Available online at: http://journal.unj.ac.id/unj/index.php/gjik
Gladi: Jurnal Ilmu Keolahragaan 15 (03) 2024, 393-404
Permalink/DOI: https://doi.org/10.21009/GJIK.153.12

INTEGRATED MEASUREMENT SYSTEM FOR ATHLETE HEALTH: HEART RATE, BLOOD OXYGEN, AND BODY TEMPERATURE MONITORING

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(Submission Track: Received: 15-06-2024, Final Revision: 29-09-2024, Available Online: 30-09-2024)

Abstract Athlete health monitoring is critical for optimizing performance and ensuring physical well-being. This study presents an integrated non-invasive system designed to measure key physiological parameters: heart rate, blood oxygen saturation (SPO2), and body temperature. Utilizing infrared LED and photodiode sensors placed on the fingertip, the system detects changes in blood volume, correlating them with heart rate fluctuations. Pulse oximetry, employing red and infrared light wavelengths, accurately measures SPO2 levels by analyzing light absorption through finger tissues. Results from testing show promising accuracy with an average error of 0.89% for SPO2 measurements and 3.095% for heart rate measurements. Body temperature readings exhibit an average error of 0.78%, underscoring the system's reliability in non-invasively monitoring temperature changes. Challenges such as environmental influences and sensor calibration are addressed to ensure consistent and precise measurements. Future enhancements may incorporate advanced signal processing techniques and artificial intelligence to further refine measurement accuracy and reliability. This integrated system holds significant potential for enhancing athlete health management, aiding in early detection of physiological anomalies, and optimizing performance through real-time health monitoring.

Keywords : athlete health monitoring; pulse oximetry; non-invasive sensors

INTRODUCTION

The human body consists of various vital organs that are interconnected and serve unique and complex functions (Ahadian et al., 2018; Nakane, 2020). The heart, as a vital organ, functions to supply oxygen to the entire body and remove metabolic wastes (such as carbon dioxide) (Kanwal et al., 2021; Zhang & Barralet, 2017). Heart disease is the leading cause of death worldwide, underscoring the importance of early detection of this condition (Einstein et al., 2021; Zhang & Barralet, 2017). Pulse rate can be measured at any point on the body where the pulsations of arteries can be felt near the surface when pressed against the underlying structure.

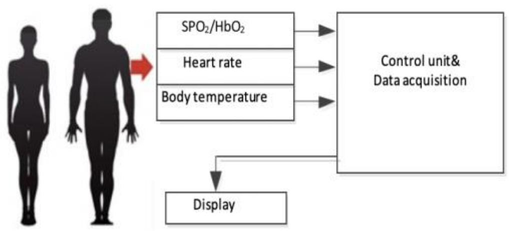
Pulse oximetry is a non-invasive method used to measure the percentage saturation of hemoglobin (Amin et al., 2023). This method utilizes differences in the wavelength of red light (660 nm) and infrared light (940 nm) captured by a sensor detector after passing through venous and capillary blood vessels at the fingertip (Budidha & Kyriacou, 2020; Ray et al., 2023; Vavrinsky et al., 2022). Pulse oximetry serves to manage long-term oxygen therapy patients and identify patients with congenital heart disease (Mao et al., 2023; Sakai-Bizmark et al., 2022). It has high accuracy in detecting congenital heart disease in newborn infants.

Photoplethysmography (PPG) is an optical technique for detecting cardiovascular (heart) pulse waves from the fingertip. It utilizes the reflection of optical sensors and warms the surrounding skin area, as evidenced by an increase in the pulsatile component of photoplethysmography. The design of an integrated signal monitoring system on a system-on-chip (SoC) platform and wireless technology in hospitals monitors parameters such as EKG and body temperature, processed using a microcontroller. The processed data results are transmitted to a web server via wireless communication (Heaney et al., 2022).

Pulse pressure detection integrates various analytical techniques for arterial blood pressure (ABP), intracranial pressure (ICP), and pulse oximetry signals (SpO2) (Heaney et al., 2022). Pulse pressure detection is used to estimate heart rate from ABP signals, classify ICP morphology, and estimate blood pressure using pulse oximeter waves (Brasil et al., 2021). Therefore, medical records in the form of heart rate, blood oxygen saturation, and body temperature are computationally calculated and studied to observe the body's health conditions without performing invasive or physical surgeries. This is expected to prevent premature human deaths due to heart abnormalities, attributed to suboptimal and unresponsive medical records.

METHODS

saturation sensors, a body temperature sensor, an Arduino Board Due, Multisim software, and Bascom Simulator software. The selection of sensor types for measuring heart rate, blood oxygen saturation, and body temperature parameters involved placing monitoring units on the fingertip. Through analyzing the operational characteristics and suitability of each component, a robust initial design was achieved, optimizing mechanical, electronic, and ergonomic aspects. The proposed method's block diagram is depicted in Figure 1, while the pulse oximetry sensor design is illustrated in Figure 2.



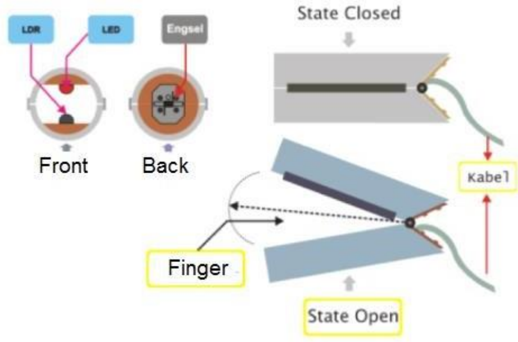


Figure 1. Block diagram of the proposed method.

Figure 2. Pulse oximetry sensor design.

RESULT AND DISCUSSION

The system is a form of heart rate detection application by sensing changes in blood volume in the finger arteries as the heart pumps blood. It consists of an infrared LED that sends an IR signal through the subject's fingertips, from the part reflected by the blood cells. The reflected signal is detected by the diode photo sensor. The change in blood volume with heart rate at photodiode output is not too large to be detected directly by the microcontroller.

Therefore, two stages are needed, namely high gain and active low pass filter, this design uses two operational amplifiers (Op-Amp) to filter and amplify the signal at the appropriate voltage level so that the analog signal can be computed by the microcontroller. Table 1 shows the results of the SPO^2 test on ten respondents with an average error of 0.89%. Table 2 shows the results of the BPM (heart rate) test to ten respondents with an average error of 3.095%. Below are the results of SPO2 Testing:

Table 1. Results of SPO2 Testing

Respondent	Led	IR	Difference
1	2.0	2.0	1.0
2	1.0	2.0	0.5
3	1.8	2.0	0.9
4	1.8	1.8	1.0
5	1.4	2.0	0.7
6	1.0	1.0	1.0
7	2.0	2.0	1.0
8	1.4	1.4	1.0
9	1.4	2.0	0.7
10	1.0	2.0	0.5

Furthermore, the results of the heart level test are presented below. For more details, please see the table below:

Table 2. Heart rate test results

Respondent	Led	IR	Difference
1	2.0	2.0	1.0
2	1.0	2.0	0.5
3	1.8	2.0	0.9
4	1.8	1.8	1.0
5	1.4	2.0	0.7
6	1.0	1.0	1.0
7	2.0	2.0	1.0
8	1.4	1.4	1.0
9	1.4	2.0	0.7
10	1.0	2.0	0.5

Selanjutnya pada tabel dibawah ini, menunjukkan nilai hasil tes suhu tubuh manusia terhadap sepuluh responden dengan rata-rata error sebesar 0,78%. Hasil pengukuran parameter detak jantung, saturasi oksigen dalam darah dan suhu tubuh disajikan dalam satuan nilai terukur yang ditampilkan pada LCD 16x2. Nilai pengukurannya berfluktuasi, karena pengukurannya menggunakan metode non-invasif (tanpa operasi).

Table 3. Heart rate test results

Respondent	Body Temperature (°C)		(%)
	Digital	Measuring	
1	37.0	37.12	0.32
2	36.5	36.76	0.71
3	36.6	36.71	0.30
4	36.3	36.76	1.26
5	35.6	36.14	1.51
6	36.6	37.02	1.14
7	36.7	36.92	0.59
8	36.8	37.12	0.86
9	36.9	36.98	0.22
10	36.7	37.04	0.92

The system created in this study has been able to work according to the plan, namely being able to measure heart rate, oxygen saturation in the blood and body temperature. From the test results, it can be concluded that the difference or difference in the measurement of the pulse oximetry sensor obtained an error value of 0.89% in the measurement of SPO2 and in the measurement of BPM (heart rate) of 3.095%. The difference or difference in body temperature sensor measurements obtained an error value of 0.78%. The difference or difference in measured and measured measurements is caused by several errors, including finger-shaped output errors for sensor readings. The average sensor response time when the device is turned on is approximately 20 seconds.

In addition to the measurement results that recorded small errors, this study also presents several challenges and considerations in the development of a non-invasive heart rate, oxygen saturation (SPO2), and body temperature detection system. One of the main challenges is sensitivity to environmental changes and the physical condition of the subjects being tested. Although the sensors and technologies used have been designed to provide stable results, fluctuations in environmental conditions such as room temperature or humidity can affect the accuracy of the measurement. This indicates the need for proper calibration and consistent environmental settings to ensure the consistency and reliability of the system in daily use.

Furthermore, while these systems are capable of measuring multiple health parameters simultaneously and providing reliable results, there is potential to improve measurement accuracy by integrating more advanced software algorithms. The use of more advanced signal processing technologies or integration with artificial intelligence (AI) can help in identifying and compensating for any interference or noise that may arise during measurements. Thus, further development in the software and analytics aspects can improve the system's ability to provide more in-depth and accurate health information to users or treating medical personnel.

CONCLUSION

From the studies conducted, it can be concluded that the developed system is successful in measuring important parameters such as heart rate, oxygen saturation in the blood (SPO2), and human body temperature in a non-invasive manner. The method used utilizes sensor technology to acquire data from the fingers, which are then processed and displayed through a microcontroller. The measurement results show that the system is able to provide fairly accurate values, even with a small error rate.

Specifically, for SPO2 measurements, the average error recorded was about 0.89%, while for heart rate (BPM) the average error was about 3.095%. These results show that although the system has successfully integrated sensor and electronic technologies well, there is still room for improved precision in heart rate measurement. Body temperature measurements also showed an average error of about 0.78%, which indicates that the system is quite reliable in providing body temperature values that are close to the actual value. In the context of medical applications, the development of this system has great potential for use in daily health monitoring and in medical settings, such as hospitals or long-term care centers. By continuously optimizing the design and technology used, it is hoped that the future measurement of these parameters can be more reliable and accurate, aiding in the early detection of health conditions that require further attention.

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