Pilot Study: Portable Non-Invasive Blood Sugar, Cholesterol, Uric Acid Monitoring System

Heni Sumarti[1*], Alvania Nabila Tasyakuranti[1], and Qolby Sabrina[2,3]

[1]*Department of Physics, Faculty Science and Technology, Universitas Islam Walisongo, Jl. Prof. Dr. Hamka No.3-5, Kota Semarang, Jawa Tengah 50185, Indonesia*

[2]*Department of Applied Chemistry, Graduate School of Engineering, Osaka University, Suita, Osaka 565-0871, Japan*

[3]*Research Center For Advanced Materials, Badan Riset dan Inovasi Nasional (BRIN), South Tangerang City, Banten 15314, Indonesia*

[*]*Corresponding author. Email: heni_sumarti@walisongo.ac.id*

Abstract— Degenerative diseases commonly associated with abnormal blood sugar, cholesterol, and uric acid levels require regular monitoring. Remote health monitoring technology enables children to monitor their parents' health conditions from a distance. This research presents a prototype development through Research and Development (R&D) methodology. This study developed a portable, low-cost, non-invasive detection system for blood sugar, cholesterol, and uric acid levels using the TCRT5000 sensor with Telegram integration. The compact device offers real-time monitoring advantages without blood sampling. The development followed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The research results show the prototype's coefficient of determination for blood sugar is 0.9733, cholesterol is 0.9411, and uric acid is 0.9610. The non-invasive prototype demonstrates measurement errors of 7.41% for blood sugar, 15.83% for cholesterol, and 14.69% for uric acid. These error rates currently exceed medical measurement standards. The system successfully integrates with the Telegram application for remote monitoring. Future research should incorporate artificial intelligence algorithms to minimize error values.

Keywords— Cholesterol and uric acid levels; Monitoring blood sugar, Non-invasive portable system; TCRT5000; Telegram

I. INTRODUCTION

As individuals age, the risk of developing degenerative diseases increases significantly [1]. These diseases, including osteoarthritis, osteoporosis, diabetes, high cholesterol, high uric acid levels, and Alzheimer's disease, result in the progressive deterioration of tissues and organs over time [2]. Notably, conditions such as diabetes mellitus, characterized by elevated blood sugar levels, and hyperuricemia, linked to high uric acid, are significant contributors to the health burden of aging populations [3]. Managing these conditions effectively requires regular monitoring of key health parameters like blood sugar, cholesterol, and uric acid levels. Traditional methods for monitoring these parameters involve invasive procedures, such as needle pricks, which can cause discomfort and pose risks of infection [4]. These methods, although accurate, can be deterrents for patients who need regular monitoring due to the pain and inconvenience involved.

Significant advancements have been made in developing non-invasive monitoring technologies in recent years. However, these technologies have yet to become standard practice due to various limitations. For example, one study [5] developed a non-invasive monitoring tool using MAX30105 and MLX90614 sensors with linear regression formulas to measure blood sugar, cholesterol, uric acid, and body temperature. The accuracy for blood sugar was 86%, cholesterol 92.5%, uric acid 86.7%, and body temperature 98.7%. Despite these promising results, the study concluded that further data collection is needed to improve accuracy. Another study [6] designed a non-invasive IoT home medical check-up tool using ESP32 WEMOS LOLIN 32 Lite, MLX90614, and MAX30105 sensors. This system measured temperature, uric acid, blood sugar, and cholesterol levels, transmitting data with a maximum delay of 0.091 seconds.

The ability to remotely monitor health parameters is becoming increasingly important, especially in the context of aging populations who may have mobility issues or live in remote areas [7]. Remote health monitoring technology has advanced significantly, enabling family members to monitor their elderly parents' health conditions from a distance. These technologies can be categorized into invasive and non-invasive methods. Traditional medical examinations often involve invasive procedures requiring blood samples, which can be uncomfortable and inconvenient, especially for elderly patients who need regular monitoring. Non-invasive monitoring methods offer an alternative approach, eliminating the need for blood sampling while still providing essential health data. Current non-invasive methods, however, still face challenges in achieving the accuracy and practicality needed for reliable medical monitoring. For example, while the Max30100 sensor and pulse sensors have provided promising results, their implementation in daily life still needs improvement due to the absence of remote monitoring capabilities [8]. Thus, there is a clear need for a solution that combines high accuracy with ease of use and remote accessibility.

To address these challenges, this research explores the potential of the TCRT5000 sensor for non-invasive health monitoring. Previous studies have shown that TCRT5000 sensors demonstrate promising results for blood sugar monitoring, with accuracy reaching 98.26% [9]. However, when applied to remote cholesterol monitoring, existing implementations only achieved 83.18% accuracy with an 8.8

Received 26 June 2024, Revised 21 April 2025, Accepted 22 April 2025.

DOI: https://doi.org/10.15294/jte.v16i1.8204

ms delay parameter [10]. This research aims to improve these limitations by developing an enhanced system that optimizes the TCRT5000 sensor's capabilities while incorporating Telegram integration for remote monitoring. The integration with Telegram, a widely accessible and user-friendly application [11], is proposed to facilitate convenient remote health monitoring while addressing the accuracy issues in previous implementations. This approach focuses on refining sensor data processing and calibration methods to improve measurement accuracy, particularly for cholesterol and other blood parameter monitoring.

Furthermore, integrating the TCRT5000 sensor with the Telegram application aims to overcome the limitations of non-invasive health monitoring. By leveraging the widespread usage and accessibility of Telegram, this system can provide real-time data to users and healthcare providers, facilitating timely interventions and continuous health management [12]. This development is particularly crucial for the elderly and individuals with chronic conditions, who require consistent monitoring to manage their health effectively.

The proposed system is designed to offer a more user-friendly approach to health monitoring, especially for aging individuals who require regular checks of their blood sugar, cholesterol, and uric acid levels. By combining advanced non-invasive measurement technology with practical remote monitoring capabilities, this research seeks to provide a solution that addresses the current limitations and improves the accessibility and usability of health monitoring tools. The comprehensive nature of this system can significantly enhance patient compliance and engagement, leading to better health outcomes and quality of life.

The paper is organized into the following sections to make it easy to follow. The methodology section details the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The results and discussion section presents the performance metrics and compares the new system's effectiveness with existing technologies. The article concludes with a summary of key findings and recommendations for future research.

II. METHODS

The development model used in this study is the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The subjects of this study are members of the academic community at the Faculty of Science and Technology, Universitas Islam Negeri Walisongo Semarang. The age range is 19-35 years, and the subjects include males and females. The study involved 15 participants. Sample collection was done using the standard Autocheck 3in1 device and the non-invasive monitoring system developed in this research. The use of this standard device complies with the recommendations of the Indonesian Ministry of Health, as regulated in Kemenkes RI AKL 20101311321. Data collection with the standard device involved drawing blood from the participants' fingertips using a lancet in a single data collection session. Meanwhile, data collection with the non-invasive system involved placing the participants' fingertips on the TCRT5000 sensor, with data collected three times. The research procedure scheme is shown in Figure 1.

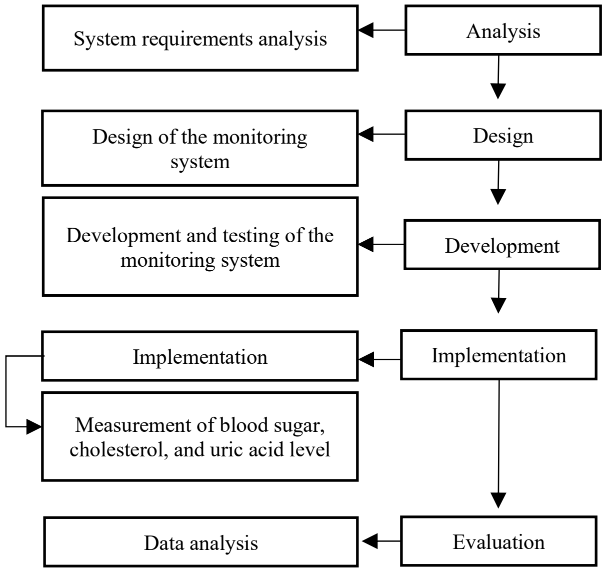


Figure 1. Research procedure scheme

Figure 2. Monitoring system design

A. Analysis

The research begins with analyzing the requirements for a remote monitoring system for blood sugar, cholesterol, and uric acid levels. It needs analysis, which is conducted through a literature review. Health monitoring is necessary to prevent further diseases resulting from exceeding normal thresholds. Regular monitoring of blood sugar, cholesterol, and uric acid levels is recommended to prevent these levels from exceeding the threshold. Therefore, a tool is needed to monitor these levels to ensure they remain within normal limits.

B. Design

The design of the non-invasive monitoring system for blood sugar, cholesterol, and uric acid levels is shown in Figure 2. This monitoring system uses the TCRT5000 sensor. The measurement sample in this study is the index fingertip, utilizing infrared light absorption. A power bank provides the voltage when the device is powered on and operates the transmission circuit. The data is then processed by the NodeMCU to be displayed on a 16x2 LCD screen and sent to the Telegram application.

1) The Determination Coefficient Test

The determination coefficient test is conducted to obtain the linear equation used to convert the Analog to Digital Converter (ADC) values from the developed non-invasive monitoring system into blood sugar, cholesterol, and uric acid levels. The linear equation is obtained from a simple linear regression between the ADC values and blood sugar, cholesterol, and uric acid levels. The simple linear regression equation is $y = a + bx$, where y is the standard measurement result, a and b are constants, and x is the ADC value from the non-invasive monitoring system. The obtained linear equation is used as a conversion factor to change ADC values (mV) into blood sugar, cholesterol, and uric acid levels (mg/dl). In contrast, the determination coefficient measures the tool's success in converting these values.

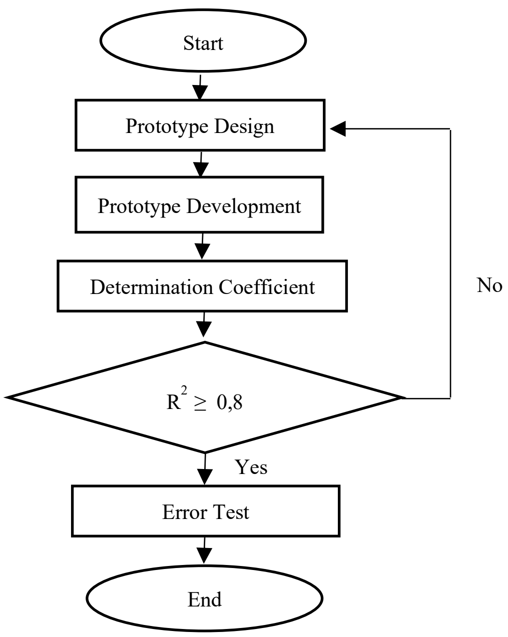


Figure 3. Monitoring system development scheme

TABLE 1. DETERMINATION COEFFICIENT INTERVAL

Coefficient Interval	Relationship Level
$0{,}00 \leq R^2 \leq 0{,}20$	Very Low
$0{,}20 < R^2 \leq 0{,}40$	Low
$0{,}40 < R^2 \leq 0{,}60$	Moderate
$0{,}60 < R^2 \leq 0{,}80$	Strong
$0{,}80 \leq R^2 \leq 1{,}00$	Very Strong

The interpretation of the correlation level in the determination coefficient is shown in Table 1. This correlation level indicates that the ADC value has a very strong relationship with blood sugar, cholesterol, and uric acid levels if the determination coefficient is greater than 0.8. If the value is $0.8 \leqslant R^2 \leqslant 1$, the device testing can proceed to the next stage. However, a redesign will be conducted if the determination coefficient is less than 0.8.

2) Error Test

The error of the monitoring system is evaluated by comparing the developed non-invasive monitoring system with a standard device. Sampling is conducted in two ways: (1) blood sampling from the fingertip artery using the Autocheck 3in1 standard measurement device and (2) placing the index finger of the test subject on the TCRT5000 sensor. The percentage error of the device can be calculated using the following equation (1).

$$\text{Percentage Error} = \frac{\text{Standard device} - \text{Monitoring system}}{\text{Monitoring system value}} \times 100\% \quad (1)$$

C. Implementation

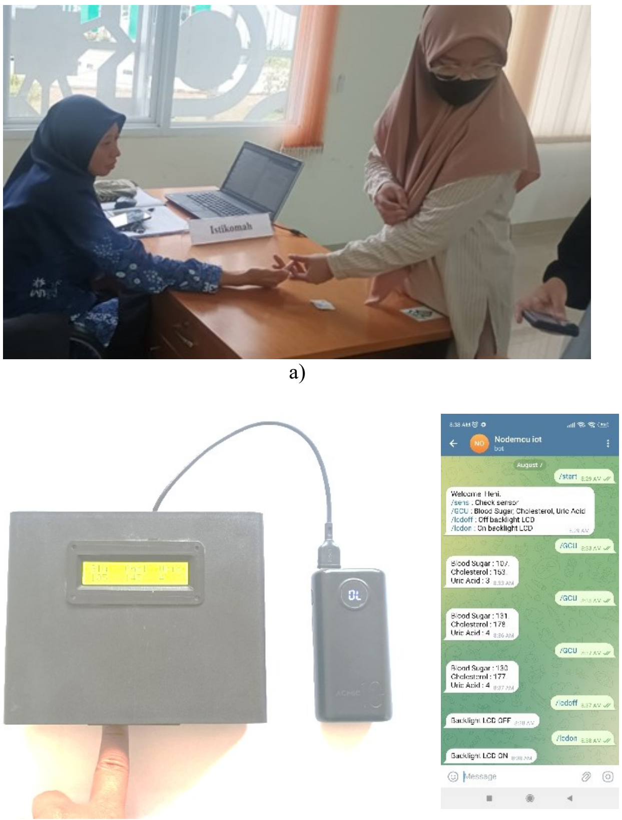
This stage involves data collection using the developed non-invasive monitoring system on test subjects. The data obtained include blood sugar, cholesterol, and uric acid levels. Subsequently, the data are analyzed based on normal thresholds.

D. Evaluation

The final stage is evaluation, which involves analyzing the data from the implementation results. The strengths and weaknesses of this study's developed non-invasive monitoring system are analyzed based on the collected data.

III. Results And Discussion

Data collection in the study is shown in Figure 4(a). Test subjects are conditioned to be relaxed and calm. Data collection begins with blood sampling using a lancet on the subject's fingertip. First, a sample is taken to measure blood sugar levels using the Autocheck 3in1 with the blood sugar pin. Next, a sample is taken to measure cholesterol levels using the Autocheck 3in1 calibrated with the cholesterol pin. Finally, a sample is taken to measure uric acid levels using the Autocheck 3in1 calibrated with the uric acid pin. After that, the subject is asked to place their finger on the TCRT5000 sensor. ADC data will appear on the liquid crystal display (LCD) screen and then be recorded. Initial ADC data is provided in mV units and will be converted into blood sugar, cholesterol, and uric acid levels in mg/dl. Figure 4(b) shows data collection using the developed non-invasive monitoring system, while Figure 4(c) displays the interface of the Telegram application.



a)

(b) (c)

Figure 4. The data collection using (a) a standard device, (b) non-invasive monitoring system, and (c) the interface on the Telegram application

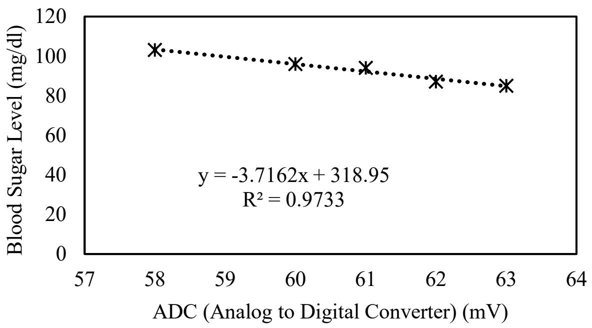


Figure 5. Graph of blood sugar level determination coefficient

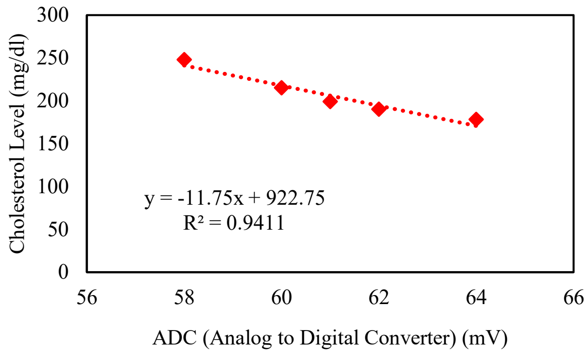


Figure 6. Graph of cholesterol level determination coefficient

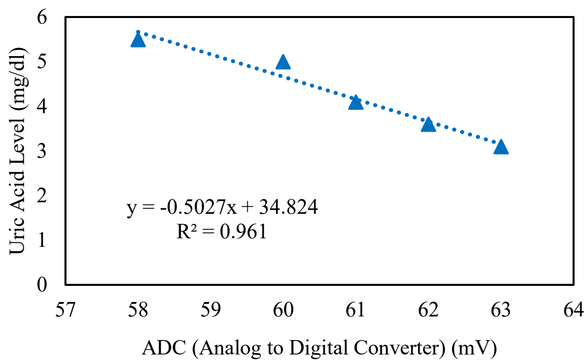


Figure 7. Graph of uric acid level determination coefficient

A. Determination Coefficient Test

The results of the determination coefficient test for blood sugar levels are shown in the linear trendline graph in Figure 5. The x-axis represents the ADC values from the non-invasive monitoring system in mV units, while the y-axis represents blood sugar levels in mg/dl. The straight line equation obtained from the linear trendline plot is y = -3.7162 x + 318.9500. This linear equation is the formula for converting ADC values into blood sugar levels. The determination coefficient is 0.9733, indicating a strong relationship between ADC values and blood sugar levels. The relationship between ADC values and blood sugar levels is inversely proportional.

The linear trendline graph of the determination coefficient test for cholesterol levels on the developed non-invasive monitoring system is shown in Figure 6. The x-axis represents the ADC values from the non-invasive monitoring system in mV units, while the y-axis represents cholesterol levels in mg/dl. The straight line equation obtained from the linear trendline plot is y = -11.75 x + 922.75. This equation is used to convert ADC values into cholesterol levels. The determination coefficient is 0.9411, indicating a strong relationship between ADC values and cholesterol levels. The relationship between ADC values and cholesterol levels is inversely proportional.

The results of the determination coefficient test for uric acid levels are shown in Figure 7. The results are presented as a linear trendline graph, with the x-axis representing the monitoring system's ADC (mV) values and the y-axis representing uric acid levels (mg/dl). The data is plotted using a linear trendline, resulting in the straight line y = -0.5027 x + 34.8240 equation. This equation is the formula to convert ADC values into uric acid levels.

B. Error Test

The error test of the device was conducted by comparing the standard device (Autocheck 3in1) with the non-invasive monitoring system developed in this research. The formula for the error test uses Equation (1). Table 2 shows the error test results for blood sugar level measurements. The lowest error value is 0.02%, and the highest error value is 13.90%. The results show that the average error of blood sugar level measurements using the non-invasive monitoring system is 7.41%. Table 3 shows the error test results for cholesterol level measurements. The lowest error value is 2.24% and the highest error value is 43.06%. The results show that the average error of cholesterol level measurements using the non-invasive monitoring system is 15.83%. Table 4 shows the error test results for uric acid level measurements. The lowest error value is 1.45% and the highest error value is 36.98%. The results show that the average error of uric acid level measurements using the non-invasive prototype is 14.69%.

TABLE 2. ACCURACY TEST RESULTS FOR MEASURING BLOOD SUGAR LEVELS

No	Autocheck 3in1 mg/dl	Prototype mg/dl	Prototype Error %
1	85.00	84.83	0.20
2	94.00	92.26	1.85
3	87.00	88.55	1.78
4	81.00	84.83	4.73
5	103.00	103.41	0.40
6	95.00	88.55	6.79
7	76.00	92.26	21.40
8	104.00	92.26	11.29
9	102.00	88.55	13.19
10	94.00	95.98	2.10
11	81.00	92.26	13.90
12	103.00	92.26	10.43
13	92.00	103.41	12.40
14	80.00	88.55	10.68
15	96.00	95.98	0.02
Average			**7.41**

TABLE 3. ACCURACY TEST RESULTS FOR MEASURING CHOLESTEROL LEVELS

No	Autocheck 3in1 mg/dl	Prototype mg/dl	Prototype Error %
1	223	182.50	18.16
2	172	206.00	19.77
3	239	194.25	18.72
4	301	182.50	39.37
5	136	182.50	34.19
6	178	170.75	4.07
7	248	241.25	2.72
8	190	194.25	2.24
9	182	206.00	13.19
10	144	206.00	43.06
11	215	217.75	1.28
12	199	206.00	3.52
13	233	206.00	11.59
14	280	241.25	13.84
15	195	217.75	11.67
Average			**15.83**

TABEL 4. ACCURACY TEST RESULTS FOR MEASURING URIC ACID LEVELS

No	Autocheck 3in1 mg/dl	Prototype mg/dl	Prototype Error %
1	3.10	3.15	1.74
2	4.10	4.16	1.45
3	3.80	3.66	3.77
4	4.10	3.15	23.08
5	5.50	5.67	3.04
6	4.40	3.66	16.90
7	6.60	4.16	36.98
8	3.30	4.16	26.04
9	3.60	3.66	1.57
10	5.00	4.66	6.76
11	3.60	4.16	15.54
12	3.30	4.16	26.04
13	6.40	5.67	11.45
14	5.40	3.66	32.29
15	5.40	4.66	13.67
Average			**14.69**

The errors for measuring blood sugar, cholesterol, and uric acid levels are 7.41%, 15.83%, and 14.69%, respectively. The highest accuracy result is in blood sugar level measurement, while the accuracy for cholesterol and uric acid measurements is almost the same. This is because blood sugar content increases along with the increase in blood sugar levels [13], consistent with the properties of infrared light absorption in the blood arteries at the fingertip. This non-invasive prototype cannot yet be used as a standard measuring device in healthcare, which must be an error of 5% or lower [14], [15], according to the regulations set by *Balai Pengamanan Fasilitas Kesehatan* (BPFK). BPFK is responsible for ensuring the safety of healthcare facilities, including infrastructure, equipment, and health devices, through testing, calibration, and radiation protection in both governmental and private sectors. Medical devices are for diagnosis and treatment, and errors above 5% can lead to errors in diagnosis and treatment. These errors can endanger patients' lives.

Previous research by Islamudin et al. [16] using the MAX30102 sensor with infrared light to measure blood glucose levels resulted in an error value of 6.026%. The lower error value was due to the sample measurement range in the previous study, which ranged from 57 to 136 mg/dl. In contrast, this study has a sample with a narrow blood glucose range, approximately 76 and 104 mg/dl. Another study by Usman et al. [17] used an Infrared (IR) Light Emitting Diode (LED) sensor with a wavelength of 940 nm to measure cholesterol levels, resulting in an average error of 6% with a sample size of 40 people and a measurement range of 158-306 mg/dl. The minor error is due to the sensor using a specific wavelength of 940 nm.

Additionally, the device was tested in the previous study by measuring total blood cholesterol with non-invasive techniques twice, before and after collecting blood samples for invasive techniques, resulting in better data than this study. Kim's research on uric acid measurement [18] using IR with a wavelength range between 1400-1700 nm resulted in an error value of 13% for normal measurement ranges. The lower error value obtained in this study is attributed to differences in the measurement procedure compared to this study. The previous research employed linear superposition theory, dedicating uric acid levels from a mixture using albumin protein, the third-largest uric acid factor. Based on the measurement data, it is indicated that the same technique could potentially be applied to actual blood, allowing for non-invasive extraction of uric acid concentration.

C. Implementation

The implementation of data involved collecting sample data from 15 research subjects. The data collection results were used for further analysis. Table 5 shows the blood sugar level measurement results using the non-invasive prototype. The lowest measurement result was 84.83 mg/dl, while the highest was 103.41 mg/dl. The measurement results indicate that the blood sugar levels of all research subjects were normal, which is less than 200 mg/dl. This threshold is the normal range for random blood sugar levels. The range of blood sugar levels that can still be measured using this non-invasive prototype is below the normal threshold. If subjects have blood sugar levels above the threshold, it cannot yet be confirmed that this device can measure them. However, the measurement samples in this study are all within the normal range.

TABLE 5. RESULTS OF MEASURING BLOOD SUGAR LEVELS USING PROTOTYPE

No	Blood Sugar Levels Autocheck 3in1 (mg/dl)	Temporary blood sugar threshold (<200 mg/dl)	Blood Sugar Levels Prototype (mg/dl)	Temporary blood sugar threshold (<200 mg/dl)
1	85.00	Normal	84.83	Normal
2	94.00	Normal	92.26	Normal
3	87.00	Normal	88.55	Normal
4	81.00	Normal	84.83	Normal
5	103.00	Normal	103.41	Normal
6	95.00	Normal	88.55	Normal
7	76.00	Normal	92.26	Normal
8	104.00	Normal	92.26	Normal
9	102.00	Normal	88.55	Normal
10	94.00	Normal	95.98	Normal
11	81.00	Normal	92.26	Normal
12	103.00	Normal	92.26	Normal
13	92.00	Normal	103.41	Normal
14	80.00	Normal	88.55	Normal
15	96.00	Normal	95.98	Normal

Table 6 shows the cholesterol level measurement results using the non-invasive prototype. The lowest measurement result was 170.75 mg/dl, while the highest was 241.25 mg/dl. The measurement results indicate that the cholesterol levels of 11 research subjects were normal, while 4 research subjects had high cholesterol levels, which is greater than 200 mg/dl. The highest range of cholesterol level measurements that can still be measured using this non-invasive prototype is 241.25 mg/dl. The error in cholesterol level measurement is considered high, so the measurement results can be said to be inaccurate. Out of 15 data points, there are 7 misdiagnosed cases: 3 cases of high cholesterol diagnosed as low, and 4 cases of low cholesterol diagnosed as high.

Table 7 shows the uric acid level measurement results using the non-invasive prototype. The lowest measurement result was 3.15 mg/dl, while the highest was 15.67 mg/dl. The measurement results indicate that the uric acid levels of all research subjects were within the normal range, 2.3 – 8.2 mg/dl. This threshold is the normal range for combined uric acid levels for both men and women. The uric acid level measurement range that can still be measured using this non-invasive prototype is within the normal range. If subjects have uric acid levels above the threshold, whether this device can measure them cannot be confirmed. The highest range of uric acid level measurements that can still be measured using this non-invasive prototype is 5.67 mg/dl. The error in uric acid level measurement is considered high, so the measurement results can be said to be inaccurate.

D. Evaluation

The evaluation consists of data analysis from the testing and implementation results of the non-invasive prototype. The measurement results for blood sugar, cholesterol, and uric acid levels were compared between measurements using the standard device (Autocheck 3in1) and the non-invasive prototype and then analyzed. This comparison is presented in a box and whisker plot. The box and whisker plot summarises the sample distribution that can depict data distribution, central tendency measures, and dispersion (variability). Figure 8 compares blood sugar levels measured using Autocheck and the non-invasive prototype. This graph shows that the measurement results using the non-invasive prototype experienced a narrowing of the measurement range compared

TABLE 6. RESULTS OF MEASURING CHOLESTEROL LEVELS USING PROTOTYPE

No	Cholesterol Levels Autocheck 3in1 (mg/dl)	Cholesterol threshold (<200 mg/dl)	Cholesterol Levels Prototype (mg/dl)	Cholesterol threshold (<200 mg/dl)
1	223	High	182.50	Normal
2	172	Normal	206.00	High
3	239	High	194.25	Normal
4	301	High	182.50	Normal
5	136	Normal	182.50	Normal
6	178	Normal	170.75	Normal
7	248	High	241.25	High
8	190	Normal	194.25	Normal
9	182	Normal	206.00	High
10	144	Normal	206.00	High
11	215	High	217.75	High
12	199	Normal	206.00	High
13	233	High	206.00	High
14	280	High	241.25	High
15	195	Normal	217.75	High

TABLE 7. RESULTS OF MEASURING URIC ACID LEVELS USING PROTOTYPE

No	Uric acid levels Autocheck 3in1 (mg/dl)	Uric acid levels threshold (2.3-8.2 mg/dl)	Uric acid levels Prototype (mg/dl)	Uric acid levels threshold (2.3-8.2 mg/dl)
1	3.10	Normal	3.15	Normal
2	4.10	Normal	4.16	Normal
3	3.80	Normal	3.66	Normal
4	4.10	Normal	3.15	Normal
5	5.50	Normal	5.67	Normal
6	4.40	Normal	3.66	Normal
7	6.60	Normal	4.16	Normal
8	3.30	Normal	4.16	Normal
9	3.60	Normal	3.66	Normal
10	5.00	Normal	4.66	Normal
11	3.60	Normal	4.16	Normal
12	3.30	Normal	4.16	Normal
13	6.40	Normal	5.67	Normal
14	5.40	Normal	3.66	Normal
15	5.40	Normal	4.66	Normal

to the measurements using the standard device (Autocheck 3in1).

Figure 9 compares cholesterol levels measured using Autocheck and the non-invasive prototype. This graph shows that the measurement results using the non-invasive prototype experienced a narrowing of the measurement range compared to the measurements using the standard device (Autocheck 3in1).

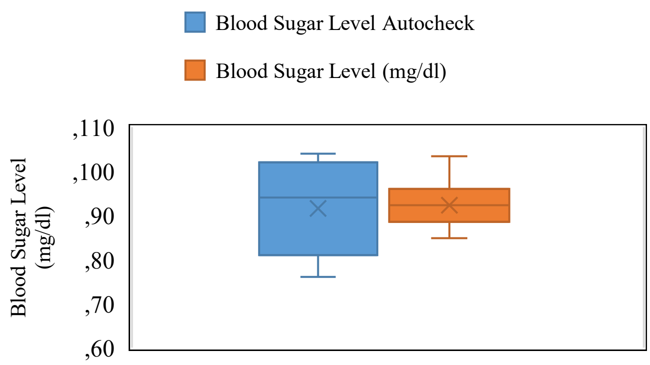


Figure 8. The comparison of blood sugar levels measured using Autocheck and the non-invasive prototype

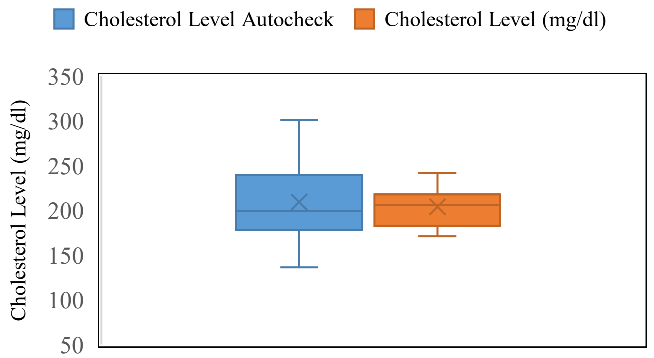


Figure 9. The comparison of cholesterol levels measured using Autocheck and the non-invasive prototype

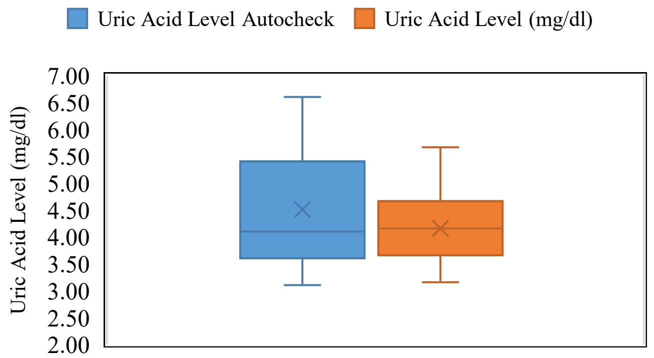


Figure 10. The comparison of uric acid levels measured using Autocheck and the Non-invasive prototype

Figure 10 compares uric acid levels measured using Autocheck and the non-invasive prototype. This graph indicates that the non-invasive prototype measurements narrow the measurement range compared to the standard measuring device (Autocheck 3in1).

The measurements of blood glucose, cholesterol, and uric acid obtained from non-invasive devices have a much narrower measurement range compared to invasive devices. The measured values do not strongly correlate with blood glucose levels, and the narrow linear range necessitates additional algorithmic corrections. Moreover, significant individual variability means the current fitting methods based on experimental samples cannot be universally applied. Additionally, complex detection methods, challenging detection sites, cumbersome procedures, high demands for detection equipment, and substantial background signal interference constrain the potential for using this technology as a commercial home glucose meter [18]. Additionally, in non-invasive systems using Near Infrared (NIR), despite employing strict calibration and signal processing, the detected light still suffers from significant scattering and absorption [19].

Previous research by Larin et al. [20] utilized an Optical Coherence Tomography (OCT) system with a wavelength of 1300 nm to measure blood glucose levels. This study found that the slope of OCT signals changed significantly, up to 2.8% per 10 mg/dl, with variations in plasma glucose levels. The strong correlation between the OCT signal slope and blood glucose concentration is attributed to the coherent detection of backscattered photons, which allows for the measurement of OCT signals from specific tissue layers without interference from signals of other tissue layers. The results of this study can serve as a foundation for further development.

The non-invasive monitoring system can function well by displaying real-time data that can be monitored using the Telegram application. It can help healthcare providers or families remotely monitor patients. Additional algorithms like artificial intelligence can be incorporated into future research to reduce error values.

Despite the need for improved measurement accuracy, the developed non-invasive monitoring system offers several significant advantages. First, the system successfully integrates the TCRT5000 sensor with the Telegram application for real-time remote monitoring, enabling healthcare providers or family members to monitor patients' conditions without being physically present. Second, patients can measure vital health parameters without the discomfort or infection risks commonly associated with invasive methods. Third, the high determination coefficients (0.9733 for blood sugar, 0.9411 for cholesterol, and 0.9610 for uric acid) demonstrate the system's promising potential for further development.

Future research could integrate multi-spectral sensors with different wavelengths to enhance measurement accuracy while maintaining the proposed solution concept. Multi-spectral sensors would enable more specific blood parameter detection since each wavelength can be optimized to detect particular blood components. For instance, a wavelength of 940 nm has proven effective for cholesterol measurements [17], while wavelengths between 1400-1700 nm show promising results for uric acid measurements [18]. This multi-spectral approach can be implemented within the existing design without altering the fundamental concept of the remote monitoring system that has been developed.

IV. Conclusion

This research successfully developed a portable, non-invasive monitoring system integrated with the Telegram application for blood sugar, cholesterol, and uric acid levels. Although the measurement accuracy (with errors of 7.41% for blood sugar, 15.83% for cholesterol, and 14.69% for uric acid) does not yet meet medical device standards, the system offers significant advantages in terms of patient comfort, remote monitoring capabilities, and broad application potential. The integration with the Telegram application enables medical personnel or family members to monitor real-time health from a distance, providing a practical solution for preventive health management. Future research will focus on implementing multi-spectral sensors and artificial intelligence algorithms to improve measurement accuracy while maintaining the advantages of the developed remote monitoring system.

Acknowledgement

Thanks to BOPTN 2022 Universitas Islam Negeri Walisongo Semarang with contract Number 1899/Un.10.0/R/HK.01.02/52022.

References

[1] E. Sri Dewi Hastuti Suryandari, H. Sarma Sangkot, A. Wijaya, and A. A. I. Citra Dewiyani, "Correlation Between Age and Degenerative Diseases in Kendalkerep Primary Health Care (PHC) Malang," *KnE Med.*, vol. 2023, pp. 315–328, 2023, doi: 10.18502/kme.v3i3.13518.

[2] E. Maldonado, S. Morales-Pison, F. Urbina, and A. Solari, "Aging Hallmarks and the Role of Oxidative Stress," *Antioxidants*, vol. 12, no. 3, pp. 1–37, 2023, doi: 10.3390/antiox12030651.

[3] A. Pan, G. G. Teng, J. M. Yuan, and W. P. Koh, "Bidirectional Association between Diabetes and Gout: The Singapore Chinese Health Study," *Sci. Rep.*, vol. 6, no. January, pp. 1–8, 2016, doi: 10.1038/srep25766.

[4] T. K. Mathew, M. Zubair, and P. Tadi, *Blood Glucose Monitoring*. 2023.

[5] R. N. Fauzi *et al.*, "Non-Invasive Detection System for Blood Sugar, Cholesterol, Uric Acid, and Body Temperature Using MAX30105 and MLX90614 Sensors," *Proceeding of the International Conference on Computer Engineering, Network and Intelligent Multimedia, CENIM*

2022. pp. 60–66, 2022, doi: 10.1109/CENIM56801.2022.10037351.

[6] H. Y. Darmawan *et al.*, “Non-Invasive IoT Home Medical Check-up Programming to Monitor Blood Sugar, Cholesterol, Uric Acid, and Body Temperature,” *2022 5th International Conference on Computer and Informatics Engineering, IC2IE 2022*. pp. 236–240, 2022, doi: 10.1109/IC2IE56416.2022.9970087.

[7] K. Boikanyo, A. M. Zungeru, B. Sigweni, A. Yahya, and C. Lebekwe, “Remote patient monitoring systems : Applications , architecture , and challenges,” *Sci. African J.*, vol. 20, 2023, doi: 10.1016/j.sciaf.2023.e01638.

[8] S. Ashraf, S. P. Khattak, and M. T. Iqbal, “Design and Implementation of an Open-Source and Internet-of-Things-Based Health Monitoring System,” *J. Low Power Electron. Appl.*, vol. 13, no. 57, 2023.

[9] T. Nurmar’atin, H. Sumarti, and A. Wulandari, “Validasi Alat Ukur Kadar Gula Darah Secara Non- Invasive Menggunakan Sensor Tcrt5000 Untuk,” *J. Inov. dan Pembelajaran Fis.*, vol. 9, pp. 51–61, 2022.

[10] T. Rahmawati, A. N. Tasyakuranti, H. Sumarti, and H. H. Kusuma, “Development of Non- Invasive Cholesterol Monitoring System Using TCRT5000 Sensor with Android Compatibilty,” *J. Fis.*, vol. 13, no. 2, pp. 77–84, 2023, doi: 10.15294/jf.v13i2.45044.

[11] A. A. Cantone, M. Esposito, F. P. Perillo, M. Romano, M. Sebillo, and G. Vitiello, “Enhancing Elderly Health Monitoring : Achieving Autonomous and Secure Living through the Integration of Artificial Intelligence , Autonomous Robots , and Sensors,” *Electronics*, vol. 12, no. 3918, pp. 1–23, 2023.

[12] A. Haleem, M. Javaid, R. P. Singh, and R. Suman, “Telemedicine for healthcare : Capabilities , features , barriers , and applications,” *Sensors Int.*, vol. 2, 2021, doi: https://doi.org/10.1016/j.sintl.2021.100117.

[13] T. K. Wolfgang Lösche, Frank Karapetow, Andreas Pohl, Carmen Pohl, “Plasma lipid and blood glucose levels in patients with destructive periodontal disease - Lösche - 2000 - Journal of Clinical Periodontology - Wiley Online Library.” 2001, doi: https://doi.org/10.1034/j.1600-051x.2000.027008537.x.

[14] M. Sulehu and A. H. Senrimang, “Program Aplikasi Alat Pengukur Kadar Glukosa Dalam Darah Non Invasive Bebasis Desktop,” *Inspir. J. Teknol. Inf. dan Komun.*, vol. 8, no. 1, pp. 16–24, 2018, doi: 10.35585/inspir.v8i2.2454.

[15] H. Suyono and Hambali, “Perancangan Alat Pengukur Kadar Gula dalam Darah Menggunakan Teknik Non-Invasive Berbasis Mikrokontroler Arduino Uno,” *JTEV (Jurnal Tek. Elektro dan Vokasional)*, vol. 06, no. 01, pp. 69–76, 2020.

[16] A. F. Islamudin and T. Rahmawati, “Improvement of Non-invasive Blood Sugar and Cholesterol Meter with IoT Technology,” *J. Teknokes*, vol. 17, no. 1, pp. 63–68, 2024.

[17] U. Usman, S. Syafruddin, and N. Ingrid, “A real time non-invasive cholesterol monitoring system,” *MATEC Web Conf.*, vol. 06005, pp. 1–10, 2020.

[18] J. Kim, "Biosensors & Bioelectronics Non-invasive Uric acid Monitoring Device using Near-Infrared Spectroscopy," *J. Biosens. Bioelectron.*, vol. 6, no. 4, 2015, doi: 10.4172/2155-6210.1000188.

[19] L. N. Bachache, J. A. Hasan, and A. Q. Al-Neami, “A Review : Non Invasive Sensing System for Detection Glucose Level A Review : Non Invasive Sensing System for Detection Glucose Level,” *J. Phys. Conf. Ser.*, vol. 1963, 2021, doi: 10.1088/1742-6596/1963/1/012125.

[20] K. V Larin, M. S. Eledrisi, M. Motamedi, and R. O. Esenaliev, "Non-invasive blood glucose monitoring with optical coherence tomography: a pilot study in human subjects," *Diabetes Care*, vol. 25, no. 12, 2002, doi: 10.2337/diacare.25.12.2263.