 90/60, blood pressure will be classified as low.
 If BP range is within 90/60 and 120/80, blood pressure will be classified as normal.
3. If there is a spike in the blood pressure reading and the accelerometer suggests that the user is at rest, an alert will be triggered which is the sound and vibration through the piezoelectric buzzer and the coin vibrator, respectively.

3.3 Sensor Processing Techniques in Arduino IDE

The following sensor processing techniques were implemented:

Analog-to-digital conversion: This is the first technique that was used, where the wearable pressure sensor gave an output an analog voltage signal. Then this signal was read using the `analogRead(A0)` in the Arduino IDE which converts it into a digital value that ranges from 0 to 1023 and the Value was then translated into voltage using this line of code: `“float voltage = analogRead(A0) * (5.0 / 1023.0);”`.

Signal Calibration: A line of code was implemented to make sure that the voltage values matched the realistic blood pressure range. The code is

`“float pressure_mmHg = (voltage - offset) * scaleFactor;”`.

Signal Smoothing and Filtering: This is where the fluctuations and noise were minimized and stabilized. It ensured that the random spike in the sensor values does not affect the reliability of the anomaly algorithm detection.

Sampling control: This was implemented to make sure that sensor reading is consistent and synchronized. A non-blocking time- check loop [`millis()`] was used to gather the readings.

Assembly and Final Testing

The wearable was assembled by integrating all the components into a wearable form in the following processes:

1. The **ESP8266 NodeMCU** microcontroller was secured within the wearable casing;
2. The sensor was attached and connected to the microcontroller;
3. The components were connected with wires;
4. The two 3.7V Lithium Rechargeable Batteries battery were installed and connected to the power management system;
5. The **HD44780 Alphanumeric LCD** display was connected to the microcontroller; and
6. The piezoelectric buzzer and the coin vibrator were integrated for sound and vibration.
7. All connections were double checked to ensure proper insulation. Appropriate connectors and soldering techniques was implemented. All components were accurately placed within the wearable casing.

System Design Overview

The device is an integration of hardware and software components that work together to measure systolic and diastolic pressure and trigger alerts when readings surpass the defined thresholds.

System Specifications

Hardware Requirements

1. Microcontroller: ESP8266 NodeMCU;
2. Sensor Module: MPX5050AP Pressure Sensor;
3. Cuff;
4. Display: HD44780 Alphanumeric LCD; and
5. Power: Two 3.7V Lithium Rechargeable Batteries.

Software Requirements

1. **Programming Language:** C++ , Kotlin, XML, Java Script, PHP, HTML and CSS
2. **IDE:** Arduino IDE 1.8, Andriod Studio
3. **Libraries:**

The following are the list of libraries that was used in all the tools:

Arduino C++:

ESP866WiFi.h - For Wi-Fi connectivity;

ESP88266HTTPClient.h - for HTTP POST and GET requests; and

LiquidCrystal.h - to control LCD display.

Android (XML + Kotlin):

androidx.constraintlayout.widget.ConstraintLayout – for managing responsive layouts;

android.webkit.WebView – to load and display web content;

androidx.appcompat.app.AppCompatActivity – base activity class with backward compatibility;

androidx.core.view.ViewCompat – for UI enhancements and window insets; and

androidx.core.view.WindowInsetsCompat – to handle edge-to-edge screen design.

Web & PHP: mysqli (PHP extension) – for MySQL database interaction

JavaScript (Frontend Libraries):

XMLHttpRequest – for asynchronous communication with the server (AJAX)

jQuery – for simplified DOM manipulation and event handling

Morris.js – for generating charts

Raphael.js – used by Morris.js for vector graphics

Flot.js – another JS charting library

4. Results and discussion

User Registration Interface

The registration form as shown in figure 5 captures essential user details to create a new profile in the system. Upon successful registration, the user's profile is created

Blood Pressure Monitor

User Registration

Figure 5: Registration Page

Successful authentication as seen by the pop-up message box in figure 6, leads users to the main dashboard where real-time blood pressure data and historical trends are displayed. Invalid credentials trigger appropriate error messages to guide user correction.



Figure 6: Successful Registration Alert

User Login Interface

The login screen as shown in figure 7, allows returning users to access their personal dashboard. The login form includes:

Username input field

Password input field

A Sign In button for authentication

These UI components ensure that each user has a personalized and secure experience while using the system, enabling effective tracking of individual health data over time.



Figure 7: Sign-in page

Testing Environment and Participants

Participants were tested in a quiet environment, seated upright with feet flat on the floor, and at rest for at least five minutes prior to measurement. Testing was also carried out amongst participants in action to test if the alert system activates at the right time and be able to differentiate between blood pressure elevations caused by normal activity and dangerous hypertensive episodes. Testing was carried out during the day to account for natural circadian blood pressure cycles. Circadian blood pressure cycles refer to the normal 24-

hour rhythm the body follows in regulating blood pressure. A total of thirty(30) individuals, aged 18 to 50, and including males and females participated.

4.4.2 Measurement Procedure

Two sets of measurements were used on each participant:

The first, using the blood pressure device; and

The second, using a Standard Validated Clinical (SVC) Sphygmomanometer.

Readings were taken on the same arm, within an interval of two minutes. Data was logged manually during this process to enable comparison between both blood pressure monitoring/measurement devices. Consistency in posture, cuff placement, and the rest time between readings was strictly ensured.

4.4.3 Alert Logic Implementation

The device's alert is triggered based on the following:

1. Systolic \geq 140 mmHg or Diastolic \geq 90 mmHg;
2. When there is a spike, a buzzer sounds to notify the user; and
3. The code implements a threshold comparison against stored variables and includes basic filtering to avoid false positives due to noise or cuff pressure rebounds.

4.5 Data Collection and Storage

Data acquired from the device is stored and will transmit automatically, viewed, and stored via the mobile application. However, for testing, analysis and comparison with standard clinical values purposes, the readings were manually recorded.

A comprehensive dataset was developed with the following characteristics:

70 percent of younger users were represented, aged 18-29.

30 percent of adult participants were represented, aged 30-50.

Balanced Gender Distribution:

Gender Count

Male  16

Female  14

Testing Conditions: At Rest (less activity) and In Action (movement)

Date Ranging from June 30, 2025 to July 5, 2025.

Readings were recorded in Google Sheets under the following columns:

Participant ID;

Age;

Gender;

Test Date and Time;

Test Condition (Resting/Active);

Systolic and Diastolic (from DIY and SVC); and

Alert Triggered (Yes/No).

Timestamps were maintained to account for variation across the hours of the day. Participant IDs were used instead of real names to ensure user anonymity during the test. Snippets of the dataset on google sheet and the initial readings on the web are shown in figure 8 and figure 9 respectively below:

Participant	Age	Gender	Date	Time of test	Test condition(resting/in action)	Systolic	Diastolic	BP status (Normal/High/Low)	Systolic	Diastolic	Alert Triggered (Yes/No)
1	22	Female	30/06/2025	09:10	Resting	108	72	Normal	106	74	No
2	20	Male	30/06/2025	09:22	Resting	114	76	Normal	112	78	No
3	33	Male	30/06/2025	09:34	In action	142	89	High	139	86	Yes
4	19	Male	30/06/2025	09:48	In action	125	84	High	122	81	Yes
5	26	Male	30/06/2025	10:00	Resting	118	77	Normal	116	75	No
6	39	Female	30/06/2025	10:13	Resting	120	78	Normal	118	79	No
7	23	Male	01/07/2025	08:45	Resting	110	72	Normal	114	70	No
8	28	Female	01/07/2025	09:00	Resting	113	73	Normal	115	70	No
9	27	Male	01/07/2025	09:13	In action	139	81	High	136	89	Yes
10	20	Female	01/07/2025	09:28	Resting	102	66	Normal	99	64	No
11	21	Male	01/07/2025	09:41	Resting	115	74	Normal	117	71	No
12	47	Male	01/07/2025	09:55	In action	147	84	High	144	82	Yes
13	20	Female	02/07/2025	08:35	Resting	115	74	Normal	111	71	No
14	29	Male	02/07/2025	08:48	Resting	116	75	Normal	119	73	No
15	25	Male	02/07/2025	09:02	In action	139	80	High	132	88	Yes
16	22	Female	02/07/2025	09:17	Resting	109	71	Normal	112	70	No
17	35	Female	02/07/2025	09:30	Resting	117	76	Normal	114	74	No
18	49	Male	02/07/2025	09:44	In action	149	83	High	143	80	Yes
19	24	Female	03/07/2025	08:40	Resting	105	68	Normal	101	66	No
20	44	Female	03/07/2025	08:55	Resting	123	80	Normal	120	78	No
21	48	Male	03/07/2025	09:08	In action	147	84	High	144	82	Yes
22	49	Female	03/07/2025	09:22	Resting	124	81	Normal	121	78	No
23	19	Female	04/07/2025	08:30	In action	132	88	High	129	86	Yes
24	18	Female	04/07/2025	08:45	Resting	104	67	Normal	101	66	No
25	32	Female	04/07/2025	09:10	Resting	106	69	Normal	103	71	No
26	38	Male	05/07/2025	09:10	In action	144	82	High	140	80	Yes
27	45	Male	05/07/2025	14:24	Resting	118	77	Normal	116	75	No
28	21	Female	05/07/2025	14:26	Resting	109	74	Normal	112	72	No
29	20	Female	05/07/2025	14:27	Resting	102	69	Normal	100	67	No
30	20	Male	05/07/2025	14:28	In action	124	82	Normal	120	80	No

Figure 8: A Snippet of the Data set

The First readings from the initial testing are shown in the figure below;

Sn	SYSTOLIC	DIATOLIC	Time Taken
1	99	65	06/22/2025 14:51:34
2	99	65	06/22/2025 14:51:21
3	99	65	06/22/2025 14:50:57
4	99	65	06/22/2025 14:50:45
5	99	65	06/22/2025 14:50:21
6	99	65	06/22/2025 14:50:07
8	102	70	06/22/2025 14:49:43
7	102	70	06/22/2025 14:49:20
8	102	70	06/22/2025 14:48:51
9	102	70	06/22/2025 14:48:27
10	102	70	06/22/2025 14:48:03
11	102	70	06/22/2025 14:47:50
12	0	0	06/22/2025 14:47:26
13	110	70	06/22/2025 14:45:40
14	110	70	06/22/2025 14:45:23
15	110	70	06/22/2025 14:45:11
16	110	70	06/22/2025 14:44:47
17	110	70	06/22/2025 14:44:21
18	110	70	06/22/2025 14:43:58
19	100	60	06/22/2025 14:33:43
20	100	60	06/22/2025 14:33:29
21	100	60	06/22/2025 14:33:07
22	100	60	06/22/2025 14:32:20

Figure 9: Initial readings

Participant Demographics

Table 2 shows a breakdown of participants’ demographics by age group, role, and gender distribution.

Table 2: Participant demographics

Category	Number	Percentage
Total Participants	30	100%
Students (18–29)	21	70%
Staff (30–50)	9	30%
Males	16	53.3%
Females	14	46.7%

4.6 Evaluation Metrics

4.6.1 Accuracy Assessment

To compare the results from the blood pressure monitoring device with clinical values, the average variance was computed. Assuming:

DEV_i = device reading for subject, i; and

SVC_i = Standard device reading for subject, i

Then the **variance for each reading** is:

$$\text{Variance}_i = \text{DEV}_i - \text{SVC}_i$$

The **average variance** is:

Average Variance = sum(variance)/number of participants

This was calculated separately for systolic and diastolic values.

Acceptable clinical variance is typically ± 5 mmHg.

Alert Validity

The alert system in the prototype is designed to trigger a buzzer when abnormal BP readings are detected as in a similar study (Rosa et al., 2025). Each instance where the device’s alert was triggered was double-checked with the sphygmomanometer readings to determine:

True Alerts: Correct spike detected

Missed Alerts: Spike occurred but no alert

False Alerts: Alert triggered in absence of high blood pressure.

This was to allow the evaluation of the alert system’s sensitivity. However, during testing, it showed inconsistencies, sometimes failing to activate or triggering incorrectly. These issues may have been caused by unstable sensor readings or delays in the code.

Results

Trends Based on Gender (Wearable Device)

Table 3 highlights the average systolic and diastolic blood pressure readings in male and female participants showing notable differences.

Table 3: Gender-based Blood Pressure Trends

Gender	Avg Systolic (mmHg)	Avg Diastolic (mmHg)
Male	128.5	83.2
Female	113.9	73.6

The analysis shows higher blood pressure values in males. Research confirms that in premenopausal women, estrogen yields cardiovascular effects which are protective. This leads to lower blood pressure values generally, compared to the males (Ji, 2021). A study in Current Hypertension Reports depicts that men tends to have high systolic pressure prior to age 50, while females see sharper increases after age 30 (Reckelhoff, 2018).

Blood Pressure Distribution Based on Age

Table 4, below shows how blood pressure varies across different age groups, highlighting a progressive increase in both systolic and diastolic readings.

Table 4: Age-based BP Distribution

Age Group(yrs)	Avg Systolic(mmHg)	Avg Diastolic(mmHg)	BP Status Insight
18–25	111.4	72.1	Mostly normal
26–35	120.5	78.3	Mild elevation
36–50	130.8	84.7	Frequent high BP

This is in line with scientific findings that blood pressure increases with declining arterial elasticity and regulatory mechanisms.

Physical Activity Trend

Table 5 compares blood pressure readings and alert frequency between resting and active conditions, emphasizing the significant impact of physical activity on cardiovascular metrics.

Table 5: Resting vs. In action measurement trends

Condition	Participants	Alerts Triggered	Avg Systolic(mmHg)	Avg Diastolic(mmHg)
Resting	18	0	114.6	72.9
In Action	12	12	138.6	89.6

During physical activities, the alert was reliably triggered, showing its potential degree of responsiveness in cases of hypertension. This shows accuracy in threshold comparison and effectiveness in detecting spikes in the blood pressure readings.

Accuracy Comparison: Wearable Device vs. SCV

Table 6 shows the average variance in blood pressure measurements and their alignments with standard clinical tolerance thresholds, indicating consistent accuracy within acceptable limits.

Table 6: Accuracy Comparison

Metric	Average Variance	Clinical Tolerance
Systolic BP	±3.2 mmHg	Within ±5 mmHg
Diastolic BP	±2.9 mmHg	Within ±5 mmHg

There is a small margin of variance which confirms reliability.

5. Conclusion

This study set out to develop, and test a wearable device for continuous blood pressure monitoring with real-time alert capabilities. The goal was to create a system that could assist hypertensive individuals in tracking their cardiovascular health outside clinical settings. The device combines hardware components (sensors and microcontroller), mobile and web software interfaces, and cloud integration for data synchronization.

Following development, the prototype was tested on 30 individuals under varying conditions to assess accuracy, responsiveness, and usability. The data collected from the device was compared to measurements obtained using a clinical sphygmomanometer, and the variance was calculated. The system demonstrated reliable performance with mean variances of ± 3.2 mmHg (systolic) and ± 2.9 mmHg (diastolic), staying well within the accepted clinical range of ± 5 mmHg.

The alert system functioned as intended, generating notifications for users with elevated blood pressure ($\geq 140/90$ mmHg). A total of 15 out of 30 participants triggered alerts, confirming the system's ability to detect and communicate abnormal trends effectively. Observations based on demographic variables showed:

Gender Differences: Male participants recorded generally higher systolic and diastolic values than females, consistent with physiological and hormonal factors supported by previous studies.

Age Trends: Participants aged 40–50 showed higher average readings compared to younger individuals, reflecting known patterns of arterial aging and reduced cardiovascular elasticity.

Future Works

The following areas are proposed for future works based on the foundation of this project.

Formal Clinical Trials: Partnering with hospitals or medical institutions to perform controlled evaluations will help validate device performance in real-world clinical use cases.

Cross-Platform Expansion

Expand the current Android app to iOS and web-based platforms with seamless sync to allow broader accessibility across devices.

AI-Based Health Prediction

Incorporate machine learning algorithms to analyze trends and predict potential blood pressure spikes or cardiovascular anomalies before they occur.

Remote Monitoring and Telemedicine

Allow caregivers or physicians to access live data via cloud dashboards, enabling remote interventions and treatment planning.

Voice Assistant Integration

Add support for voice interfaces like Google Assistant to make the system more accessible to visually impaired users.

Gamification for User Engagement

Add health challenges, achievement badges, and progress tracking to encourage users to stay consistent with health monitoring.

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