Infant-Wrap (*InfaWrap*) Device as Pediatric Technology Tool: The Heart Rate and SpO^2 Monitoring for Neonates

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Abstract Today, advances in science and technology may contribute to the resolution of medical devices for pediatric. This research focused on the development of the *InfaWrap* device; a tool to monitor neonate's heart rate and SpO^2. *InfaWrap* is designed to help the clinicians and parents to observe the baby's heart rate and oxygen saturation. The *InfaWrap* device uses a pro mini Arduino as a microcontroller, a MAX30100 oximeter sensor to measure SpO^2 and heart rate, and an LM35 to measure body temperature. Besides, we focus on the design and convenience wear criteria, including design characteristics, and structures to ensure the device is lightweight and more comfortable. The proposed *InfaWrap* device embedded an advanced wireless network sensor system. The data will be appeared in the mobile application installed on the doctor's or parent's mobile phone via Bluetooth module. Overall, based on three different babies as a subject in this study, we obtained that the *InfaWrap* device accuracy results reach the average of 96% for SpO^2, 81 bpm for baby heart rate, and 36.4 °C for baby body temperature.

Keywords Neonates · Medical device · Mobile application · InfaWrap · Pediatrics · Oximeter

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1 Introduction

Newborns are monitored for oxygen saturation from the first life until six months of age because of its possible adverse effects on brain development [1–4]. The American Academy of Pediatrics (AAP) and the American Heart Association (AHA) in 2010 [5] determined the SpO^2 objectives for the first 10 min after birth, establishing the arterial oxygen saturation that a baby must-have in the first minutes after birth [5]. The SpO^2 objectives table has assisted in the assessment of recovery and in avoiding the unnecessary administration of oxygen in newborns [5].

A study was performed in which 90% of babies with congenital cyanotic heart disease [6, 7] were detected using a pulse oximeter for use of screening within a few hours of birth. According to the evidence, infants with cyanotic heart disease is a critical sudden infant death syndrome (SIDS) may also be linked genetically to congenital coronary cyanotic diseases. It may be difficult to identify the major causes of SIDS [8, 9] most parents are making an extraordinary effort for their baby's health. By using the wireless healthcare technology, People who use sensing devices can move freely openly without being hindered by complicated wires [10, 11], and doctors at a remote care center can keep a close watch on the patient's health and thus offer patient recovery advice and long-term care in real time [12, 13].

This paper discusses the intelligent baby wrap model framework, *InfaWrap*, developed together with an accuracy test. One of the special aspects of the *InfaWrap* device features uses a wireless sensor to reduce clinicians and parents' load. This system is assembled and bundled in a compact, micro and Android smartphone using Bluetooth connectivity. This device is often fitted with battery charging cards, so that it can be refilled without changing the battery once the power runs out. It is easy to use this measurement device by connecting one of the foot sole to the specified sensor, then the three parameters of the scale would conveniently show on the LCD and Android mobile.

2 Methodology

2.1 Design Specification

The *InfaWrap* prototypes were designed using SolidWorks 2019 software and then shaped directly using 3D printing technology. For convenient wear of the *InfaWrap* device, the structure's design consequently had to be smaller, more comfortable to wear, and user-friendly. *InfaWrap* device is designed to monitor SpO^2, heart rate, and neonatal temperature through a cable-free wrapping concept.

This device is designed to have a small screen to prevent too many electronic parts inside the device. *InfaWrap* device is so lightweight with maximum total weight is 44.36 g. Figure 1 shows the final product of the *InfaWrap* device. By using the

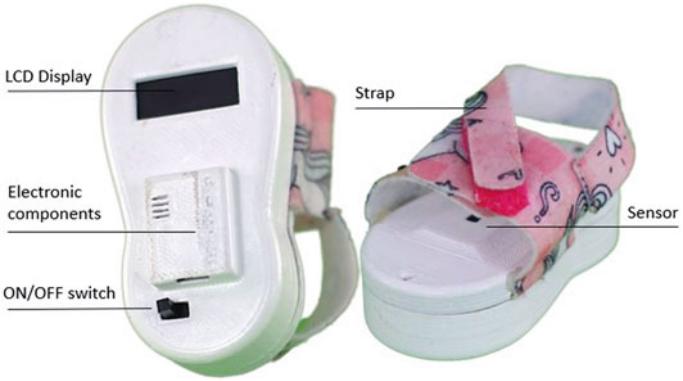

Fig. 1 Final product of *InfaWrap* device

Arduino board, all the measured values were monitored, analyzed, and displayed on the LCD screen. The results will be sent to an android application.

2.2 Device Components

Two sensors were used to measure three different conditions using this device. Figure 2 shows the complete system and electronic components of *InfaWrap*. The Arduino microcontroller is utilized to control the whole system. The SpO^2 and heart rate are measured using the MAX30100 sensor. Meanwhile, for LM35 sensor is used to measure of temperature [14, 15]. The HC-05 Bluetooth module is used to transfers measurement data from device to MyI-Wrap application or mobile app.

Figure 3b shows the development of the MyI-Wrap mobile app, which allows parents or doctors to monitor their baby's health status from anywhere, in a quick

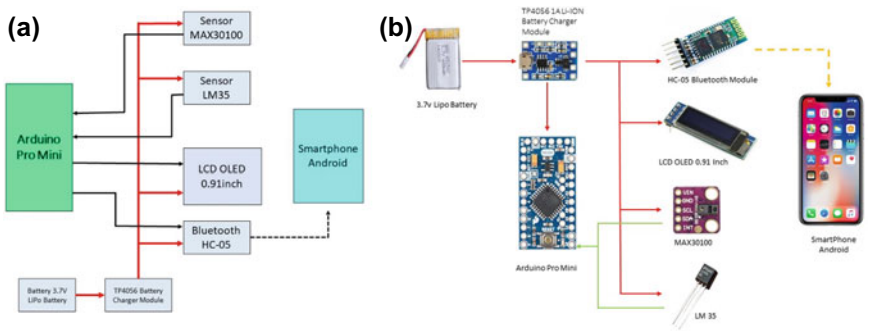

Fig. 2 Represented the; **a** block diagram of system; and **b** the electronic components of the *InfaWrap* device

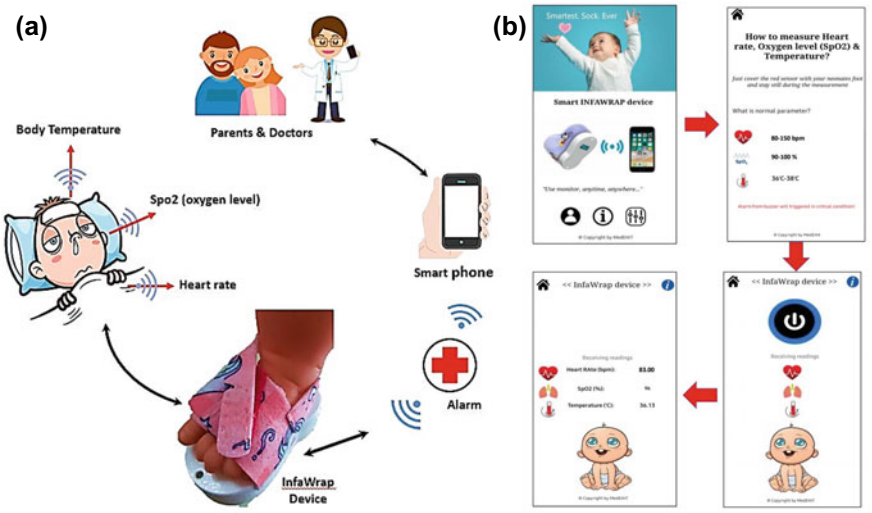

Fig. 3 **a** *InfaWrap* working; **b** *My*I-Wrap mobile application

and efficient manner. This software is available free through Google Play. Parents may also monitor their children's health while they sleep with this MyI-Wrap. As illustrated in Fig. 3a, the monitoring process is split into two steps; (1) data from the sensor was gathered; (2) data will be shown on the device and mobile phone via Bluetooth connection [16].

3 Results and Discussions

The *InfaWrap* device is specifically designed for newborns to assist clinicians and parents in monitoring their baby's heart rate, SpO^2 and temperature. Besides, this device needs several criteria requirements, such as small [17], light-weight, ergonomics, and low power consumption (or long battery life) that shows in Fig. 4. This section discusses the functionality of the *InfaWrap* device [18], standard operation how to wear the *InfaWrap*, and the sensor's accuracy based on three participants with differences in demographic data [19].

3.1 Accuracy Test

The participants involved in this study were two baby girls and one baby boy. All of them are the Malaysian citizens. The participants were volunteer for their contribution. Details about the participants as shows in Table 1.

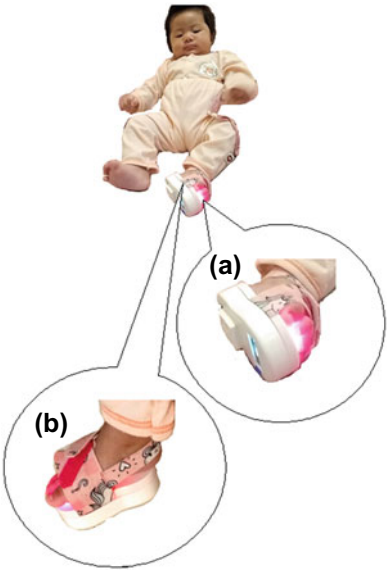

Fig. 4 The process of wearing the *InfaWrap* device to the baby; **a** bottom view with LDC monitor; and **b** top view wrapping or attach the device on baby foot sole

Table 1 Demographics information

Criteria	Subject 1	Subject 2	Subject 1
Gender	Female	Female	Male
Age (days)	97	102	91
Height (cm)	56.2	55.1	58.2
Weight (kg)	6.3	5.4	5.8

A reliability test is conducted to measure the *InfaWrap* device performances by repeated the measurement in 10 times. Table 2 shows the heart rate values obtained in 10 min' duration. Figure 5 clearly shows the trend of heart rate in 10 min reading. In the starting evaluation, subject 3 shows higher in heart rate. This is due to the situation where this baby a bit afraid and he cried during wearing the *InfaWrap* device.

Table 3 shows the SpO^2 of the babies in 10-time reading. Figure 6 shows the normal percentage of the SpO^2 for the baby is around 98–100%. We observed the trend of the SpO^2 for the three babies are good and acceptable which is around 97–99% [20]. For the resuscitation, stabilization and continuing treatment of the extremely low birth weight baby the optimum oxygen saturation values remain mostly undefined. We examined existing evidence for the usage of clinical oxygen in newborns. Median SpO^2 in babies delivered vaginally was 3% greater than for those born in the first 10 min of life in the previous research than in infants born with cesarean delivery.

Table 2 Heart rate reading in 10 min

Time (s)	Heart rate (bpm)		
	Subject 1	Subject 2	Subject 3
60	80	80	91
120	79	79	83
180	81	81	81
240	84	83	84
300	82	84	82
360	85	85	85
420	83	83	86
480	79	78	85
540	80	80	80
600	79	75	81

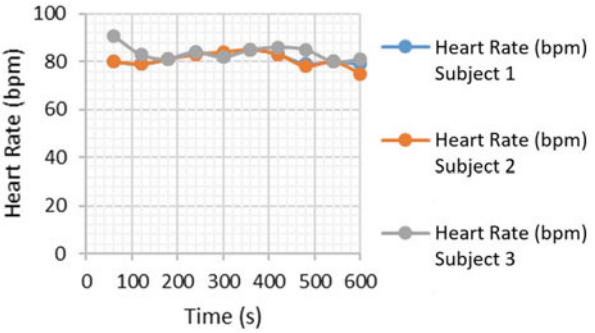

Fig. 5 Trend of the heart rate on difference participants. The values obtained in the morning session

Table 3 SpO^2 reading in 10 min

Time (s)	SpO^2 (%)		
	Subject 1	Subject 2	Subject 3
60	97	98	98
120	97	98	99
180	96	97	97
240	96	96	98
300	97	96	97
360	98	96	98
420	98	97	98
480	98	97	99
540	98	98	98
600	98	98	98

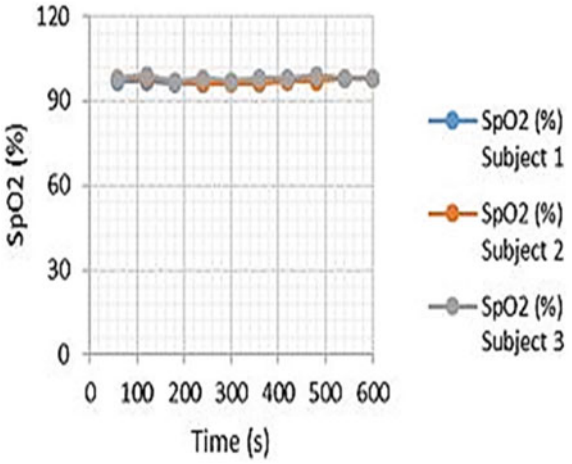

Fig. 6 Trend of the SpO^2 on difference participants. The values obtained in the morning session

Term infants had considerably greater saturation and saturation than preterm infants amounted to 90% quicker namely 4.7 min versus 6.5 min.

Table 4 shows the temperature level of the baby. Temperature is essentially important to know the condition of the baby especially during daily activities. Figure 7 shows the three babies' healthy condition without fever. The temperature value also presented good in detected the baby body temperature. A normal temperature for your baby is defined as a rectal reading between 36.5 and 37.0 °C; a temperature of 37.7 °C or higher is called a fever.

Table 4 Temperature reading in 10 min

Time (s)	Temperature (°C)		
	Subject 1	Subject 2	Subject 3
60	35	35	36
120	35	36	36
180	36	36	36
240	37	37	35
300	36	37	35
360	34	36	36
420	36	36	36
480	35	37	36
540	36	36	36
600	36	37	36
60	35	35	36
120	35	36	36

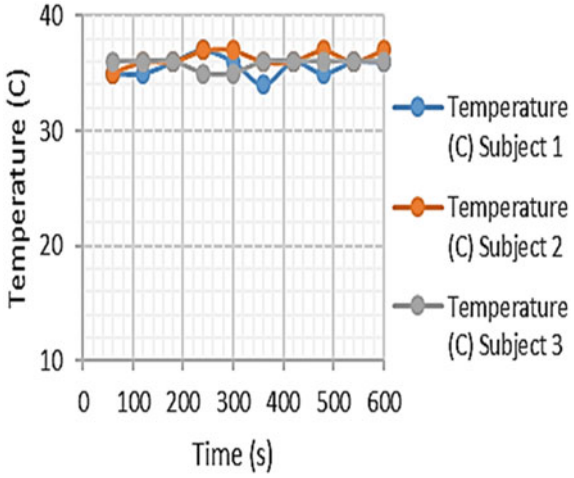

Fig. 7 Trend of the temperature on difference participants. The values obtained in the morning session

When a baby's temperature is abnormally high, it can indicate infection and it is better to meet a pediatrician, particularly if other symptoms such as a stuffy nose, sore throat, or cough continue. Based on the observation of the heart rate, SpO^2 and temperature values, the *InfaWrap* device's performance shows good and acceptable value especially in the accuracy of the data analysis.

4 Conclusion

This paper presented the product of the *InfaWrap* device that has successfully developed. The studies were focused on the functionality of the *InfaWrap* device, standard operation of wearing the *InfaWrap* device, and the sensor's accuracy based on three participants with differences in demographic data. The *InfaWrap* device is designed to monitor oxygen saturation SpO^2, heart rate, and temperature neonatal through a cable-free wrapping concept. Besides the measured value, it can analyze the health status for warning indicators are sent through mobile applications via Bluetooth to be stored and shared with the parents and clinicians. Besides, the *InfaWrap* device also has been developed to provide patients with the necessary support.

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