Faculty of Electronics and Computer Technology and Engineering

DEVELOPMENT OF NON-INVASIVE LDL AND HDL CHOLESTEROL METER USING A NIR LIGHT SENSOR WITH IOT APPLICATIONS

NOR ZAHIRAH BINTI ZULKIFLY

Bachelor of Electronics Engineering Technology with Honours

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DEVELOPMENT OF NON-INVASIVE LDL AND HDL CHOLESTEROL METER USING A NIR LIGHT SENSOR WITH IOT APPLICATIONS

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**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours**

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2024

DECLARATION

I declare that this project report entitled "Development of Non-Invasive LDL and HDL Cholesterol Meter Using a NIR Light Sensor with IOT Applications" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Student Name : Nor Zahirah Binti Zulkifly

Date : 12/1/2024

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology with Honours.

Signature :

Dr. Vigneswaran Narayanamurthy
Senior Lecturer
Department of Engineering Technology
Faculty of Electronics and Computer Technology and Engineering
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
Ph: (Office) +6 06 270 4324 (Mobile) +6 010 536 9493

Supervisor Name : Dr. Vignewaran Narayanamurthy

Date : 12/1/2024

ABSTRACT

Controlling and monitoring of Low-density lipoproteins (LDL) and High-density lipoproteins (HDL) of the total cholesterol level is essentially important for preventing an elevated risk of cardiovascular disease such as coronary heart disease, stroke, peripheral vascular disease, diabetes and high blood pressure. The purpose of this project is to carry out a non-invasive method for measuring cholesterol level and develop a hardware prototype for a non-invasive cholesterol meter. Heart rate sensor is used for detecting and determining the cholesterol in the blood. Cholesterol levels can be measured in a circulating bloodstream within a subject, by obtaining light absorbance data at about 1720 nm +/15 nm, or at about 2300 nm +/15 nm, in combination with a closely spaced reference wavelength, the latter being relatively insensitive to cholesterol content. Android apps has been developed to display and store the data into cloud server. The percentage of accuracy is 97% with compared to the existent device. Percentage difference between new non-invasive and invasive device is 0.6 to 3.1% and still acceptable. This innovation has created an alternative in getting painless cholesterol reading and reducing the usage of cholesterol strips.

ABSTRAK

Mengendalikan dan mengawasi lipoprotein berkepadatan rendah (LDL) dan lipoprotein berkepadatan tinggi (HDL) daripada jumlah kolesterol pada asasnya adalah penting untuk mencegah risiko peningkatan penyakit kardiovaskular seperti penyakit jantung koronari, strok, penyakit vaskular periferal, diabetes dan tinggi tekanan darah. Tujuan projek ini adalah untuk menjalankan kaedah bukan invasif untuk mengukur tahap kolesterol dan membina prototaip perkakasan untuk meter kolesterol bukan invasif. MAX30100 digunakan untuk mengesan dan menentukan kolesterol dalam darah. Tahap kolesterol boleh diukur dalam aliran darah yang beredar dalam satu subjek, dengan memperoleh data penyerapan cahaya pada kira-kira 1720 nm + / 15 nm, atau pada kira-kira 2300 nm + / 15 nm, dengan kombinasi dengan panjang gelombang rujukan jarak dekat, tidak sensitif terhadap kandungan kolesterol. Aplikasi Android telah dicipta untuk memaparkan dan menyimpan data ke pelayan awan. Peratusan ketepatan adalah 97% berbanding dengan peranti sedia ada. Perbezaan peratus antara peranti bukan invasif dan invasif baru ialah 0.6 hingga 3.1% dan masih boleh diterima Inovasi ini telah mencipta alternatif dalam mendapatkan bacaan kolesterol yang tidak menyakitkan dan mengurangkan penggunaan jalur kolesterol.

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V	-	Voltage
LDL	-	Low-density lipoprotein
HDL	-	High-density lipoprotein
HPLC	-	High-Performance Liquid Chromatography
PAD		Peripheral Arterial Disease

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CHAPTER 1

INTRODUCTION

1.1 Background

Cholesterol meters are intended to provide individuals with an indication of their cholesterol levels, allowing them to monitor their cardiovascular health. They are not meant to replace laboratory-based testing, but rather to serve as a screening tool or to help individuals track their cholesterol levels between visits to healthcare professionals.

A cholesterol meter, also known as a cholesterol test kit or cholesterol monitor, is a portable device used to measure cholesterol levels in the blood. It provides a convenient and rapid way for individuals to monitor their cholesterol levels at home or in other non-clinical settings. The primary function of a cholesterol meter is to provide a quantitative measurement of total cholesterol, as well as sometimes high-density lipoprotein (HDL) cholesterol and triglyceride levels.

1.2 Sustainable Development – 3 (Good Health and Well Being)

In Malaysia, stroke or cerebrovascular disease holds the position of being the third leading cause of death. In 2019, there were total of 47,911 reported cases of stroke, resulting in 19,928 fatalities. The prevalence of stroke cases was found to be 443,995, with a significant loss of 512,726 disability-adjusted life years (DALYs). Over the years, consecutive national health and morbidity surveys conducted since 2006 have revealed a consistent increase in the occurrence of risk factors such as diabetes, hyperlipidemia, and obesity. These risk factors have been identified as contributing factors to the rising incidence of stroke among individuals below the age of 65. Notably, there has been a substantial increase of 53.3% among men and 50.4% among women within the age group of 35-39, representing the highest surge. Thus, is it very important for us to have consciousness to make a full body checkup frequently especially on cholesterol levels. By checking and monitoring cholesterol levels in our body will prevent many kind of serious diseases such as stroke and hypertension. Additionally, by using cholesterol meter to keep our cholesterol level in stable condition can reduce the death rate in Malaysia.

Overall, a non-invasive cholesterol meter project can be a powerful tool in the fight against strokes, providing crucial data and storing data in cloud server easily. Governments are obligated under the Sustainable Development Goals (SDGs 3) to take action to guarantee the good health and well-being of all individuals, regardless of age. Specific goals for addressing non-communicable illnesses, such as stroke, which constitute a significant obstacle to sustainable development in all nations, are included in SDG 3.

1.3 Problem Statement

Currently, the Cholesterol Pro Kit presents challenges in terms of usability due to its requirement of a blood sample for testing. This aspect can induce fear and pain in users. Additionally, the invasive nature of the method necessitates the use of non-reusable strips, which can lead to infections. Furthermore, the test strips have an expiration date, resulting in the need to incur high costs when purchasing new ones for each cholesterol level check. Visiting pharmacies or clinics for cholesterol level checks is time-consuming, as it takes a significant amount of time to obtain the results. Lastly, the demand for non-invasive cholesterol testing products is relatively low in Malaysia.

1.4 Project Objective

The main aim of this project is to propose a systematic and effective methodology to read a cholesterol levels in our body with reasonable accuracy. Specifically, the objectives are as follows:

a) To study the design and construction of Non-invasive cholesterol.
b) To develop a hardware prototype for non-invasive cholesterol meter and an Android Applications in Smartphone.
c) To analyze an effectiveness of Non-Invasive cholesterol meter using a NIR Light Sensor with IoT Application.

1.5 Scope of Project

The scope of this project are as follows:

a) A prototype of cholesterol meter that were developed will helps people monitoring their cholesterol level frequently.

b) To create an Android Applications to strore datas of cholesterol levels for easily tracking.

c) To integrated cholesterol meter with LDL and HDL for detecting the cholesterol level early helps people to make a preventions and caution if their measurement near to high level of cholesterol.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter details the literature review that informs the purpose of this project. High cholesterol levels can lead to cardiovascular diseases such as stroke, high blood pressure, and heart attack. To prevent this trend from continuing, this product helps people measure their cholesterol levels from time to time. In this part, we will discuss the comparison between invasive and non-invasive methods. Related information and other additional features are summarized below.

2.2 Background of Cholesterol

Cholesterol was first discovered in the late 18th century by the French chemist François Poulletier de la Salle. It was initially identified in solid form from gallstones (chole in Greek means "bile" and stereos means "solid"). Later, it was also found to be present in animal tissues and in the bloodstream.

Cholesterol is a sterol, which is a type of lipid molecule. It belongs to the larger class of lipids known as sterols, which are essential for the structure and functioning of cell membranes. Cholesterol is primarily produced by the liver and is also obtained from dietary sources such as animal-based foods.

Cholesterol, depicted in Figure 2.1 for its chemical structure, is a fatty steroid that is synthesized in various tissues, with the liver and intestinal wall being particularly significant. It plays a vital role in the production of hormones and cell membranes, and it circulates in the bloodstream. As an essential component of cell membranes, cholesterol helps regulate membrane permeability and fluidity. It also plays a crucial role in the synthesis of bile acids, steroid hormones, and Vitamin D. While small amounts of cholesterol are necessary for proper bodily function, high levels can have detrimental effects on arteries and are potentially associated with cardiovascular diseases such as heart disease. Towards the end of its life cycle, cholesterol is recycled and eliminated by the liver into the digestive tract. Approximately 50% of the excreted cholesterol is then reabsorbed by the small intestine and returned to the bloodstream.

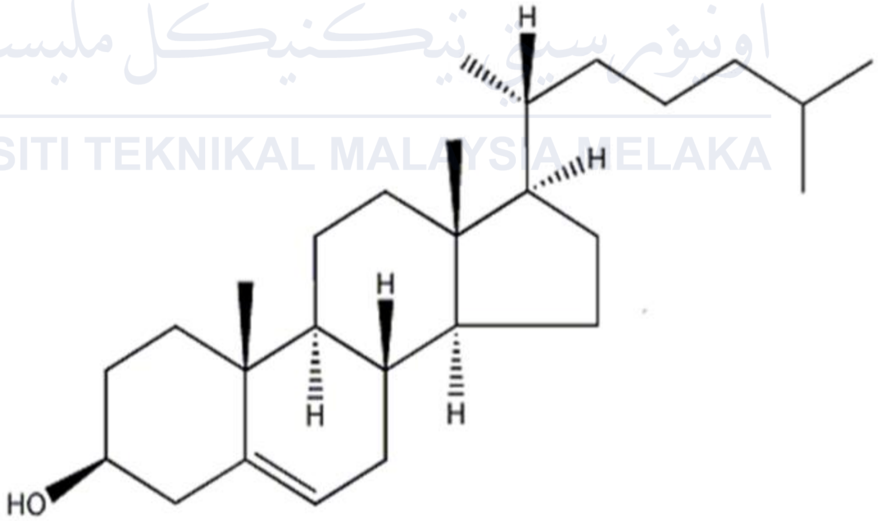

Figure 2.1 Chemical Structure of Cholesterol

Cholesterol plays a crucial role as a key component of cell membranes, contributing to their unique properties and influencing their flexibility. Within the membrane structure, cholesterol's hydroxyl group interacts with the polar head groups of phospholipids, while its steroid and hydrocarbon chain are embedded within the membrane. This arrangement allows cholesterol to affect the overall structure and function of the membrane.

One significant effect of cholesterol is its ability to reduce the permeability of the plasma membrane to protons (positively charged hydrogen ions) and sodium ions. By doing so, cholesterol helps regulate the movement of these ions across the membrane. This regulation is essential for maintaining the proper balance of ions inside and outside the cell, which is vital for various cellular processes, including signal transduction and maintaining the electrochemical gradient.

Furthermore, cholesterol's presence in the membrane contributes to its fluidity and stability. It acts as a buffer, preventing the membrane from becoming too rigid or too fluid under different physiological conditions. This property allows the membrane to adapt to changes in temperature and other environmental factors, ensuring its optimal functioning.

Cholesterol's distinctive properties as a component of cell membranes contribute to their flexibility, stability, and regulation of ion permeability. By interacting with phospholipids and modulating membrane structure, cholesterol plays a crucial role in maintaining cellular integrity and facilitating various physiological processes.

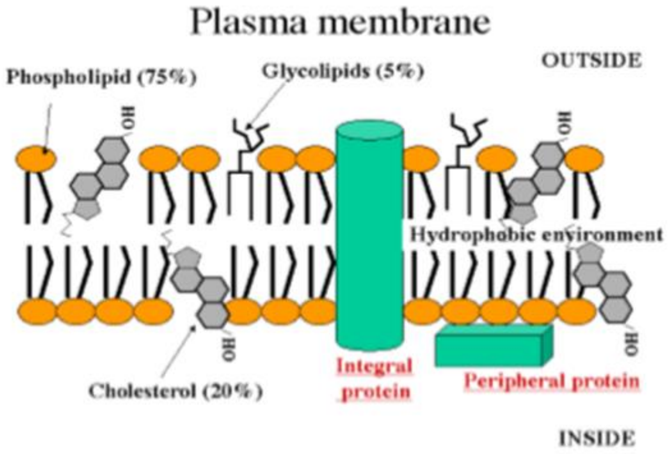

Figure 2.2 Plasma Membrane

Cholesterol is a lipid molecule that plays essential roles in cell membranes, hormone production, vitamin D synthesis, and bile production. While necessary for normal bodily functions, imbalances in cholesterol levels can contribute to health issues, particularly cardiovascular diseases. A comprehensive understanding of cholesterol has guided research and interventions aimed at maintaining healthy cholesterol levels and promoting overall well-being.

Cholesterol also serves as a precursor in various biochemical pathways. In the liver, it is converted into bile, which is then stored in the gallbladder. Bile salts, derived from cholesterol, play a vital role in the absorption of fat molecules and fat-soluble vitamins like Vitamin A, D, E, and K in the intestines. Cholesterol is thus an essential precursor molecule for the synthesis of Vitamin D and steroid hormones such as cortisol, aldosterone, progesterone, estrogens, testosterone, and their derivatives.

Furthermore, some research suggests that cholesterol may act as an antioxidant. In its unoxidized state, it acts as a protective agent against diseases caused by free radicals and cancer by serving as a safeguard for cell membranes.

2.3 Cholesterol Disorder

Hypercholesterolemia is a medical condition characterized by high levels of cholesterol in the blood. Cholesterol is a waxy substance produced by the liver and is also present in certain foods. It is essential for the body's normal functioning, as it plays a role in cell membrane structure, hormone production, and bile acid synthesis.

However, when cholesterol levels become excessively high, it can lead to health problems. Hypercholesterolemia is often associated with the buildup of cholesterol in the walls of arteries, a condition known as atherosclerosis. This buildup can restrict blood flow and increase the risk of cardiovascular diseases such as heart disease, heart attacks, and strokes.

Low-density lipoprotein (LDL) and high-density lipoprotein (HDL) are the two forms of cholesterol. HDL cholesterol is regarded as "good" cholesterol because it aids in the removal of LDL cholesterol from the bloodstream, whereas LDL cholesterol is frequently referred to as "bad" cholesterol because it causes arterial plaque.

Hypercholesterolemia can arise from a blend of genetic elements and lifestyle decisions, including an unhealthy diet, sedentary lifestyle, smoking, and obesity. To effectively manage and regulate cholesterol levels, it is essential to make lifestyle changes such as adopting a healthy eating plan, engaging in regular physical activity, maintaining a healthy weight, and, if necessary, following medication prescribed by a healthcare provider. Consistent monitoring and control of hypercholesterolemia play a vital role in minimizing the likelihood of cardiovascular complications.

2.3.1 High Cholesterol statistic in Malaysia

Cholesterol plays essential roles in the functioning of cells, but it can have negative effects on the body if its blood levels become abnormal. In 2008, high cholesterol ranked as the 5th leading cause of mortality due to risk factors. It is also considered a significant modifiable risk factor for cardiovascular diseases, specifically atherosclerotic cardiovascular disease (CVD). Recent data indicates an increasing trend of hypercholesterolemia based on the National Health and Morbidity Survey conducted in 2011 and 2015, with the prevalence rising from 35.1% to 47.7%. However, more recent figures show an overall prevalence of 38.1% among adults aged 18 and above.

Hypercholesterolemia is not only a concern for adults but also prevalent among the elderly population in Malaysia. Among the elderly screened for hypercholesterolemia, the prevalence was 75.5%. A study conducted in a rural community in Sarawak reported a prevalence of 63.1% among subjects aged 55 years and above.

Maintaining a healthy balance of cholesterol through lifestyle choices, such as a balanced diet, regular exercise, and avoiding smoking, is important for overall cardiovascular health. It's also crucial to work with healthcare professionals to monitor cholesterol levels and manage any abnormalities effectively.

2.4 Risk of High Cholesterol Level in bloodstream

Having high levels of cholesterol in the bloodstream can pose several risks to your health. High cholesterol is a major risk factor for developing cardiovascular diseases, such as coronary artery disease, heart attacks, and strokes. Elevated levels of cholesterol can lead to the formation of plaques in the arteries, which can restrict blood flow and increase the risk of clot formation. Besides that, Atherosclerosis occurs when cholesterol and other substances accumulate in the artery walls, forming plaques. These plaques can harden and narrow the arteries, reducing blood flow to vital organs and increasing the risk of heart disease and stroke. High cholesterol levels can contribute to high blood pressure, which further strains the heart and blood vessels. Hypertension increases the risk of heart disease, stroke, and other complications. Moreover, elevated cholesterol levels can also affect the arteries that supply blood to the limbs, causing PAD. PAD can result in leg pain, reduced mobility, and in severe cases, it may lead to amputation.

It is important to note that the risk associated with high cholesterol is not solely determined by the total cholesterol level, but also the balance between different types of cholesterol (such as LDL and HDL) and other risk factors such as smoking, obesity, and family history. Managing cholesterol levels through lifestyle changes, medication (if necessary), and regular monitoring can help reduce these risks and promote cardiovascular health. It is recommended to consult a healthcare professional for personalized advice and guidance regarding your cholesterol levels.

2.4.1 High Cholesterol Level Prevention

Preventing high cholesterol or managing it effectively involves adopting a healthy lifestyle. Here are some measures you can take to help prevent high cholesterol by following a balanced diet that is low in saturated and trans fats. Choose lean proteins (such as poultry, fish, legumes, and tofu), whole grains, fruits, vegetables, and healthy fats (such as avocados, nuts, and olive oil). Limit your intake of processed foods, fried foods, sugary snacks, and high-fat dairy products. Then, limit your dietary cholesterol. Although dietary cholesterol has a smaller impact on blood cholesterol levels compared to saturated and trans fats, it's still advisable to limit high-cholesterol foods like organ meats, shellfish, and egg yolks.

Additionally, you should exercise regularly and do at least 150 minutes of moderate-intensity aerobic activity per week, such as brisk walking, cycling, or swimming. Physical activity helps increase HDL cholesterol (good cholesterol) and lower LDL cholesterol. Also, avoid smoking. Smoking damages blood vessels and lowers HDL cholesterol. Quitting smoking improves your cholesterol profile and reduces your risk of heart disease. Monitor your cholesterol levels with regular health checkups and cholesterol tests. This allows for early identification of potential problems and timely intervention.

Remember, it is essential to consult with your healthcare provider for personalized advice on managing your cholesterol levels, especially if you have a family history of high cholesterol or other risk factors for cardiovascular diseases.

2.5 Methods used for determination of cholesterol levels

The electrical impedance technique can be used to estimate cholesterol levels indirectly by measuring the impedance of blood or serum samples. Here is a step-by-step explanation of how this technique can be applied:

Firstly, by principle. The electrical impedance technique is based on the fact that the electrical properties of a solution, such as blood or serum, can be influenced by the presence of cholesterol. Cholesterol molecules affect the conductivity and permittivity of the solution, which can be measured as changes in electrical impedance.

Secondly, by sample preparation. Obtain a blood or serum sample from the individual whose cholesterol levels you want to measure. The sample should be handled and stored according to standard laboratory protocols.

Thirdly, using impedance measurement. Use an impedance measuring device, such as an impedance analyzer or impedance meter, to measure the electrical impedance of the sample. The device applies an alternating current to the sample and measures the resulting voltage and current.

Next, calibration. To establish a correlation between the measured impedance and cholesterol levels, a calibration curve is created using samples with known cholesterol concentrations. These samples can be prepared by adding known amounts of cholesterol to a standard serum or using cholesterol reference materials. Measure the impedance of these calibration samples using the same impedance measuring device.

Moreover, by data analysis. Plot a calibration curve by plotting the known cholesterol concentrations against the corresponding impedance values obtained from the calibration samples. This curve represents the relationship between impedance and cholesterol levels.

Lastly, by having a sample analysis. Measure the impedance of the unknown blood or serum sample using the same impedance measuring device. Use the calibration curve to determine the corresponding cholesterol level based on the impedance value obtained from the sample.

The need for a simple and painless means of measuring total blood cholesterol levels is on the rise. One of the proposed approaches involves the use of electrical impedance techniques. This technique measures the impedance (Z) or admittance (Y=1/Z) of a specific test volume, such as plasma, by evaluating the conductivity distribution of substances such as cholesterol particles carried by lipoproteins. Measurements are performed by applying a small current (I) between the electrodes and measuring the voltage (V) induced across the surface. In quadripolar impedance measurements, a pair of electrodes (known as the sensing or passive electrodes) are connected while a small electrical current is passed between two separate electrodes (known as the driving or active electrodes) placed on the surface of the body.

Impedance is determined by observing the voltage drop between (Z =V/I). When measuring cholesterol, various factors such as the size, concentration, and distribution of lipoproteins involved in the transport of cholesterol particles can influence the measured impedance.

The electrical impedance technique has proven to be effective in numerous biological measurements, particularly in assessing various aspects of blood. These include determining body fluid volume, fat content, glucose levels, blood coagulation, haematocrit (the fraction of erythrocyte volume, EVF), white blood cell count, and other blood-related measurements. However, all these methods for measuring blood parameters require invasive procedures to extract blood from the body.

As previously mentioned, the impedance technique involves measuring the conductivity distribution of objects, such as cholesterol particles carried by lipoproteins, within a specific test volume like blood plasma. This is achieved by assessing the impedance through the measurement of voltage induced on surface-attached electrodes. The impedance is calculated using the measured voltage and current (Z=V/I). The mathematical modeling of living tissue allows for theoretical exploration of the potential of impedance technique in directly and non-invasively measuring cholesterol levels in the blood.

However, a significant challenge lies in simulating and determining various design parameters of the measurement circuit. These parameters encompass aspects such as electrode material, size, shape, number, alignment, placement, current level, frequency, and others, which are crucial for ensuring the appropriate distribution of current (electric field) and induced electric potential between the electrodes. While the mathematical principles governing conduction are well-established, accurately describing the current and potential fields between and around impedance electrodes, especially when attached to tissue, presents greater complexity. This complexity arises from factors such as skin-electrode impedance, capacitance effects of the skin, and the distinct layers of the skin (epidermal, dermal, subcutaneous layers, etc.).

Finite element (FE) models are employed to examine the impact of various factors on the distribution of alternating currents and electric potential within a specific problem domain, resulting in voltage drops. These factors include physiological aspects such as the level and distribution of lipoproteins and other blood components, as well as material properties like dielectric permittivity and conductivities of blood components.

Furthermore, electrical variables such as measurement circuitry, excitation frequency, electrode geometry, and placement are taken into account. The modeling challenge lies in establishing a suitable and distinguishable functional relationship between the unknown potential distribution and the cholesterol level in the blood, considering the diverse physiological components within the blood and tissue. This relationship is determined through simulation.

By utilizing advanced analysis of biomedical signals, the impedance data obtained through the methods described earlier, including finite element simulation and experimental investigations on prototypes, can be used to establish a meaningful correlation between the voltage drops across the measuring electrodes (thus, impedance values) and the concentration of lipoproteins in the blood.

2.5.1 Invasive Method

Reference Method: There is a standard method for measuring cholesterol levels. This step involves hydrolysis of serum cholesterol esters with alcoholic KOH (potassium hydroxide). The cholesterol is then extracted with hexane and dried. The dried residue is then treated with acetic acid, acetic anhydride, and sulfuric acid (Lieberman-Burchard reagent), resulting in a color reaction measured at 620 nm. This method has minimal positive bias compared to the final mass spectrometry method for cholesterol measurements. Results can be expressed in molar concentration (c_i) or mass concentration (ρ_i) using the formula ρ_i (mg/dL) = 38.7 * c_i (mmol/L) (1.3-1). Although this method is highly accurate, it is time-consuming and not amenable to automation, making it impractical for routine testing. Therefore, enzymatic methods were developed for such purposes.

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Ultracentrifugation: Ultracentrifugation is a technique employed in biochemistry to determine and analyze components of blood, serum, or plasma. Ultracentrifuges are designed to spin rotors at extremely high speeds, generating acceleration of up to 1,000,000 g (9,800 km/s²). There are two main types of ultracentrifuges exist which is preparative and analytical. Both types find valuable applications in molecular biology, biochemistry, and polymer science. In analytical ultracentrifuges, operators can observe the real-time spinning of a sample through an optical detection system, monitoring phenomena such as ultraviolet light absorption or interference optical refractive index.

By analyzing the observed data, concentration profiles and molar mass differences among various macromolecules dissolved in the analyzed solution can be determined. However, the high rotational kinetic energy of the rotor in an operating ultracentrifuge poses a serious risk, as rotor failure can occur due to prolonged use and exposure to chemical solutions. Therefore, proper maintenance, adherence to recommended limits, and corrosion prevention are essential to avoid hazards. Additionally, the capacity of an ultracentrifuge is typically limited to six samples, which may be insufficient in a hospital setting where a larger volume of tests is required. For total cholesterol measurement, only one rotation cycle is needed, while for HDL/LDL separation, two or more cycles may be necessary.

Enzymatic Colorimetric Test: The enzymatic colorimetric test begins with the withdrawal of blood from a patient, which is then placed in a labeled sample holder and transferred to the biochemistry laboratory. In the initial stage, the blood is centrifuged with the addition of a buffer solution to separate the blood plasma from the blood cells. The plasma is then transferred to a separate holder and inserted into an automated clinical chemistry analyzer. In the analyzer, a series of chemical reactions takes place involving different reagents and catalysts to measure the cholesterol levels.

For cost reasons, LDL values have long been estimated using the Friedewald formula (or a variant):

TC [total cholesterol] −HDL [total HDL] – 0.2TG [20% of the triglyceride value] = estimated LDL.

The main idea is that TC is defined as the sum of HDL, LDL, and VLDL. Usually just the total, HDL, and triglycerides are measured. The VLDL is calculated as one-fifth of the triglycerides.

$$cholesterol\ esters + H_2O \xrightarrow{cholesterol\ esterase} cholesterol + RCOOH$$

$$cholesterol + O_2 \xrightarrow{cholesterol\ oxidase} cholest\text{-}4\text{-}en\text{-}3\text{-}one + H_2O_2$$

Under the catalytic activity of peroxidase, the produced hydrogen peroxide combines with 4-aminophenazone and phenol to make a red color. Photometric analysis may be used to determine the color intensity, which is directly correlated with the cholesterol levels.

For HDL-cholesterol direct method with PEG-modified enzymes is used:

$$HDL\text{-}cholesterol\ esters + H_2O \xrightarrow{PEG\text{-}cholesterol\ esterase} HDL\text{-}cholesterol + RCOOH$$

$$HDL\text{-}cholesterol + O_2 \xrightarrow{PEG\text{-}cholesterol\ oxidase} \Delta^4\text{-}cholestenone + H_2O_2$$

$$2H_2O_2 + 4\text{-}amino\text{-}antipyrine + HSDA + H^+ + H_2O \xrightarrow{peroxidase} purple\text{-}blue\ pigment + 5H_2O$$

The technique employed to measure triglycerides relies on the research conducted by Wahlefeld, who developed a lipoprotein lipase sourced from microorganisms. This lipase enables the efficient and swift breakdown of triglycerides into glycerol. The glycerol is subsequently converted into dihydroxyacetone phosphate and hydrogen peroxide through oxidation. In the presence of peroxidase, this resulting product interacts with 4-aminophenazone and 4-chlorophenol to generate a red dyestuff, known as the Trinder endpoint reaction. The intensity of the red color is directly proportional to the concentration of triglycerides.

Typically, each of these tests generally takes around 10-15 minutes to finish on average. Nevertheless, there is a notable risk of human errors associated with various factors, including labeling and transferring blood samples to the laboratory, proper handling of samples, and ensuring accurate recording of results in the relevant files. Due to the lower priority given to serum cholesterol tests in biochemistry labs, it may take up to a week to obtain the test results.

Electrophoresis is a process that involves the separation and migration of charged particles in a solution under the influence of an electric field. It is commonly used in various scientific and analytical techniques to separate and analyze molecules based on their size, charge, and other characteristics. A ‘stacking’ gel is placed on the top of the separating (‘running’) gel to sharpen the bands before they enter the gel (Figure 2.3)

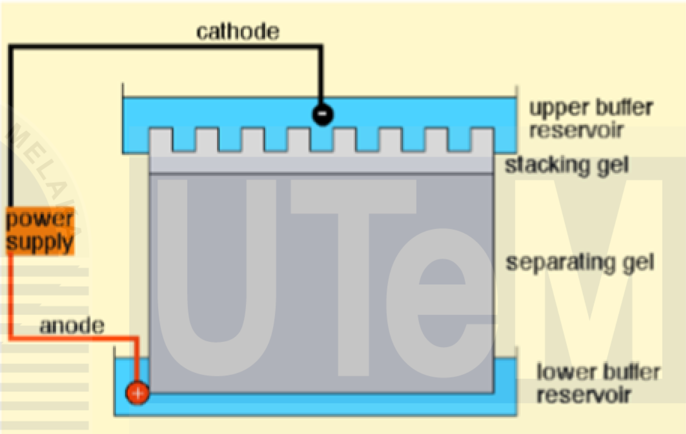

Figure 2.3 Electrophoresis Set

The electrophoresis process typically involves the following steps:

1. Sample Preparation: The sample containing the molecules of interest is prepared. This can include DNA, RNA, proteins, or other charged molecules. The sample is often mixed with a buffer solution to maintain a stable pH and provide the necessary ions for conductivity.
2. Gel Preparation: A gel matrix is prepared, which serves as the medium through which the charged particles will migrate. The most commonly used gels are agarose and polyacrylamide gels. Agarose gels are typically used for larger molecules such as DNA, while polyacrylamide gels are used for smaller molecules such as proteins.

3. Loading: The sample is carefully loaded onto the gel. This is usually done by creating wells or slots in the gel where the sample is placed. Multiple samples can be loaded on the same gel for comparison.
4. Application of Electric Field: The gel is immersed in a buffer solution and connected to an electrical power supply. Electrodes are placed at opposite ends of the gel, creating an electric field. The negative electrode, called the cathode, is placed at the end where the molecules need to migrate, while the positive electrode, called the anode, is placed at the opposite end.
5. Electrophoresis: When the electric field is applied, the charged molecules in the sample migrate through the gel at different speeds depending on their charge and size. Smaller, more negatively charged molecules move faster towards the positive anode, while larger or positively charged molecules move more slowly towards the negative cathode.
6. Visualization: After electrophoresis is complete, the molecules in the gel can be visualized and analysed. This is usually done by staining the gel with dyes specific to the type of molecule being analysed. For example, DNA can be stained with ethidium bromide, while proteins can be stained with Coomassie Brilliant Blue.
7. Analysis: The separated molecules can be quantified and analysed based on their migration distances and patterns. This information can be used to determine molecular weight, charge, purity, or other characteristics of the molecules.

High-Performance Liquid Chromatography (HPLC) operates on the principle that the solution passing through the column is slowed down by specific interactions with the stationary phase inside the column. The velocity of this solution movement depends on the sample nature and the composition of the stationary phase. The time at which a specific sample emerges from the column is known as the retention time, which serves as an identifying characteristic of the sample under specific conditions.

The lipoprotein samples that are extracted by ultracentrifugation are ready for examination in HPLC. The lipoprotein samples are extracted using a chloroform-methanol mixture to produce total lipid extracts. Choleryl heptadecanoate is then added to aliquots of the lipid extracts. After evaporating the extraction solvent and resolving the lipids in tetrahydrofuran-acetonitrile, the lipoprotein extracts are prepared for HPLC analysis. The liquid chromatograph is filled with this solution by injection. With the use of a linear water gradient, cholesterol and cholesteryl esters are removed from the column. Using a solvent flow rate of 2.0 ml/min, the water content in acetonitrile-tetrahydrofuran is progressively lowered from 3% to 0% over the course of 20 minutes at 37°C. The ultraviolet absorbance of the eluted cholesterol and cholesteryl esters at 123 nm is used to identify them. The mass of cholesterol is calculated from standard curves of mass versus peak area by the following formula:

$$Sample\ mass = \left(\frac{Mass\ of\ standard}{Peak\ of\ standard} \times Peak\ area\ of\ standard\right) \div$$

$$\div\ (\%\ Recovery\ of\ standard)/100$$

Compared to regular silica columns, reversed phase columns are more resistant to damage. They can tolerate aqueous acid to a certain extent, but prolonged exposure should be avoided as it may harm the metallic components of the HPLC equipment. To ensure optimal separation capabilities, it is important to minimize the metal content in the columns. However, a drawback of this method is the requirement for ultracentrifugation prior to chromatographic analysis.

2.5.2 Non-Invasive Method

A rule-based expert system has been created to categorize total cholesterol (TC) levels by employing bioelectrical impedance analysis (BIA). The system utilizes various predictors, including body capacitance (BC), basal metabolic rate (BMR), extracellular mass (ECM), and lean body mass (LBM). Based on these parameters, the system can classify subjects' TC levels as either normal (<= 5.2 mmol/L) or abnormal (>5.2 mmol/L).

In the preliminary evaluations of the system, it was found that it achieved an overall accuracy rate of 70% in categorizing total cholesterol (TC) levels using a probability threshold of 0.6 for predictions. The system exhibited a sensitivity of 67%, indicating its capability to accurately detect abnormal TC levels, and a specificity of 74%, indicating its ability to correctly identify normal TC levels. In the validation phase using independent data, the system demonstrated a successful classification rate of 6 out of 10 subjects.

On the contrary, the PreVu Non-Invasive Cholesterol Test is a technique utilized to predict levels of cholesterol in the skin. Although these skin cholesterol levels are not directly linked to cholesterol levels in the bloodstream, they have demonstrated their usefulness in providing insights into the likelihood of developing coronary artery disease (CAD). The test procedure involves placing a foam pad with three wells on the patient's palm, secured in place with medical adhesive. A detector solution is applied, and after a minute, a co-polymer (Digitonin & HRP) forms a bond with the skin cholesterol. Subsequently, an indicator solution (TMB) is introduced, resulting in a color change within the well of the foam pad. This resultant blue color can be measured using a handheld spectrophotometer and translated into a numerical value representing the individual's risk level.

Although this non-invasive method offers insights into cholesterol levels and the potential presence of coronary artery disease (CAD), it does not establish a direct correlation with the measurements obtained through routine screening. This lack of correlation poses no concerns for individuals with low cholesterol levels. However, for those with elevated cholesterol levels, the prescribed dosage of statins (medication for cholesterol management) is directly associated with their blood cholesterol levels. Hence, regular blood tests remain necessary in such circumstances.

Figure 2.4 PreVu Test Performance

2.5.3 Comparison between Invasive and Non-Invasive methods

After examining all the existing methods (as shown in Table 1), it becomes evident that there is a pressing requirement to develop a portable, non-invasive, rapid, and reliable method for measuring a parameter strongly associated with serum cholesterol levels. The research presented here will demonstrate that blood impedance serves as such a measure.

Table 1 Cholesterol Measurement Method

	Method	Priciple	Advantages	Disadvantages
Invasive	Reference Method	A sequence of chemical reactions occurs, and the intensity of color is measured.	Very accurate	Time-consuming not suitable for automation
	Ultracentrifugation	Ultraviolet light absorption test after high-speed centrifugation	Accurate	Low capacity, time-consuming
	Enzymatic colorimetric test	A sequence of chemical reactions occurs, and the intensity of color is measured.	Accurate	Low priority test performed in hospitals
	Electrophoresis	Electrophoresis separation followed by product staining and colour intensity analysis	Reliable, accurate	Time-consuming not suitable for automation
	HPLC	Lipoproteins are separated in accordance with their mass, then ultraviolet absorption measrured	Reliable	Needs ultracentrifugation prior to chromatography
	Accutrend Plus	Chemical reaction producing colour on a test strip	Portable system, quick results	Indicates cholesterol level as 'high' or 'low'
Non-Invasive	Classification BIA	Rule based system	Non-invasive	Low accuracy
	PreVu	The results of chemical reactions are measured using a portable spectrometer.	Non-invasive	Measured cholesterol levels do not correlate with serum cholesterol

2.6 Internet of Thing (IoT)

The Internet of Things (IoT) refers to the integration of Internet connectivity into physical devices and everyday objects. These devices, equipped with various hardware such as electronics, internet connectivity, and sensors, can communicate with each other over the internet. It can also be monitored and controlled remotely.

Real-time analytics, machine learning, commodity sensors, embedded systems, and the convergence of many technologies have all contributed to the evolution of the notion of the Internet of Things. The Internet of Things is being advanced by a number of sectors, including automation (including automation of buildings and homes), wireless sensor networks, control systems, embedded systems, and others. IoT technology is most frequently linked to "smart home" devices in the consumer sector. Lighting fixtures, thermostats, cameras, home security systems, and other appliances are some examples of these gadgets and appliances. They may be managed by linked devices such as smart speakers and smartphones, and they are made to support one or more common ecosystems.

However, the concept of the IoT has faced significant criticism, particularly regarding privacy and security concerns associated with these devices and their pervasive presence in everyday life.

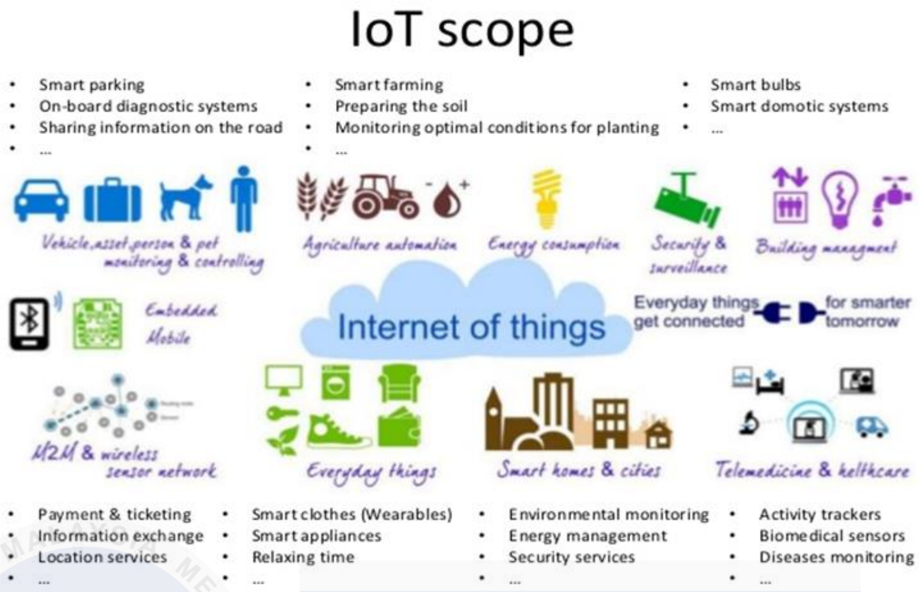

Figure 2.5 IoT Concept

2.7 Summary

This project will give impact to society by preventing a cardiovascular disease at early stage. In this chapter, it is cover on how cholesterol being calculated. By using impedance technique that involves measuring the conductivity distribution of objects, such as cholesterol particles carried by lipoproteins, within a specific test volume like blood plasma. Comparison also have been made between invasive and non-invasive method to check cholesterol level. It is shown that by invasive method will get more accurate results than non-invasive method.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, accuracy and effectiveness are considered the two conflicting requirements of any cholesterol meter devices to calculate cholesterol levels in bloodstream. Here, accuracy refers to how close the results using this Non-Invasive Cholesterol Meter compare with Invasive Method. Typically, the more accurate the model, the higher resources it requires (i.e. computation effort and time, amount of data and cost). Meanwhile, effectiveness refers to ability of the Non-Invasive Cholesterol Meter to estimate the cholesterol reading with the least resources but, with reasonable loss of accuracy.

3.2 Methodology

This study presents methods and techniques for designing, collecting, and analyzing data to create a complete design study. A methodology describes how a problem is investigated, the components used in the project, and the reasons for using a particular method or technique. The purpose of this methodology is to explain the research process so that the application of the method can be more fully understood. The components used for this project are an ESP32 WiFi and Bluetooth module, a MAX30200, and a 500mAh Li-ion battery.

Methodology also implies knowledge of the method or discipline used when conducting a particular study to achieve a particular purpose. The research methodology refers to the most appropriate method of conducting research and determining an effective procedure to answer the problem of study.

3.2.1 Experimental Setup

The experimental setup process involves the preparation and arrangement of equipment, instruments, and materials required for conducting a scientific experiment or investigation. It typically begins with identifying the objective of the experiment and the variables to be measured or manipulated. It also involves following specific protocols, making necessary adjustments, and ensuring safety precautions are in place. The experimental setup process is crucial for obtaining reliable and accurate results in scientific research. To fulfill the goal of this project, the experiment procedure process will be continued in this section.

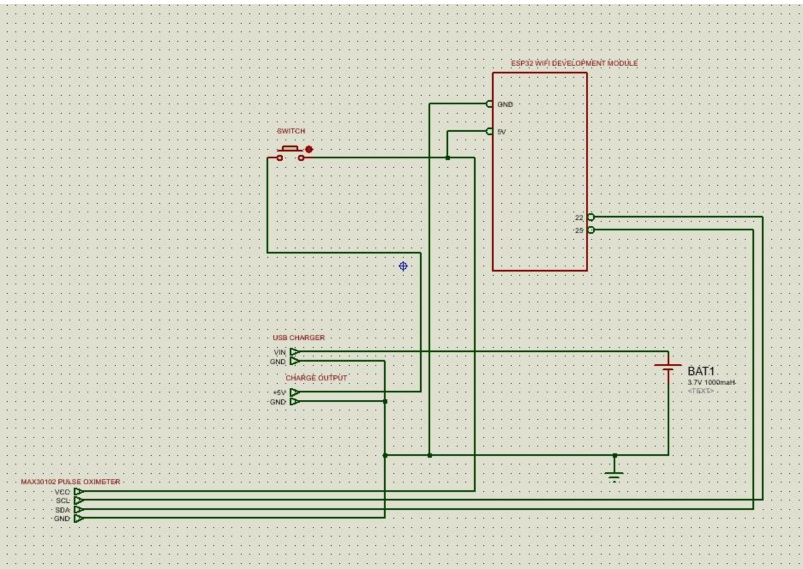

Figure 3.1 Schematic Diagram of Non-Invasive Cholesterol Meter

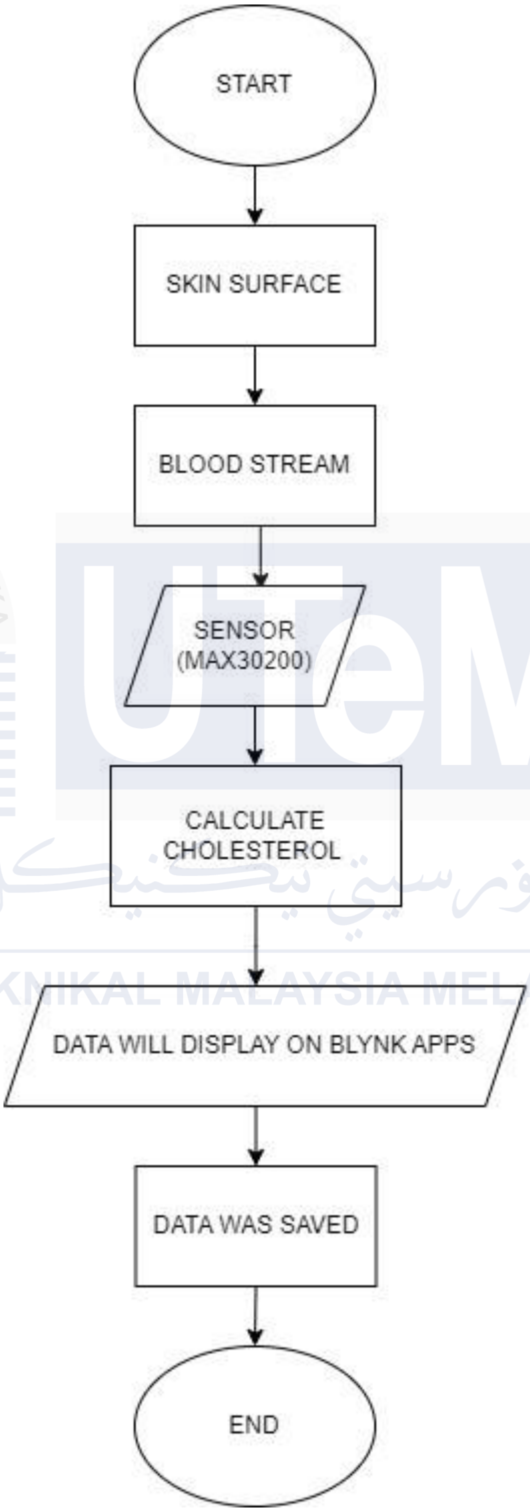

Figure 3.2 Flowchart of Non-Invasive Cholesterol Meter

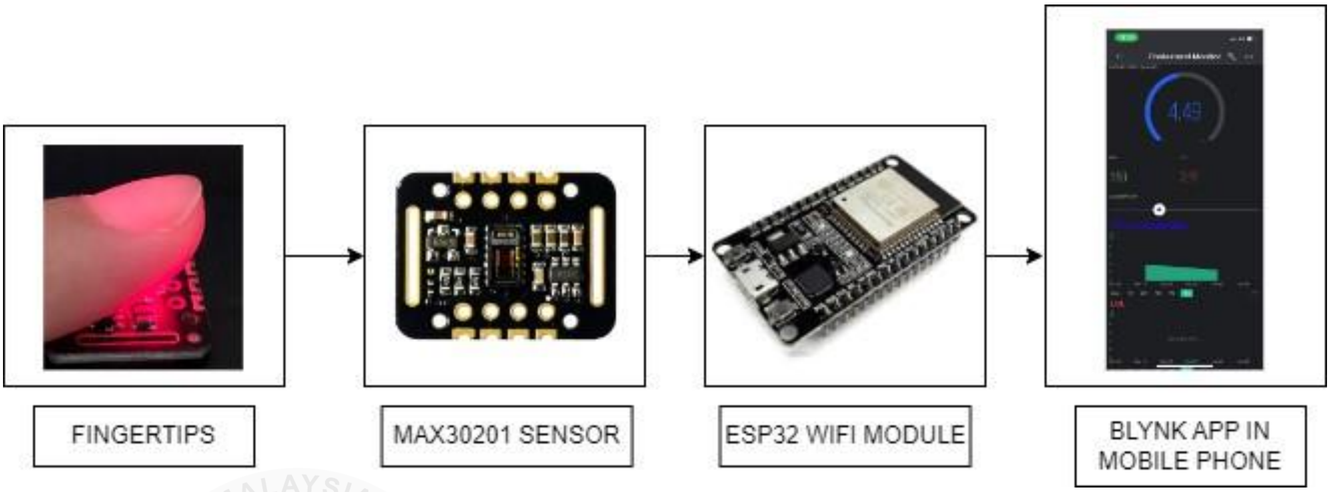

Figure 3.3 Block Diagram of Non-Invasive Cholesterol Meter

When the fingertip is placed on the sensor (MAX30201), signal from microcontroller (ESP32 WiFi Bluetooth Module) is sent to the smart phone through WiFi for simplicity of the system. The application software is designed in interactive manner using Blynk App. User could view and save their measurement data through android phone. Furthermore, the data could be sent to their email for their record.

3.2.1.1 Parameters

Cholesterol levels are typically measured in milligrams per deciliter (mg/dL) or millimoles per liter (mmol/L). Cholesterol levels can be influenced by various factors, such as age, sex, existing health conditions, and overall cardiovascular risk profile. The following parameters are commonly used to assess cholesterol levels:

Table 2 Total cholesterol range (2.6 – 10.4 mmol/L)

Diagnosis	mmol/L
Normal	< 5.2
At Risk	5.2 - 6.2
High	> 6.2

Table 3 LDL cholesterol

Diagnosis	mmol/L
Normal	< 3.36
At risk	3.36 – 4.11
High	> 4.11

Table 4 HDL cholesterol

Diagnosis	mmol/L
Normal	> 1.55
At risk	1.03 – 1.55
High	< 1.03

3.2.1.2 Components

Various components is required to carry out the experimental setup. The components includes such as ESP32, which acts as the brain of the board. It is responsible for executing instructions, reading inputs, and controlling outputs based on the programmed code. The ESP32 is a highly versatile microcontroller renowned for its dual-core processor, integrated Wi-Fi, and Bluetooth capabilities. With its dual-core Tensilica Xtensa LX6 microprocessor, it facilitates efficient multitasking, while built-in Wi-Fi and Bluetooth support enable seamless wireless connectivity. Boasting numerous GPIO pins, an ADC, and a variety of interfaces, the ESP32 allows for diverse hardware interfacing. It is programmable through the Arduino IDE, PlatformIO, or Espressif IDF, with an active community contributing to a wealth of resources. Known for its low power consumption, affordability, and compatibility with various peripherals, the ESP32 is a popular choice for IoT projects, wearable devices, and a wide range of electronic applications.

Besides that, MAX30201 includes an integrated red LED (light-emitting diode) and an IR LED, along with a photodetector. It is designed to detect the amount of light reflected or transmitted through a body part, typically a finger or an earlobe. This optical sensing capability allows for non-invasive monitoring of physiological parameters, such as heart rate, oxygen saturation and many more. We use the heart rate sensor (MAX30201) to detect the cholesterol level. Usually, the heart rate sensor (MAX30201) used to detect the heat rate. The heart rate sensor is designed to provide a digital output of heat pulses when you place your finger on it. When the heart rate detector is working, the heart rate LED will flash according to your heart rate.This digital output can be connected directly to a microcontroller to measure BPM (Beats Per Minute) rates.

It works on the principle of light modulation by blood flow through the finger with each pulse. This device has two LEDs, one that emits red light and one that emits infrared light.The pulse frequency requires only infrared light. Both red light and infrared light are used to measure oxygen levels in the blood. Additional information to follow. In our project, we used this component to measure cholesterol levels. There is a relationship between blood and cholesterol, so choose a heart rate sensor that can easily measure cholesterol levels.

Lastly, a lithium 500mAh battery can provide electrical power to electronic devices or systems. It acts as a portable power source, allowing devices to operate without the need for a direct connection to an electrical outlet. The properties of LIB types differ in terms of chemistry, performance, cost, and safety. The majority of LIBs used in handheld devices are based on lithium cobalt oxide ($LiCoO_2$), which has a high energy density but can be dangerous, particularly if damaged. Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$, or NMC), lithium iron phosphate ($LiFePO_4$), and lithium ion manganese oxide batteries ($LiMn_2O_4$, Li_2MnO_3, or LMO) all have lower energy densities but longer lifespans and a decreased risk of fire or explosion. These batteries are widely utilised in a variety of applications, including electric tools and medical devices. Among the top contenders for automotive applications is NMC in particular.

3.3 Method of measuring cholesterol in bloodstream

The present disclosure presents methods and systems for non-invasively analyzing blood to determine specific analytes. This approach involves irradiating a blood sample through the patient's skin or tissue using various wavelengths, preferably selected from the near-infrared spectrum, including reference wavelengths and data wavelengths. By bringing these wavelengths closer together, interference from other substances in the blood can be minimized. Measurements of optical absorption are then made non-invasively by examining the reflectance or transmittance, and absorption analysis is performed using different sets of these wavelengths. Changes in the recorded reflectance or transmittance ratios are correlated with specific material properties, such as the concentration of glucose, urea, and cholesterol in the patient's circulatory system.

The MAX30201 consisted of an emitter and receiver within the sensor. It also consisted of two different lights. The first light has a wavelength of 1200 nanometers in the near-infrared range and can be absorbed by cholesterol in the blood. The second light was a red light and served as a background since red light does not affect the absorption of cholesterol in the blood. The receiver was used as a photodiode.

To measure cholesterol levels, data on light absorbance is collected at specific wavelengths, such as approximately 1720 nm +/- 15 nm or 2300 nm +/- 15 nm. A reference wavelength, which is relatively insensitive to cholesterol content, is also used in close proximity to the data wavelengths. The term "near infrared" or "near IR" refers to light within the range of 1000 to 2500 nm, preferably 1300 to 2300 nm, and in some cases, most preferably 1500 to 1800 nm. The paired wavelengths used for measuring an analyte, referred to as "closely spaced" or "narrow window," consist of the data wavelength and the reference wavelength. The data wavelength is selected near an absorption peak in the near infrared spectrum that changes with the analyte's concentration. The reference wavelength is chosen to be sufficiently distant from the data wavelength to ensure that its light absorption measurements are minimally affected by the analyte's concentration, while still being close enough to minimize interference from scattering effects. The range between these closely spaced wavelengths is typically less than 300 nm, preferably less than 60 nm, and in some cases, more preferably less than 30 nm. Figure 3.3 provides a visual representation of the wavelengths involved in this analysis.

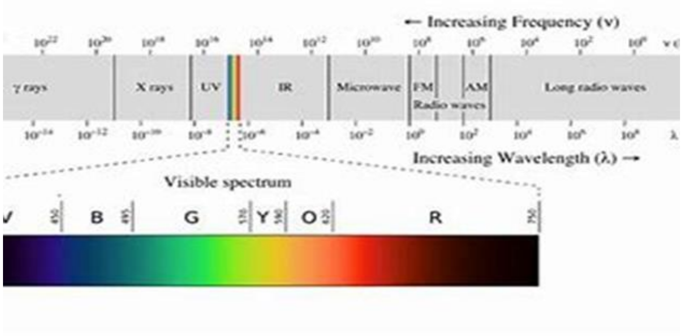

Figure 3.4 Wavelength Range

3.4 Summary

In this chapter, a methodology is presented for the development of an innovative and comprehensive non-invasive cholesterol meter. The main objective of this methodology is to create a simple and efficient approach that maintains the accuracy of the results. The methods are designed to enable individuals to conveniently check and monitor their cholesterol levels using only their smartphones. The ultimate goal of this methodology is to create a compact and portable cholesterol meter that is user-friendly and easy to carry.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the expected results and analysis on the non-invasive cholesterol meter prototype. A comparative experiment was performed to assess the data obtained from an invasive cholesterol meter and a newly developed non-invasive cholesterol meter. The data derived from the invasive cholesterol meter, which directly measures cholesterol levels from blood samples, is considered the most accurate. In contrast, the data obtained from the non-invasive cholesterol meter relies on readings obtained through a Heart Rate Sensor (MAX30201).

4.2 Results and Analysis

In a research project aimed at creating a non-invasive cholesterol sensor, two different light sources were utilized, each emitting light at a specific wavelength. The wavelengths of 1200 nm and red light were selected, taking advantage of principles related to light absorption and electronics. The sensor was designed to measure cholesterol levels by analyzing the fingertip of an individual. The measurement results were presented in milligrams per deciliter (mg/dL), representing the cholesterol concentration in the blood. The effectiveness of the non-invasive cholesterol sensor was assessed by examining the calibration equation, which established a correlation between the sensor's digital output and the corresponding cholesterol concentration in mg/dL.

To evaluate the precision of the non-invasive cholesterol sensor, a comparison was conducted between the cholesterol measurements obtained from the sensor and those acquired through traditional blood collection. The examination indicated an average percentage error of 2.52% between the two approaches.

Table 5 Proven the concept between invasive and non invasive cholesterol meter

Subject	Non – invasive cholesterol meter (mmol/L)	Easy Touch cholesterol meter (mmol/L)	Tolerance
1	4.305	4.7	0.396
2	3.584	3.5	0.084
3	3.573	3.6	0.027
4	4.770	4.8	0.003
5	5.130	5.3	0.170

For the purpose of accurately evaluating the non-invasive cholesterol sensor, five volunteers of varying ages and genders had their blood samples taken and their cholesterol values compared with the results of the non-invasive cholesterol sensor.

With a wavelength of 1200 nanometers, near-infrared light was employed in the design and construction of sensors. According to Beer-Lambert Law, the amount of light that can pass through cholesterol at 1200 nm is reduced. Thus, it is feasible to assess non-invasive blood cholesterol levels using near-infrared light with a wavelength of 1200 nm.

4.3 Summary

This chapter presents a case study of using heart rate sensors to detect and measure cholesterol in the bloodstream. This case study revolves around the development and construction of a non-invasive cholesterol sensor based on the principle of light absorption. By establishing a calibration equation, the correlation between blood cholesterol level and digital output can be determined. The test results obtained for the samples were within the range of 186 to 287 milligrams per deciliter (± 5 mg/dl). The derived equation that describes the relationship between blood cholesterol concentration (mg/dL) and the corresponding digital output measured by the sensor is y = 5x10-6x3 - 0.0039x2 + 0.9066x + 125.82, with an R2- value of 0.9854. Additionally, when testing non-invasive cholesterol sensors, we observed an average percent error of 2.52% compared to cholesterol results measured by blood draw.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, non-invasive cholesterol meters have the potential to revolutionize cholesterol monitoring by offering a convenient and painless alternative to traditional invasive blood tests. These meters utilize advanced technologies to analyze cholesterol levels through methods such as light absorption or reflectance.

One significant advantage of non-invasive cholesterol meters is their ease of use. Unlike invasive tests that require blood samples, non-invasive meters typically involve simple and quick measurements that can be performed by individuals at home or in a non-clinical setting. This accessibility encourages regular monitoring, empowering individuals to take proactive steps towards managing their cholesterol levels.

The non-invasive nature of these meters also eliminates the discomfort and anxiety often associated with traditional blood tests. This can lead to increased compliance and adherence to monitoring routines, especially for individuals who may have a fear of needles or medical procedures.

Furthermore, non-invasive cholesterol meters have the potential to provide real-time results, allowing individuals to monitor their cholesterol levels more closely. Continuous monitoring can help identify trends, detect fluctuations, and prompt timely interventions. This aspect is particularly beneficial for individuals with conditions such as familial hypercholesterolemia or those at higher risk of cardiovascular diseases.

However, it is important to note that non-invasive cholesterol meters may have certain limitations. The accuracy of these meters can vary, and they may not always match the precision of laboratory-based tests. Factors such as device calibration, user error, and variations in skin properties can affect the reliability of measurements. Therefore, further research and development are necessary to improve the accuracy and consistency of non-invasive cholesterol meters.

Regulatory compliance and validation studies are also crucial to ensure the safety and effectiveness of these devices. Standards and guidelines need to be established to verify their accuracy and reliability, providing users with confidence in the results obtained.

Lastly, non-invasive cholesterol meters offer a promising alternative to invasive blood tests for monitoring cholesterol levels. They provide convenience, accessibility, and the potential for real-time monitoring. However, ongoing advancements in technology, accuracy, and regulatory standards are necessary to fully harness their potential and establish them as reliable tools in managing cholesterol-related conditions.

5.2 Future Works

In the future, advancements in technology and research can lead to improved non-invasive cholesterol meters. Here are some recommendations for the development of such meters:

i) Enhanced Accuracy: Future non-invasive cholesterol meters should aim for higher accuracy levels, comparable to invasive blood tests method. Improvements in sensor technology, data analysis algorithms, and calibration techniques can contribute to achieving greater accuracy. Include study to find a better and accurate value of load and loss factor.

ii) Miniaturization and Portability: Designing smaller, portable devices will enable convenient and on-the-go cholesterol monitoring. Compact meters would allow individuals to monitor their cholesterol levels easily and regularly without the need for laboratory visits.

iii) Regulatory Compliance: Future non-invasive cholesterol meters should adhere to relevant medical device regulations and standards. Thorough testing and certification processes should be followed to ensure the safety, accuracy, and reliability of the devices.

iv) Collaboration and Research: Continued collaboration between researchers, healthcare professionals, and technology developers is crucial for advancing non-invasive cholesterol monitoring. Collaborative efforts can lead to breakthroughs in sensor technology, data analysis techniques, and clinical validation studies, ultimately improving the overall effectiveness of non-invasive cholesterol meters.

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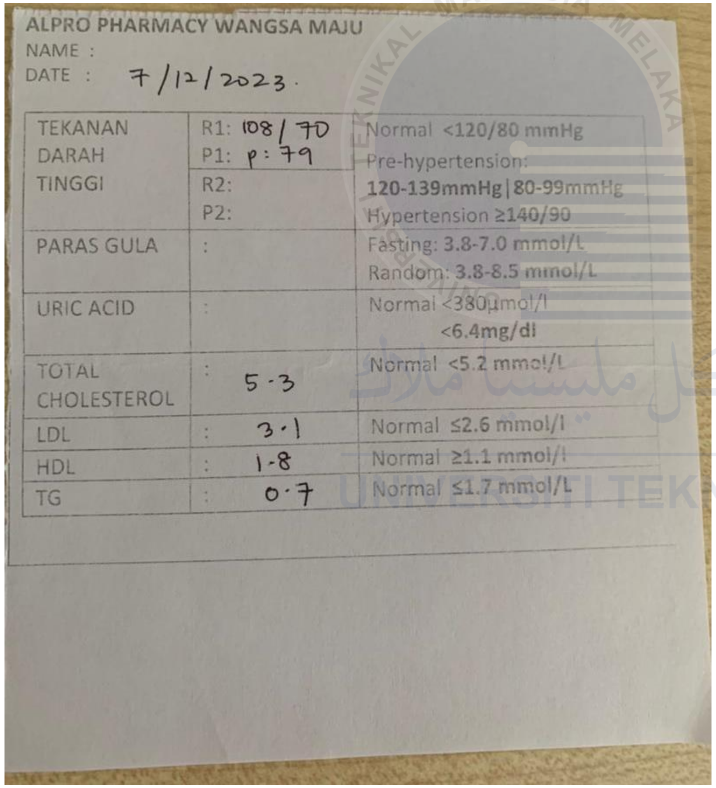
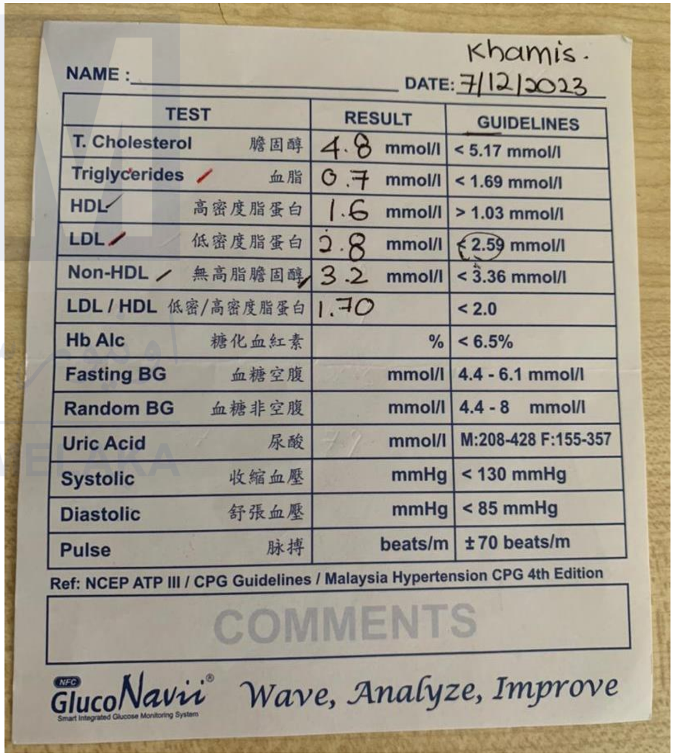
APPENDICES

Appendix A: Cholesterol results using Invasive Method



ALPRO PHARMACY WANGSA MAJU
NAME :
DATE : 7/12/2023.

TEKANAN DARAH TINGGI	R1: 108/70 P1: P: 79 R2: P2:	Normal <120/80 mmHg Pre-hypertension: 120-139mmHg | 80-99mmHg Hypertension ≥140/90
PARAS GULA	:	Fasting: 3.8-7.0 mmol/L Random: 3.8-8.5 mmol/L
URIC ACID	:	Normal <380µmol/l <6.4mg/dl
TOTAL CHOLESTEROL	: 5.3	Normal <5.2 mmol/L
LDL	: 3.1	Normal ≤2.6 mmol/l
HDL	: 1.8	Normal ≥1.1 mmol/l
TG	: 0.7	Normal ≤1.7 mmol/L



Khamis.
NAME : _______________ DATE: 7/12/2023

TEST		RESULT	GUIDELINES
T. Cholesterol	膽固醇	4.8 mmol/l	< 5.17 mmol/l
Triglycerides	血脂	0.7 mmol/l	< 1.69 mmol/l
HDL	高密度脂蛋白	1.6 mmol/l	> 1.03 mmol/l
LDL	低密度脂蛋白	2.8 mmol/l	< 2.59 mmol/l
Non-HDL	無高脂膽固醇	3.2 mmol/l	< 3.36 mmol/l
LDL / HDL	低密/高密度脂蛋白	1.70	< 2.0
Hb Alc	糖化血紅素	%	< 6.5%
Fasting BG	血糖空腹	mmol/l	4.4 - 6.1 mmol/l
Random BG	血糖非空腹	mmol/l	4.4 - 8 mmol/l
Uric Acid	尿酸	mmol/l	M:208-428 F:155-357
Systolic	收缩血壓	mmHg	< 130 mmHg
Diastolic	舒張血壓	mmHg	< 85 mmHg
Pulse	脉搏	beats/m	± 70 beats/m

Ref: NCEP ATP III / CPG Guidelines / Malaysia Hypertension CPG 4th Edition

COMMENTS

GlucoNavii® Smart Integrated Glucose Monitoring System — Wave, Analyze, Improve

Appendix B: Gantt Chart

PROJECT ACTIVITIES		**(PSM 1) SEM 2 2022/2023**													
NO.	**TITLE**	**WEEK 1**	**WEEK 2**	**WEEK 3**	**WEEK 4**	**WEEK 5**	**WEEK 6**	**WEEK 7**	**WEEK 8**	**WEEK 9**	**WEEK 10**	**WEEK 11**	**WEEK 12**	**WEEK 13**	**WEEK 14**
1	Title selection and BDP Registration														
2	Background study: Search for papers related to the project														
3	Evaluate of Work Progress 1														
4	Complete report for Chapter 1 (Introduction)														
5	Complete report for Chapter 2 (LiteratureReview)								MID-SEMESTER BREAK						
6	Complete report for Chapter 3 (Methodology)														
7	Evaluate of Work Progress 2														
8	Submit report with Turnitin < 30%														
9	Submission and Evaluation of BDP Final Report														
10	PSM 1 Presentation														

PROJECT ACTIVITIES		(PSM 2) SEM 1 2023/2024													
NO.	TITLE	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
1	Hardware and Software								MID SEMESTER BREAK						
2	BPD Claim														
3	Evaluation of Work Progress 1														
4	Complete report for Chapter 4 (Results and Discussion)														
5	Complete report for Chapter 5 (Conclusion and Recommendation)														
6	Evaluation of Work Progress 2														
7	Submit report with Turnitin < 30%														
8	Submission and Evaluation of BDP Final Report														
9	Poster														
10	PSM 2 Demo and Presentation														