ASSESSING THE EFFECTIVENESS OF POINT-OF-CARE DEVICES AND AUTOMATED CHEMISTRY ANALYZERS IN THE MANAGEMENT OF DIABETES MELLITUS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES

OF

NEAR EAST UNIVERSITY

By

MUBARAK TAIWO MUSTAPHA

In Partial Fulfillment of the Requirements for the Degree of Master of Science

in

Biomedical Engineering

NICOSIA,2019

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To my friends, colleagues and adversary, thanks for making me who I am.

To God Almighty and my Family

ABSTRACT

Diabetes Mellitus (DM) is a metabolic disorder associated with hyperglycemia over a prolong time. Diabetes as it is usually called has a unique group of symptoms; polyuria, polydipsia and polyphagia. Its complication include damage to the eye, stroke, chronic liver disease, foot ulcers, cardiovascular disease, diabetic ketoacidosis and death if left untreated.Diabetes is caused by two things; inability of the pancreas to produce insulin or poor response of the body cells to respond to the insulin produced. Diabetes characterized by pancreas inability to secret insulin is referred to as type 1 diabetes mellitus while type 2 result from the body's inability to utilize the insulin produced. Insulin is an important hormone needed to regulate blood glucose level. The main objective of this study is to shed more light on the parameters that affect the different devices used in the management of diabetes and how these parameters affect the preference ranking of each technique. In this study, the most common glucometers and chemistry analysers are analysed based on some parameters that are likely to affect the outcome of the treatment methods. This analysis and ranking were carried using fuzzy PROMETHEE (Preference ranking organization method for enrichment evaluations), a multi-criteria decision-making tool. The results of the analysis suggest that Omnitest 3 is the most favourable devices for the management of diabetes and Selectra Pro S is the least favourable device. This ranking is based on the weights, criteria and parameters used for the analysis.

Keywords: Analyser; Decision-making; Diabetes-Mellitus; Fuzzy PROMETHEE; Glucometer; Hyperglycemia; Ketoacidosis;

ÖZET

Diabetes Mellitus (DM), uzun süre hiperglisemi ile ilişkili metabolik bir hastalıktır. Genellikle denilen diyabetin kendine özgü semptomları vardır; poliüri, polydipsia ve polifali. Komplikasyonunda göze hasar, inme, kronik karaciğer hastalığı, ayak ülserleri, kalp damar hastalığı, diyabetik ketoasidoz ve tedavi edilmezse bırakılması vardır. Diyabet iki şeyden kaynaklanır; pankreasın insülin üretememesi veya vücut hücrelerinin üretilen insüline cevap vermesi için zayıf tepkisi. Pankreasın gizli insülin yetersizliği ile karakterize edilen diyabet, tip 1 diabetes mellitus olarak adlandırılırken, tip 2 vücudun üretilen insülini kullanmadaki yetersizliğinden kaynaklanır. İnsülin, kan şekeri seviyesini düzenlemek için gerekli olan önemli bir hormondur. Bu çalışmanın temel amacı, diyabet yönetiminde kullanılan farklı cihazları etkileyen parametrelere ve bu parametrelerin her tekniğin tercih sıralamasını nasıl etkilediğine ışık tutmaktır. Bu çalışmada, en yaygın glukometreler ve kimya analizörleri, tedavi yöntemlerinin sonucunu etkileyebilecek bazı parametrelere dayanarak analiz edilmiştir. Bu analiz ve sıralama, çok kriterli bir karar verme aracı olan bulanık PROMETHEE (Zenginleştirme değerlendirmeleri için tercih sıralaması organizasyon yöntemi) kullanılarak yapıldı. Analiz sonuçları, Omnitest 3'ün diyabet yönetimi için en uygun cihaz olduğunu ve Selectra Pro S'nin en az kullanılan cihaz olduğunu göstermektedir. Bu sıralama, analiz için kullanılan ağırlıklara, kriterlere ve parametrelere dayanmaktadır.

Anahtar Kelimeler:çözümleyici; Bulanık PROMETHEE;şeker hastalığı; terapötik teknikler; glukometre; hiperglisemi; asidoketoz.

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ABBREVIATIONS

AHP	Analytic Hierarchy Process
CT	Computer Tomography
DM	Diabetes Mellitus
ELECTRE	Elimination and Choice Expressing Reality
FBP	Filtered Back Projection
GDH	Glucose Dehydrogenase
GO_x	Glucose Oxidase
HBGM	Home-Blood-Glucose-Monitoring
HCOs	Health-Care-Provides
HPI	High Poverty Index
IDDM	Insulin-Dependent Diabetes Mellitus
IDF	International Diabetes Federation
IPTR	Internal Pancreas Transplant Registry
ISE	Ion-Selective Electrode
ISO	International Standard Organization
LM	List Mode
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision-Making
MRI	Magnetic Resonance Imaging
MSE	Mean Square Error
MTF	Modulation Transfer Function
NICU	Neonatal Intensive Care Unit
OE	Origin Ensemble
OSEM	Ordered Subset Expectation Maximization

PET	Positron Emission Tomography
POC	Point-of-Care
POCGMD	Point-of-Care-Glucose Monitoring Device
POCT	Point-of-Care Testing
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluations
RC	Resolution Compensation
SMART	Simple Multi-Attribute Rating Technique
SPECT	Single Positron Emission Tomography
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

Diabetes Mellitus (DM) is a metabolic disorder symbolized by polyphagia, polydipsia, and polyuria associated with hyperglycemiaover a prolong time(Piero, Nzaro & Njagi, 2015). Diabetes as it is usually called has a unique group of symptoms; polyuria, polydipsia and polyphagia. Its complication include damage to the eye, stroke, chronic liver disease, foot ulcers, cardiovascular disease, diabetic ketoacidosis and death if left untreated(Kitabchi, Umpierrez, Miles & Fisher, 2009).Diabetes is caused by two things; inability of the pancreas to produce insulin or poor response of the body cells to respond to the insulin produced(Shoback & Gardner, 2011). Diabetescharacterized by pancreas inability to secret insulin is referred to as type 1 diabetes mellitus. Insulin is an important hormone needed to regulate blood glucose level. Insulin reduces blood glucose level to normal(WHO, 2019). In type 2 diabetes mellitus, the body cells are not able to utilize the insulin secreted, thereby, causing increase in blood sugar level. Gestational diabetes occurs only during pregnancy and offset soon after delivery(WHO, 2019).

Relatively, 150 million of the world population have diabetes mellitus and it may as well rise by double by 2025 (WHO, 2019). A lot of this increase will occur in countries with high poverty index (HPI) due to increase in population, ageing, obesity, and unhealthy diet. By 2025, people of age 65 or more in developed countries will have diabetes while people age 45-64 in developing countries will have diabetes(WHO, 2019). Early diagnosis is the key in managing diabetes because it has no cure(Buse et al., 2009). There is also no known preventive measure for type 1 diabetes(WHO, 2019), however, type 2 diabetes mellitus can be prevented by maintaining a normal body weight and consuming a healthy diet(WHO, 2019). As mentioned earlier, diabetes has no cure but management of the disorder is achievable. Medications can be used to reduce blood glucose level.

Point-of-care testing (POCT) refers to medical testing or diagnosis done in close proximity to the patient(Quesada-González& Merkoci, 2018). This could be at the patient’s home, workplace, gym, or summer home. The POCT is different from conventional testing which involve being at the hospital or laboratory and using medical devices such as the use of fully or semiautomated chemistry analyser. A typical example of POCT device is the glucometer. This device is handy and can be used anywhere and anytime. It requires no maintenance or special training. A glucometer is usually simple to use, portable, accurate, and precise in the management of diabetes.

In this study, common medical equipment and devices used to monitor blood glucose level in diabetes are considered and analysed in order to obtain a ranking of the techniques in relation to the cost of devices, cost of maintenance, accuracy, volume of sample required and ease of use. The analysis and ranking are done using a multi-criteria decision-making method known as fuzzy PROMETHEE.

1.1 Thesis Problem

- By 2016, 422 million people already had diabetes(WHO, 2019). This make diabetes the 8th leading cause of death worldwide, hence, effective management of the disorder is paramount.
- Diabetes has no cure(Piero, Nzaro & Njagi, 2015), thus, management of the disorder plays a very important role in the wellbeing of people living with diabetes mellitus.
- Prolong increase in blood glucose level may become impossible to manage.

1.2 Aims of the Study

- To analyse and rank conventional hospital equipment and glucometer in the management of diabetes mellitus using fuzzy PROMETHEE.
- To simulate and determine the most desirable device and equipment in the management of diabetes mellitus base on some very important criteria that determines their effectiveness to the person living with diabetes.
- To determine with a degree of confidence the most efficient equipment and device.

1.3 Significance of the Study

- The findings of this study will enable the physician in informing the choice of blood-monitoring glucose device for people living with diabetes.
- This study will enable the patients to have at their disposal information on the devices to consider in monitoring their blood glucose level and therefore managing diabetes.
- The findings of this study will provide an outright ranking of devices or equipment not based on just one factor, but in consideration of a number of factors.

1.4 Limitations of the Study

- All the data used for the research are secondary data, no original data was obtained in order to verify the consistency of the obtained data.
- Different specialists have different opinions about the weight of each parameter.
- No other decision-making software was readily available to make analysis in order to verify the results obtained from the VISUAL PROMETHEE software.

1.5 Overview of the Thesis

Chapter 1 is an introductory chapter of the whole thesis work, outlining the thesis problem, aim of the study, significance of the research and the limitations of the study. Chapter 2 is a detailed clinical background of the diabetes, including the cause, common symptoms, prevention, treatment and management types.Chapter 3 is a literature review of previous studies carried out and related to the present research. Chapter 4 outlines the method used for the analysis of the treatment techniques of retinoblastoma. Chapter 5 is the results of the analysis; the conclusion and discussion are contained in chapter 6.

CHAPTER 2

CLINICAL BACKGROUND

2.1 Diabetes

The term diabetes mellitus is usually referred to as diabetes, so the two words are interchangeable. Diabetes mellitus is the metabolic disorder associated with chronic hyperglycaemia. This result in defects in the insulin secretion as in the case of type 1 diabetes and insulin action as in the case of type 2 diabetes or both (Standard of Medical Care in Diabetes, 2013). Globally, diabetes was found to be 9.8 percent in men and 9.2 percent in women with observed regional inequity(Kaur &Kochar, 2017).

Diabetes is one of the earliest known diseases to humanity (Desveaux, 2013). Ancient scientist diagnosed the disease when an individual has a sweet taste of urine; this is most commonly done when an individual is suspected to have diabetes. Other diseases presented with diabetes mellitus include hypertension and heart disease. According to the international diabetes federation (IDF) in 2018, 422 million people have diabetes worldwide (IDF, 2018), with over 1 million children and adolescent being diagnosed of type 1 diabetes (IDF, 2018). Two third (279 million) of people living with diabetes are working class and those living in urban area (IDF, 2018)while 1 in every 6 birth (327 million) is affected by hyperglycemia in pregnancy (IDF, 2018). Diabetes is prevalent in people of black origin and 50 percent more prevalent in females (IDF, 2018). Nonetheless, the male gender is susceptible to type 1 diabetes. The economic impact of diabetes affects both the public finances and that of the family of individual suffering from the disease. Also, 1 in every 11 adult (425 million) has diabetes and 1 in every 2 persons with diabetes is undiagnosed (IDF, 2018).

Three main types of diabetes occur; type 1 diabetes occurs when the pancreas fails to produce necessary insulin hormone needed by the body(Goldenberg and Punthakee, 2013). It is sometimes referred to as juvenile diabetes or insulin-dependent diabetes mellitus (IDDM) and the cause is unknown(Goldenberg & Punthakee, 2013). Type 2 diabetes result in when the body cells are unable to utilize the insulin secreted by the pancreas (Nandimath et al., 2016). Type 2 diabetes is sometimes referred to as non-insulin dependent diabetes mellitus (NDDM) or adult-onset diabetes (Nandimath, Swamy, Nandimath, Jatti & Jadhav, 2016).Gestational diabetes mellitus result when an expectant mom without prior history of diabetes suddenly develops hyperglycemia (Mirghani Dirar& Doupis, 2017).

2.2 Types

2.2.1 Type 1 diabetes

Type 1 diabetes arises when there is a destruction of the beta cells of the islet of Langerhans in the pancreas resulting in insulin insufficiency (Soleimanpour and Stoffers, 2013). Type diabetes occurs in two circumstances;

a) Immune-mediated cause or
b) Idiopathic cause

Type 1 diabetes related to immune-mediated cause arises when the immune system is flawed, dysfunctional or deteriorated. Idiopathic cause occurs from and unknown cause (Soleimanpour & Stoffers, 2013). Most type 1 diabetes is of immune-mediated cause thereby resulting in 10 percent of diabetes mellitus cases in Canada, USA, and Europe (Soleimanpour & Stoffers, 2013). In this case, sensitivity and receptivity to insulin are usually normal. Type 1 diabetes can also be lay down from generations (inherited) (Soleimanpour & Stoffers, 2013), with several genes prompting the risk of diabetes (Soleimanpour & Stoffers, 2013). Type 1 diabetes can also result in from environmental factors, which include diet and viruses (Soleimanpour & Stoffers, 2013). Dietary causes include gliadin while no specific factor associated with viruses has been supported (Haupt-Jorgensen, Holm, Josefsen & Buschard, 2018). Type 1 diabetes is mostly diagnosed during children (Streisand & Monaghan, 2014).

2.2.2 Type 2

Type 2 diabetes mellitus is associated with insulin resistance, which sometimes comes with comparatively inadequate insulin secretion (Diagnosis and Classification of Diabetes Mellitus, 2008). This occurs because the insulin receptor designated to respond to insulin action is defective, nonetheless, the specific defects are not known. Type 2 diabetes constitutes the major occurrence of the metabolic disorder (Nsiah, Shang, Boateng & Mensah, 2015). Type 2 diabetes usually has prior evidence of pre-diabetes in the course of their life before being confirmed to have type 2 diabetes mellitus. Type 2 diabetes can also be a result of the lifestyle of an individual (Prasad & Groop, 2015), however, genetic implication also persists(Prasad & Groop, 2015). The lifestyle in question here includes lack of exercise or any other physical activity, obesity as a result of unhealthy consumption of diet and stress (Forouhi & Wareham, 2014). Consuming sugar-sweetened drinks in excess also result in increased risk (Chaput et al., 2011).

2.2.3 Gestational diabetes

Gestational diabetes manifests like type 1 and type 2 diabetes mellitus. It usually comprises insufficient insulin production and receptivity. In a study conducted by the US Department of Health and Human Services, about 5-10 percent of women are found to have diabetes mellitus (Hu & Malik, 2010). Unlike type 1 and type 2 diabetes, gestational diabetes is fully treatable with patient having full recovery. Although medical supervision is required throughout the course of pregnancy. If left untreated, gestational diabetes could dangerous top both the health of the foetus and mother. Such foetus could manifest diseases such as congenital heart failure, central nervous system abnormalities, skeletal muscle malfunction and macrosomia.

2.3 Signs and Symptoms

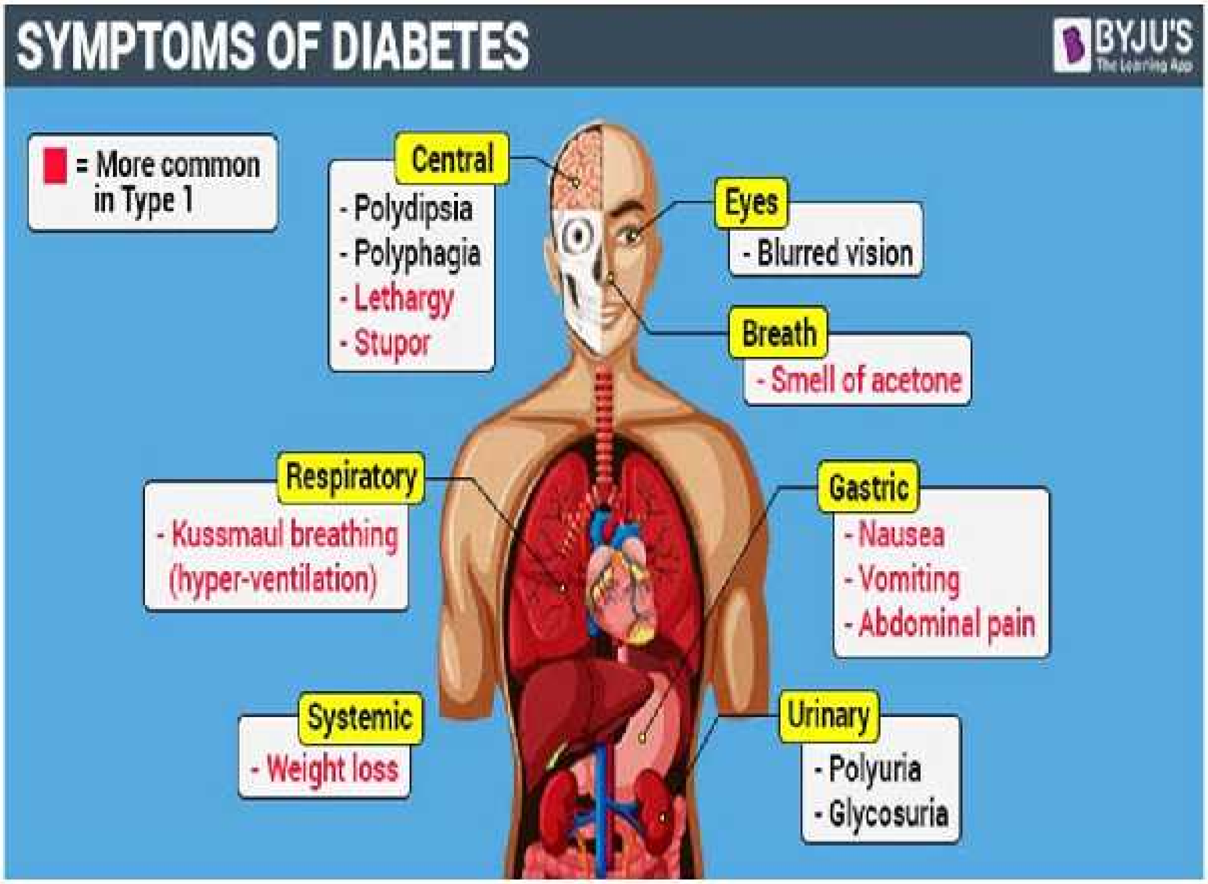


Figure 2.1: Symptoms of diabetes (Spanakis & Golden, 2013)

The predominant symptoms of chronic diabetes include;

a) Polyuria (Increased urination)(Lupo, 2019)
b) Polydipsia (Increased thirst)(Lupo, 2019)
c) Polyphagia (Increased hunger)(Lupo, 2019)

Usually, symptoms manifest within weeks or months in type 1 diabetes and take longer to show in type 2 diabetes mellitus. There are recoded cases where symptoms do not show in type 2 diabetes mellitus (Wu, Ding, Tanaka & Zang, 2014). Other symptoms include weight loss, tiredness, diabetes keto-acidosis, diabetic retinopathy, diabetic dermatomes, itchy skin, blurred vision, headache, fatigue, slow healing of cuts, vision changes and skin rashes (Wu, Ding, Tanaka & Zang, 2014; Olokoba, Obateru & Olokoba, 2012).

2.3.1 Complication

When the three types of diabetes are left untreated, long-term complication is inevitable(Cerf, 2013). The symptoms may manifest in weeks, months and even years. Complications range from coronary artery disease (Cerf, 2013) to macro-vascular disease such as stroke and peripheral artery disease. Diabetes could also raise the risk of having cataracts, glaucoma and other retina problems.

2.4 Pathophysiology

The essential hormone responsible for the regulations of glucose uptake from the blood to the cells of the body, muscle, tissues and liver is insulin. So, defect in insulin producing cells and insensitivity plays a major role in all form of diabetes mellitus (Roder, Wu, Liu & Han, 2016). Glucose is supplied to the body from three sources;

a) Intestinal absorption of food
b) Glycogenolysis (catabolism of stored glucose in the liver)
c) Gluconeogenesis (generation of glucose from non-carbohydrate substrates) (Yu et al., 2017).

Insulin plays a major role in adjusting glucose levels in the body. It can inhibit catabolism of glycogen, transport of glucose into muscular and adipose tissue, and can initiate the storage of glucose in form of glycogen. When there is a rising level of glucose in the blood stream, the beta cells present in the islets of Langerhans in the pancreas is released. This typically brings the blood glucose level to normal. Conversely, when there is fasting or starvation, the beta cells present in the islets of Langerhans in the pancreas stimulate the release of glucagon thereby raising the glucose level to normal.

This process is usually controlled by glucagon act in reversed manner to insulin (Wherrett & Daneman, 2009). In an event that the measure of insulin is inefficient or if cells react inefficiently to insulin, then absorption of glucose by the body will not occur and it is not properly stored in the liver and muscle. Glycosuria occurs when the concentration of glucose in the body persist over a certain period of time. This is as a result of the kidney reaching its reabsorption threshold (Quianzon & Cheikh, 2012). This further leads to inhibition of the reabsorption of water by the kidney resulting in polyuria. Dehydration also occurs leading to increased thirst (polyphagia).

2.5 Diagnosis

Diagnosis of diabetes mellitus can be done with the use of point-of-care testing or conventional laboratory equipment. An individual with glycated haemoglobin ≥48mmol/L is considered hyperglycemic, hence, diabetes is imminent. Also, an individual with a fasting plasma level ≥7.0mmol/L and plasma glucose ≥11.1mmol/L is considered high. It is recommended than when hyperglycemia persists, a repeat of the test should be done to be sure. It is desirable to measure a fasting glucose level due to the simplicity of estimation.

Table 2.1 WHO Diabetes criteria(Quianzon &Cheihk, 2012; WHO, 2019)

Condition	**2-Hours glucose**	**Fasting glucose**	**HbA_{1C}**	
Unit	Mmol/L (mg/dL)	Mmol/L (mg/dL)	Mmol/L	DCCT%
Normal	≥7.8 (140)	<6.1 (<110)	<42	6.0-6.4
Impaired fasting glycaemic	≥7.8 (140)	≥6.1 (>110) And <7.0 (126)	4.2-4.6	6.0-6.4
Impaired glucose tolerance	≥7.8 (140)	>7.0 (126)	4.2-4.6	6.0-6.4
Diabetes	≥ 11.1 (≥200)	≥7.0 (126)	≥48	≥6.5

mellitus

2.6 Prevention

Type 1 diabetes has no known preventive measure (Hampson et al., 2010), but type 2 diabetes mellitus which account for about 85-90 percent of cases worldwide can be prevented by abstaining from consuming unhealthy diet and maintaining a normal weight (Hampson et al., 2010). A study conducted by (Kyu et al., 2016) indicated that the risk of having diabetes could be reduced by 28 percent by maintaining more than 90 minutes of physical activity per day(Kyu et al., 2016). Dietary source identified to efficient in preventing (Haupt-Jorgensen et al., 2018) diabetes includes grains, fibre, good fat such as unsaturated fat found in fish, vegetable oils and nuts (Quianzon & Cheihk, 2012).

Despite the fact that the gene inherited by an individual may influence the development of type 2 diabetes, there are still secondary to behavioural and lifestyle factors. Information gotten Nurses' Health study shows that 90 percent of women living with type 2 diabetes are predispose to the following factors, excessive weight, lack of physical activity, consumption of unhealthy diet, excessive alcohol consumption and smoking (Quianzon &Cheihk, 2012). This is similar to the male gender too.

2.7 Management

2.7.1 Hospital Management

a) Insulin Pump

Insulin is the oldest therapy available for diabetes. It was discovered in 1921, and clinical testing in human started in 1922(Quianzon & Cheihk, 2012). The insulin pump is an electrical device that is programmed in order to re-act the insulin in a way that delivers all of the infusion of the insulin itself throughout a tube that is inserted in a critical way in the abdominal area. The pump generally delivers such small pulses of insulin to make sure that the blood glucose is enhanced in a range between the meals and overnight.

b) Pancreas transplantation

Pancreas is transplanted surgically as a treatment for the diabetic patients with type 1 diabetes. This averts the intensive needs of insulin treatment (insulin independence) and usually this could help to improve the life quality and expectancy of life. The first surgery for transplanting a pancreas was held at the Minnesota university. In 1996, USA improves this therapy and more than 23,000 successful pancreas transplantation therapies reported to Internal Pancreas Transplants Registry (IPTR) (Quianzon & Cheihk, 2012).

c) Medical Nutrition Therapy

Medical nutrition therapy was introduced in1994 (Diagnosis and Classification of Diabetes Mellitus, 2008). People with Type 1 and type 2 diabetes must maintain a healthy diet for managing diabetes. So, medical nutrition therapy is one of the main treatments that are suggested by doctors for the patients (Diagnosis and Classification of Diabetes Mellitus, 2008). These patients are placed under close monitoring throughout the sessions to reduce diabetes. It is most helpful for the patients with type2 diabetes and it's normally a number of nutrients given to the body daily in the food that the patient intake throughout the day

d) Metformin

Metformin is one of the best treatments that are used to improve the glucose tolerance for the type 2 diabetes by lowering the basal and postprandial plasma glucose. The pharmacology of this treatment differs from the antihyperglycemic agents. The metformin usually decreases the production of the glucose and at the same time it improves the insulin sensitivity. It does not produce hypoglycaemia and does not cause hyperinsulinemia.

2.7.2 Laboratory Management

a) Chemistry analyser

Chemistry analysers are medical laboratory devices used to calculate the concentration of certain substances within samples of serum, plasma, urine and/or other body fluids. Substances analysed through the instruments includes certain metabolites, electrolytes, proteins and/or drugs. Clinical chemistry analysers are highly automated for speed, consistency of results, avoidance material, and walkaway capability. Onboard refrigerated reagent storage, connection to a water supply, and automated recalibration allow for long periods of intervention-free operation.

Clinical chemistry analysers are used in variety of settings, including small clinics, research labs, and high-throughput hospital labs. Chemistry analysers are highly automated to maximize throughput, to improve user safety from biohazards, and to diminish the risk of cross-contamination. Samples are loaded into the machine and tests are programmed by the user. A probe measures an aliquot of sample and places it into a reaction vessel. Reagents are added from an on-board refrigerated supply. Incubation time is allowed if required; then photometric or ion-selective electrode (ISE) testing determines the concentration of analytes. Results are displayed on screen or sent to a printer or computer.

Usually, the choice of chemistry analyser depends on the types of test to be run. Other factors include sample handling, degree of automation, data management, operating costs, footprint, and whether the machine can handle micro volume samples. The most common test method is photometry. The sample is mixed with the appropriate reagent to produce a reaction that results in a colour. The concentration of the analyte determines the strength of colour produced. The photometer shines light of the appropriate wavelength at the sample and measures the amount of light absorber, which is directly correlated to the concentration of the analyte in the sample. The other major analytical method is the use of ion selective electrode to measure ions such as Na^+, K^+, Cl^-, and Li^+. An ISE is a sensor that determines the concentration of ions in a solution by measuring the current flow through an ion selective membrane.

b) Glucometer

A glucometer is used to determine the concentration of glucose in the blood. It is a keyelement of home-blood-glucose-monitoring (HBGM) by people with diabetes mellitus. A small drop of blood obtained by pricking the skin with a lancet is placed on a disposable test strip that the meter reads and uses to calculate the blood glucose level. Results are displayed in mg/dl or mmol/l. Many glucometers employ the oxidation of glucose to gluconolactone catalyzed by glucose oxidase (GOx). Others uses a similar reaction catalyzed instead by another enzyme, glucose-dehydrogenase (GDH). This has the advantage of sensitivity over GOx but is more susceptible to interfering reactions with other substances. In the blood glucose monitoring industry, it is well accepted that there are three “C” terms that drive people’s willingness to test: cost, comfort, and convenience. The comfort advantage of noninvasive technology is easily understood.

CHAPTER 3

LITERATURE REVIEW

Many researchers have carried out studies on multi-criteria decision-making (MCDM) techniques and how they can be applied in various fields such as chemistry, engineering, medicine and even social studies to improve the quality of life. Such MCDM techniques include, Analytic hierarchy process (AHP), Simple Multi-Attribute Rating Technique (SMART), ELECTRE (Outranking), PROMETHEE (Outranking) to mention but a very few of the numerous techniques that are available (Weistroffer, Smith & Narula, 1989).

PROMETHEE ranking is one of the most common of these decision-making tools, which was developed as an outranking method to obtain either a partial or complete outranking of a defined set of practical actions (Brans, Vincke & Mareschal, 1986).

Rajendran and Rayman (2014) conducted an evidence-based review on the point-of-care blood glucose testing for diabetes care in hospitalized patients. Emphasize was made on the history, accuracy, clinical use, and cost-effectiveness of point-of-care blood glucose testing for diabetes. Point- of-care devices have evolved from 1.2 kg instruments with no informatics to handheld lightweight portable devices with advanced connectivity features. Their accuracy however remains a subject of debate, and new standards for their approval have now been issued by both the International Organization for Standardization and the Clinical and Laboratory Standards Institute. While their cost-effectiveness remains to be proved, their clinical value for managing in patients with diabetes remains unchallenged. This evidence-based review provides an overall view of its use in the hospital setting.

Ceriotti et al. (2014) carried out a comparative performance assessment of point-of-care testing devices for measuring glucose and ketones at the patient bedside. In the study, the interferences assessed includes acetoacetate, acetaminophen, ascorbic acid, galactose, maltose, uric acid, and sodium. The accuracies of both Optium ketone and glucose measurements were significantly influenced by varying levels of haematocrit and ascorbic acid. StatStrip ketone and glucose measurements were unaffected by the interferences tested with exception of ascorbic acid, which reduced the higher-level ketone value. The accuracy of Accu-Chek glucose measurements was affected by hematocrit, by ascorbic acid, and significantly by galactose. The method correlation assessment indicated differences between the meters in compliance to International Standard Organization (ISO) 15197 and CLSI 12-A3 performance criteria. Combined POC glucose/ketone methods are now available. The use of these devices in a hospital setting requires careful consideration with regard to the selection of instruments not sensitive to hematocrit variation and presence of interfering substances.

Khan et al. (2017) conducted a study in advancing point-of-care (PoC) testing using human saliva as liquid biopsy. In the study, the necessity for the development of point-of-care (PoC) technology, the potential of saliva, identification and validation of biomarkers through salivary diagnostic toolboxes, and a broad overview of emerging technologies is discussed. Furthermore, novel advanced techniques incorporated in devices for the early detection and diagnosis of several oral and systemic diseases in a non-invasive, easily-monitored, less time consuming, and in a personalized way is explicated. The latest technology detection systems and clinical utilities of saliva as a liquid biopsy, electric field-induced release and measurement (EFIRM), biosensors, smartphone technology, microfluidics, paper-based technology, and how their futuristic perspectives can improve salivary diagnostics and reduce hospital stays by replacing it with chairside screening is also highlighted.

Ferri et al. (2011) carried out a study on the review of glucose oxidase and glucose dehydrogenases: A bird’s eye view of glucose sensing enzymes. The study summarizes the present knowledge of redox enzymes currently utilized in commercially available glucose monitoring systems to promote a fuller appreciation of enzymatic properties and principles employed in blood glucose monitoring to help avoid potential errors.

Rebel et al. (2012) conducted a study on the accuracy of point-of-care glucose measurements. In the study, currently available point-of-care-glucose monitoring devices (POCGMDs) exhibit the greatest accuracy within the range of physiological glucose levels but become less reliable at the lower and higher ranges of BG levels. This issue raises serious safety concerns and the importance of understanding the limitations of POCGMDs. This review will discuss potential interferences and shortcomings of the current POCGMDs and stress when these may impact the reliability of POCGMDs for clinical decision-making.

In a study conducted by Reddy(2014), the author focused on the comparison of point of care (POC) testing of glucose by B Braun glucometer and hemocue glucose 201+ analyser versus centralized testing in neonatal intensive care unit (NICU). Their study indicated that thereis no significant difference between the capillary and venous sample estimated in both the instruments. Their study reveals that HemoCue glucose 201+ analyser appears to be a suitable point of care (POC) blood glucose measurement device in neonates on both capillary and venous blood samples, as it showed a good correlation with central laboratory values without significant interference from Hct.

In a study conducted by Klonoff (2014), accuracy of point-of-care blood glucose meter accuracy in the hospital setting was evaluated. Proper inpatient glycaemic management requires timely blood glucose results with careful consideration of sample size, patient comfort, test time, nursing work flow, cost, and ability to automatically transfer results into the electronic medical record so they are readily available to clinicians to make treatment changes. Prescription blood glucose monitors for use by Health-care-providers (HCPs) at the bedside are already widely used for this purpose. Regulatory bodies in the United States and Europe are requiring progressively greater levels of accuracy for these products. Even with accurately performing monitors, it is necessary to follow proper procedures to avoid errors. Pre-analytical errors resulting from poor sampling or strip storage can cause inaccuracy. Measurement errors caused by perturbations in patients' physiological state or interference from concomitant use of medications can result in analytical errors. Improper data-handling can result in post-analytical errors. Proper training for health care staff and knowledge of how these devices work is both necessary to get the highest quality and most useful information from blood glucose monitoring in the hospital setting.

Ozsahin et al. (2017) conducted a study, which evaluated cancer treatment alternatives using fuzzy PROMETHEE. They applied the principle of multi-criteria decision-making theories on various cancer treatment techniques. Their study was focused on comparing the treatment techniques of chemotherapy, radiation therapy, hadron therapy, immune-therapy, hormone therapy and surgery with regards to some primary factors that could affect the outcome of a chosen treatment technique, such as treatment duration, cost of treatment, side effects and survival rate. Their results concluded that hadron therapy, which emerged with the highest survival percentage, shortest treatment time and combined net-flow value of 0.4931 was the most suitable treatment technique for a cancer patient.

Ozsahin et al. (2017) carried out a research to evaluate and compare the most common nuclear medicine imaging devices available, using a multi-criteria decision-making technique. In this study, they made comparisons between Positron Emission Tomography (PET), Single Positron Emission Computed Tomography (SPECT), PET/CT, SPECT/CT and PET/MRI using cost of treatment, average radiation dose, spatial resolution, sensitivity and specificity of the device, energy resolution and average scan time as parameters for the comparison. In their analysis, they used Yager Index to find the magnitude of the triangular fuzzy numbers. Finally, they utilized Visual PROMETHEE Decision Lab Program with the Gaussian preference function to arrive at their results. Their analysis concluded that PET with a net-flow of 0.0005 is a more beneficial and advisable imaging device based on the parameters used.

Ozsahin et al. (2018) carried out a study that examined and compared the most commonly employed techniques of image construction algorithms in nuclear medicine, using the method of fuzzy PROMETHEE. In their study, they compared Ordered Subset Expectation Maximization (OSEM), Origin Ensemble (OE), List Mode-OSEM (LM-OSEM) and Filtered Back Propagation (FBP), which are the most commonly used image construction algorithms to decide on the most effective technique which would likely produce a higher quality image, an important and desirable feature in nuclear imaging. The parameters they used to make the comparison in the study are, Modulation Transfer Function (MTF), Mean Square Error (MSE), Bias, Run Time, Variance, Resolution Compensation (RC) and Uniformity. The results of their study show that according to the parameters used, FBP is a superior algorithm for higher quality images, with a net-flow of 0.0031.

Ozsahin et al. (2018) used Fuzzy Preference Ranking Method for Enrichment Evaluations to evaluate x-ray based medical imaging devices. They used Fuzzy PROMETHEE to assess the image quality parameters of these x-ray-based devices in order to portray the efficiency, potentiality and negativity of each device. The parameters utilized in their studies to make this analysis were, sensitivity, specificity, radiation dose, cost of treatment and the cost of the machine. The parameters were chosen and analysed based on the effects they have on the patient as well as the hospital. The devices that were put into consideration for these analyses are conventional x-ray machine, angiography, Computed Tomography (CT), fluoroscopy and mammography. They used Yager index to view the magnitude of the parameters of the alternatives. Their results rank the conventional x-ray machine as a suitable imaging device when the cost of machine is not put into consideration with a net flow of 0.0017. While mammography outranked the other medical imaging devices when the cost of machine is put into consideration with a net flow of 0.0015.

Ozsahin and Ozsahin (2018) made a fuzzy PROMETHEE approach for breast cancer treatment techniques to analyse and rank the most suitable treatment technique for patients diagnosed with breast cancer. In their research, they made analysis on surgery, radiotherapy, chemotherapy and hormone therapy treatment techniques for breast cancer, using parameters such as treatment time, cost of treatment, side effects and overall survival rate of each technique. They applied Yager index to defuzzify the triangular fuzzy numbers and calculate the weight of each criterion. The conclusion of their studies ranked surgery as the most suitable treatment technique for patients with breast cancer, amounting a net flow of 0.5156, based on the parameters that they used. Other studies conducted on fuzzy PROMETHEE can be seen on (Ozsahin, Nyakuwanikwa, Wallace & Ozsahin, 2019; Musa, Ozsahin & Ozsahin, 2019; Ozsahin, Uzun Ozsahin, Maisaini & GSP MOK, 2019; Ozsahin, Uzun Ozsahin, Nyakuwanikwa & Wallace Simbanegavi, 2019; Taiwo Mubarak, Ozsahin & Uzun Ozsahin, 2019; Uzun, Sarigul Yildirim, Sayan, Sanlidag & Uzun Ozsahin, 2019; Sayan et al., 2019; Sultanoglu et al., 2019; Ozsahin, Uzun Ozsahin & Uzun, 2019; Uzun Ozsahin, ALMuhisen & Gokcekus, 2019; Maisaini, Uzun, Ozsahin & Uzun Ozsahin, 2019).

Silas and Rajsingh (2016) used different multi-criteria decision methods such as ELECTRE, PROMETHEE and AHP to analyse healthcare services application. The analysis was done based on certain criteria such as, the average overhead incurred in selection of the health care services, the time taken to select the health care services, degree of human intervention and patient satisfaction based on the overall performance. The results of their analysis indicate that PROMETHEE is a suitable MCDM tool for application in healthcare service analysis with 95% of users preferring PROMETHEE algorithm for the selection of a healthcare service.

Amaral and Costa (2014) applied PROMETHEE II in a research to analyse and support decision-making and resource management in an emergency department. The method of their analysis was validated using experimental data from a public hospital in Brazil. Six months after implementing the solution of the analysis obtained from their research the waiting time during overcrowding periods in the waiting room had been reduced by about 70%. Using PROMETHEE enables the decision maker to choose the best option to solve problems that result in overcrowding in the emergency departments of hospitals and can also be extended to other departments.

CHAPTER 4

METHODOLOGY

4.1. Fuzzy Logic

Obtaining crisp data that accurately defines real life situations is a very challenging feat. Additional to this challenge is the description of imprecise data or information that is not completely true or false. Boolean logic has a system of extremities, a situation is either true (1) or false (0), no room for in-betweens or uncertainties is allowed. In fuzzy logic however, a machine can treat situations with a degree of uncertainty attached. For instance, Boolean logic in treating the temperature of a room will either state that the room is hot or cold, but at what point does the temperature cross over from being cold to being hot? Fuzzy logic however provides an alternative of very cold, cold, warm, hot, very hot and so on in order to solve the problem associated with uncertainty.

Fuzzy logic is preferred and has an advantage over other methods such as predictable logic, Bayesian control, probability theory, classical theory and so many such systems because on fuzzy logic provides a system of computing with words, meaning words are used to represent numbers in computing and reasoning (Zadeh, 1996).

4.2. Multi-criteria Decision-Making

Multi-criteria decision-making (MCDM) also referred to as multiple-criteria decision analysis (MCDA) is a research area that makes analysis of various available choices in a situation or research area which spans daily life, social sciences, engineering, medicine and many other areas. (Zionts, 1979) defined the term as solving a problem with multiple conflicting objectives. MCDM is one of the most popular decision-making tools utilized in various fields (Mardani et al., 2015).

MCDM analyses the criteria involved in a parameter that makes the parameter a favourable or unfavourable choice for a particular application and attempts to compare this parameter based on the selected criteria, against every other available option in an attempt to assist the decision maker in selecting an option with the minimal compromise and maximum advantages. The criteria used in the analyses of these parameters can be either qualitative or quantitative parameters.

Division of MCDM can be made into two categories based on the method used to determine the weight of each alternative (Majumder, 2015):

i. Compensatory decision-making: involves evaluating the criteria of the parameters including the weak points and strong points of the parameters and allowing the strong points of each parameter to make up for the weak points, thereby putting all the criteria of the parameters into consideration. An example of compensatory decision-making tool is the Analytical Hierarchy Process (AHP) a technique mostly used when the environment for the analysis is complex, it is used in the comparison of parameters that are difficult to quantify.

ii. Outranking decision-making: this method compares the criteria of the parameters in couples in order to determine which parameter ranks higher than the others based on the comparisons (Yang, Wang & Wang, 2012). A popular example of an outranking decision-making method is Elimination and Choice Expressing Reality (ELECTRE) a method that is used to choose, rank and sort out alternatives to solve a problem.

4.3. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)

PROMETHEE is a multi-criteria decision-making tool that allows a user to analyse and rank available alternatives based on the criteria of each alternative. PROMETHEE compares the available alternatives based on the selected criteria.

PROMETHEE is preferred over other multi-criteria decision methods for reasons such as;

- PROMETHEE can be used to handle qualitative and quantitative criteria simultaneously.
- PROMETHEE deals with fuzzy relations, vagueness and uncertainties.
- PROMETHEE is easy to handle and provides the user maximum control over the weights of the criteria.

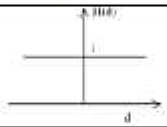
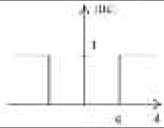
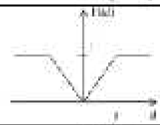
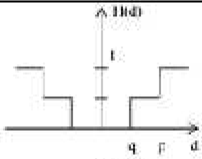
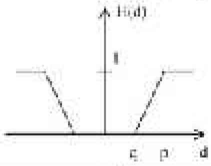
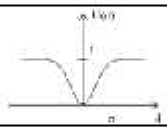
Using PROMETHEE requires only a couple of information from the decision maker, an information regarding the weights of the selected criteria and the preference function to be used in comparing the alternatives’ contribution as regards each criterion (Macharis, Springael, De Brucker & Verbeke, 2004).

Different preference functions (P_j) are available on PROMETHEE for the definition of different criteria. The preference function defines the difference between the evaluations with two alternatives (a and a_t) in relation to a specific criterion and a preference degree ranging between 0 and 1. The preference functions for practical purposes that can be used at the discretion of the decision maker include; usual function, V-shape function, level function, u-shape function, linear function and Gaussian function. A detailed description of the preference functions used, their ranking and how to make a decision on which function best suits a scenario was discussed by J. P. Brans et al. a quick summary of the preference functions is shown in Table 4.1 (Brans, Vincke & Mareschal, 1986). Generally, type III (V-shape) and type V (linear) preference functions are mostly used for data with quantitative measures, while type I (usual shape) and type IV (level) preference functions are mostly used for qualitative data.

The significance of the parameters to be defined are as follows;

- q indicates a threshold of indifference.
- p is a threshold that indicates strict preference.
- σ is an intermediate point between q and p.

Table 4.1: Types of Generalised Criteria

Type of generalized criteria	Analytical definition	Shape	Parameters to define
Type I. Usual criterion	$H(d) = \begin{cases} 0, & d = 0; \\ 1, & \lvert d \rvert > 0 \end{cases}$		
Type II. Quasi-criterion	$H(d) = \begin{cases} 0, & \lvert d \rvert \le q; \\ 1, & otherwise \end{cases}$		q
Type III. Criterion with linear preference	$H(d) = \begin{cases} \frac{\lvert d \rvert}{p}, & \lvert d \rvert \le p; \\ 1, & \lvert d \rvert > p. \end{cases}$		p
Type IV. Level-criterion	$H(d) = \begin{cases} 1, & \lvert d \rvert \le q, \\ 1/2, & q < \lvert d \rvert \le p; \\ 1, & otherwise \end{cases}$		q, p
Type V. Criterion with linear preference and indifference area	$H(d) = \begin{cases} 1, & \lvert d \rvert \le q, \\ \frac{\lvert d \rvert - q}{p - q}, & q < \lvert d \rvert \le p; \\ 1, & otherwise \end{cases}$		q, p
Type VI. Gaussian criterion	$H(d) = 1 - \exp\left(-\frac{d^2}{2\sigma^2}\right)$		σ

4.3.1. The Steps of the PROMETHEE Method

The creators of the technique (Brans, Vincke & Mareschal, 1986) have discussed the complete steps of the PROMETHEE method, this method has not been altered in any way for this research.

1. Define a specific preference function p_j (d) for each criterion j.

2. Determine the weight of each criterion $w_t = (w_1, w_2, \ldots, w_k)$. Normalization of weights or equality of weights can be decided at the discretion of the decision maker based on the application.

3. For every alternative $a_t, a_{t'}$ A, determine the outranking relation π.

$$\pi(a_t, a_{t'}) = \sum_{k=1}^{K} w_k.\left[p_k\big(f_k(a_t) - f_k(a_{t'})\big)\right], \qquad A \quad \rightarrow [0,1]$$

4. Determine the positive and negative outranking flows;

- Positive outranking flow for a_t: $\Phi^{+}(u_t) = \frac{1}{n-1}\sum_{\substack{t'=1 \\ t'\neq t}}^{n} \pi(u_t, u_{t'})$
- Negative outranking flow for a_t: $\Phi^{-}(u_t) = \frac{1}{n-1}\sum_{\substack{t'=1 \\ t'\neq t}}^{n} \pi(u_{t'}, u_t)$

n refers to the number of alternatives, and each alternative is compared to an n-1 number of alternatives.

The positive outranking flow is an expression of how a particular alternative best the other alternatives. The higher the positive outranking value of a particular alternative is, the better the alternative.

The negative outranking flows is an expression of how a particular alternative is bested by other alternatives. The lower the negative outranking value is, the better the alternative.

5. Define the partial pre-order on the alternatives of A. In PROMETHEE I alternative u_t is preferred to alternative $u_{t'}$ $(u_t P u_{t'})$ if it satisfies the one of the following conditions:

$(u_t P u_{t'})$ i ;

$$\begin{cases} \Phi^{+}(u_t) > \Phi^{+}(u_{t'}) \; a \quad \Phi^{-}(u_t) < \Phi^{-}(u_{t'}) \\ \Phi^{+}(u_t) > \Phi^{+}(u_{t'}) \; a \quad \Phi^{-}(u_t) = \Phi^{-}(u_{t'}) \\ \Phi^{+}(u_t) = \Phi^{+}(u_{t'}) \; a \quad \Phi^{-}(u_t) < \Phi^{-}(u_t, u_{t'}) \end{cases}$$

If there are two alternatives(u_t and $u_{t'}$), withsimilar or equal leaving and entering flows, u_t is indifferent to $u_{t'}$ ($u_t I u_{t'}$):

$$(a_t I a_{t'}) \text{ if: } \Phi^{+}(a_t) = \Phi^{+}(a_{t'}) \; a \quad \Phi^{-}(a_t) = \Phi^{-}(a_{t'}).$$

$a_t$is incomparable to $a_{t'}$ $(a_t R a_{t'}$) if;

$$\begin{cases} \Phi^{+}(u_t) > \Phi^{+}(u_{t'}) \; a \quad \Phi^{-}(u_t) > \Phi^{-}(u_{t'}) \\ \Phi^{+}(u_t) < \Phi^{+}(u_{t'}) \; a \quad \Phi^{-}(u_t) < \Phi^{-}(u_{t'}) \end{cases}$$

6. Determine the net outranking flow for each alternative

$$\Phi^{n} \; (u_t) = \Phi^{+}(u_t) - \Phi^{-}(u_t)$$

Using PROMETHEE II, the complete preorder can be obtained by the net flow and defined by:

$u_t$is preferred to $u_{t'}$ ($u_t P u_{t'}$) if Φ^{ne} (u_t) > Φ^{n} ($u_{t'}$)

a is indifferent to $u_{t'}$ ($u_t I u_{t'}$) if Φ^{n} (u_t) = Φ^{n} ($u_{t'}$).

In other words, the better alternative is the one having the higher Φ^{n} (u_t) value.

4.4. Application of PROMETHEE to the Project

To determine the weight of each criterion, Yager index was used to defuzzify the triangular fuzzy numbers. The use of Yager index was preferred over other methods because it puts into consideration all the points and is not hugely affected by extreme values or weights.

Table 4.2 shows the importance of the parameters on a linguistic scale, using a triangular fuzzy scale.The weights of these parameters are based on an expert opinion, arrived upon from experiencesof endocrinologist and other health-care providers with patient suffering from diabetes. This factors also ensures the factors that contribute the most in ensuring the patients get the maximum results from a treatment alternative. These weights can also be altered depending on the decision maker, condition of the patient and most importantly discretion of an expert.

Table 4.2: Linguistic scale of importance

Linguistic scale for evaluation	Triangular fuzzy scale	Importance ratings of criteria
Very high (VH)	(0.75, 1, 1)	Cost of device, accuracy
Important (H)	(0.50, 0.75, 1)	Turnaround time
Medium (M)	(0.25, 0.50, 0.75)	Samplevolume needed
Low (L)	(0, 0.25, 0.50)	Ease of use, maintenance
Very low (VL)	(0, 0, 0.25)	

After all the parameters needed for the management of diabetes were collected, Gaussian preference function was applied for each criterion using visual PROMETHEE decision lab program. Table 4.3 shows the parameters and weights of the criteria including the values of the parameters as used for the analysis. Gaussian preference function has been preferred over the other preference functions due to the fact that it does not take into account and is not affected by minute and inconsequential deviations in the input values of the parameters (Parreiras & Vasconcelos, 2007).

Table 4.3: Visual PROMETHEE Application for the management of Diabetes Mellitus.

Criteria	**Cost of Device**	**Accuracy**	**Turnaround time**	**Maintenance**	**Ease of use**	**Sample volume**
Unit	*$*	*Impact*	*Sec*	*Impact*	*Impact*	*uL*
(min/max)	*Min*	*Max*	*min*	*min*	*min*	*min*
Weight	*0.92*	*0.92*	*0.75*	*0.25*	*0.25*	*0.50*
Preference Fn.	*Gaussian*	*Gaussian*	*Gaussian*	*Gaussian*	*Gaussian*	*Gaussian*
Selectra pro S	35452.00	Very high	60	Moderate	Low	Moderate
Microlab	20,000	High	60	Moderate	Moderate	Moderate
Eon one	3323.64	High	30	Moderate	Moderate	Moderate
Accu-chek aviva	92.50	Moderate	5.0	Low	Very low	Low
True Track	36.70	Moderate	10.0	Low	Very low	Low
Omnitest 3	32.27	Moderate	3.0	Low	Very low	Low

Selectra Pro S: https://www.elitechgroup.com/product/selectra-pro-s
Microlab: https://www.elitechgroup.com/italy/product/microlab-300
Eon one: http://pdf.medicalexpo.com/pdf/vital-diagnostics/eon-one-chemistry-analyser/70474-71818.html
Accu-chek: https://www.accu-chek.com/
True Track: https://www.amazon.com/McKesson-TRUEtrack-Blood-Glucose-Meter/dp/B00JLNGQ64
Omnitest 3: https://www.news-medical.net/Omnitest-3-Blood-Glucose-Monitor-from-BBraun

CHAPTER 5

RESULTS

The results of the analysis show that with minimum cost of device, lowest turnaround time, ease of use, sample volume and maintenance, the glucometer Omnitest 3 is the most favourable and most preferred device used in the management of diabetes mellitus. However, the result may differ if a different weight is chosen by the endocrinologist, patient, relatives and other decision makers.

Table 5.1 shows a complete ranking of the devices used in the management of diabetes mellitus, showing the positive, negative and net outranking flow values.

Table 5.1: Complete Ranking of devices used in the management of Diabetes Mellitus.

Complete Ranking	Alternative	Positive outranking flow	Negative outranking flow	Net Flow
1	Omnitest 3	0.4248	0.0158	0.4091
2	True Track	0.3434	0.1202	0.2233
3	Accu-chek aviva	0.3235	0.1266	0.1970
4	Eon one	0.1944	0.2977	-0.1033
5	Microlab	0.0596	0.3908	-0.3312
6	Selectra pro S	0.0377	0.4324	-0.3947

Figure 5.1 shows the ranking of each device on a net flow-ranking pole of -1 to +1, with Omnitest 3 as the most favourable device lying at a net flow point value of 0.4091 and Selectra pro S lying at net flow point value of -0.3947 as the least favourable devices based on its ease of use, maintenance, sample volume, turnaround time and cost of device.

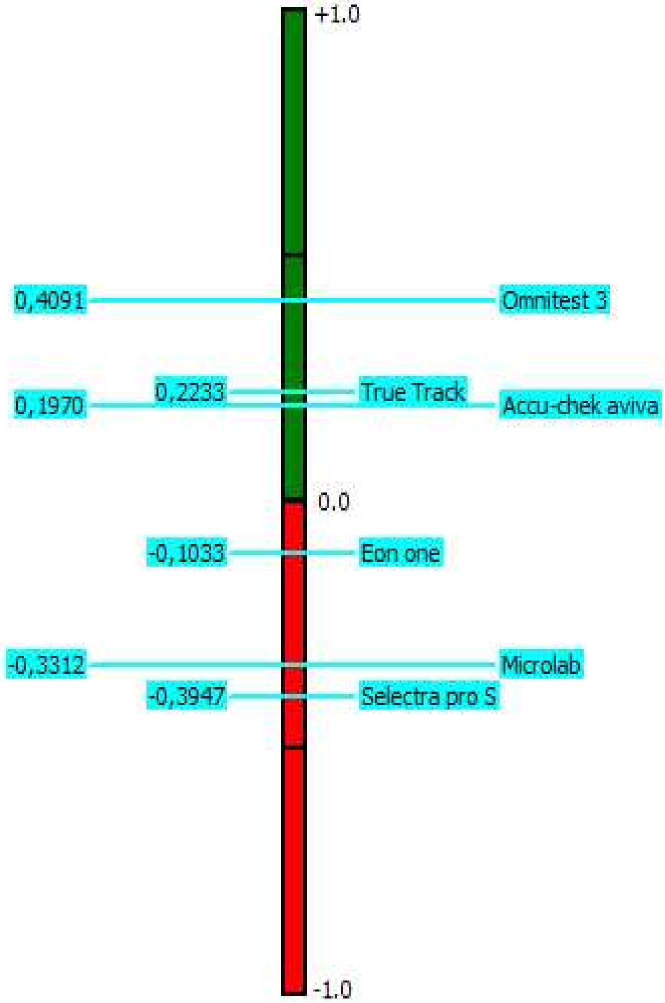


Figure 5.1: Flow-ranking Pole of devices used in the management of Diabetes Mellitus.

Figure 5.2 shows an action profile of the strong points and weak points for Omnitest 3, having a high positive ranking in cost of devices and turnaround time but showing a low ranking in accuracy, maintenance, ease of use and sample volume.

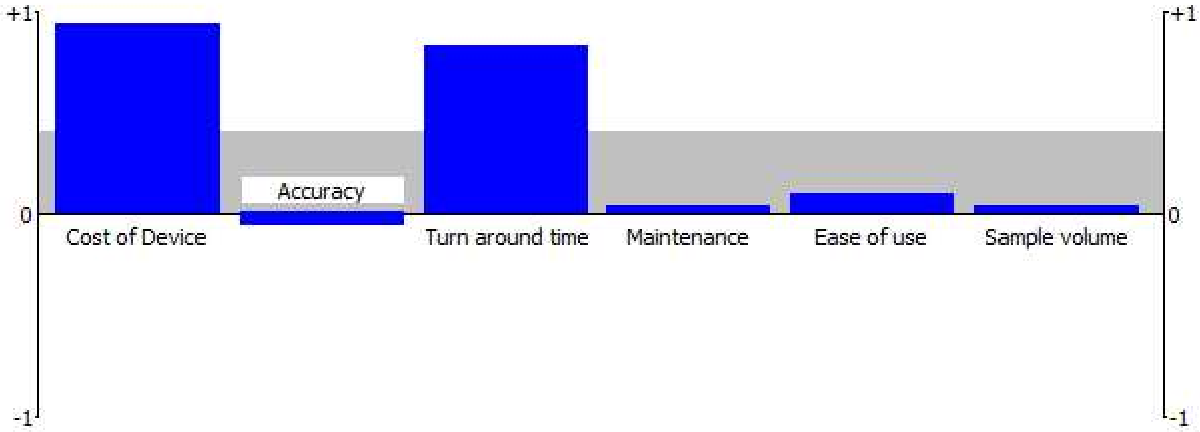


Figure 5.2: Action Profile for Omnitest 3

Figure 5.3 shows very strong point for cost of device in relation to True track glucometer in the management of diabetes mellitus, but a negative ranking as regards the accuracy of the device, with maintenance and sample volume at a very low point.

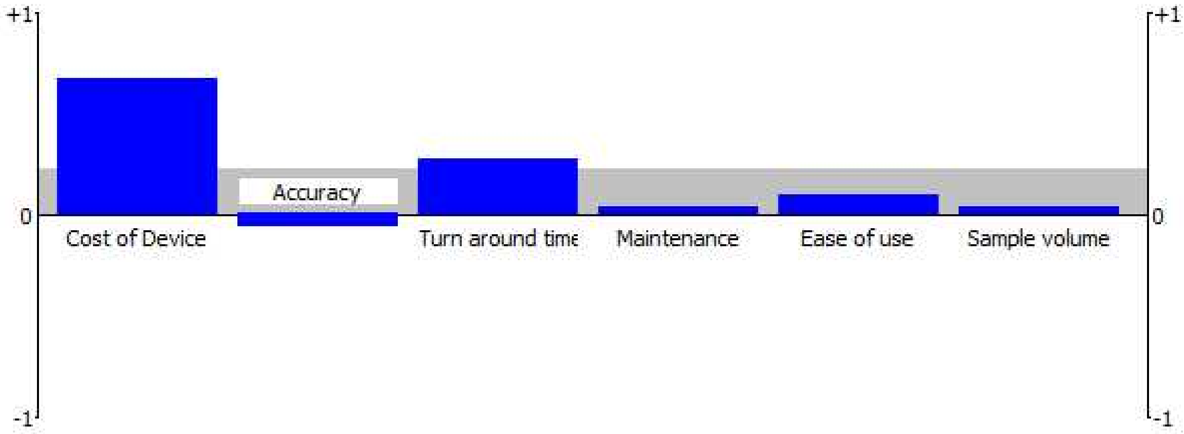


Figure 5.3: Action Profile for True track

Figure 5.4 shows the action profile for Accu-chek glucometer shows very low ranking of maintenance and sample volume with a low ranking of ease of use, but negative ranking of accuracy.

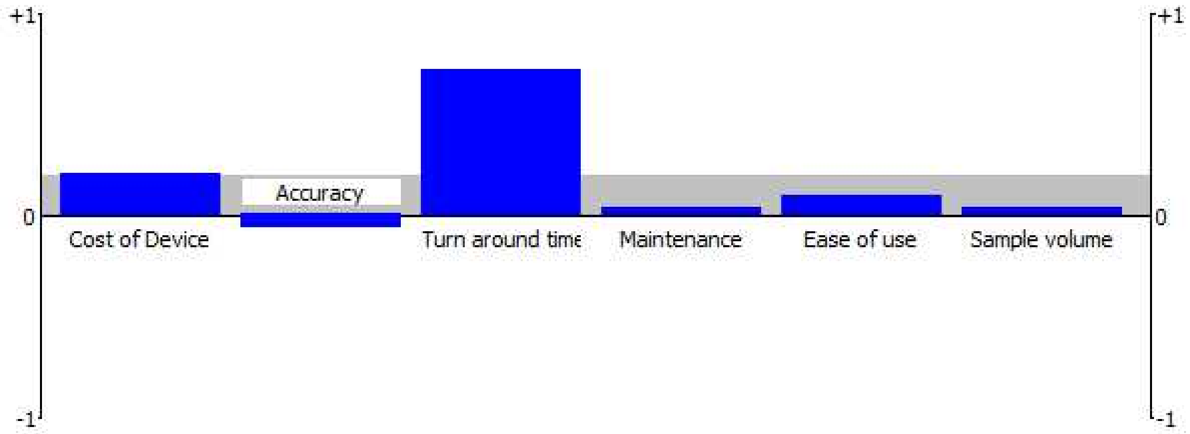


Figure 5.4: Action Profile for Accu-chek

Figure 5.5 shows the action profile of Eon one glucometer indicates high negative ranking of cost of device, turnaround time. The ease of use is also on a negative rank, albeit less than that of the cost of device and turnaround time. Only accuracy is ranked positively and not even very highly. The very low ranking and negative ranking of -0.1033 obviously accounts for the negative net-flow ranking of eon one device in the management of diabetes mellitus.

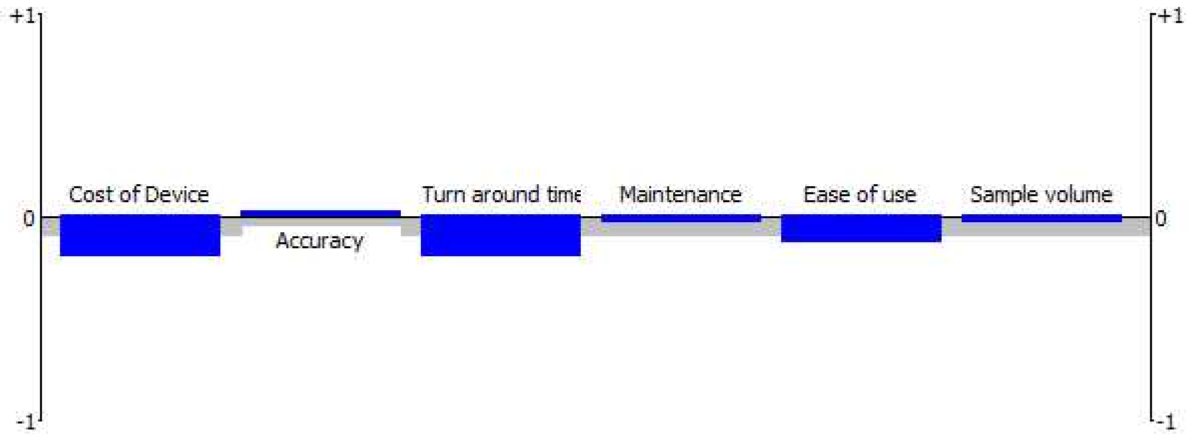


Figure 5.5: Action Profile for Eon one

Figure 5.6 is the net-flow for Microlab device as regards management of diabetes mellitus. The net flow of -0.3312 is backed by the fact that the cost of device and turnaround time have very low positive ranking, the ease of use, sample volume and maintenance is also low on the negative rank.

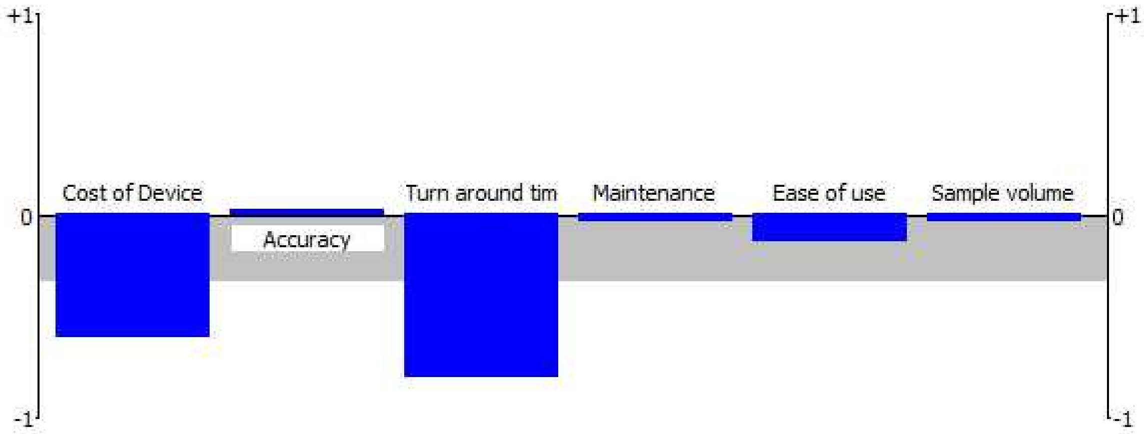


Figure 5.6: Action Profile for Microlab

Figure 5.7 is an action profile for Selectra Pro S device. It shows a very low positive ranking of cost of device and turnaround time, a low positive ranking on ease of use and a relatively high positive ranking on accuracy.

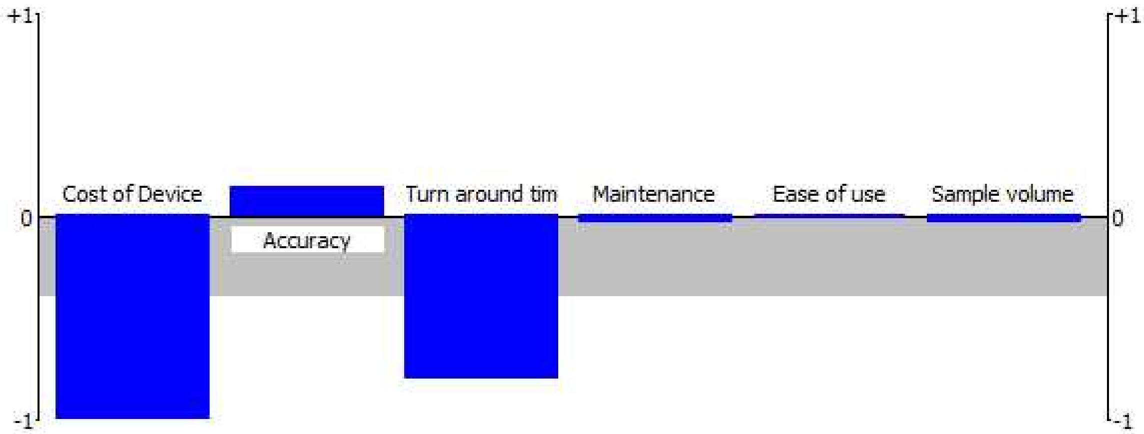


Figure 5.7: Action Profile for Selectra Pro S

Figure 5.8 shows a comprehensive rainbow ranking of the devices used in the management of diabetes and the criteria that either make a device favourableor unfavourable.

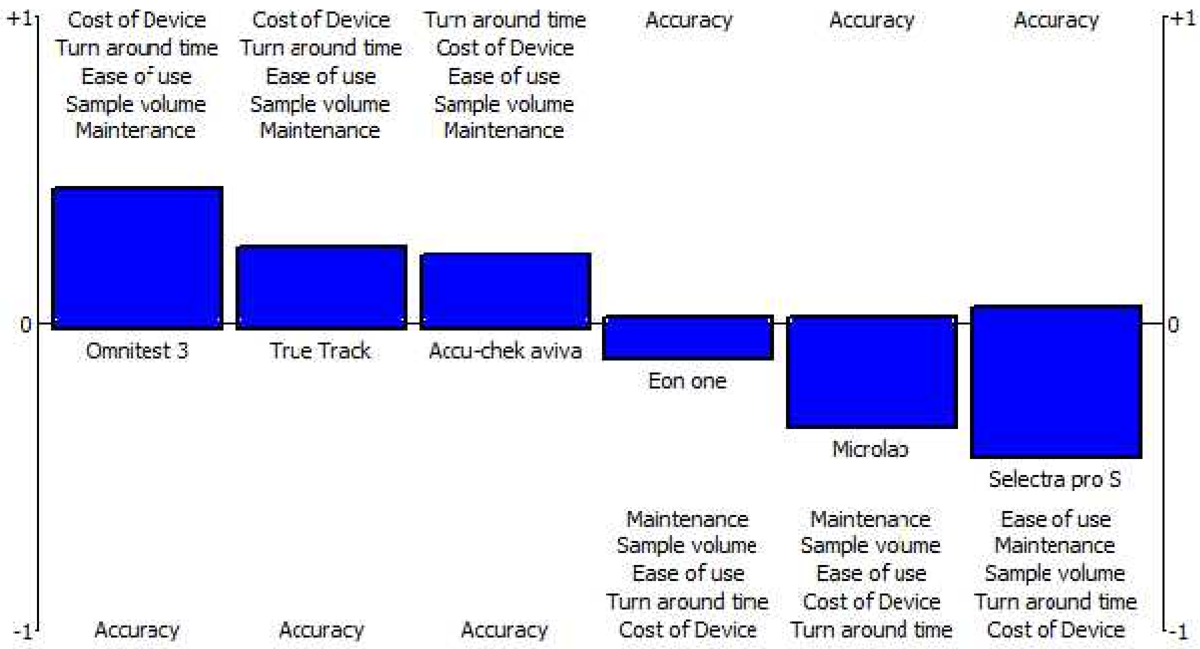


Figure 5.8: Rainbow Ranking of the devices used in the management of Diabetes Mellitus

Figure 5.9 is a network ranking view of the alternatives with the negative and positive outranking values. This network view can be used to clearly outline how the devises are ranked and the order in which they can be used, from the most favourable, to the least favourable.

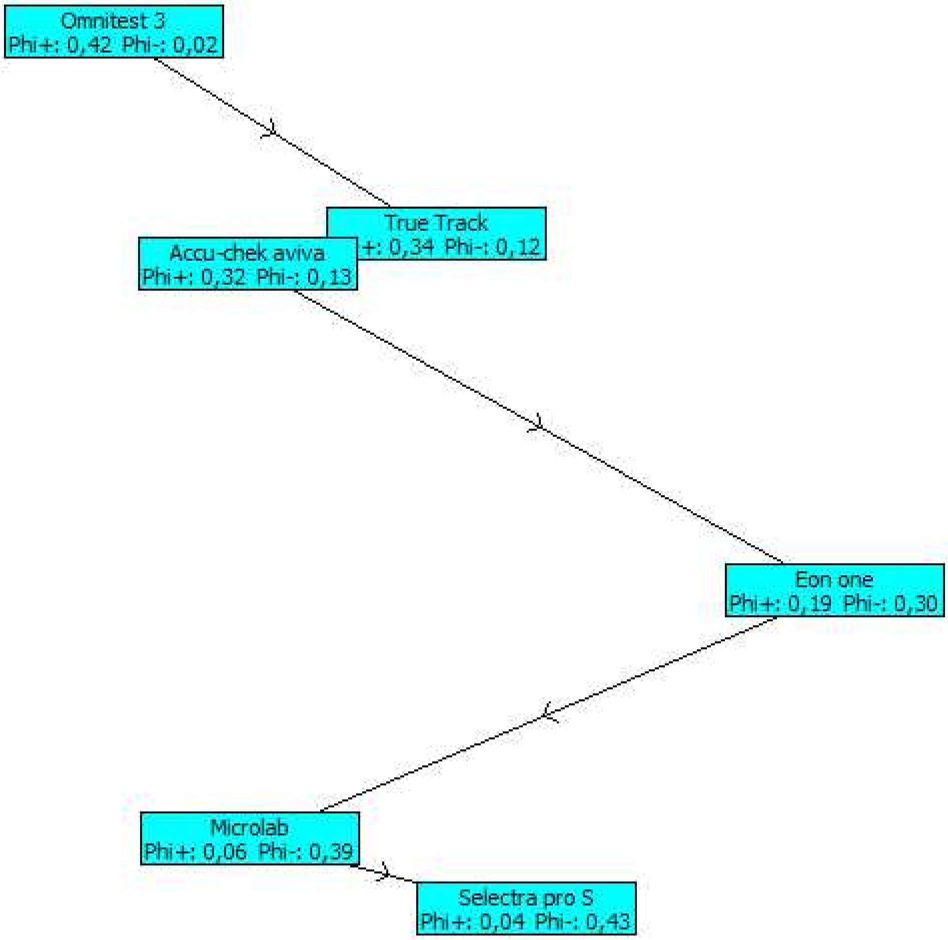


Figure 5.9: Network Ranking View of the devices in the management of Diabetes Mellitus.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1.Discussion

The analysis of these results show that the glucometer Omnitest 3 clearly outclasses other devices selected for the management of diabetes mellitus with a net-flow ranking of 0.4091. This is due largely to the fact that Omnitest 3 glucometer feature relatively low cost, turnaround time and sample volume compared to the other two glucometers and automated chemistry analysers. The two other glucometers; True track and Accu-chek comes second and third in the ranking with a net-flow ranking of 0.2233 and 0.1970 respectively. The negative net-flow ranking of Eon one, Microlab and Selectra Pro S with -0.1033, -0.3312 and -0.3947 indicate that automated chemistry analyser even though has a relatively higher accuracy than glucometer, its higher turnaround time, cost, maintenance, sample volume and low ease of use makes it less favourable. However, the ranking could differ depending on the decision-maker.

Fuzzy PROMETHEE is an effective method to employ in decision-making situations. It gives the user complete control over the parameters and their importance, fuzzy PROMETHEE weighs these parameters against each other to determine the combination of parameters that make an option better than other available options.

Changing the weights of any of the criteria in the analysis will likely result in different ranking of the treatment techniques, the weights used in this analysis is a generalized weight based on expert opinion of most likely and commonly seen scenarios. However, the weights can be changed based on the desires and health condition of the patient or the discretion of the endocrinologist in order to arrive at a different ranking that will best suit the patient.

6.2.Conclusions

It is of utmost importance that the preferential ranking methods are solely to be used in assisting a specialist or decision maker in coming up with a decision and is not to be relied upon solely. As it can be seen from this project, the three glucometer devices selected are ranked higher than three chemistry analysers even though the chemistry analysers are usually the recommended devices relied upon in the hospital laboratory for the management of Diabetes Mellitus.

It is widely known and accepted that the accuracy of chemistry analysers surpasses that of glucometers, however, glucometers are easy to use, relatively cheap, has very low turnaround time and utilizes very low sample volume. Also, complications resulting from diabetes can be fatal and cause death, hence, patients are required to constantly check their blood sugar level and how best can that be done other than using a handy, easy to use, relatively accurate device (glucometer). As it can be seen from the result of this research, Omnitest 3 is ranked as the most preferred device for the management of diabetes mellitus.

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