UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF TYPE 1 DIABETES MELLITUS BLOOD GLUCOSE LEVEL SIMULATION MOBILE APPLICATION

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By

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DEVELOPMENT OF TYPE 1 DIABETES MELLITUS BLOOD GLUCOSE LEVEL SIMULATION MOBILE APPLICATION

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June 2020

Chair : Mohd Halim Shah Ismail, PhD
Faculty : Engineering

Most diabetes mobile applications in the market right now only focused on receiving input of a diabetes patients' previous food consumption, insulin intake and their corresponding measured blood glucose to help them manage the condition by displaying the information back in a more organized form. This research proposes a new application that instead process the input from the user and generate a simulation of the patient's predicted future blood glucose level trend. The application has been developed in this study which is then compared and validated with other works. The mathematical model used has already been validated by Lehmann & Deutsch (1992), and hence in the study, the application was tested if it can replicate the simulation of clinical data used by them. The application's simulation is slightly off due to lack of initial condition data but for the most part was close to the original simulation. The features and purpose of each section in the application was discussed with a demonstration on how the application works. This study found that although application can be used to show the trend of blood glucose from meal consumption and administration of insulin, it is not reliable enough to be able to predict with 100% accuracy of future blood glucose level with just the information from user input data. The application however, has potential as an educational tool where diabetes patient can learn about the effect of carbohydrate, insulin, and the change of these input to their blood glucose level. This was shown by a simulation of different insulin injection time using the application to show the effect it has on blood glucose level which demonstrate some of the things that T1DM patients can learn from the application. One of the limitations of the application is it does not incorporate physical activity into the simulation. Hence, it is recommended that future application to take physical activity into consideration. Further studies on glucose-insulin dynamics with physical activity is also recommended as only a few existing models for this are currently found.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah *Master Sains*

PEMBINAAN APLIKASI MUDAH ALIH MERAMAL GLUKOSA DARAH DIABETES MELITUS JENIS 1

Oleh

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Kebanyakan aplikasi mudah alih diabetes yang sedia ada di pasaran sekarang hanya menumpukan perhatian pada pengambilan input makanan, insulin dan glukosa darah daripada pesakit diabetes pengguna-nya dan memaparkannya kembali kepada pengguna didalam bentuk yang lebih mudah difaham. Di dalam thesis ini, aplikasi baru yang sebaliknya memproses input dari pengguna tersebut dan menghasilkan simulasi trend tahap glukosa darah sebagai ramalan kepada pesakit telah dicadangkan sebagai penyelesaian yang lebih baik. Aplikasi tersebut telah dibina dalam kajian ini yang kemudian dibandingkan dan disahkan dengan karya lain. Model matematik yang digunakan telah disahkan oleh Lehmann & Deutsch (1992), oleh itu, kajian mereka digunakan untuk dibandingkan dengan aplikasi yang telah dibina. Simulasi aplikasi hampir dengan simulasi mereka kecuali pada bahagian awal simulasi dimana kekurangan data keadaan awal menyukarkan aplikasi untuk menyerupai simulasi mereka. Ciri dan tujuan setiap bahagian dalam aplikasi dibincangkan dengan demonstrasi bagaimana aplikasi berfungsi. Kajian ini mendapati bahawa walaupun aplikasi dapat digunakan untuk menunjukkan kecenderungan glukosa darah dari penggunaan makanan dan penggunaan insulin, ia tidak cukup untuk dapat meramalkan dengan ketepatan 100% tahap glukosa darah masa depan hanya dengan maklumat dari input pengguna data. Namun aplikasi ini berpotensi sebagai alat pendidikan di mana pesakit diabetes dapat mengetahui tentang kesan karbohidrat, insulin, dan perubahan input ini ke tahap glukosa darah mereka. Ini ditunjukkan oleh simulasi masa suntikan insulin yang berbeza menggunakan aplikasi untuk menunjukkan kesannya terhadap kadar glukosa darah yang membuktikan beberapa perkara yang dapat dipelajari oleh pesakit T1DM dari aplikasi tersebut. Salah satu batasan aplikasi adalah tidak memasukkan aktiviti fizikal ke dalam simulasi.

Oleh itu, disarankan agar aplikasi masa depan mengambil kira aktiviti fizikal. Kajian lebih lanjut mengenai dinamika glukosa-insulin dengan aktiviti fizikal juga disyorkan kerana hanya terdapat beberapa model yang wujud pada masa kini.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
AAS	Apple App Store
CINAHL	Cumulative Index of Nursing and Allied Health Literature
DBMS	Database Management System
Hb1Ac	Haemoglobin A1C
NHGB	Net Hepatic Glucose Balance
NPH	Nuetral Protamine Hagedorn
RMSE	Root Mean Square Error
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
UI	User Interface

CHAPTER 1

INTRODUCTION

1.1 Background

Diabetes is a condition where a person's body is unable to regulate blood sugar level within normal condition which result in hyperglycemia. The blood sugar is known as glucose which is the simplest form of sugar and is the basic source of energy for human body. In a healthy person, glucose level is regulated by hormones secreted by the pancreas that increase or reduce glucose depending on the current glucose level. The hormone responsible for reducing and increasing blood glucose level is insulin and glucagon respectively. In a diabetic patient, these hormones are either lacking or fail to serve its function to control blood sugar level to normal.

From 1980 to 2014, the number of people with diabetes has risen from 108 million to 422 million. Among adults over the age of 18, this is an increase from 4.7% to 8.5% globally. Diabetes is a major cause of kidney failure, blindness, stroke, heart attacks and lower limb amputation. An estimated of 1.6 million deaths were directly caused by diabetes in 2016 with another 2.2 million deaths were attributed to high blood glucose in 2012(World Health Organization, 2019).

Figure 1.1 shows the surveys by The National Health and Morbidity Survey (NHMS) on the prevalence of diabetes in Malaysia in adults across different age groups for the year of 1996, 2006, and 2011. The prevalence of diabetes is shown to increase over the years across all age groups. The increase in prevalence of diabetes between 2006 and 2011 is also similar to between 1996 and 2006 although it takes a shorter duration amount of time which is alarming.

There are a three major types of diabetes which are diabetes type 1, type 2 and gestational diabetes. Type 1 is a condition where the body stop producing insulin due to its own autoimmune system destroying the beta cell in the pancreas that secretes insulin. Type 2 diabetes is where the body does produce insulin but there is insufficient insulin action to reduce the glucose level which are said to be insulin resistant. Gestational diabetes on the other hand, is a condition when a pregnant woman develop diabetes during pregnancy.

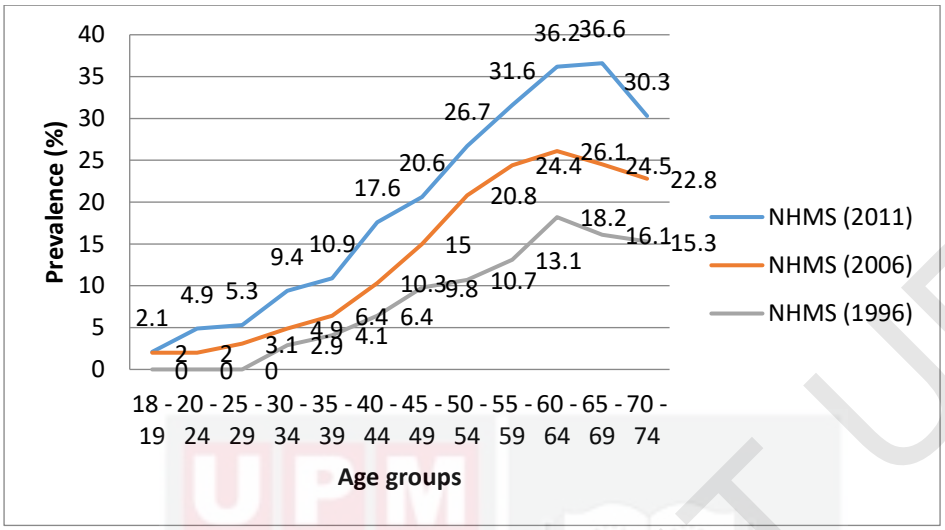

Figure 1.1: Prevalence of Diabetes for adults by age groups (1996, 2006, 2011)

The focus on this thesis is on Type 1 Diabetes Mellitus (T1DM), and the proposed tool to help T1DM patients improve the management of their condition. Type 1 diabetes accounts for 5 to 10% of all diabetics in the world. The symptoms usually appear early on in the life of type 1 diabetics and can only be manage with no cure and thus will have a long-term impact on their life. Management of type 1 diabetes require continuous attention to many aspects, including insulin administration, blood glucose monitoring, meal planning, and screening for comorbid conditions and diabetes-related complications (Daneman, 2006).

In this thesis, a tool based on mobile platform which help T1DM patients estimate their blood glucose level was proposed. Mobile phones have become a common device to own in the 21st century and its capability is increasing every year, matching the performance of computers from several years ago. Having mobile phones as a tool to manage blood glucose will be beneficial to people with diabetes as the management device is already in their pocket. Acquiring such tool is then as easy as installing an application on a mobile phone.

1.2 Problem Statement

There is already a few diabetes mobile application in the market right now. The most common feature on these applications is to provide a way for users to input their previous blood glucose measurement and meal consumptions which is then stored and displayed it back to the users for them to observe their trend

of blood glucose level and meal consumption from the history. The information is usually displayed back to the users as line graphs, bar charts or in another format.

This feature however only takes the available information from the users and display it back in other form that is more presentable to the users. These applications usually do not process the input and provide extra information to the user that is outside of their knowledge. For example, there is a lack of feature that predict and simulate future blood glucose level from meal and insulin consumption. Simulating future blood glucose from meal consumption would teach users on the direct impact of their meal on the blood glucose. It would teach and help them visualize how different type of food with different nutritional content and its quantity can affect their blood glucose level. Simulating by taking into accounts the insulin injections will also teach the users on the impact of different type and dosage of insulin on their blood glucose. This would help them understands why they have to take the dosage prescribe by doctors and probably adjust if needed when they have an anomaly in their meal intake.

Besides that, there are also not enough diabetes application that focus on T1DM patients. A T1DM patient needs constant attention on their blood glucose level and requires multiple insulin injections a day to maintain a healthy glucose level. They need a once or twice basal insulin injections and regular insulin after every meal throughout the day. Because of this, they are in more need of an application that simulate future blood glucose as they need to supervise their blood glucose level more often than their T2DM counterpart. T1DM patients also need to plan their meals where this is also where an application can come to aid for these patients. Being able to see the simulated effect of the food they ate or going to eat should help them better manage and plan their meals. Besides that, any food they consume that deviates from their meal planning can also be immediately simulated on the application to ensure they are fine or have to adjust their insulin intake. The effect of dosage of insulin can also be simulated which would help them estimate the amount of insulin to take.

An application that takes meal consumption as input requires it to give a selection of meals as option for it to be user friendly. In order to do that, there needs to be a storage place for the food data to be place in. Including all the data together with the application as a package would not be too practical as it takes up precious storage space on the phone while also being inflexible to changes as the users need to update the application every time new data is added. Hence, the solution is to have a database storage in the cloud where the application just needs to load the information when it needs and new update only needed to be done on the server without interfering client application.

1.3 Objectives

Based on the problem statement, the following objectives were constructed for this thesis. A new diabetes mobile application for both Android and iOS will be built with features that would help diabetes type 1 patients estimate their blood glucose level based on their meal and insulin intake. The application should have the capability to store previous input from users and predict future blood glucose from there.

The following main objectives were listed for this thesis: -

1. To develop Android and iOS mobile application for Type 1 Diabetes Mellitus, T1DM patient which predicts blood glucose and insulin level based on meal and insulin intake of the patients.

2. To compare and validate the developed application's simulation of blood glucose and insulin level against time by comparing it with clinical patient data and other simulation study.

1.4 Scope of research

The scope of this research is on developing a diabetes type 1 glucose mobile application that predicts blood glucose level using the available Lehmann & Deutsch (1992) mathematical model. The application was only developed for Android and iOS platform. Both Android and iOS will be developed natively meaning the code is developed specifically for the targeted platform. Programming language used is Java and Swift for Android and iOS respectively for their native development.

Online MySQL cloud database was developed to support the application. Providing a complete data of nutrition information in the database on all the existing food in the world is outside the scope of this research. The database was constructed to support and supply nutrition information to the application and can be alter and tweak later in the future to include more food.

The following assumption and limitation for this thesis: -

a) The application did not take into account the effect of exercise on blood glucose level. The patients or users being simulated on the application are assumed to all have the same normal level of daily physical activity.

b) In the event that there are no data from the previous day provided, the application assumes that there are no insulin and meals taken on the previous day as well.

c) The application did not provide instructional message to the users on the amount of food they should consume on their next meal. It merely shows the effect of food they take on their blood glucose in the form of graph.

1.5 Contribution of research

The research was done to help diabetes type 1 patient better plan their daily meal and insulin intake. The application developed in this research would simulate blood glucose in the form of blood glucose against time. The rise of and fall of blood glucose would then be observe from the graph and hence, any hyperglycemia and hypoglycemia in the simulation can be seen by the patients.

1.6 Thesis Organization

Chapter 1 is where the introduction of the thesis takes place where a brief background was written. This is followed by the problem statement which give rise to the objectives of the research.

Chapter 2 gives a brief explanation on Type 1 Diabetes Mellitus (T1DM). Literature review was provided to strengthen the application development. Previous literature on diabetes mobile application was studied together with existing mathematical model on blood glucose and insulin dynamics.

Chapter 3 is where the methodology was placed which explains the steps taken in developing the application. This methodology can be divided into developing the cloud database, the application's user interface and the application's simulation code.

Chapter 4 is where the discussion of the research take place. The features of and roles of each section in the application were described. A brief explanation of how to use the application were also explained followed by a small section discussing the glucose simulations. This is then followed by validation of the application's simulation by comparing the simulation with other study using the same mathematical model.

Chapter 5 is where the conclusion and future recommendation from this research were given.

The developed source code was given in APPENDIX B.

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