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Non-Invasive Tool of Cholesterol Level Measurement Prototype Using TCRT 5000 Sensor To Reduce Medical Waste

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Abstrak: Pada penelitian ini, kami mengembangkan alat ukur kadar kolesterol non-invasif menggunakan sensor TCRT 5000. Alat tersebut menggunakan Arduino sebagai prototipe elektronik dan sensor TCRT 5000 sebagai detektor. Penelitian ini menggunakan desain R&D (Research and Development) melalui tahapan perencanaan, pengolahan, dan pengujian alat. Pengembangan alat kolesterol non-invasif ini dapat menjadi alat inovatif yang mudah, murah, tidak menambah penumpukan limbah medis dan tidak menyakitkan (invasif). Pengembangan ini juga dapat membantu mengurangi penumpukan limbah medis biodegradable non-invasif. Akurasi pada alat yang dibuat peneliti pada pengukuran 14 sampel menunjukkan nilai rata-rata kesalahan sebesar 2,42% dengan akurasi alat 97,58%.

Kata Kunci: Arduino, Kolesterol, Non-Invasif, Sensor Biomedis, TCRT 5000

Abstract: In this study, we develop non non-invasive tool for cholesterol level measurement using the TCRT 5000 sensor. The tool used Arduino as an electronic prototype and the TCRT 5000 sensor as a detector. The study employs the R&D (Research and Development) design, progressing through the stages of planning, development, and testing of the tool. The development of a non-invasive cholesterol tool can be an innovative tool that is easy, cheap, reduces medical waste, and is not painful (invasive). This development can also help reduce the buildup of non-invasive biodegradable medical waste. The accuracy of the tool developed by the researcher for measuring 14 samples yielded an average error value of 2.42%, with a tool accuracy of 97.58%.

Keywords: Arduino, Biomedical Sensor, Cholesterol, Non-Invasive, TCRT 5000

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Introduction

This pattern of life and human physical activity is one of the determinants of human life. Research shows that 64% of the causes of a person's death depend on their lifestyle (Pangkahila, 2013). The risk of being affected by a disease in the body is closely related to the pattern of human life (Liu et al., 2012). Unhealthy lifestyles, characterized by a diet of unhealthy foods, insufficient physical activity, and inadequate exercise, can negatively impact human health. One of the impacts of this lifestyle can trigger high cholesterol levels (hypercholesterolemia), which can increase the incidence of other health problems, such as atherosclerotic cardiovascular disease (Raal et al., 2020), hypertension, heart problems, obesity, insulin resistance, diabetes mellitus, and stroke (Al Rahmad, 2018).

Cholesterol is a component of fat in the blood (Lestari et al., 2020). Cholesterol is a fatty substance that is waxy and yellowish in color and is produced by the liver. Cholesterol is a non-hydrolyzed lipid group and is the main sterol in human tissues. Cholesterol is a major constituent of plasma lipoproteins, and the plasma membrane is a precursor to a large number of steroid compounds (Morika et al., 2020). Cholesterol in the blood is useful for the body, but in excessive amounts, it will tend to cause disease (Anggaini & Fathrah, 2018; Lestari et al., 2020). Naturally, 80% of cholesterol in the blood is produced by the body (Mulyani et al., 2018). Genetic control of heredity regulates humans according to their DNA (Pangkahila, 2013). Therefore, the level of consumption of foods containing cholesterol or saturated fat is relatively minimal, which can cause more cholesterol production than in other people (Mulyani et al., 2018). High cholesterol levels (hypercholesterolemia) are a disorder of fat levels in the blood. Normal cholesterol levels in the blood are <200 mg/dl. Cholesterol levels at moderate risk range from 200 to 240 mg/dl and high risk at >240 mg/dl (Sinulingga, 2020). High total cholesterol levels are very dangerous because they can form atherosclerosis, which can cause hypertension and blockage of the blood vessels of the brain, heart, and leg blood vessels (Lestari et al., 2020). Several methods can generally do measurement of cholesterol levels, one of which is the Liebermann Burchard method (Atinafu, 2011), the Iron Salt Acid method, the Electrode-Based Biosensor method, and the CHOD-PAP method (Setyaningrum et al., 2017). Generally, the measurement of cholesterol levels is carried out invasively with a test strip, a portable, easy-to-use blood check tool. Easy Touch/ GCU is a tool used to measure uric acid (Rahmawati et al., 2018), cholesterol, and blood sugar. The measurement is done by placing blood on a strip, and the instrument will measure the cholesterol level on its screen (Fitri & Maisoha, 2020). Invasive measurement of cholesterol levels has accurate results. However, its use requires a fairly expensive checking fee, a long laboratory analysis, and pain arises in the part of the body that is pierced by a needle, which causes fear for some people (Fitri & Maisoha, 2020). The act of taking capillary blood using a test strip and a portable, easy-to-use device will certainly result in a buildup of medical waste that is difficult to decompose and dangerous, such as needles, used blood test strips, and alcohol swabs from the patient's blood (Samaria et al., 2018). Therefore, medical waste must be managed properly so as not to harm humans and the environment (Shareefdeen, 2012). Invasive testing of cholesterol levels has several shortcomings; therefore, many studies have been developed to measure cholesterol levels non-invasively. Based on research conducted by Marhaendrajaya, Hidayanto, and Arifin (2017), non-invasive testing of cholesterol levels can be done using near infrared (NIR) absorption based on Atmega 8535 as a minimum system for controlling digital output values. The resulting product achieved a tool accuracy of nearly 97%, indicating that the results obtained are quite accurate. Another non-invasive infrared-based study was conducted by Umar and Amin (2019) to measure glucose levels in the blood using a photoacoustic sensor. The research method used is the R&D research method, followed by the experimental method, with a fairly high error value ranging from 5% to 8%. Another research conducted by Fitri and Maisoha (2020) using the R&D method shows that non-invasive cholesterol level testing using an oxygen saturation light sensor can measure blood cholesterol levels in about 10-30 seconds with an error value of 17.72%.

Researchers are well aware that there is still a lot to be done regarding the development of noninvasive cholesterol testing tools. The development of a non-invasive cholesterol test kit can assist medical personnel in conducting testing efficiently. This development can also help reduce the buildup of non-biodegradable medical waste. In the research conducted, researchers used the TCRT 5000 sensor as an infrared reflector in the absorption of color and intensity emitted by the transmitter (IR LED). Arduino was used as the main microcontroller because it is easy to program, affordable, and compatible with the TCRT 5000 sensor (Marin et al., 2024; Tsebesebe et al., 2025). With the realization of this product, researchers hope that this non-invasive cholesterol level measuring tool with TCRT 5000 Sensor can be an alternative cholesterol level measurement tool that is easy, cheap, does not increase the accumulation of medical waste, and is not painful (Invasive).

Method

Research in the manufacture of Non-Invasive Cholesterol Measuring Instruments is carried out by researchers using Research and Development designs. The research was conducted by tools planning, processing, and testing.

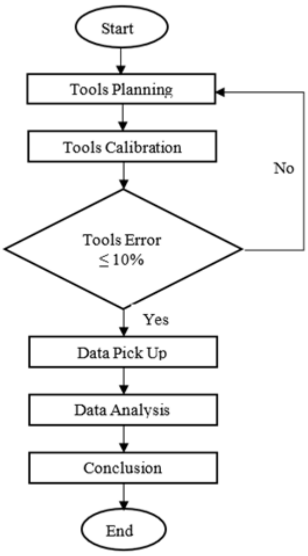

Figure 1. Block diagram of non-invasive cholesterol measurement using the TCRT 5000 sensor

At the planning stage, the researcher designed a hardware setup for a non-invasive cholesterol measuring device using a TCRT 5000 sensor, which was integrated with Arduino, as shown in Figure 1. Research in the manufacture of Non-Invasive Cholesterol Measuring Instruments is carried out by researchers using Research and Development designs. The research was conducted by tools planning, processing, and testing. At the planning stage, the researcher made a hardware design for a non-invasive cholesterol measuring device using the TCRT 5000 sensor, which was integrated with Arduino, as shown in Figure 1.

The TCRT 5000 sensor is an infrared reflective sensor (Mnati et al., 2021). The working principle of the TCRT 5000 sensor is to detect color based on color absorption and the intensity of infrared light emitted by the transmitter (IR LED) and received by the receiver (phototransistor). This identity difference is used as a bias in the phototransistor base found in the TCRT 5000 sensor (Limantara et al., 2020). In its utilization, the TCRT 5000 sensor can be used to detect lines on line follower robots (Ridarmin et al., 2019).

Arduino acts as an open-source electronic prototype. Arduino is a combination of hardware and a sophisticated Integrated Development Environment (IDE). IDE is a software that plays a very important role in writing programs, compiling them into binary, and uploading them to the microcontroller memory (Budi & Pramudya, 2017). The TCRT 5000 sensor readings will be forwarded to the microcontroller with the set parameter (Suryowinoto & Wijayanto, 2020).

Figure 2. Hardware circuit and LCD

The processing stage is carried out by compiling a non-invasive cholesterol level measuring device. The hardware has been integrated into the upload program using the Arduino software. Figure 2 illustrates the process that occurs when the sensor detects a change and reflection of light. The Arduino Software then displays the ADC conversion data, and the output is shown on the LCD.

The first stage of testing the tool is calibration. The calibration stage serves to improve the accuracy and quality of the data (Xinwei & Bate, 2019). The calibration stage involves comparing the participants' samples for cholesterol levels, both invasively and noninvasively, to obtain a linear regression value. Each age group has different metabolic characteristics and lifestyle patterns, so the sample was taken from three groups: adolescents, adults, and the elderly. This selection was made to gain a more comprehensive understanding of cholesterol level variations at different stages of life. On the LCD prototype display, the measurement results displayed are the ADC values read by the sensor and the conversion of cholesterol levels (mg/dl), which must go through a calibration stage so that the data is appropriate. The tool that has been set for calibration can then be used to test cholesterol levels by accurately displaying the cholesterol level in mg/dl.

Result and Discussion

The prototype was initially tested by measuring 5 samples of cholesterol levels using both invasive and non-invasive methods to calibrate the instrument. The relationship between ADC values and cholesterol levels at Easy Touch GCU can be seen in Figure 3. It resulted in Equation (1) with a regression correlation R^2 = 0.9803. The value of the coefficient determination in the correlation regression is between $0<R^2<1$. Based on the correlation interpretation, an interval value between $0.8 \leq R^2 \leq 1$ is a very strong level of relationship type (Ndruru et al., 2014), so the R^2 value is 0.9803, including the relationship type with a very strong level.

$$y = 14.6698x - 434.6604 \quad (1)$$

The next stage involves testing cholesterol levels non-invasively, comparing them with the invasive method in 14 participants randomly sampled from the 13-60 age group, including both males and females. Invasive measurements were carried out with the Easy Touch GCU, and non-invasive measurements were made using a prototype that the researcher had made. The test results with the prototype show that there are differences in the ADC values in each sample, as seen in Figure 3. This is due to differences in the absorption and reflection of light in body tissues, which serve as an indicator of cholesterol levels in the body.

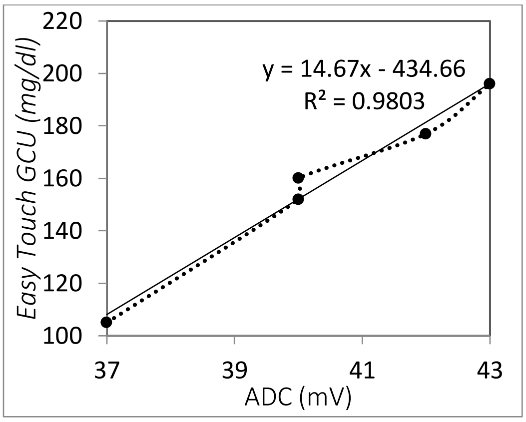

Figure 3. Linear graph of calibration between cholesterol level measurements using Easy Touch GCU (mg/dl) and ADC prototype

Tool validation is done by comparing cholesterol levels using invasive and non-invasive methods. Measurable data from invasive devices is highly accurate because it utilizes blood samples from each person. In contrast, measurements from non-invasive devices rely on the absorption and reflection of light detected by the TCRT 5000 sensor, as detailed in Table 1.

Table 1. Comparison of invasive and non-invasive cholesterol level measurement

Subject	Invasive (mg/dl)	Non-Invasive (mg/dl)	Error
A	105	108	2.85%
B	115	108	6.08%
C	132	137	3.78%
D	132	137	3.78%
E	135	137	1.48%
F	150	152	1.33%
G	152	152	0%
H	152	152	0%
I	160	152	5%
J	177	181	2.25%
K	189	181	4.23%
L	196	196	0%
M	214	210	1.86%
N	237	240	1.26%
Average			2.42%

Table 1 shows the error value with an average percentage of the error value 2.42%. The consistency of these low error values across 14 Samples indicates that the sensor response and calibration process work effectively. The minimal deviation between the two measurement methods demonstrates that the TCRT5000 sensor can accurately capture the reflective light intensity that correlates with cholesterol concentration in body tissues. Thus, the invasive cholesterol level measuring instrument using the TCRT 5000 sensor has an average accuracy of 97.58%. The prototype made by the researcher is classified as feasible to use because its accuracy has met the accuracy standard of medical devices that can be used for humans, with a value of 95% (Suyono & Hambali, 2019).

The findings of this study are consistent with those reported by Marhaendrajaya et al. (2017), who developed a noninvasive cholesterol measurement device using near infrared (NR) sensors and an Atmega microcontroller, achieving performance results. Similarly, Umar et al. (2020) compared invasive and noninvasive cholesterol testing and found a significant correlation between both measurement methods. Compared with these previous studies, the present work shows a smaller measurement error, indicating that the combination of the TCRT 5000 reflective optical sensor and Arduino microcontroller offers high stability and precision in detecting cholesterol-related light reflection changes. Thus, this study strengthens the evidence that low-cost optical sensors can serve as a sustainable and environmentally friendly alternative to invasive cholesterol testing and helping to reduce medical waste.

Conclusion

A non-invasive method for measuring cholesterol levels was successfully developed using Arduino and a TCRT 5000 Sensor. Cholesterol level measurement data obtained using an invasive method were compared with data obtained using a non-invasive method. The accuracy of the tool made by the researcher on the measurement of 14 samples shows an average error value of 2.42% with the tool accuracy 97.58%. Non-invasive method development of measuring cholesterol levels, an innovative alternative cholesterol level measuring instrument is created that is easy, cheap, does not increase the accumulation of medical waste, and is not painful (invasive). For future research, it is recommended to improve the design and casing of the device to make it more ergonomic and user-friendly. In addition, further calibration and testing using a larger number of samples are necessary to enhance measurement accuracy and reliability. Integration with mobile-based monitoring applications can also be considered to increase practicality and accessibility for users.

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