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Development Reflective Optical Sensor for Blood Cholesterol Measurement Using LED Infrared 940 nm

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Abstract

Hypercholesterolemia is one of cause of cardiovascular disease which is one of the most significant causes of death in world. This could be anticipated by monitoring blood cholesterol levels regularly. The current method of monitoring total blood cholesterol by using an invasive technique of taking a painful blood sample. A simple device is needed to measure blood cholesterol level without collecting blood samples. This Study aims to develop an optical sensor to measure blood cholesterol levels by utilizing infrared rays so that people with and without hypercholesterolemia can easily monitor their blood cholesterol levels regularly. The method of developing the application of reflective optical sensor focuses on the use of an infrared lighting emitting diode (IR LED) wavelength of 940 nm as a transmitter and a photodiode use a detector and microcontroller as a minimum system used to process electronic signals into total cholesterol values with an algorithm to classify total blood cholesterol. The measurement results were tested using variance analysis by comparing the result of non-invsive and invasive measurement with a p-value less than 0.05 which means the results could be accepted.

Keywords: Blood Cholesterol, Optical Sensor, Infrared, LED, Photodiode

1. INTRODUCTION

The human body consists of cells which contain cholesterol and have important functions. Cholesterol comes from food and is produced by the body in a waxy and fat-like appearance. It is a kind of oil, so it cannot dissolve in water-based blood plasma.[1]. To maintain and control the balance of cholesterol levels in the body, it is necessary to carry out regular check-up. In general, individuals pay less attention to their cholesterol levels due to the expensive cost of blood cholesterol monitoring. Research has been done on the topic of blood cholesterol levels, among others; research on the correlation between the increase of blood cholesterol levels and cardiovascular. diseases occurrence, such as arteriosclerosis, hypertension and stress.[2][3][28].

Hypercholesterolemia is a symptom of high blood cholesterol levels, including Low Density Lipoprotein (LDL), which contributes to the increase population of cardiovascular disease, a disease of the heart and blood vessels and the main cause of death in the world.[4][5][6] The Data from WHO predicted the number of death increased up to 23.4 million in 2030 compare to 17.5 million deaths in 2012 and 80% will be caused by heart attacks and strokes, and more than 75% will occur in low and middle income countries. Around 34% deaths attributable to cardiovascular disease occurred before the age of 70.[7][25]. Excessive proteins carried by cholesterol and triglycerides or Low-Density Lipoprotein (LDL) flowing in the blood plasma can cause myocardial infarction (heart attack), stroke or peripheral vascular disease.[8].

Device for measuring total cholesterol available in general clinical laboratories is the one with invasive technique such as Autocheck, Accu-check, Nesco and Easy Touch (GCU) which use strips for collecting blood samples. Invasive technique procedure requires blood samples collection which poses a risk of bruising and inflammation. However, the advanced in health technology nowadays has a positive impact that makes it easy for individuals to monitor blood cholesterol levels quickly. Measuring cholesterol levels with non-invasive techniques or without using strips and bloods samples has been widely research such as; measurement of total blood cholesterol using a near-infrared sensor.[1] Estimating total cholesterol with bioelectric impedance.[8][9]. Monitoring total cholesterol in the blood using a smart phone camera, yet this research still used blood samples collected on the strip then scanned using a smart phone camera.[10]. This research focuses on developing a total cholesterol level monitoring device with a non-invasive procedure, using a sensor (LEDs) wavelength 940 nm, as an emitter and photodiode as a detector with a spectral bandwidth range of 400 nm - 1100 nm, The aim is that hypercholesterolemia sufferers can monitor total cholesterol at all times at low cost.

2. LITERATURE STUDY

Cholesterol has a chemical formula C27H46O, a small molecule, which in biology is a waxy lipid, mixed in blood plasma. Cholesterol is almost insoluble in the blood, so it moves in the bloodstream with very small concentration.[8]. It is transported by lipoprotein within the blood to all tissues of the body so that it can affect blood cholesterol levels. Cholesterol flow can cause clogged arteries due to lipoprotein accumulation. Lipoproteins are classified into Low Density Lipoprotein (LDL) and High Density Lipoprotein (HDL).[10].

In 2013, The Ministry of Health of Republic Indonesia established an ideal standard for total blood cholesterol by referring to the National Cholesterol Education Program - Adult Treatment Panel (NCEP-ATP III).[11]. As shown in the table below:

Table 1. Total blood cholesterol reference values.

Category	LDL (mg/dl)	Total (mg/dl)
Optimal	<100	
Desirable		<200
Near optimal/above optimal	100-129	
Borderline High	130 - 159	200 - 239
High	160 - 189	>240
Very High	> 190	

(LDL) volume can be determined if the total cholesterol, (HDL) and triglyceride values are identified, which are measured directly in the blood.[1][8][12].

$$L = C - H - kT \quad \ldots\ldots\ldots\ldots \quad (1)$$

H = HDL cholesterol, L = LDL cholesterol, C = total cholesterol, T = triglycerides and k = 0.20 when using unit measurement of mg/dl and k = 0.45 when using mmol/l

The description of light propagation in a homogeneous medium as described by the Lambert Beer's law stated that when radiation interacts with biological tissue, the light is weakened by absorption and scattering, so that light attenuation can be described by the absorptions of light at specific wavelengths in homogeneous solution.[13], which can be determined accurately using the following equation;

$$I_x = I_O \cdot e^{-\varepsilon(\lambda)\beta L} \quad \ldots\ldots\ldots\ldots (2)$$

Equation 2, IX is the reflected light intensity, IO is light intensity incidence, ε is media absorption and media absorption coefficient, β is the concentration of absorption and L is the length of the light path.

The reflected light, the input voltage (Vin) and the output voltage (Vout) are the substitution of the reflected of light intensity Ix and light incident Io, as described in the following linear equation (3):

$$\frac{V_{in} - V_{out}}{V_{in}} = 10^{-\varepsilon\beta L} \frac{V_{in} - V_{out}}{V_{in}} = 10^{-\varepsilon\beta L} \quad \ldots\ldots\ldots\ldots (3)$$

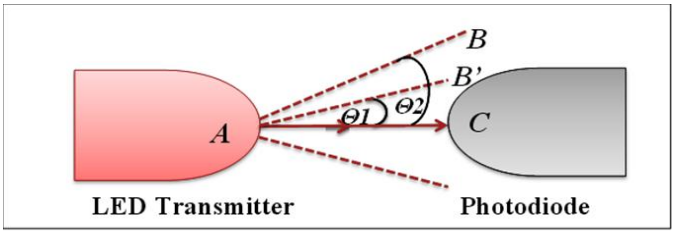

Figure 1. IR (LED) light reflection angle

Figure 1 describes the refractive index (η2) in measuring cholesterol levels by connecting points A, B and C. Blood cholesterol concentration is closely related to the light reflectance angle and has direct correlation between light intensity Ix and output voltage (Vout) as described on equation (3). Therefore, the decrease of reflection angle (θ2) in the figure indicates the increase of cholesterol levels in the blood, so that line AB moves closer to line AC and creates a new line AB'. Mathematically, the refractive index (η2) can be calculated using Snell's law, with the following equation (4):

$$\eta_2 = \frac{\eta_1(\sin\theta_1)}{\sin\theta_2} \quad \ldots\ldots\ldots\ldots (4)$$

The refractive index of cholesterol is represented by η2, and η1 represents the refractive index of water with value of 1.333. The bias angle of water and cholesterol are represented by θ1 and θ2 respectively.

The reflection angle (θ2) decreases as the blood cholesterol level increases which reduces the reflected index (η2) and increases output voltage (Vout) because many photons touch the photodiode. The radius of BC on (LED) light also decreases when light rays curving to AC which causes the increase of cholesterol levels according to Snell's law.[14].

Near infrared (NIR) sensors is used in non-invasive technique to measure components in the blood such as blood glucose, hemoglobin, SPO2, and heart rate. Research on non-invasive technique to measure blood glucose levels use near infrared sensors (NIR) with Emitter (LED) 1550E, FGA10 photodiode with 800 - 1800nm wavelength.[15]. Blood glucose monitoring with a near infrared spectroscopy sensor with a wavelength of 940 nm and radiation at 700 – 1100nm.[13], [14], [16]–[19]. Development of monitoring blood glucose by utilizing laser light refraction.[20], [21] Measurement of blood cholesterol with near infrared sensors with wavelengths between 700 - 1400 nm[1]. Measurement of cholesterol levels using eye images.[22][26].

Analysis of Variance (ANOVA) is a statistical test to determine differences in several data sets (averages). This research uses one-way ANOVA to analyze significant data differences between the two results of invasive and non-invasive measurement techniques.[23]. The result of ANOVA test obtains P and F-values that can be used to determine data that are statistically very significant and discriminatory. The data are leveled based on F-values which then used for selecting data groups. The average and standard deviations are calculated with MATLAB to get the P-value in order to determine

significant data differences between the mean values of the invasive and non-invasive measurement data. Statistical analysis that produces P-values can be used to measure the parameter accuracy. Statistically, data is significant if P-values < 0:05 are acceptable, and if P-values > 0:05 are ignored or unacceptable.[24][27].

3. METHODS AND MATERIALS

Measurement of blood cholesterol levels in the development of optical sensor applications by irradiating blood on body tissues such as ear lobe and fingers using light wavelengths. Infrared (LEDs) and photodiodes have been developed previously to determine blood components such as SPO2, Glucose, Hemoglobin, and Heart Rate showed good results. Absorption of light at wavelengths is used by measuring transmission or reflectance and analyzing absorption ratios over various sets of wavelengths. The use of optical infrared sensors is a spectroscopic technique that uses the infrared wavelength region of the electromagnetic spectrum

a. Block diagram of the device

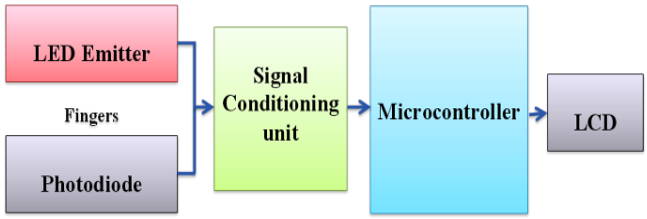

Figure 2. Diagram block of the blood cholesterol level monitor

Figure 2. When the sensor is installed at the finger, the light from the LED will be absorbed by the finger tissue while the unabsorbed one is reflected and received by the photodiode detector. The light received by the photodiode becomes a light attenuation value and is converted into an electric current value, then becomes a voltage due to the presence of a load resistor on the anode. The voltage released by photodiode depends on the amount of light received. The more light received, the greater the voltage will be released by the photodiode that is between 0 V and 5 V. However, the voltage value of the photodiode is still too low, so the variation on voltage values is less noticeable. To deal with this, an IC LM358N amplifier circuit is installed to strengthen the voltage. The voltage value of the photodiode is read by a 10-bit ADC microcontroller and this ADC value is reconverted into a voltage value. Then, this value is entered into a polynomial or linier equation to change it into total blood cholesterol value. The results of total cholesterol conversion are grouped according to the standards of the National Cholesterol Education Program - Adult Treatment Panel (NCEP-ATP III) with the equation y <200 mg/d for normal category, y = 200 - 239 for medium category and y> 240 for high category.

The measurement results were displayed on the (LCD) and smartphone. A compatible (LCD) with a microcontroller and 4 x 16 (LCD) screen was used and installed directly on 4 pin on the microcontroller main board. The monitor display showed 25-second countdown timer for the sensor, total cholesterol value in mg/dl and cholesterol categories of low, normal and high.

b. Materials

This research used Near Infrared (NIR) sensors with IR (LED) 333-A Everlight as an emitter with a wavelength of 940nm, 100mA continuous current, and 1-A peak current. The detector used PT 333-3C Everlight photodiode with a spectral bandwidth of 400nm - 1100nm, and spectral sensitivity at a wavelength of 940nm and maximum voltage of 5 volts. The photodiode absorbed the reflected light emitted by the (LED) emitter, then converting it into output voltage to the microcontroller. The blood cholesterol monitor device was designed to convert the output voltage into the total cholesterol value in mg/dl.

Figure 3, a series of sensors consists of IR (LED) 940 nm as emitter that emits infrared light, photodiode is used as a detector that absorbs or receives light and conditioning units as voltage amplifier for photodiode

The voltage signal from the photodiode is received by LM358N IC which is an op-amp circuit that serves as a voltage amplifier. The voltage value of the photodiode is still too low so that variations in the value of the voltage are less noticeable the difference, to overcome this we need an amplifier circuit.

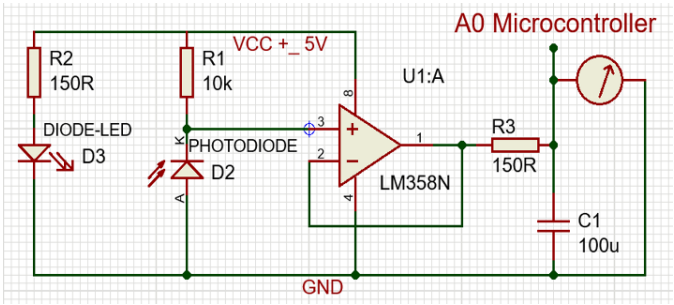

Figure 3. Schematic diagram of a cholesterol monitoring system

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c. Device proses diagram

Flowchart of the process of the device being developed, shows that data processing consisting of infrared (LED) sensors that radiate light to the fingers which then absorbed by the bloodstream. The unabsorbed light is reflected and received by the photodiode. The absorption results are converted and calculated by polynomial or linear equations in the device microcontroller software. The readings are displayed on the (LCD) monitor.

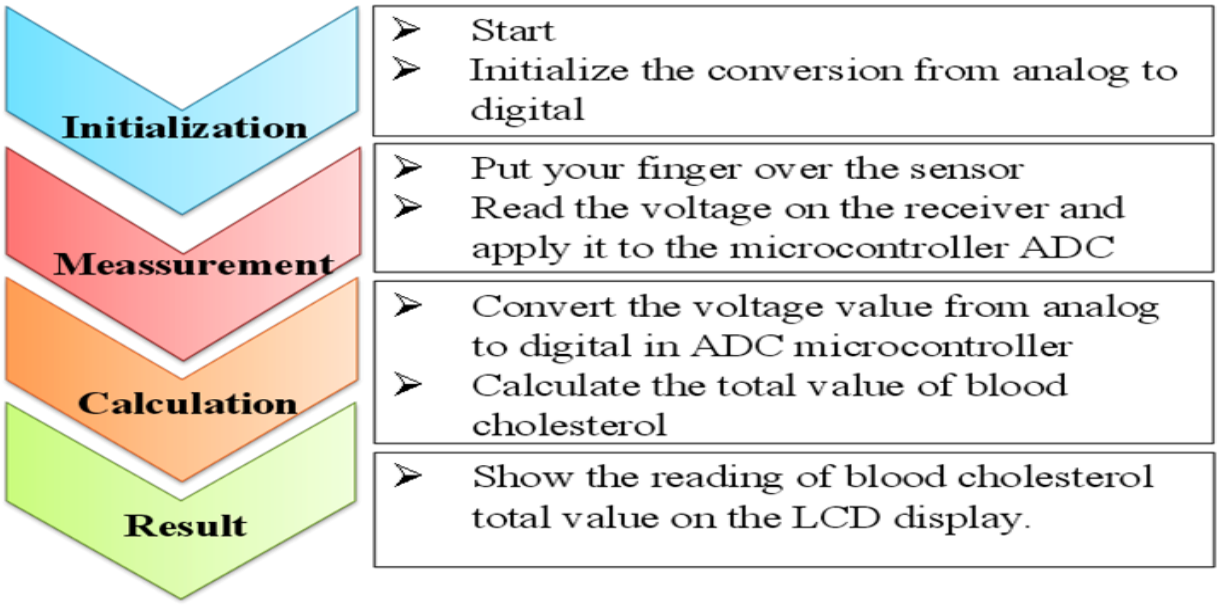

Figure 4. Diagram of methodology process

d. Device Testing

The device was tested by taking sample from 50 people with ages varied from 20 - 70 years of male and female participants. Blood cholesterol total data was collected using invasive measuring device Autocheck, and then continued with measurement of voltage using the designed replective optic sensor a few minutes later. For data collection of sensor voltage output values, each participant was measured five times. The data was collected by measuring sensor output voltage twice before taking a blood sample for an invasive technique measurement and then thrice afterwards. Sensor output voltage stability, as long as the sensor was at the finger for about 25 seconds, the output voltage value was averaged.

e. Analysis

Data analysis was carried out to determine the standard deviation and standard error value of each measurement using t-test and analysis of variance (ANOVA).Each data was tested for significance to determine discrimination in data classification. Average values and standard deviations were calculated with MATLAB to get the P-value used for measuring parameter accuracy.

4. Experiment and Result

The results of invasive measurement technique carried out on male and female participants showed a correlation between sensor voltage output and total cholesterol values. The difference in sensor output voltage was found due to the difference on the absorption and reflection of light in the body's tissues. These differences caused each people have different blood cholesterol value as well. In figure 5 and 6, a simple correlation of the total cholesterol values and sensor output voltage use algorithm equation $Y = 269{,}5x - 172.79$, and regression correlation coefficients $R^2 = 0.8644$. The sensor voltage value has not been linear with blood cholesterol values due to several factors including the inconsistent of sensor installation, the possibility of other light received by the photodiode thus producing impure light reflection and the skin thickness affecting the light absorption in the finger tissue.

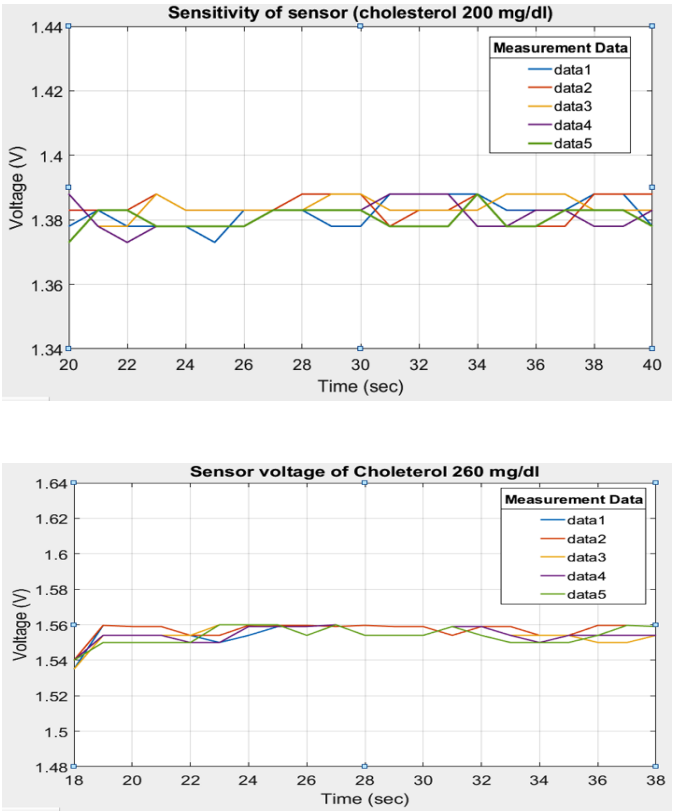

Figure 5. Sensor sensitivity on cholesterol measurement compared to invasive techniques

Table 2. Measurement of the sensor output voltage and total blood cholesterol

Subject	Avarage Voltage (V)	Invasive Autocheck (mg/dl)	Subject	AvarageVoltage (V)	Invasive Autocheck (mg/dl)
1	1,31	153	13	1,41	235
2	1,31	155	14	1,47	240
3	1,32	160	15	1,54	245
4	1,34	176	16	1,55	248
5	1,34	181	17	1,59	252
6	1,33	187	18	1,59	255
7	1,33	194	19	1,49	256
8	1,37	200	20	1,65	260
9	1,38	210	21	1,70	275
10	1,38	227	22	1,79	288
11	1,40	230	23	1,81	303
12	1,48	233	24	1,89	357

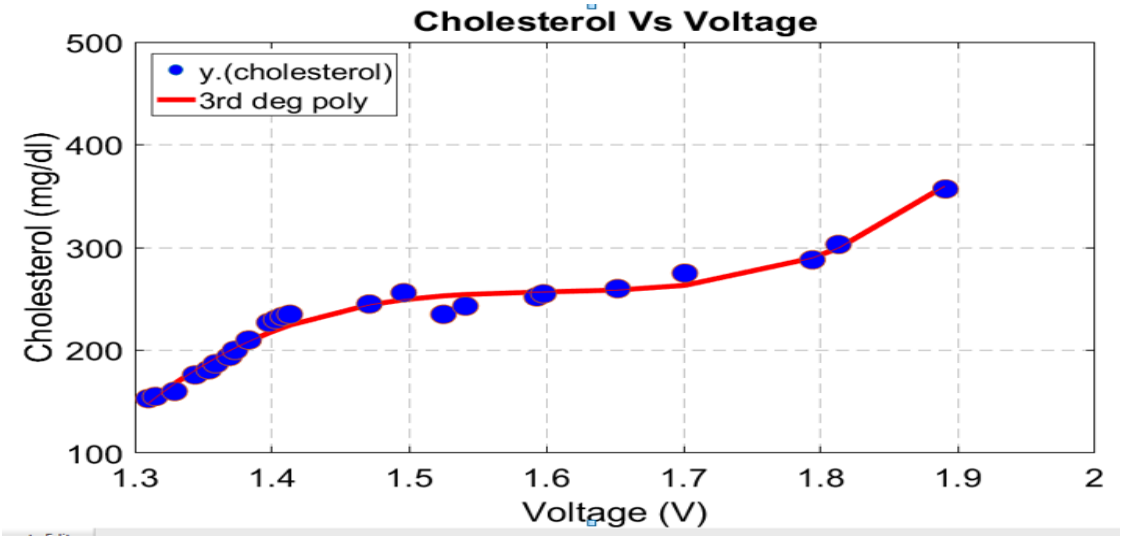

Figure 6. Polynomial equation graph

A low square regression value (R^2) affected the accuracy of cholesterol values and the linearity of replective optic sensor output voltage to the blood cholesterol value measured by invasive techniques. To increase the value of R^2, a polynomial equation was needed. From the data, it was obtained *X* as the sensor voltage (v) and *Y* as the value of cholesterol (mg/dl), the results of invasive measurements (mg/dl), with n = 24, so that the polynominal equation $y' = 4008{,}7x^3 - 19277x^2 + 30925x - 16294$, with square regression R^2 = 0,9761. This polynomial equation was used as a formula on the microcontroller to calculate and determine the cholesterol value (y') displayed on the monitor.

The predetermined polynomial regression equation was entered into the designed device program which then validated by comparing the measurements results of total blood cholesterol obtained using an invasive (Auto-check) and a designed non-invasive measuring devices. Data obtained using invasive measurement device is very accurate because using blood samples while data obtained with a non-invasive measurement device depend on the reflective optic sensor detection. Several test samples were taken to test the concept. The device testing was done by comparing the measurement result of blood cholesterol with non-invasive techniques twice before and after collecting blood samples for invasive techniques.

Table 3. The measurement results using invasive device and voltage with noninvasive sensors.

Subject	Invasive (mg/dl)	Non-Invasive (mg/dl)	Std Dev	Std Error
A	257	256	0.71	0.50
B	223	226	2.12	1.50
C	200	202	1.41	1.00
D	197	195	1.41	1.00
E	357	360	2.12	1.50
F	154	148	4.24	3.00
G	160	167	4.95	3.50
H	301	299	1.41	1.00
I	260	258	1.41	1.00
J	275	263	8.49	6.00
K	217	219	1.41	1.00
L	158	154	2.83	2.00
M	226	227	0.71	0.50
N	252	255	2.12	1.50
O	267	280	9.19	6.50
P	290	294	2.83	2.00
Q	306	300	4.24	3.00
R	315	321	4.24	3.00
S	347	360	9.19	6.50
T	365	372	4.95	3.50

From Table 3, it could be seen that the difference in data measurement between both devices has a standard deviation of 0,71 to 9.19 and an average of 3.5, standard errors 0.5 to 6.5 and an average of 2.8. This value both

Table 4. The result of Variance Analysis (ANOVA)

Source	SS	df	MS	F	Prob>F
Columns	163868.3	19	8624.65	448.62	3.10783e-22
Error	384.5	20	19.23		
Total	164252.8	39			

Table 4. T-test results of invasive and non-invasive measurements

t-Test: Paired Two Sample for Means		
	INVASIVE	*NON-INVASIVE*
Mean	256.35	257.8
Variance	4178.344737	4465.431579
Observations	20	20
Pearson Correlation	0.996123202	
Hypothesized Mean Diff	0	
df	19	
t Stat	-1.04835297	
P(T<=t) one-tail	0.153814676	
t Critical one-tail	1.729132812	
P(T<=t) two-tail	0.307629352	
t Critical two-tail	2.093024054	

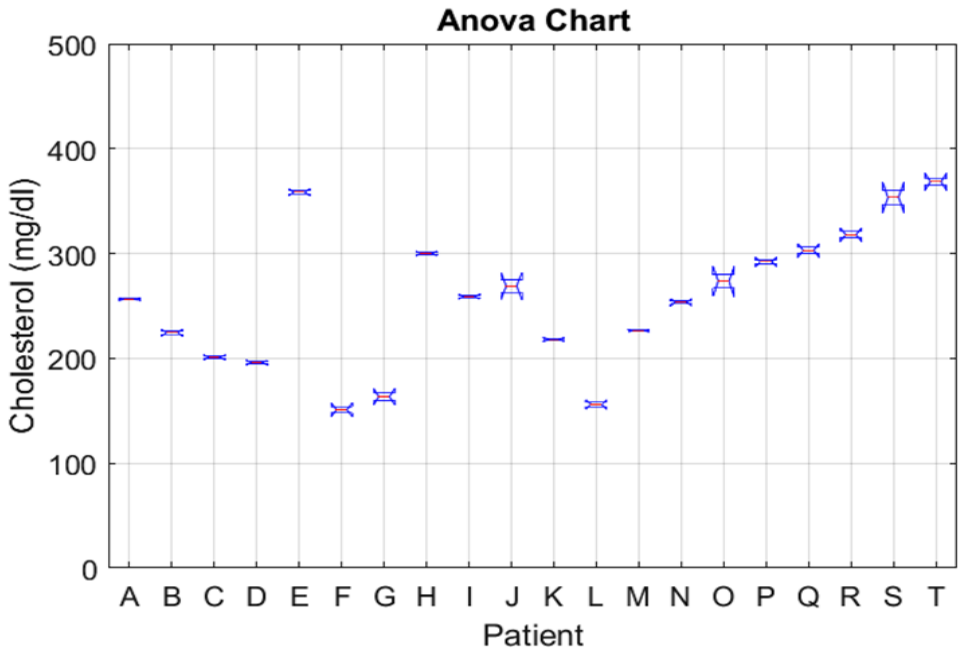

Figure 7. Box plots of cholesterol Y from different patient,

Fig. 7 represents the box plot of the values of Y. The standard deviations (n = A, B, C, D, E....T) of Y in those columns are shown in Table 3. It shews that the standard deviation of A and M is smallest among all chambers and could be selected as the golden columns.

5. DISCUSSION

This section explains the results of research that developed a blood cholesterol monitoring device using sensors consisting of LEDs and photodiodes. The sensor output is the voltage compared to the results of blood cholesterol measurements with an invasive procedure. Both results are correlated using linear or polynomial regression to get an equation between voltage and blood cholesterol. Linear regression equation obtained the coefficient of determination R2 0.86, this value indicates that 14% independent data, to reduce the dependent data used nonlinear polynomial regression with a value of R2 0.97 is better. Polynomial regression equations are inserted in the microcontroller program to calculate the voltage value into the value of blood cholesterol. Testing and validation are done by measuring the two invasive and non-invasive procedures and the results are analyzed by t-test and ANOVA. Table 3, shows the results of measurements of both invasive and noninvasive procedures, there are differences in results between the two devices, the maximum standard deviation is 9.19, and the average standard error is 2.48. Based on the National Cholesterol Education Program (NCEP) standard, the

measurement of cholesterol ± .8.9%.[20]. T-test to analyze the normalization of measurement data using the t-test: paired two samples for means. Table 4, shows the t-test with the results of t-count (t-stat) compared with the value of t-table (t-critical), the results obtained t-count is smaller than t-table (1.048 < 2.093) which means that there are differences in the variables between the invasive procedure and non-invasive.

The interpretation of measurement results in the ANOVA table stated that the null hypothesis means that there is no difference in the values of measurement results obtained from both cholesterol measurement techniques. Data in Table 3 shows the differences between both invasive and non-invasive measurement techniques, to find out the value of the measurement data variant was analysis with ANOVA on Matlab. the results of the One-Way ANOVA variant analysis using Matlab. Prob> F value is the p-value for all model tests, as a reference to determine the decision to accept or refuse a hypothesis. Table 5, shows value of Prob> F = 3.1078e-22. Statistically, the significance received must be less than 5% and if a P-value <0.05 is acceptable, and if a P-value > 0.05 is ignored or not accepted. ANOVA analysis results P- value < 0.05, so the results could be accepted.

ANOVA One Way forms a box plot as shown in Figure 7. Describes monitoring for each participant in y that shows a visual comparison of the measurement results. The box plot dimension is based on the standard deviation value and the standard error, if the large standard deviation value will show the large box plot size, if both values are small then the box plot size is also small. Box plots in participants are small because the standard deviation value is small 1.41 and participants with a standard deviation 9.19 show a bigger box plot.

6. CONCLUSION

The data presented in this paper are the results of cholesterol measurements using noninvasive technique that has been developed using sensors consisting of IR LED emitters and photodiode detector. The measurement validation results were the comparison between invasive and noninvasive technique procedures. The development of this tool is an alternative innovation that can be used to measure cholesterol that is easy to use and does not use cholesterol strips. The accuracy of the instrument develops quite well seen from the results of the polynomial equation with a maximum standard deviation of 9.19, the average standard error of 2.48 and the t-test proves there are differences in the variables of the two measurement procedures. ANOVA analysis with a value of Prob > F = 3.1078e-22 as the p-value for all model tests, but the results are acceptable by reason of the P-value is less than 0.05 significant values.

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REFERENCES

[1] E. Aristovich dan S. H. Khan, "Non-invasive measurement of cholesterol in human blood by impedance technique: An investigation by 2D finite element field modelling," J. Phys. Conf. Ser., vol. 459, no. 1, 2013.

[2] E. Law, M. Kakani, M. Agarwal, dan M. Rizkalla, "Electromagnetic Simulation for the Diagnosis of Lipoprotein Density in Human Blood , a Non-Invasive Approach," hal. 1–11, 2017.

[3] E. V Karpova, E. V Shcherbacheva, A. A. Galushin, D. V Vokhmyanina, E. E. Karyakina, dan A. A. Karyakin, "Noninvasive Diabetes Monitoring through Continuous Analysis of Sweat Using Flow-Through Glucose Biosensor," 2019.

[4] Espinosa, A. H. R., Estevez, A. G., Roche, J. R. F., Figarola, Y. M., & Rodriguez, D. L. (2018). Psychological intervention for development of disease awareness in addicts: Villa Colibri therapeutic community of Santiago de Cuba. *International Journal of Health Sciences*, *2*(3), 72-80. https://doi.org/10.29332/ijhs.v2n3.232

[5] G. A. Roth et al., "Demographic and epidemiologic drivers of global cardiovascular mortality," N. Engl. J. Med., vol. 372, no. 14, hal. 1333–1341, 2015.

[6] G. Balachander dan K. S. Shankar, "Non-Invasive Blood Glucose Analysis Based On Galvanic Skin Response For Diabetic Patients," vol. 30, no. 1, hal. 1–8, 2018.

[7] H. Ali, F. Bensaali, dan F. Jaber, "Novel Approach to Non-Invasive Blood Glucose Monitoring Based on Transmittance and Refraction of Visible Laser Light," IEEE Access, vol. 5, hal. 9163–9174, 2017.

[8] I. M. M. Yusoff, R. Yahya, W. R. W. Omar, dan L. C. Ku, "Non invasive cholesterol meter using Near Infrared sensor," Proc. - 2015 Innov. Commer. Med. Electron. Technol. Conf. ICMET 2015, no. November, hal. 100–104, 2016.

[9] J. Yadav, A. Rani, V. Singh, dan B. M. Murari, "Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy," Biomed. Signal Process. Control, vol. 18, hal. 214–227, 2015.

[10] K. J. Lackner dan D. Peetz, "National Cholesterol Education Program," hal. 1723–1724, 2019.

[11] M. A. Al-Dhaheri, N. E. Mekkakia-Maaza, H. Mouhadjer, dan A. Lakhdari, "Noninvasive blood glucose monitoring system based on near-infrared method," Int. J. Electr. Comput. Eng., vol. 10, no. 2, hal. 1736–1746, 2020.

[12] M. A. Al-Rawhani et al., "A Colorimetric CMOS-Based Platform for Rapid Total Serum Cholesterol

Quantification," IEEE Sens. J., vol. 17, no. 2, hal. 240–247, 2017.

[13] M. M. and D. E. V. Oncescu, "Lab on a Chip," no. 207890, 2013.

[14] M. Milanič, A. Bjorgan, M. Larsson, P. Marraccini, T. Strömberg, dan L. L. Randeberg, "Hyperspectral imaging for detection of cholesterol in human skin," Opt. Diagnostics Sens. XV Towar. Point-of-Care Diagnostics, vol. 9332, hal. 93320W, 2015.

[15] M. S. Mohktar, F. Ibrahim, dan N. A. Ismail, "Non-invasive approach to predict the cholesterol level in blood using bioimpedance and neural network techniques," Biomed. Eng. - Appl. Basis Commun., vol. 25, no. 6, hal. 1–7, 2013.

[16] P. L. Jaramillo et al., "Blood-Pressure and Cholesterol Lowering in Persons without Cardiovascular Disease," hal. 1–12, 2016.

[17] P. Narkhede, S. Dhalwar, dan B. Karthikeyan, "NIR based non-invasive blood glucose measurement," Indian J. Sci. Technol., vol. 9, no. 41, 2016.

[18] Paramita, D. P., Adiatmika, I., Kuswardhani, T., & Mustika, I. W. (2018). Physiological and psychosocial change and the need of health intervention model for elderly. *International Journal of Health Sciences, 2*(2), 61-67. https://doi.org/10.29332/ijhs.v2n2.160

[19] R. A. Buda dan M. M. Addi, "A portable non-invasive blood glucose monitoring device," IECBES 2014, Conf. Proc. - 2014 IEEE Conf. Biomed. Eng. Sci. "Miri, Where Eng. Med. Biol. Humanit. Meet," no. December, hal. 964–969, 2014.

[20] S. E. E. Profile, "Non-Invasive Measurement of Cholesterol Levels Using Eye Image Analysis," vol. 14, no. October 2016, hal. 33–42, 2018.

[21] S. Haxha dan J. Jhoja, "Optical Based Noninvasive Glucose Monitoring Sensor Prototype," IEEE Photonics J., vol. 8, no. 6, 2016.

[22] Suhron, M., A Yusuf, R Subarniati, "Assessment of Stress Reactions and Identification of Family Experiences in Primary Care Post Schizophrenic Restrain in East Java, Indonesia. Mixed-Method: Sequential Explanation, "Indian Journal for Public Health Research & Development, vol. 10, no. 12, pp. 1849-1854, 2018.

[23] Suwitri, N. P. E., & Sidiartha, I. G. L. (2018). Omega-6 and omega-3 fatty acid content and ratio of commercial complementary foods. *International Journal of Health Sciences, 2*(1), 21-28. https://doi.org/10.29332/ijhs.v2n1.90

[24] T. H. Pan, D. S. H. Wong, dan S. S. Jang, "Chamber matching of semiconductor manufacturing process using statistical analysis," IEEE Trans. Syst. Man Cybern. Part C Appl. Rev., vol. 42, no. 4, hal. 571–576, 2012.

[25] T. Lin, "Non-Invasive Glucose Monitoring: A Review of Challenges and Recent Advances," Curr. Trends Biomed. Eng. Biosci., vol. 6, no. 5, hal. 1–8, 2017.

[26] Vicnesh dan Y. Hagiwara, "Accurate Detection Of Seizure Using Nonlinear Parameters Extracted From Eeg Signals," J. Mech. Med. Biol., vol. 19, no. 1, hal. 1–14, 2019.

[27] Widana, I.K., Sumetri, N.W., Sutapa, I.K., Suryasa W. (2020). Anthropometric measures for better cardiovascular and musculoskeletal health. Comput Appl Eng Educ, 1–12. https://doi.org/10.1002/cae.22202

[28] World Health Organization (WHO)., "Technical package for cardiovascular disease management in primary health care.," Report, hal. 1–76, 2016.