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RESEARCH ARTICLE

Consistency of the Non-Invasive Monitoring Preemie Car Seat (*PreeCASE*) Device in Assessing Heart Rate, SpO2 Level, and Body Temperature of the Infants

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ABSTRACT - Advancements in technology have made pulse oximeter devices the preferred choice for parents monitoring their baby's health. However, existing devices present challenges for infants, especially preemies, who need continuous monitoring after being discharged from the hospital. Using conventional baby car seats with wired connections and unstable external vital sign monitors may lead to inaccurate data readings. To resolve this issue, the non-invasive monitoring preemie car seat (*PreeCASE*) device is well-developed. In this study, we focus on investigating the consistency of the *PreeCASE* device in assessing the heart rate, SpO2 level, and body temperature of healthy infants. For the methods, ten healthy infants are selected to use the *PreeCASE* device, and the data is collected and analyzed using standard procedure. The *PreeCASE* device provides consistent data readings for the three main physiological parameters, heart rate SpO2 level, and body temperature that are displayed on an LCD screen based on the user's respective levels. The *PreeCASE* device is precisely designed to facilitate easy and rapid monitoring of infants, especially preemie infants. This innovative device holds significant potential to improve and support pediatricians in effectively caring for infants in Malaysia.

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1. INTRODUCTION

The development of medical devices in the treatment of infants is developing very rapidly. The field of biomedical engineering is very helpful in this development. However, the progress is less appreciated, especially in handling premature babies. Premature infants, also called preemie infants, are thus attached to a ventilator and intravenous feed since they cannot breathe or eat on their own [1, 2]. In addition, they have numerous health issues and are at increased risk for hospital complications. Premature infants may have some health problems, such as breathing difficulty, brain hemorrhage (IVH), heart problems (PDA, bradycardia), severe jaundice, and visual problems (ROP) [3]. A premature infant is more likely to suffer from apnea, which is described as a loss of breath or cessation of breathing. The likelihood of a baby developing apnea increases with the degree of prematurity. An undeveloped central nervous system is the most common cause of prematurity apnea. The development of breathing centers is incomplete, and they may be unreliable [4]–[8].

There are not many devices that can meet the needs of premature infants. This situation caused many researchers to start creating and producing products related to infants. An example is a pulse oximeter, which is a device that measures heart rate and oxygen saturation for adults and children. Pulse oximetry is a straightforward and non-invasive device used to assess heart rate and oxygen saturation (SpO2) in different body regions [9]–[13]. Specifically, it evaluates the proportion of oxygen-carrying hemoglobin and blood proteins without causing discomfort [3]

To compare the two monitoring methods, the present device employs just two metrics; heart rate and SpO2 level. Meanwhile, the newly created design employs three parameters and a temperature sensor [10, 14]. Presently, the new technology relies heavily on cable connectivity, which poses challenges when the infant begins to move. Aside from that, the common idea is inappropriate and may have an emotional impact on the infant. Currently, car seat monitoring systems rely on cable connections, but the size and power consumption make them cumbersome and difficult to transport. The system becomes obsolete with the advancement of modern technologies [11, 15]. Utilizing wireless healthcare technologies has several benefits. In addition, the physician in the distant server center may carefully monitor the premature baby's health and make real-time recommendations for the premature baby's recovery and long-term care [16]–[21].

To overcome these problems, the *PreeCASE* device is well-developed. The *PreeCASE* device can utilize a wireless network sensor and can be equipped with various sensors, including an oximeter and BME280, capable of measuring a

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range of data. The *PreeCASE* device also features an alarm and a display to increase awareness among doctors and parents when parameter values indicate high or low levels. This study aims to investigate the consistency of the *PreeCASE* device in assessing the heart rate, SpO2 level, and body temperature of healthy infants. Also, the *PreeCASE* device can provide a comprehensive solution for monitoring infants during transportation, ensuring the condition of infant health and safety are effectively monitored in real-time.

2. METHODOLOGY

2.1 *PreeCASE* Device

The *PreeCASE* device consists of three main components; vital signs, a monitoring system, and a mobile application. Figure 1 shows the detailed operation process flow of the *PreeCASE* device. The monitoring of the *PreeCASE* device comprises MAX30100 and BME280 sensors. MAX30100 integrates LEDs, a photodetector, optimized optics, and low-noise analog signal processing to measure heart rate and SpO2 levels. BME280 is utilized to monitor the body temperature of preterm infants. This sensor is safe for infants as it does not emit harmful electromagnetic waves. The device's main body is constructed using Flexible TPU filament, while the interior of the *PreeCASE* is insulated with a sponge to protect the infant's skin. Upon receiving output feedback from the microcontroller, the device displays the preterm infant's heart rate, SpO2, and temperature levels. A buzzer alerts clinicians or parents in case of unhealthy readings. The microcontroller chosen for this device is the ESP32 due to its multitasking capability, enabling the simultaneous execution of multiple tasks or processes. This feature is precious in industries requiring parallel and efficient operations. Additionally, the ESP32 is equipped with built-in Wi-Fi and Bluetooth modules, facilitating wireless network connectivity and communication with other devices. This medium makes it highly suitable for IoT (Internet of Things) and networked applications. Table 1 shows the detailed components of the non-invasive monitoring *PreeCASE* device.

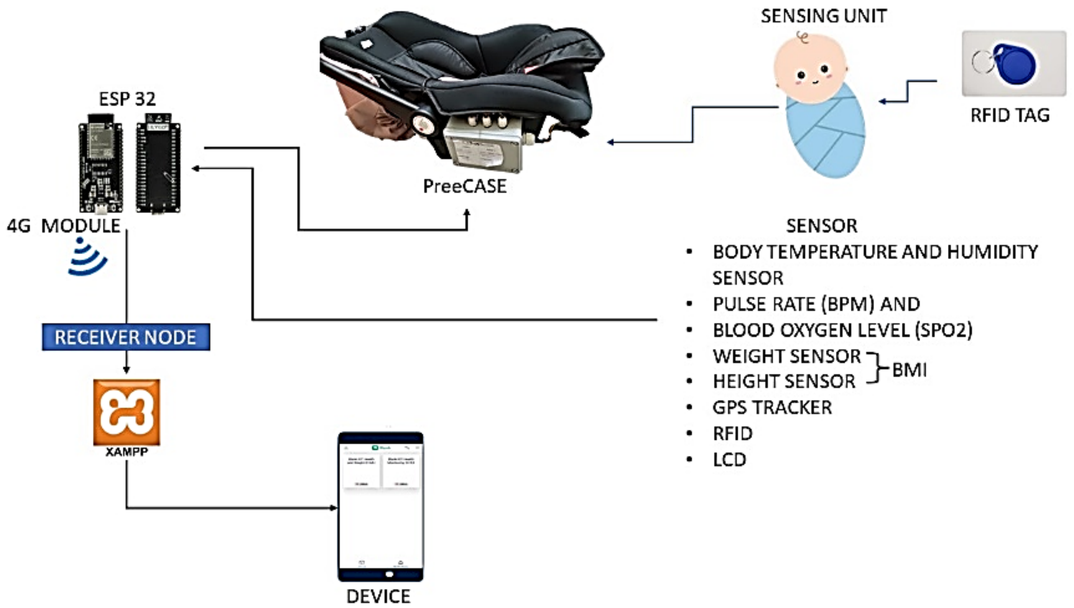

Figure 1. Details operation process flow of the PreeCASE device

Table 1. Details components of the non-invasive monitoring *PreeCASE* device

Criterion	Component	Details
Power Supply	Rechargeable battery Lippo battery 11.1v 1800mah USB to DC power adapter and power bank	Rechargeable system
Display	LCD 2.4 tft spi (240x320) (rgb)	LCD with a resolution of 240x320 offers better image detail
Connection Option	Smartphone app (own apps = *PreeCASE* device app) Using PCB	*PreeCASE* device apps and used middleware XAMPP to get real-time data add on PCB
Monitoring Detail	Body temperature and humidity sensor Pulse rate (bpm) and Blood oxygen level (spo2) Weight sensor Height sensor BMI GPS tracker RFID	Height and weight sensor for calculating BMI and upgrade system using RFID and buzzer

2.2 Monitoring System Interface

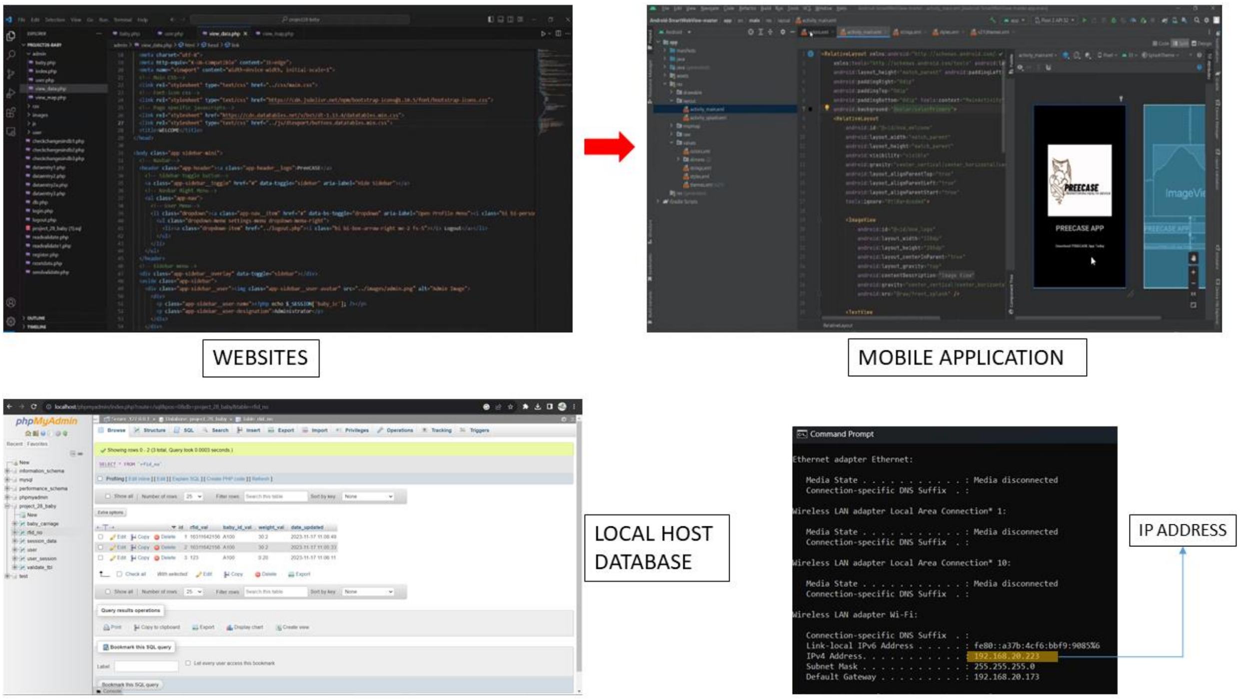

Figure 2. Web development, mobile applications, and a local database

Based on Figure 2, the mobile application development is depicted through another IDE set up for Android development, with the application's structure and a mobile emulator for testing. The database aspect is managed through phpMyAdmin, a tool for handling MySQL databases, shown here, operating on a local server. Finally, the network configuration necessary for these components to communicate is presented via a command prompt output, showing the *ipconfig* command, which reveals the local IP address configuration. This setup demonstrates a full-stack development workflow, integrating front-end, back-end, and network setup to create a cohesive digital solution.

a) **Websites**: The top-left portion shows an Integrated Development Environment (IDE) with HTML and PHP code, indicating a website's or web application's development. This is where the website's front-end and back-end code are written and edited.

b) **Mobile Application**: The top-right portion displays another IDE, but this time, it is focused on developing a mobile application, as evidenced by the Android package structure and an emulator running a mobile app, indicating a test or development version of the app.

c) **Local Host Database**: The bottom-left shows a phpMyAdmin interface, a web-based database management tool. It displays a table with entries that suggest it is part of the back end for storing data related to the project. phpMyAdmin typically manages MySQL databases running on a local server (localhost).

d) **IP Address**: The bottom-right segment of the image displays a command prompt with the *ipconfig* command output. This command is used in Windows to display the current network configuration, including IP addresses. This particular output shows the local IP address assigned to the machine, which could be used to access the local server hosting the database or for the mobile device to connect to local services during development and testing.

2.3 Enhance *PreeCASE* Device with IoT Applications

The mobile application is developed to record and display the heart rate, SpO2 level, and body temperature of the infant [22],[23]. The data is kept in the storage system as a black box function. This data will be used as the emergency tread record or research activity. Then, after connecting the microcontroller ESP32 to the internet and using a local server with a local IP address, we can simply monitor the infant's vital signs. The ESP 32 will connect to Wi-Fi using a 4G module. Data will also be sent through XAMPP cloud middleware, as shown in Figure 3. The sensor data will enter the APK application, and real-time data will be displayed and analyzed. The *PreeCASE* device incorporates XAMPP, an open-source, cross-platform web server solution, to facilitate data management and analysis. XAMPP provides a robust environment for hosting a local web server, enabling seamless communication between the *PreeCASE* device and other devices or systems. With XAMPP, the collected data from the various sensors can be securely stored and processed, ensuring reliable data management and efficient retrieval. Healthcare professionals can leverage XAMPP's comprehensive suite of tools, including Apache, MySQL, PHP, and phpMyAdmin, to develop customized web applications or interfaces for data visualization, analysis, and reporting. This integration of XAMPP enhances the *PreeCASE* device's capabilities by enabling real-time access to vital sign data, facilitating comprehensive monitoring, and empowering healthcare professionals with valuable insights for informed decision-making and improved care outcomes for preterm infants.

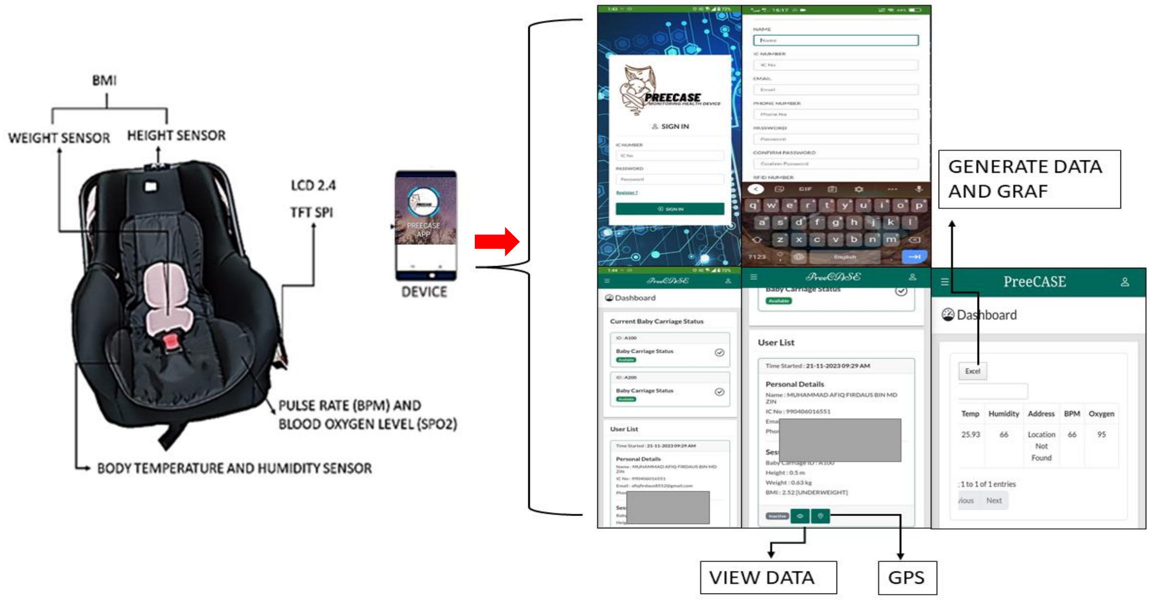

Figure 3. Demonstrated the mobile apps using the integration of XAMPP with the PreeCASE device

In addition to vital sign monitoring, the *PreeCASE* device incorporates a GPS tracker using the NEO 6m GPS module. This cutting-edge module establishes a reliable connection with GPS satellites, enabling real-time tracking of the infant's location. By accurately monitoring the infant's movements and providing precise location data, healthcare professionals can ensure the safety and security of preterm infants within medical facilities while facilitating seamless monitoring during transport. For the GPS tracker result, click on the icon of GPS in the application and it will direct to Google Maps for directions. The system will respond to provide longitude and latitude, as well as a Google Maps link to the phone number that has been encoded on the smartphone system. The user just needs to click on the link to find out the location of the infant car seat. This allows the device to track the baby's location in real-time and alert parents if the baby is left unattended in the car seat and has moved more than 3 meters away from the car. The alarm notification feature is triggered by the device's microcontroller, which is programmed to detect when the baby has moved beyond a certain distance from the car. The alarm is then sent to the parent's smartphone via the *PreeCASE* app, providing them with timely and accurate information about their baby's location and safety. An RFID system is implemented within the *PreeCASE* device to ensure accurate identification and data management. Each preterm infant is assigned a unique RFID tag or card containing identification information. The device incorporates an RFID reader that swiftly scans the tag or card, enabling swift recognition of the baby and seamless association of relevant data with the specific infant. This feature streamlines data collection processes, enhances data accuracy, and supports effective care coordination among healthcare providers.

2.4 Security Features of *PreeCASE*

As shown in Figure 3, In the *PreeCASE* project dedicated to monitoring the health of premature babies, the paramount concern is ensuring the utmost data security and user authentication. The system incorporates usernames, passwords, and RFID recognition to achieve this. This multi-layered approach is essential due to the sensitivity and confidentiality of the health data we collect. Unauthorized access to such information could have severe consequences, so strictly adhere to data privacy regulations to maintain data security and compliance. Usernames and passwords serve as the first line of defense, allowing only authorized healthcare professionals and caregivers access to the system. This authentication method protects the data and allows for personalized care tailored to each premature baby's unique needs. Additionally, RFID recognition technology provides an extra layer of security and simplifies the login process for healthcare providers who are continuously attending to the infants' needs. Moreover, our system goes beyond security by facilitating data analysis and visualization. It generates data in Excel format for easy tracking and offers graphical representations, such as graphs and charts, for a comprehensive understanding of the baby's health over time. This combination of security measures and data accessibility reflects our unwavering commitment to the safety and well-being of premature infants, ensuring that their health is monitored with the utmost care and precision.

Figure 4 shows a flowchart that will be used to explain the process flow of the attendance device using RFID technology. From the flowchart, the sensor works to get the information and statistics and how the device keeps the information.

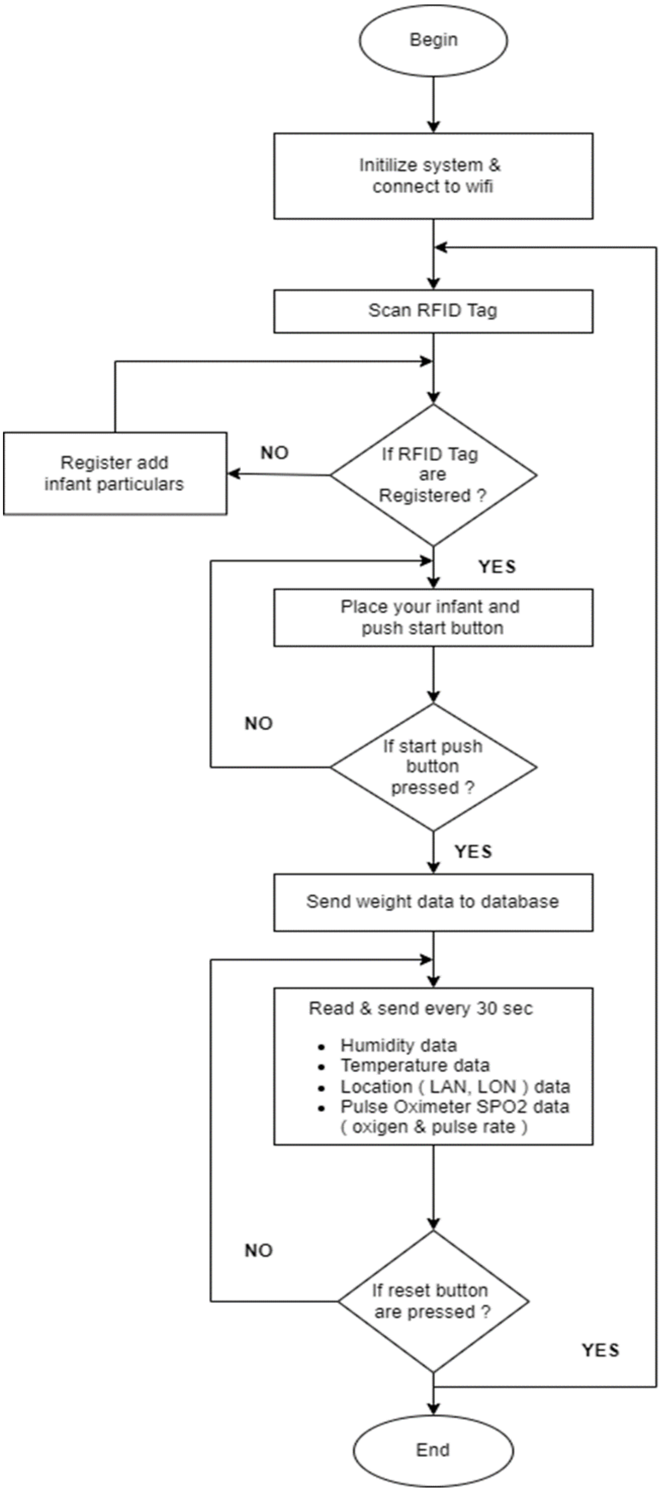

Figure 4. The process flow of the attendance device using RFID technology

2.5 Consistency Parameters of the *PreeCASE* Device

The testing and verification of data collection using the *PreeCASE* device is conducted at Health Clinics around Kuantan. Before conducting the study, a consent form must first be obtained to get permission from the parents of the infants who want to take the heart rate, SpO2 level, and temperature using the *PreeCASE* device [22],[24]. The detailed procedure to acquire the consistency of the parameter reading can be obtained based on the flow chart shown in Figure 5.

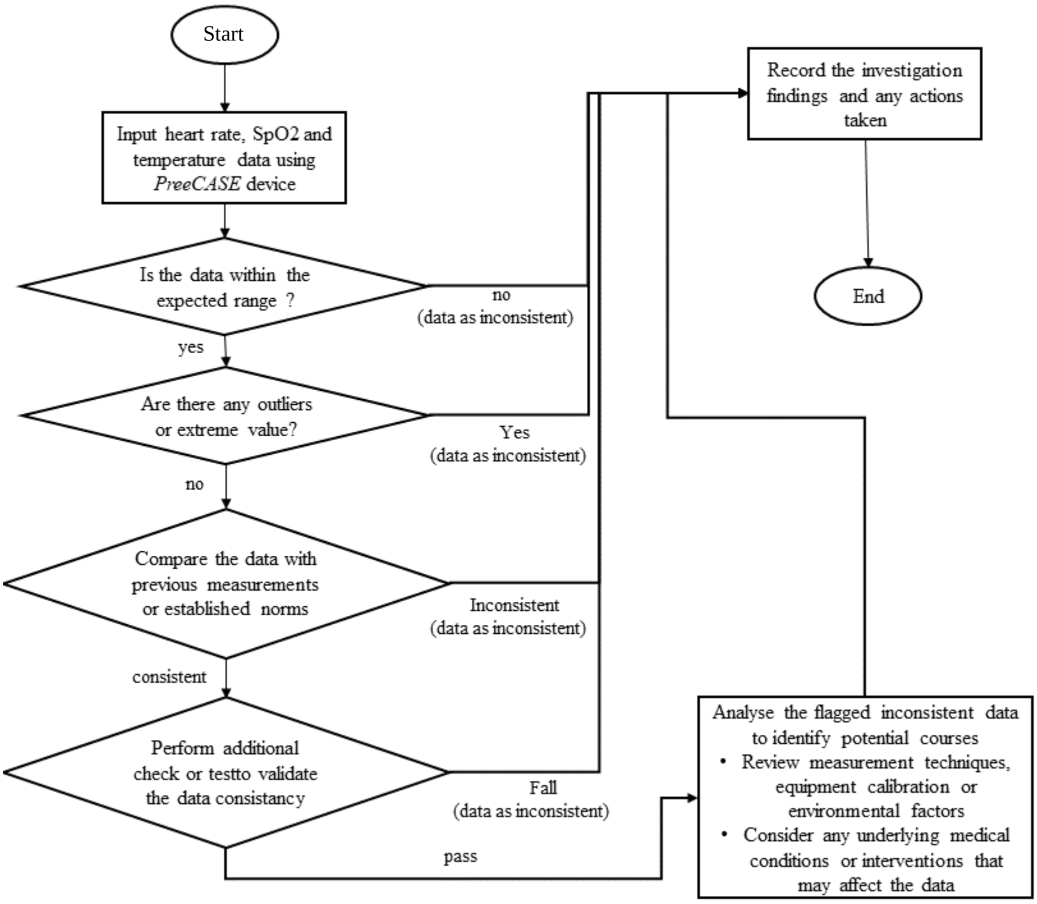

Figure 5. Procedure to investigate the consistency data heart rate, SpO2, and temperature obtained from the non-invasive monitoring *PreeCASE* device

3. RESULT AND DISCUSSION

As a result, the *PreeCASE* device demonstrates exemplary design and development standards. This cutting-edge device excels in healthcare monitoring, leveraging a wireless network sensor for seamless data collection. It has the versatility to accommodate many sensors, including the high-precision oximeter (MAX30100) and BME280, enabling the measurement of a wide range of vital parameters. Moreover, integrating Internet of Things (IoT) technology and real-time data processing via dedicated applications, the device incorporates an alarm system and a display interface. This sophisticated combination serves to significantly augment the awareness of healthcare professionals and parents alike by promptly signaling and visually presenting deviations from normal parameter values, whether indicating elevated or decreased levels.

3.1 Improvement of *PreeCASE* Device

The *PreeCASE* device utilizes a comprehensive array of sensors to enhance the monitoring capabilities of infants. It incorporates a BME280 sensor, renowned for its accuracy and reliability, to capture precise body temperature and humidity measurements. By ensuring optimal environmental conditions, healthcare professionals can closely monitor the infant's thermal comfort and identify potential risks associated with temperature and humidity fluctuations. In addition, the device integrates the MAX30100 sensor, which employs advanced pulse oximetry technology, enabling real-time tracking of pulse rate and blood oxygen saturation levels. This invaluable information allows healthcare providers to assess the respiratory well-being of preterm infants and promptly address any abnormalities. To accurately track the weight of infants, the *PreeCASE* device incorporates a weight sensor consisting of a bar load cell and an HX711 module. This configuration ensures high precision in weight measurements, enabling healthcare professionals to monitor the growth and development of infants with exceptional accuracy. Furthermore, a sophisticated ultrasonic sensor is employed to measure the height of preterm infants. By utilizing ultrasonic waves and precise time-of-flight calculations, this sensor provides healthcare providers with valuable data on the infant's growth trajectory, facilitating comprehensive monitoring of physical development. Details of improvement of the *PreeCASE* are shown in Table 2.

Table 2. The latest improvement of the *PreeCASE* device

Criterion	Before	After	Details
Power Supply	Battery 12v	Lippo battery 11.1v 1800mah USB to DC power adapter and power bank Rechargeable battery	Changed from a non-rechargeable to a rechargeable battery
Display	1 LCD size (16x2)	2 LCD size (16x2) & (8x2) LCD 2.4 tft SPI resolution 240x320 (RGB)	The LCD with a resolution of 240x320 offers better image details
Connection Option	Smartphone App (using Blynk IoT)	Smartphone App (using own Apps named *PreeCASE* device Apps.) Using PCB	Changed from Blynk IoT to *PreeCASE* device apps and used middleware xampp to get real-time data Add on PCB
Monitoring Detail	Body temperature and humidity sensor Pulse rate (bpm) blood oxygen level (Spo2) Weight sensor	Body temperature and humidity sensor Pulse rate (bpm) Blood oxygen level (SpO2) Weight sensor Height sensor BMI RFID GPS tracker	Add height sensor to calculate BMI and upgrade system using RFID & GPS tracker

The *PreeCASE* device goes beyond physiological parameters measurements and extends functionality to include automatic BMI calculation through dedicated applications. By leveraging the measured weight and height values, these applications employ standard BMI formulas to immediately assess the infant's body composition. This feature offers valuable insights into the nutritional status and overall health of preterm infants, aiding healthcare professionals in making informed decisions regarding dietary interventions and personalized care plans. The *PreeCASE* device also includes a 2.4-inch LCD TFT SPI display with a resolution of 240x320 pixels. This high-quality display provides a straightforward and user-friendly interface for visualizing measurements, alerts, and other essential information. Healthcare professionals can easily interpret the displayed data, ensuring swift decision-making and facilitating effective communication with caregivers and families. The *PreeCASE* device integrates a comprehensive range of state-of-the-art sensors and technologies to deliver enhanced monitoring capabilities for preterm infants. By providing consistent and accurate measurements of vital parameters, including heart rate, SpO2, BMI, temperature, and GPS tracking, this innovative device empowers healthcare professionals with valuable insights into the infants' well-being, enabling timely interventions and personalized care to promote optimal growth and development in this vulnerable population.

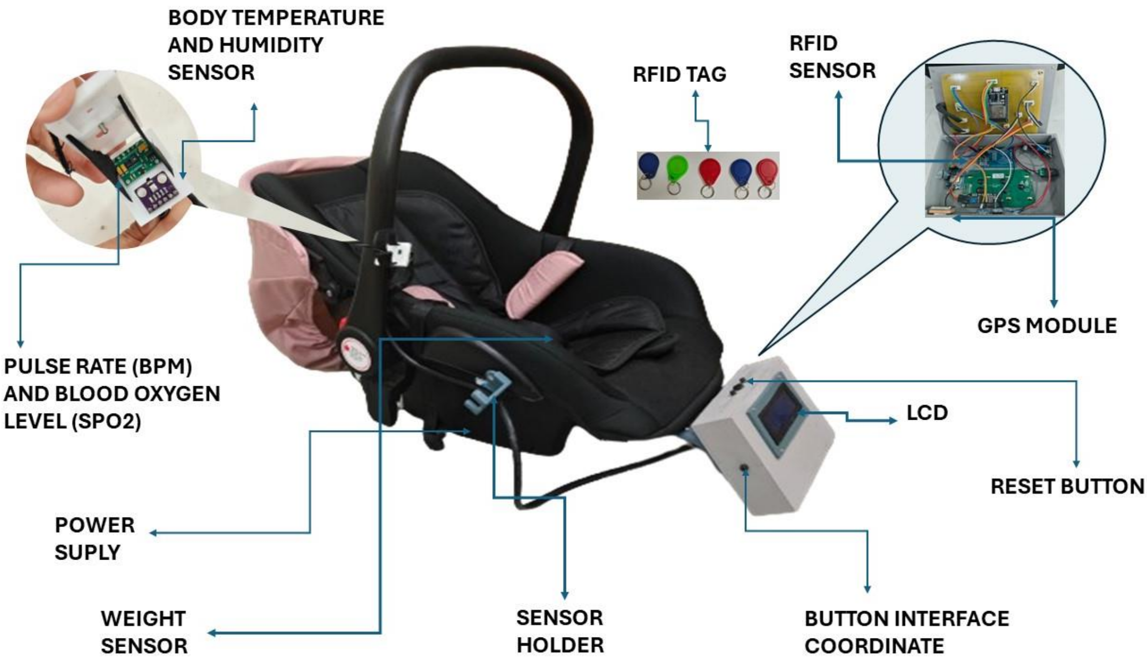

Figure 6. Improvement of the non-invasive monitoring *PreeCASE* device

3.2 *PreeCASE* Device Data Network

Figure 6 shows the system can provide a web application that allows administrators to manage user accounts, add or edit patient records, view reports and analytics, and perform system maintenance tasks. Doctors can log in to the system and input information about a patient's disease and also access medical records, review test results, and prescribe medications. On the other hand, patients can install the *PreeCASE* device mobile application on their phones to view upcoming appointments and access medical records and prescriptions. The design interface also helps the clinician solve the problem, especially in monitoring the baby's parameters such as heart rate, SpO2 level, and temperature through mobile applications. By mapping out these various use cases, the system can be designed to satisfy the requirements of all its consumers and enhance the overall quality of healthcare services. The web application is a central hub for managing patient information and facilitating communication between patients, doctors, and administrators. Through the data network system, users can find out the patient's condition directly through mobile apps. In addition, the facility for doctors or nurses to identify the status of their patients also becomes faster and more effective. It allows for better management of healthcare services and improved patient outcomes.

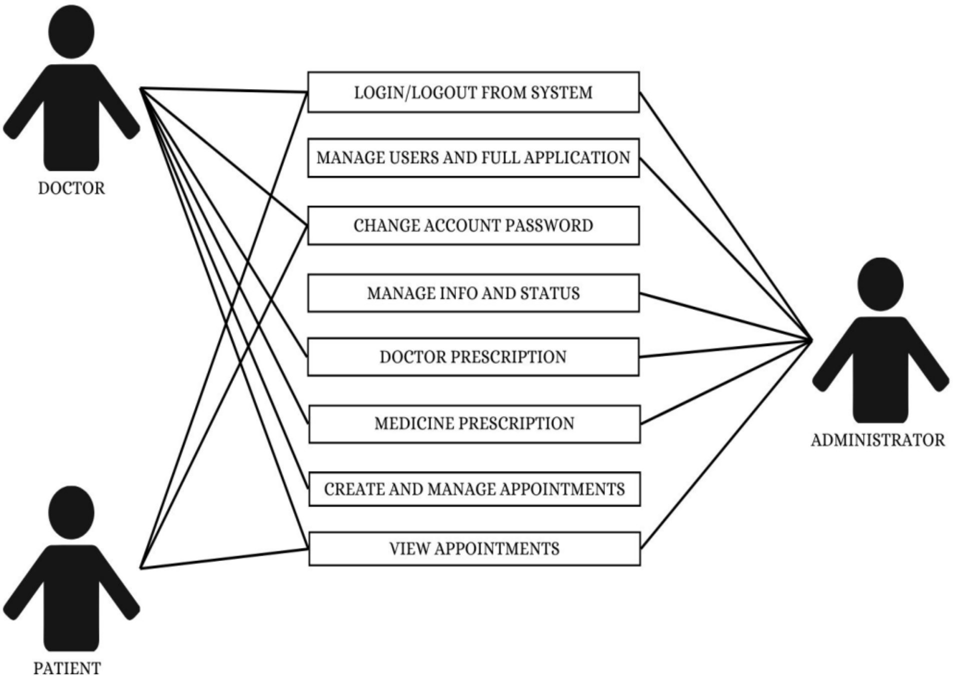

Figure 7. The *PreeCASE* device data network using mobile applications

3.3 Consistency of the Physiological Parameters Using *PreeCASE* Device

The results in Figure 7 show the consistent data reading on heart rate, SpO2 oxygen level, temperature, and weight of the ten healthy infants using the non-invasive monitoring *PreeCASE* device. The data obtained from this study show that the PreeCASE device has good reading consistency and meets the measurements of common devices available in the market, such as Joylee @ Medical Pro Fingertip Pulse Oximeter. For Figure 8(a), the SpO2 level shown is an average of 96%, equivalent to the actual value where the patient needs to reach a SpO2 level of 99%. As for the heart rate data, Figure 8(b) shows that the heart rate reading for the infants is in the range of 121bpm~158bpm, which is 97% accurate with the actual reading. This proves that the *PreeCASE* device has a very high level of reading efficiency and consistency. Referring to Figure 8(c) and Figure 8(d), the readings obtained are also very satisfactory for body temperature (Fridababy thermometer) and infant's weight (Marsden M-400-80D Baby Scale), which readings are almost the same as readings on existing devices.

The accuracy of the *PreeCASE* device is a critical aspect of its performance. The device's ability to provide consistent and accurate readings is essential for effective monitoring of premature infants. The results showed that the device achieved high accuracy in measuring physiological parameters, which is a testament to its design and development standards. Repeatability is another important aspect of the device's performance. The device's ability to provide consistent readings over time is crucial for monitoring the health of premature infants. The results showed that the device was able to provide consistent readings over time, which is a testament to its reliability. Validity is also an essential aspect of the device's performance. The device's ability to measure physiological parameters accurately and reliably is crucial for making informed decisions about the health of premature infants. The results showed that the device was able to measure physiological parameters accurately and reliably, which is a testament to its validity.

Through the results, problems in handling clinical data of infants such as heart rate, SpO2, and body temperature can be effectively overcome where the process of collecting these data can be stored and accessed very fast and safely. In addition, clinicians and parents can also monitor the physiological parameter level of their babies easily and anywhere. The effectiveness of this *PreeCASE* device is very high and is suitable for use in a health clinic or hospital to monitor newborn infants.

4. EXPERIMENTAL SETUP

The experimental setup used to measure the performance of the *PreeCASE* device involved testing the device on ten healthy infants. The device was used to measure heart rate, SpO2 level, and body temperature, and the results were compared with existing devices. The experimental setup was designed to simulate real-world scenarios and to test the device's performance under various conditions. The study was conducted to evaluate the performance and accuracy of the *PreeCASE* device in monitoring the vital signs of preterm infants. The experimental setup involved the following steps:

a) **Participant Selection**: Ten healthy preterm infants were recruited for the study. The infants were selected based on their age, weight, and overall health status.

b) **Device Configuration**: The *PreeCASE* device was configured to measure the following vital signs:

- Heart rate (bpm)
- Blood oxygen saturation (SpO2, %)
- Body temperature (°C)
- Weight (kg)
- Height (cm)

The device was powered by a rechargeable Lithium-ion battery and connected to a smartphone via Wi-Fi for data transmission and monitoring.

a) **Data Collection**: The *PreeCASE* device was placed on the infant's hand, and the vital sign data was collected. The data was transmitted to a smartphone in real-time using the *PreeCASE* mobile application. Scan RFID to recognize the user.

b) **Comparison with Existing Devices**: The data collected from the *PreeCASE* device was compared with the measurements obtained from commercially available devices, such as the Fingertip Pulse Oximeter and a digital thermometer. This comparison was done to assess the accuracy and reliability of the *PreeCASE* device.

c) **Data Analysis**: The collected data was analyzed using statistical software. The analysis included calculating the mean, standard deviation, and correlation between the *PreeCASE* device and the existing devices for each vital sign parameter.

d) **Alarm Notification Feature**: The *PreeCASE* device was also tested for its ability to detect abnormal vital signs and trigger an alarm notification. The device was equipped with a GPS tracker using the NEO 6m GPS module, which enabled real-time tracking of the infant's location. The alarm notification feature was designed to alert parents or healthcare professionals if the infant was left unattended in the car seat and had moved more than 3 meters away from the vehicle.

Here are the steps to use the *PreeCASE* device and mobile app:

Step 1: Register in the *PreeCASE* App and Scan RFID for User Detection

- Registration: Download and install the *PreeCASE* mobile app on smartphone.
- User Authentication: Open the app and register by providing a username and password.
- RFID Scanning: Scan the RFID tag to the preterm infant using the RFID reader integrated into the *PreeCASE* device.
- User Verification: The app will verify user identity and ensure that the user has permission to access the infant's data.

Step 2: Place Baby in *PreeCASE* and Detect Weight, SpO2, BPM, and Temperature

- Weight Detection: Place the baby in the *PreeCASE* device and ensure the weight sensor is properly aligned.
- SpO2 and BPM Detection: Place the pulse oximeter sensor on the baby's wrist or finger to measure blood oxygen saturation (SpO2) and pulse rate (BPM).
- Sensor Alignment: Ensure all sensors are properly aligned and securely attached.

Step 3: Transfer Data to App Using Wi-Fi

- Wi-Fi Connection: Ensure the *PreeCASE* device is connected to a stable Wi-Fi network.
- Data Transfer: The device will automatically transfer the collected data to the mobile app using Wi-Fi.

Step 4: Collect Data in the App

- Data Display: Open the app and navigate to the data display section.
- Data Visualization: The app will display heart rate, SpO2, body temperature, and weight.
- Data Analysis: Use the app's analysis features to track vital signs over time and identify trends.
- Alert System: Set up alerts for abnormal vital signs or changes in the baby's condition.

The experiment setup for the *PreeCASE* device was designed to simulate real-world scenarios and to test the device's performance under various conditions. The results of the experiment showed that the *PreeCASE* device was able to accurately measure the vital signs of the infants and provide more accurate and reliable data compared to existing devices. The *PreeCASE* device has the potential to improve the monitoring of premature infants and enhance the quality of healthcare services. Additionally, the device's alarm notification feature ensures the safety of the baby by alerting parents when the baby is left unattended in the car seat and has moved more than 3 meters away from the car. This feature provides an added layer of security and peace of mind for parents, ensuring that their baby is always safe and secure.

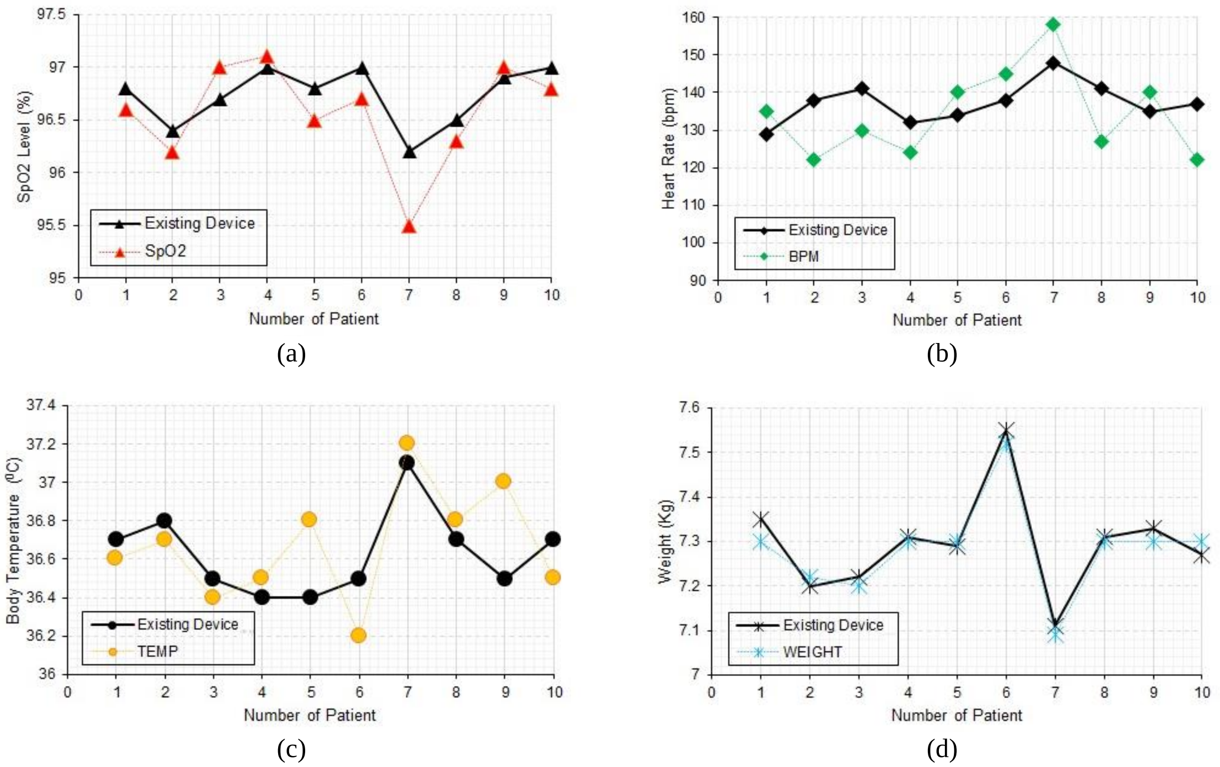

Figure 8. Illustrated the consistent data reading on; (a). SpO2 level; (b). heart rate; (c) temperature; and (d) weight, using existing compared with the present non-invasive monitoring *PreeCASE* device on ten healthy infants

The analysis of Figure 8 provides valuable insights into the performance of the *PreeCASE* device compared to existing devices across four key physiological parameters: SpO2, heart rate, body temperature, and weight. This comprehensive evaluation offers a nuanced understanding of the new system's capabilities and potential areas for improvement. SpO2 measurements, as depicted in subplot (a), demonstrate generally close alignment between the *PreeCASE* device and the existing device. Most readings fall within the 96-97% range, indicating good overall consistency. However, a notable discrepancy is observed for patient 7, where the new sensor records a significant drop to approximately 95% while the existing device maintains a higher reading. This divergence suggests that the *PreeCASE* device may possess enhanced sensitivity to oxygen saturation fluctuations, potentially offering earlier detection of desaturation events.

Heart rate data, presented in subplot (b), reveals more pronounced variability between the *PreeCASE* device and the existing device. The *PreeCASE* device frequently records higher heart rates, with a particularly striking spike observed for patient 7. Despite these differences, both devices generally capture similar trends in heart rate changes across patients. This pattern may indicate that the *PreeCASE* device employs a different measurement technique or exhibits heightened responsiveness to rapid heart rate fluctuations. Body temperature readings, shown in subplot (c), display good overall agreement between the *PreeCASE* device and the existing device. Both systems successfully detect a significant temperature elevation in patient 7, underscoring their ability to identify fever events. It's worth noting that the *PreeCASE* device consistently reports slightly lower temperature values compared to the existing device, suggesting a potential need for calibration adjustment to align more closely with established standards. Weight measurements, illustrated in subplot (d), demonstrate remarkable consistency between the *PreeCASE* device and the existing device. The near-identical readings across all patients indicate high reliability and precision in weight assessment, instilling confidence in this aspect of the new system's performance.

5. CONCLUSIONS

In conclusion, this research has successfully developed and validated the *PreeCASE* device, an innovative solution addressing the critical need for improved monitoring of premature infants' vital signs during travel. The device demonstrated high accuracy (>96%) in measuring oxygen saturation, heart rate, and body temperature across a sample of ten healthy infants. *PreeCASE* effectively integrates vital sign monitoring with car seat support, while its IoT-enabled real-time data transmission facilitates immediate access for parents and clinicians. The incorporated safety alarm system further enhances its utility by alerting caregivers to potentially dangerous situations. Despite limitations in sample size and study duration, these findings suggest significant potential for improving infant care quality and safety. Future research should focus on expanded clinical trials, long-term reliability assessments, and comparative analyses with existing technologies. The *PreeCASE* device represents a promising advancement in infant health monitoring technology, offering a comprehensive solution that could substantially enhance care for vulnerable infants while providing valuable data for healthcare providers and peace of mind for parents.

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