Mobile Diabetes Management System for Saudi Arabia Embedding Social Networking and Cognitive Behavioral Therapy Modules

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Abstract

We present in this thesis the design and development of a new mobile diabetes management system for social behavioural change and management tailored for Saudi diabetic patients (SANAD – Saudi Arabia Networking for Aiding Diabetes). The key goals of SANAD are to close the diabetes management loop by providing remote monitoring for diabetic patients, a further therapeutic channel to the patient, an opportunity to increase diabetic patients' health awareness, and feedback to help diabetic patients maintain a regular blood glucose level. The key system components consist of: (i) a smart mobile diabetes management module (MDM-M) used for collecting blood glucose data; (ii) a social networking module (SN-M), acting as an enhancement module for the MDM-M, the key function of which is currently focused on education purposes; and, (iii) a cognitive behavioral therapy module (CBT-M), acting as a supplementary module to MDM-M. This module was designed on the smart mobile platform and used only by patients who require CBT therapeutic intervention.

A usability study for the SANAD system is also presented in this thesis to validate the acceptability of using mobile technologies amongst diabetic patient in KSA and Gulf region. The preliminary results of the study indicated general acceptance of the patients in using the system with higher usability rating in type 2 diabetic patients. In general, the study concluded that the concept of SANAD system is considered acceptable tool in particularly with Type 2 diabetes patients.

A clinical evaluation study of SANAD system is also conducted in this thesis to evaluate the clinical effectiveness of the system. The primary aim of this study was to evaluate the effect of SANAD system on: 1) improve glycaemic control; 2) improve health awareness; and 3) enhance self-efficacy. Secondary aims qualitatively evaluated the content of communication in SANAD system. The key preliminary results of this study provided an evidence that SANAD has a positive impact on promoting knowledge of diabetes in individuals living with type 2 diabetes, and reflects the generally positive outcomes of reducing glycated hemoglobin control (HbA1c (%)), and increasing self-efficacy.

Glossary

a) [DSM]: Diabetes Self-Management

b) [EPR]: Electronic Patient Records

c) [NIDDM] : Non-Insulin Dependent Diabetes Mellitus

d) [IDDM]: Insulin Dependent Diabetes Mellitus

e) [IDF] : International Diabetes Federation

f) [IEEE] : Institute of Electrical and Electronics Engineers

g) [NHS] : National Health Service

h) [NICE] : National Institute for Health and Clinical Excellence

i) [UI] : User Interface

j) [WHO] : World Health Organization

k) [KSA]: Kingdom of Saudi Arabia

l) [MSN]: Mobile Social Network

m) [NCDs]: Non-Communicable Diseases

n) [ADA]: American Diabetes Association

o) [BG]: Blood Glucose

p) [BP]: Blood Pressure

q) [SMS]: Short Message Service

r) [MMS]: Multimedia Messaging Service

s) [BMI]: Body Mass Index.

t) [SNSs]: Social Network Sites

u) [LBS]: Location Based Services

v) [SPSS]: Statistical Package for the Social Sciences

w) [KFUH]: King Fahd University Hospital

x) [UD]: University of Dammam

y) [MINT]: Medical Information and Network Technology

z) [IT]: Information Technology

aa) [SANAD]: Saudi Arabian Network for Aiding Diabetes

bb) [RCT]: Randomise Control Trial

cc) [ICT] Information and Communications Technology

dd) [UKPDS] United Kingdom Prospective Diabetes Study

ee) [PAD] Peripheral Arterial Disease

ff) [IGT] Impaired Glucose Tolerance

gg) [IFG] Impaired Fasting Glucose

hh) [OGTT] Oral Glucose Tolerance Test

ii) [HbA1c] Glycated Haemoglobin or Glycaemic Control

jj) [SMBG] Self-Monitoring Of Blood Glucose

kk) [DSMA] Diabetes Self-Management Activities

ll) [SN] Social Networking

mm) [AAFP] American Academy of Family Physicians

nn) [HBM] Health Belief Model

oo) [PMT] The Protection Motivation Theory

pp) [TRA] Theory of Reasoned Action

qq) [TPB] Theory of Planned Behaviour

rr) [IMSM] Information Motivation Strategy Model

ss) [SCT] Social Cognitive Theory

tt) [CBT] Cognitive Behavioural Therapy

uu) [CCBT] Computerized Cognitive Behavioural Therapy

vv) [CBGT]Cognitive Behavioural Group Training

ww) [BGAT] Blood Glucose Awareness Training

xx) [MET] Motivational Enhancement Therapy

yy) [MDM-M] Mobile Diabetes Management Module

zz) [SN-M] Social Networking Module

aaa) [CBT-M] Cognitive Behavioural Therapy Module

bbb) [UML] Unified Modelling Language

ccc) [PHP] Hypertext Preprocessor

ddd) [MS-SQL] Microsoft Structured Query Language

eee) [SDK] Software Development Kit

fff) [3G] Third Generation

ggg) [4G] Fourth Generation

hhh) [HCI] Human Computer Interaction

iii) [QUIS] Questionnaire for User Interaction Satisfaction

jjj) [DKT] Diabetes Knowledge Test

kkk) [DMSES] Diabetes Management Self-efficacy Scale

lll) [IM] Intervention Mapping

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Chapter 1 Introduction

The global prevalence of diabetes is alarming. In particularly, it is estimated that about 382 million people would be affected by diabetes mellitus with a projection of 592 million by the year 2035 [1]. This prevalence in the developing countries is more acute in particularly in the gulf countries. Among the countries in the Gulf region, Saudi Arabia has one of the highest number of diabetic population. Table 1.1 shows the top 10 countries for highest prevalence of diabetes where three of these are in Gulf region.

Table 1-1 Top 10 Countries for Highest Prevalence of Diabetes [1]

Country Name	Prevalence (%)
Tokelau	37.5
Federated States of Micronesia	35.0
Marshall Islands	34.9
Kiribat	28.8
Cook Islands	25.7
Vanuatu	24.0
Saudi Arabia	24.0
Nauru	23.3
Kuwait	23.1
Qatar	22.9

Many complications can be arise if the diabetes is not properly controlled, of which the major complications include micro (damage of small blood vessels) and macro-vascular diseases (damage of large blood vessels), which in turn can lead to other serious diseases like peripheral vascular diseases, stroke, and ischemic heart disease; and can affect other organs like eyes, nerves, kidneys etc. [2]. These major risk factors can be related to behavioural aspects or risks like poor diet or nutrition, lack of physical exercise, inactive lifestyles etc.[3]; and these factors are correlated and can be seen in people with diabetes, as they can rarely cause the condition independently[4]. Therefore people with type 2 diabetes are prone to different risks, as a result, they require wide range of treatments for different comorbid conditions (dyslipidaemia, hypertension etc.) identified by the abnormal levels of lipids and lipoproteins [5]. This issue is made chronic in Middle Eastern countries and kingdom of Saudi Arabia due to conservative culture and social habits and norms

One of the main objectives of diabetes self-management is to achieve the normal or near blood glucose levels, which can help in reducing the complications arising from micro-vascular diseases [6]. The achievement of this objective can lead reducing the risk of complication and improving the quality of life of the diabetes patients.

An effective diabetes management system can achieve potential long-term outcomes, and health status, as it can be identified in different studies[7]. However, one of the major reasons identified for sustainable self-management include the poor implementation of patient care guidelines as prescribed by the healthcare providers[8]. Different barriers to the guidelines and implementation are found, which include the patient's understanding or perception about the seriousness of the disease and the need for treatment, inappropriate guidelines, and resistance from the patients to change their lifestyles [9][10][11].

Diabetes self-management is an approach, where the patients' skills, knowledge, and confidence are improved by specific educational tools in order to manage their condition on their own on a daily basis [12]. In this approach, the patients' identifies their conditions and tries to solve or manage them by developing the required skills and knowledge[13]. In general, the diabetes self-management programmes focus on improving the patients' communication, logical, analytical, decision making, and problem solving skills which ensures an effective approach of delivering preventive services [12].

These self-care therapy for diabetic is a complex process, as patients need to undergo difficult lifestyle changes, which would include maintaining reasonable body weight, appropriate intake of food, physical exercise, practicing self-glucose monitoring, following prescribed medication, and other similar preventive measures[14].

Studies have shown that minimum levels of diabetes knowledge are essential for the patients to effectively participate in the diabetes self-management program, in order to improve their condition [15] [16][17]. It is not an easy task to learn all the necessary skills by the patients in managing their condition [18]; therefore diabetes care skills are considered as one of the most important aspect of the diabetes self-management educational programmes. Other behavioural management features like motivation, increasing the confidence levels are also considered as an important part of these educational programmes.

In the last decade, mobile health is seen as an important enhancing approach for the diabetes self-management. M-health was originally defined in 2004 as "mobile computing, medical sensor and communication technologies for health care"[19]. Since then it become one of key pillar of ICT for health together with telemedicine, telehealth and ehealth. From the mobile diabetes management perspective, the basic architecture is shown in figure 1.1.

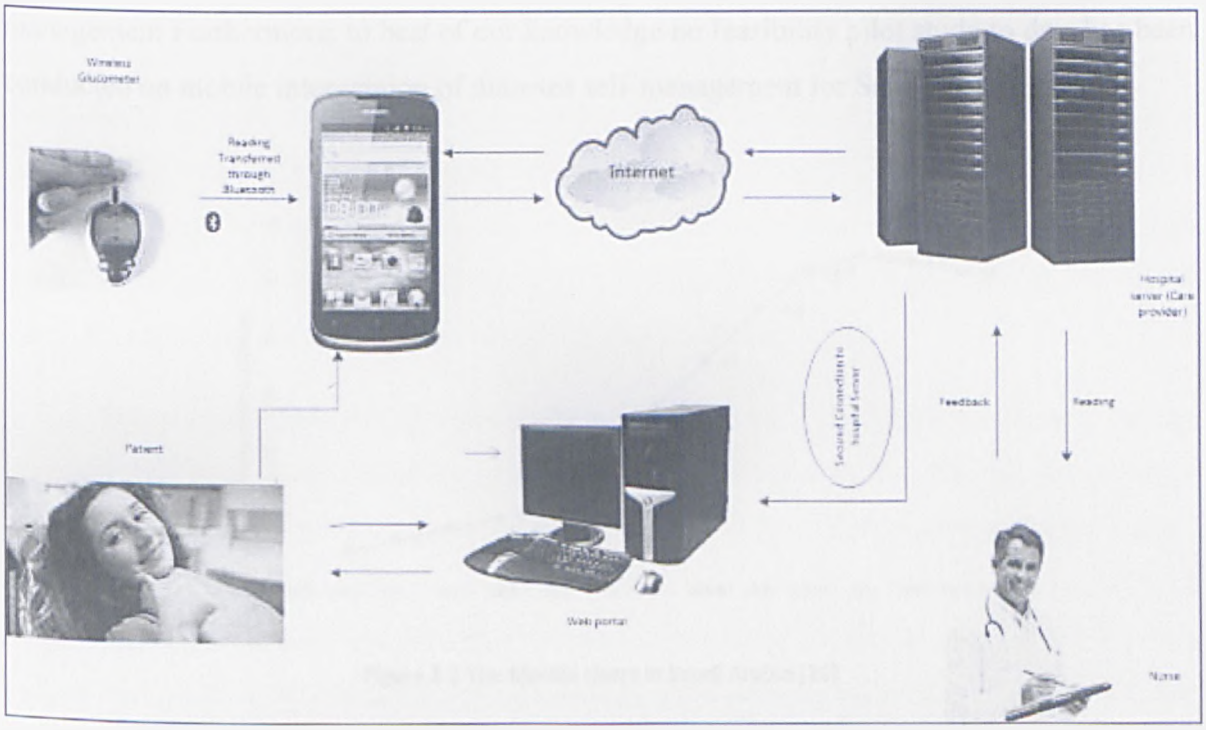

Figure 1-1 The Basic Functioning and The Use of The Mobile Diabetes Management System

As it can be seen in figure 1.1, the frontend consist of a glucometer, which the patients either wirelessly (via a Bluetooth connectivity linked to the patient's glucose monitor) transfers the reading to a smart mobile application, or the patients manually enters the reading through smart mobile application. The readings are stored in a server, from where the physicians view the readings and provide the feedback to the patients. Feedback may be received through SMS message to the patient's mobile application.

Although, major studies and pilots of mobile diabetes management were conducted globally [20]. However, few studies if any were conducted in the kingdom of Saudi Arabia, which is subject of this thesis. Saudi Arabia has one of the highest level of prevalence of diabetes globally. It also has one of the highest users of smart phones and social networks globally. The total number of mobile users in Saudi Arabia reached around 51 million at the

end of 2013, with penetration rate of 170% as shown in figure 1.2. Furthermore, the estimated number of Internet users in the Kingdom of Saudi Arabia is 16.4 million users at the end of Q3 2013, with a population penetration 55 % as shown in figure 1.3 [21]. In addition, The total number of social networking users using in Saudi Arabia reached around 7.8 million Facebook's users, 1 million LinkedIn users and more than 5 million Twitter users at the end of 2013 [22]. To date, this wide use of mobile devises and social networks in the kingdom is not effected in their wide use for healthcare application including diabetes management Furthermore, to best of our knowledge no feasibility pilot study to date has been conducted on mobile intervention of diabetes self-management for Saudi's patients.

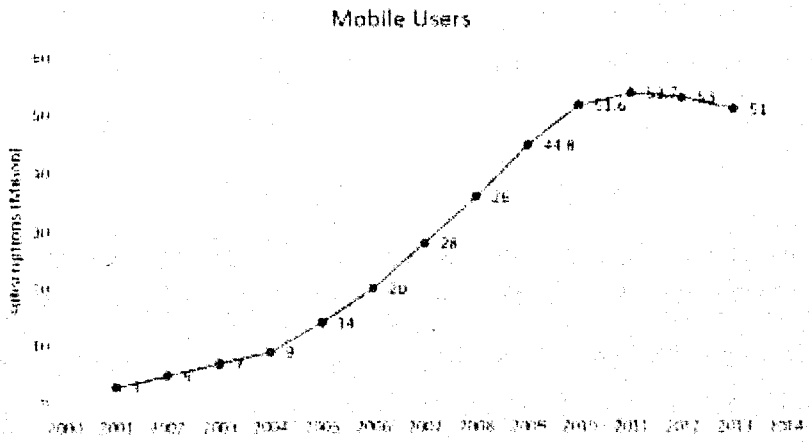

Figure 1-2 The Mobile Users in Saudi Arabia [21]

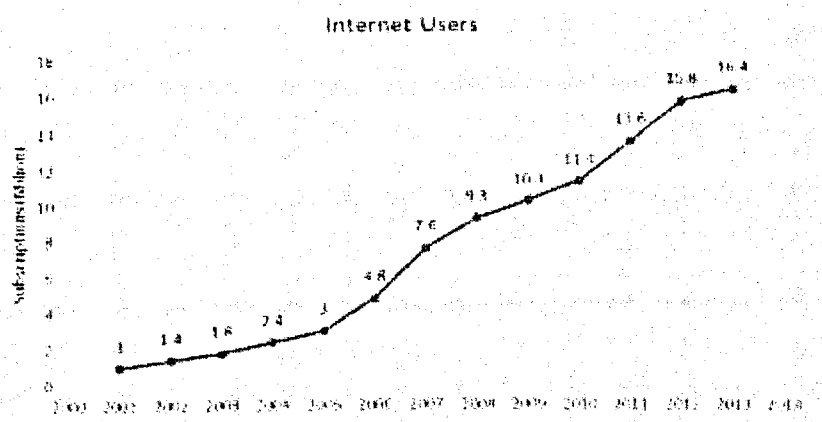

Figure 1-3 The Internet Users in The Kingdom of Saudi Arabia [21]

1.1 Motivation

In resent year, the kingdom has witnessed an increasing level of sedentary lifestyles and western food styles. These nutritional and wellbeing habits contributed significantly to

the increase in diabetes amongst the KSA population. Saudi Arabia population comprises of highest number of diabetes patients in the world (about 24 %). It is estimated that there would be a rapid increase in the diabetic population in the Middle East by 2030, by analysing an increase of 163% compared to the year 2000 [23]. Furthermore, diabetes mellitus is one of the major causes of deaths in Saudi Arabia[24], and the prevalence of impaired glucose tolerance, a precursor to diabetes, was as high as 14.1%[25].

In addition, diabetes in the kingdom is associated with increased macro-vascular complication and increased cardio-vascular diseases [26]. It was also found that the diabetes is associated with the micro-vascular disease has been of higher prevalence with nephropathy (12.8%)[27], retinopathy (25.3%) [28], and neuropathy (56%) [29]. It is estimated that 3.5% of the total inpatient days in the hospitals in the kingdom are accounted to the diabetes and its related problems, covering annual costs of $ 2.2 billion in 2010, and these costs are estimated to reach at $ 4.8 billion in Saudi Arabia by the year 2030 [30].

The effectiveness of intensive treatments for type 1 and type 2 diabetes in the kingdom has been documented in many studies[31]. However, the clinical outcomes of diabetic care have been unsatisfactory with only 27% of the diabetic patients have reached the target blood glucose levels in a study conducted by Akbar [32]. In other studies, 77% of the diabetic patients have recorded for poor control of blood glucose levels [33] with an overall basis, 49% of the diabetes patients attending the primary healthcare centres are found to be with the case of poor control of blood glucose levels [34]. In addition, it was found that the large numbers of diabetes patients are developing high risk for diabetes complications due to poor control of their blood glucose levels [35]. The alarming prevalence of diabetes in Saudi Arabia has been called an epidemic by many studies [36][37][38]. It has been identified that factors like obesity, lack of exercise, and other behavioural aspects are the prominent factors for increase in the diabetes among the people of Saudi Arabia [25].

These major healthcare challenges motivated this study to design and developed a mobile diabetes management system integrating social networking and behavioural change modules tailored for Saudi patients. Most of earlier clinical studies that indicte poor clinical outcomes in KSA diabetic patients are due to lack of self-education, the behavioural issues of Saudi patients and the lack of knowledge of the seriousness of their diabetic conditions and the need of self-management and change of life style and diet behaviours. It is therefore

timely for studies on the potential of mobile diabetes systems to be applied for Saudi diabetic particularly for type 2 diabetes.

1.2 Aims and Objectives

The specific aims of this research are:

- To conduct a feasibility and user perspective study on the requirements and needs study of mobile diabetes system from the Saudi Arabian perspective.
- To design and develop an advanced mobile diabetes management system tailored for KSA patients that integrates the behavioural change, and the social networking concepts.
- To conduct a feasibility clinical study on the effectiveness of the system in Saudi Arabia.

1.3 Contribution of the Research

The major contributions of this thesis can be summarized in the following:

(1) A detailed literature systematic review to identify the current status and potential impact of using mobile diabetes management system embedding social networking in the gulf countries and particularly in the kingdom of Saudi Arabia (KSA).

(2) A detailed review to identify the most relevant behavioural change theories that integrates diabetes management and social networking.

(3) A preliminary study on the perceptions with the aim of Saudi diabetic patients and medical staff requirements and needs for mobile diabetes management in KSA.

(4) Design and development a new mobile diabetes management system embedding social network and behavioural change intervention modules tailored for Saudi diabetic patients (SANAD – Saudi Arabia Networking for Aiding Diabetes).

(5) A preliminary usability study on evaluating the SANAD system in the KSA and in analysing the aspects of user satisfaction and interaction.

(6) A preliminary clinical pilot study on the effectiveness of the SANAD in KSA type 2 diabetic patients.

1.4 Structure of the Thesis

Chapter 2: Literature Review: This chapter discusses the concepts of diabetes management in general and its challenges in Saudi Arabia. It also presents the following literature review studies relevant to this work (i) a general review of mobile diabetes management system, (ii) a detailed review of the previous and the current status of mobile diabetes management system embedding social networking in the Gulf region, (iii) a review of social networking for diabetes management and a detailed discussion to provide the gap of knowledge and why this study is timely and important.

Chapter 3: Cognitive Behavioural Therapy for Diabetes Management: This chapter discusses health behavioural models, Cognitive Behavioural Therapy, and their impact on the diabetes management.

Chapter 4: Saudi Arabia Networking for Aiding Diabetes (SANAD): This chapter presents the system overview and the framework of SANAD system. It also presents the development process of the system including a preliminary study, the study setting; methods used and the results of the study in designing the system. Moreover, the design and implementation process along with the different technology solutions used are explained.

Chapter 5: Usability Study of SANAD System: This chapter presents the usability study results of SANAD system among Saudi Type 2 diabetes patients. It also presents an overview of the importance of usability factors with mobile health particularity in SANAD system, addresses the methodology used in this study, and the preliminary results of this study and discussion. It also concludes this study.

Chapter 6: Clinical Study on the Effectiveness of SANAD System: This chapter presents both the clinical study of SANAD system among Saudi Type 2 diabetes patients and qualitative evaluation of the content of communication in SANAD social networking module. It also addresses the methodology used in this study and presents the preliminary results of this study and discussion. It also concludes this evaluation study.

Chapter 7: Conclusions and Future Work: This chapter summarises the contributions of this thesis. In addition, the possible future research directions in this area is also discussed.

Chapter 2 : A Literature Review

2.1 Introduction

This chapter presents a detailed literature review of the research topic related to this thesis. These include:

1) A general introduction on diabetes and its prevalence in Saudi Arabia.
2) An extensive literature review of a mobile diabetes management system.
3) A review of social networking in healthcare in general and diabetes specifically.
4) A literature review of the previous and the current status of mobile diabetes management system and social networking for healthcare particularly in the Gulf region.
5) Discussion and conclusion of these literature review studies.

2.2 Diabetes Mellitus

Diabetes is considered to be one of the serious public health concerns and a major chronic disease across the globe, and mainly in developing and developed nations. According to the World Health Organization diabetes is a metabolic disorder of multiple aetiology characterized by chronic hyperglycaemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action, or both. There are serious effects of diabetes which include long term damage or dysfunction or failure of various organs [24]. Diabetes is a chronic disease which may occur due to two major reasons: when the insulin produced by the pancreas is not used effectively; and when the pancreas could not produce enough insulin. The problem of high blood sugar levels, which otherwise called as Hyperglycaemia is the result of uncontrolled diabetes which can cause serious damage to various organs of the body, especially blood vessels and nerves in the long run. Increased urination, weight loss, fatigue, and increased hunger and thirst are the major symptoms of diabetes [24].

The World Health Organization classified diabetes into three major type [24]. The first type is known as type 1 diabetes or Insulin dependent diabetes, which is mainly observed

in children and young adults. It was also known as juvenile diabetes. In this type, the pancreas does not produce insulin (the hormone required to convert the carbohydrates, fats and sugar in to energy) [39]. It is caused when the immune system of the body destroys the beta cells in pancreas that produce insulin, and therefore it is recognized as an auto-immune disease[40]. Type 1 diabetes accounts 10-15% of all the people diagnosed with diabetes, and can appear at any age, mostly under 40 [1]. It can be triggered by different factors such as diet, viruses, and chemicals in genetically predisposed people. Type 1 diabetes can be effectively managed by a prescribed diet and an effective exercise plan .

The second type is known as Type 2 diabetes or non-insulin dependent diabetes. It accounts 85-90% of all the people diagnosed with diabetes. This type of diabetes is mainly caused as a result of insufficient insulin production by the pancreas to maintain appropriate blood glucose levels or when the body becomes resistant to the effects of insulin. The major concern with this type is that the symptoms may not appear instantly and may take long time. But, by the time symptoms are observed, serious problems might be already developed in the body. Therefore it is also known as late-onset diabetes. Changes in the diet, proper exercise plan and medication can help in effective management of type 2 diabetes, although insulin might be required at later stages[24].

The third type is known as Gestational diabetes, which is usually developed during the pregnancy due to high blood sugar or glucose levels during pregnancy, although the pregnant women may not be diagnosed with diabetes before. The major concern with this type is that almost 70% of the pregnant women diagnosed with gestational diabetes may develop type 2 diabetes at later stage. This type of diabetes accounts 4% of all pregnant women [41]. Figure 2.1 shows a brief description of these three types.

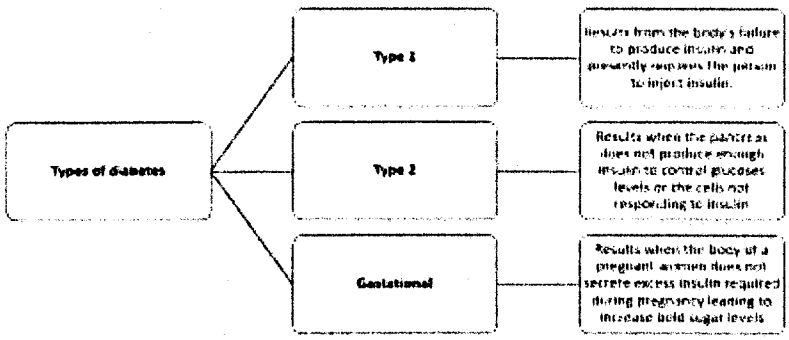

Figure 2-1 Types of Diabetes [24]

2.2.1 Complications of Diabetes

Many complications can be arise if the diabetes is not properly controlled, of which the major complications include micro (damage of small blood vessels) and macro-vascular diseases (damage of large blood vessels), which in turn can lead to other serious diseases like peripheral vascular diseases, stroke, and ischemic heart disease; and can affect other organs like eyes (retinopathy), nerves (neuropathy), kidneys (nephropathy) etc.[42]. Considering longer survival time for diabetes patients with increased prevalence, diabetic nephropathy is considered to be the single leading cause of end-stage renal disease [43]. According to UK Prospective Diabetes Study (UKPDS), after diagnosing the patients with type 2 diabetes, the 10 years prevalence of microalbuminuria (an indicator which precedes renal failure) was 25% [44].

In England and Wales, the medical conditions like blindness and partial sight are caused mainly due to diabetes retinopathy , and about 10,000 new cases of diabetic retinopathy are found every year in the United States [45]. In addition, about 90-100% of people with type 1 diabetes and about 60% of people with type 2 diabetes will show some degree of diabetic retinopathy within 20 years of diabetes onset. About 21% of the people with type 2 diabetes are found with diabetic retinopathy at the time of diagnosis

[45].Microvascular complications like foot ulcers are the result of diabetic neuropathy which cause about 80% of amputations [46].

Diseases related to heart, Peripheral Arterial Disease (PAD), and Stroke are the few examples of macro-vascular diabetic complications . Diseases related to heart can be caused by the increase in the levels of cholesterol, which may build plaques in arteries that might cause cardiovascular complications. About 70% of deaths of diabetic patients are due to cardiovascular complications [42]. Diabetes is considered to be a risk factor and a major concern for cardiovascular diseases. The adult persons with diabetes (24.5%) are more likely to get coronary heart diseases than the adult persons without diabetes (6.6%) [47].

2.2.2 Risk Factors for Diabetes

Though the exact cause of type 2 diabetes is not completely clear, there is a strong hereditary component associated with the risk of developing diabetes. There is a chance of 10%-15 % of developing the type 2 diabetes for an individual if the parent or sibling of that individual is already diagnosed with type 2 diabetes . The studies on the impact of hereditary component have found that there is a 6.4% prevalence of diabetes for an individual, if the father is diabetic, 10% if the mother is diabetic, and 14.94% if both are diabetic. These results show there is a strong influence of family history associated with the occurrence of diabetes [48].

In addition, the lifestyles of the people, environmental and medical factors can also have an impact in the occurrence of diabetes. Inactive lifestyles, improper or poor diet of an individual with genetic tendency can trigger the chances of having type 2 diabetes. The sedentary lifestyles, irregular diet, high fat consumption, and subsequent obesity are some contributing factors for the increase in the prevalence of type 2 diabetes . Among these, obesity is found to be the highly correlating factor, as it is found that about 80% of the type 2 diabetic patients are clinically obese. There are few medical factors which are considered to be the risk factors for developing diabetes or pre-diabetes conditions, and these conditions include impaired glucose tolerance (IGT), impaired fasting glucose (IFG), and insulin resistance. These conditions are metabolic stages which can be considered as intermediate stages between normal carbohydrate metabolism and diabetes [49][50]. Figure 2.2 shows the major causes of diabetes that can be seen attributed to several complication factors.

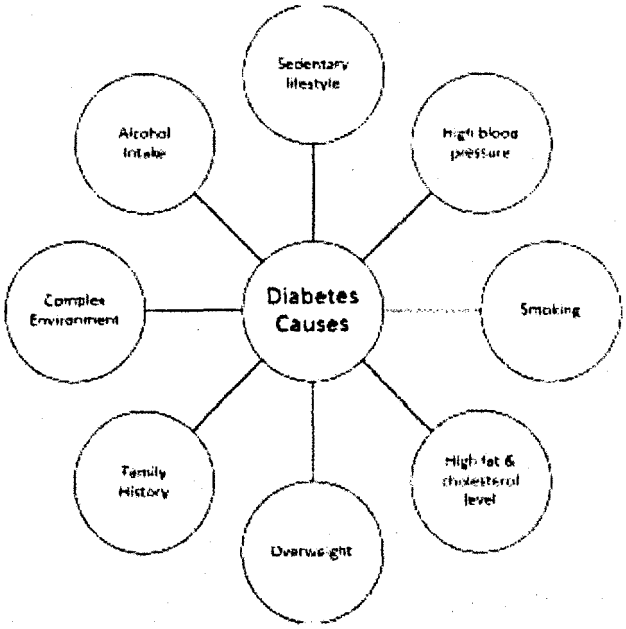

Figure 2-2 Major Causes of Diabetes [24]

2.2.3 Diagnosis of Diabetes

Fasting blood glucose test is considered to be the conventional method of diagnosing diabetes. However, World Health Organization has revised the criteria for diagnosing the diabetes in the late 1990's. Oral glucose tolerance test (OGTT) was additionally recommended in the diagnosis process in order to avoid the chances of missing some diabetic cases by undertaking only Fasting plasma glucose test [24]. According to World Health organization's and shown in Table 2.1 that summarises the WHO recommendations for the diagnostic criteria for diabetes and intermediate hyperglycaemia. On the other hand, Glycated Haemoglobin (HbA1c) can be used as a diagnostic test for diabetes. An HbA1c of 6.5% is recommended as the cut point for diagnosing diabetes. A value of less than 6.5% does not exclude diabetes diagnosed using glucose tests. HbA1c reflects average plasma glucose over the previous eight to 12 weeks It can be performed at any time of the day and does not require any special preparation such as fasting [51].

Table 2-1 Summary The 2006 WHO Recommendations for The Diagnostic Criteria for Diabetes and Intermediate Hyperglycemia [24]

Diabetes	
Fasting plasma glucose 2-h plasma glucose*	≥ 7.0 mmol/l (126mg/dl) Or ≥11.1mmol/l (200mg/dl)
Impaired glucose Tolerance(IGT)	
Fasting plasma glucose 2-h plasma glucose*	< 7.0 mmol/l (126mg/dl) and ≥ 7.8 and <11.1 mmol/l (140mg/dl and 200mg/dl)
Impaired Fasting glucose (IFG)	
Fasting plasma glucose 2-h plasma glucose*	6.1 to 6.9 mmol/l (110mg/dl to 125mg/dl) and (if measured) <7.8mmol/l (140mg/dl)
***Venous plasma glucose 2-hours after ingestion of 75g oral glucose load *If 2-h plasma glucose is not measured, status is uncertain as diabetes or IGT cannot be excluded.**	

2.2.4 Prevention of Diabetes

There has been a wide focus on the prevention of type 2 diabetes in the medical research for many years. There are several studies which have explained the possibility of preventing the type 2 diabetes [52]. However, the possibility of preventing the type 2 diabetes was first explained in the trials conducted in the Finnish Diabetes Prevention Study in the by changing lifestyles[53]. Many nations have been implementing the suggestions from the study which focus on excess weight loss, physical exercise, proper diet etc., in preventing the diabetes. The follow up study of these trials have shown the 43% reduction in the risk of developing type 2 diabetes, in the intervention group when compared with the control group [53]. In addition, other studies have found that intake of whole grain food and increase in the

intake of cereal fibres can also be the additional dietary factors in preventing the diabetes [54].

2.2.5 Treatment of Diabetes

Changing the lifestyles is the additional factor which needs to be adopted for optimum management of diabetes in both type 1 and type 2 diabetic patients. However, for type 1 diabetic patients, insulin intake is the only option for diabetes management, while for the type 2 diabetic patients there are other options which can be used to lower the blood glucose levels [55]. Three different classes of medications are classified in order to reduce hyperglycaemia. These include oral anti-diabetic medications are metiglinides and sulfonylureas, biguanides and thiazolidinediones, and alph- glucosidase inhibitors. These medications are prescribed according to the condition and the needs of different patients as they act in different ways.

For stimulating the insulin secretion, Metiglinides and sulfonylureas like Gliclazide and Glipizide are used, and for increasing the insulin sensitivity and for slower absorption of insulin in the stomach and intestine biguanides and thiazolidinediones like Metformin and Glucophage are used. Alph- glucosidase inhibitors like Acarbose act in different ways by reducing the breakdown of complex carbohydrates into glucose within the stomach and intestines. However, even after using the oral medication, many type 2 diabetic patients will need insulin within 6-10 years in order to maintain appropriate glucose levels[56]. The UKPDS longitudinal study has found that intensive insulin therapy has achieved significant results in declining the progression of diabetes complications [57].

2.3 Diabetes Management

2.3.1 Diabetes Self-Management

Diabetes self-management has been considered as an effective approach in managing diabetes and preventing subsequent risks of developing other diseases, and long term complications, by adopting the healthy lifestyles, proper exercise plans, along with the help of medication and physician medical advice. This concept of self-management refers to the various activities and behavioural changes of diabetic patients in order to promote their health by effective management of the diabetes [58]. In this process, there is a need for care team, that includes nurse, physician, educator, dietician, social worker, psychologist, and the

general practitioner, that regularly interacts with the patient in managing the diabetes through different means [58]. Though there is a support from the care team, the patient is the most crucial member among all the team members, as he/she must make informed decisions about adopting different changes in the lifestyles, and how to lead a quality life along with the illness, because about 95% of the diabetes management is done by the patient alone in the whole team.

There is a need to educate the diabetes patients regarding the self-management techniques, update their knowledge and skills, so that they can effectively manage their condition. For this purpose, using such advances technology for diabetes self-management has to be developed to the patients as it helps in training the patients in adopting the recommended changes in the behaviour, lifestyles, diet, and physical exercise. In addition, the administration of medication, self-monitoring of blood glucose levels and the foot care will help in effective self-management of diabetes.

Diet control is one of the most important, safe, and natural methods of managing diabetes. According to the condition of the patients, the appropriate strategy for managing the diet has to be selected along with the medical nutrition therapy. However other strategies has to be considered in diet management like making right choices in the selection of types of food, meal planning, and controlling portions of food [59]. A dietary guideline specification can help in encouraging the responsibility in improving the blood glucose levels of the people with type 2 diabetes. However, at the same time, it is also necessary to observe that the suggested nutrition recommendations must be practical and achievable. Different studies have shown significant improvements in the effective management of diabetes and its associated complications by following the recommended diet plans[60]. Adopting a healthy diet plan would also reduce overall healthcare costs as there would be a reduction in the hospitalization, and medical consumption [61].

In addition to the diet management and medication, physical exercise is one of the most recommended activities for the type 2 diabetic patients. Usually aerobic exercises are most suitable for the patients as they are easy to follow. But there are studies which have recommended that an effective exercise plan, which includes both aerobic exercise and circuit type resistance training are necessary in order to improve glycaemic control, and to reduce cardiovascular complications[62]. In addition, it was found that circuit type resistance

training has a positive effect on the psychological function with the older people diagnosed with type 2 diabetes. As sudden engagement in physical exercise may be difficult, the engagement process has to be gradually increased so that the patients may find it easy.

Oral medication is usually prescribed when the behavioural activities like diet and exercise are not enough to control the blood glucose levels [55]. According to the study conducted by the European Society of Cardiology and European Association for the Study of Diabetes, metiglinides and sulfonylureas are the major oral medications prescribed in order to reduce hyperglycemia [55]. It is necessary to adopt prescribed medication for improving glycaemic control and to reduce diabetic complications. Many studies have found that the adherence to the medication was acceptable, but it becomes worse when the combinations of medications are prescribed [63].

More recently, SMBG (Self-monitoring of blood glucose) is also considered as an effective approach for managing diabetes [64]. This process requires a medical device called glucose meter, which identifies the blood glucose levels. Based on the readings the patients need to take appropriate actions by interpreting the results, and also by taking the advice from the medical practitioners. SMBG can be used with both type 1 and type 2 diabetic patients . However, it is necessary to educate the patients and improve their skills and knowledge regarding the disease, before they could start SMBG. Different studies have supported the concept of SMBG, as there is a significant reduction in HbA1c of the diabetic patients in intervention group practicing SMBG than the control group which did not use SMBG method [65][66].

Considering the diabetic complications and its associated risk factors, foot care is one of the important aspect to be taken in order to prevent Ischemia and Peripheral neuropathy, as these two are the major reason for foot ulcer which is a common problem found in about 15% of the diabetic patients [46]. This could in addition create other complications like gangrene by damaging the tissue parts. However, these diabetic complications can be reduced if proper prevention methods are put in to use. The studies in this aspect has found varying results, which reflects the little evidence on identifying the preventive measures, Few studies [67] have found that foot care education programmes are effective in preventing the foot ulcers, while other studies [68] have found that these education programmes are ineffective in preventing the foot ulcers. However regular care and daily monitoring guidelines are

prescribed by the National Institute for Clinical Excellence for foot care include examining in preventing the foot ulcers by identifying the symptoms early and by routine examination by healthcare professionals [69]. Figure 2.3 shows that both self-management activities linked to behavioural change approach are key to successfully diabetes self-management and avoiding complications.

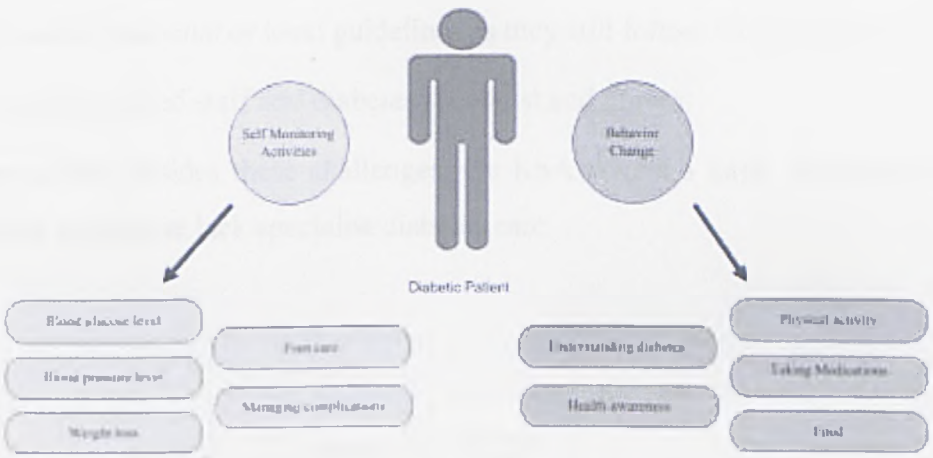

Figure 2-3 Diabetes Self-Management Activities [70]

2.3.2 Challenges of Diabetes Management in the Kingdom of Saudi Arabia

As described earlier, there is an increasing adoption of unhealthy eating habits and limited physical activities with increase prevalence of Type 2 diabetes mellitus due to social norms [71] [72]. Managing diabetes in KSA is a difficult task. Various factors are contributing to this chronic diseases prevalence, such as; family history, obesity, smoking habits and limited health awareness and education. In addition, hypertension, diabetes along with coronary artery diseases has become an extreme challenge to the countries health care system.

Figure 2.4 shows the major challenges affecting diabetes management in KSA. These are summarized as following:

1) Prevalence of obesity and other chorine diseases such as blood pressure.

2) Social norms and culture issues such as gender inequality and conservative restrictions.

3) Low awareness and poor health education and motivation

4) High prevalence of smoking.

5) Unhealthy eating as in eastern society the unhealthy and food with high levels of carbohydrates and poor nutrition that contribute to diabetes onset.

6) No specific national or local guidelines as they still follow NICE guidelines[73].

7) Limited qualified staff and diabetes specialist and nurses.

In addition to that, besides these challenges, the KSA covers a large geographical with desert and remote towns that lack specialist diabetes care.

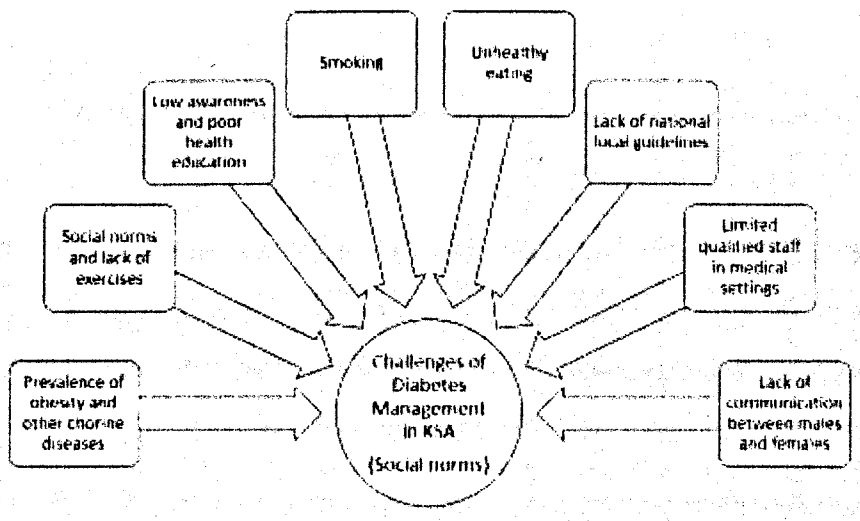

Figure 2-4 Challenges of Diabetes Management in KSA

2.4 Mobile Diabetes Management Systems

2.4.1 Literature Review of Mobile Diabetes Management System

In this section, we will present the meta-analysis, review papers, and analyse their outcomes .We present some of the pilot and clinical studies conducted in UK and their outcomes.

Table 2.2 shows the key literature review papers on mobile diabetes management and their perspectives analysis. The first comparative study reviewed 18 studies on mobile diabetes management [20]. The study aimed to evaluate the impact of mobile interventions for persons with diabetes and/or obesity in improving health care outcomes, and the processes of care for persons with diabetes and/or obesity. The key outcomes of this comparative study are summarized as follows: (i) 9 out of 10 studies that measured HbA1c reported significant improvement among those receiving education and care support, (ii) most of the studies indicated that the use of mobile diabetes intervention improved interaction between patients and providers, and between parents and children, and their greater satisfaction with care.

The second systematic review study cited to date 21 studies on diabetes management via mobile phone [74]. In this systematic review a detailed of 21 studies was addressed with the objective to identify the most common uses of mobile phones in monitoring and managing diabetes, their potential roles in a clinical setting, and the current state of research in the field. The key outcomes of this study are summarized as follows: (i) most of the reviewed studies reported that there was a significant improvement in HbA1c, (ii) another important finding was that the use of such technology improved self-efficacy and diabetes knowledge (iii) the study also pointed out that most studies report extremely positive opinions of patients towards such intervention, but tell nothing about the opinions of the providers[74].

The third study is the meta-analysis that reviewed 22 studies [75] with the objective to study the effect of mobile phone usage on glycaemic control in diabetes management. This study cited high cell phone penetration as an opportunity to exploit this quest. Cell phones were used to deliver test results and SMS reminders of visits were also sent. The key outcomes of this meta-analysis are summarized as follows: (i) mobile interventions for diabetes management reduced HbA1c values by a mean of 0.5% [6 mmol/mol ; 95%

confidence interval, 0.3–0.7% (4–8 mmol⁄mol)] over a median of 6 months follow-up duration, (ii) 11 studies among Type 2 diabetes patients reported significantly greater reduction in HbA1c than studies among Type 1 diabetes patients [0.8 (9 mmol⁄mol)vs.0.3%(3 mmol⁄mol); P = 0.02].

From the UK perspective, table 2.3 shows the mobile diabetes management studies conducted in the last decade in UK. From these systematic review papers, meta-analysis and UK papers, we can conclude that the common trends and outcomes of the effectiveness on mobile diabetes management system are summarized as follows:

1) There is a clear evidence and significant improvement in HbA1c, self-efficacy and diabetes knowledge among those using mobile diabetes systems compared to traditional care.

2) There is a clear evidence on improvement in the interaction between patients, providers, parents and children.

3) There is clearly no studies in the Gulf region on using mobile technology for for type 2 diabetes management particularly in Saudi Arabia.

4) There is a need for a further research studies to develop and evaluate of such system specifically tailored to the Gulf region particularly in Saudi Arabia.

Table 2-2 Summary of Systematic Reviews on Mobile Diabetes Management Systems

No.	Author, Year	Reviewed Studies	Details	Outcomes/Analysis
1	Krishna & Boren 2008 [20]	20 articles representing 18 studies	13 studies measured health outcomes, and 5 studies evaluated process of care. 9 out of 10 studies reported significant improvement in HbA1c levels in the control group	Mobile phone and SMS services interventions improved the communication between the patients and doctors, and also increased the satisfaction levels.
2	Holtz & Lauckner 2012 [74]	21 articles	62% of the total studies reported HbA1c values as an outcome measure, out of which 85% of them reported significant improvements in HbA1c values. 24% of the studies reported no changes. Out of 48% studies reporting satisfaction as an outcome measure, more than 90% of them were satisfied.	Mobile phone interventions can increase the satisfaction levels, and can to an extent reduce the HbA1c levels. It can help the patients in expanding their horizons in education related to their health condition and other health related aspects.
3	Liang et al. 2010 [75]	22 trials, 1657 patients	Mobile phone interventions for diabetes self-management reduced HbA1c values by mean of 0.5%. 11 studies related to type 2 diabetes reported significant reductions in HbA1c values than the type 1 diabetic studies [0.8 (9 mmol/ mol) vs. 0.3% (3 mmol / mol); P = 0.02].	Mobile phone interventions significantly reduced the HbA1c levels in type 2 diabetes patients group, than in the type 1 diabetes patient group.

Table 2-3 Summary of UK Studies on Mobile Diabetes Management Systems

No.	Author, Year	Sample Age	Sample Population	Duration	Study Location	Study Design	Diabetes Type	Data Input Methods & Functions	Result	Comments
1	Larsen et al. 2010 [76]	57.6	23 patients	6 months	UK	RCT	Type 2	Internet enabled Mobile Phone, Electronic Diary	Mean decrease in the HbA1c levels of 0.66% with a mean increase in the insulin dose by 17 units	Mobile phone interventions can improve the control of blood glucose levels.
2	Franklin et al. 2008 [77]	8-18	64 patients	12 months	UK	RCT	Type 1	SMS/ automated text messaging	Automated text messaging "Sweet Talk" service helped the patients in receiving additional support and increased their satisfaction levels	Automated text messaging can be used extensively with young diabetic patients, which can improve their knowledge and satisfaction levels.
3	Turnet et al. 2009 [78]	58	23 patients	3 months	UK	RCT	Type 2	Mobile app	Tele-health services like telephone monitoring has achieved greater satisfaction levels in the early diabetic patients as the system was easy to use and the frequent visits to the clinics were reduced to a great extent.	Additional support to the elderly diabetic patients can lead to improved glycaemic control, as the satisfaction levels, motivation, and the services are improved.
4	Curran et al. 2010 [79]	NA	6 Patients	2 Weeks	UK	RCT	N/A	Mobile Devices, Neural Network application	Intensive insulin therapy has a value and needs to be further investigated.	Artificial intelligence can be integrated with m-health technologies in developing systems which are more effective and accurate in generating the insulin doses based on the readings entered.
5	Istepanian et al. 2009 [80]	60 (intervention group), 57 (control group)	137 72 (intervention group), 65 (control group)	9 months	UK	RCT	Type1 Type 2	Mobile phones, Web based applications	Patients in the intervention group (7.76%) achieved low levels of HbA1c than those in the control group (8.4%). Higher satisfaction levels towards m-health intervention. Few technical difficulties.	The technical compatibility and the usability of the devices in implementing m-health technologies must be carefully assessed before starting the trial.

2.4.2 Smart Phone Applications for Diabetes Management

In this section, we summaries some of the main smart phone applications (Apps) available for mobile diabetes management. In recent survey, there is currently nearly 1400 apps on iPhone platform and Android based smart platform and most of the details of these apps are described elsewhere [81]. Table 2.4 presents some of the most successful commercial apps available and describe the key functions and characteristics. These include data tracking, alerts, trend chart, logbook view, social networking, data synchronizing and behavioral change.

Table 2-2-4 Summary of the Key Functions and Characteristics of The Most Successfully Apps.

Apps Name/ Features	Diabetes Log	Diabetes Pilot	Log Frog DB	Wave Sense Diabetes Manger	Your Diabetes Diary	Glucose Buddy
Blood Glucose monitoring	x	x	x	x	x	X
Weight monitoring		x	x		x	
Physical Activity		x	x		x	x
Diet (self-monitoring)		x			x	x
Blood Pressure (self-monitoring)		x	x		x	
Alerts	x	x	x	x	x	x
Trend chart		x	x	x	x	x
logbook view	x	x	x	x	x	x
Social Networking						x
Data synchronizing with HCP	x	x	x	x	x	x
Coaching and Behaviroal Change						

In summary, these apps have in general common features for diabetes management. However, there is no smartphone application that has linked the social networking and behavioral therapy modules with mobile diabetes management.

2.5 Mobile Diabetes Management System in the Gulf Region

2.5.1 Introduction

In this section, we review the work carried out in the Gulf region on using mobile for diabetes management in the context of social networks for healthcare. An extensive review was conducted to identify such published work in this area.

2.5.2 Methods

This review study reviewed the peer-reviewed articles in electronic medical databases. Both English and Arabic databases were used in the search. The English databases included the PubMed, Web of Science and IEEE Xplorer , while the Arabic databases used include Al Manhal, Mandumah and AskZad. The search terms used in the databases included numerous mixtures of the expressions "diabetes", "mobile phones", "cell phones", "smart phone" , "social network" and the name of the country. In order to get specific results for the different countries being studied, the search terms specified the country, for instance "mobile phones and diabetes and Saudi Arabia".

The selected articles for the review study were identified on the following criteria: a) if the studies had mobile phones as the principal intervention tool for self-management of diabetes, b) if the study in the article had either a randomized controlled trial, managed before-after trial, quasi randomized trial or managed limit trial, c) if the articles were dated between 2002 and 2013, d) if the articles were published in English and Arabic language, e) if the articles were published in peer reviewed publications or peer reviewed international conference proceedings. Furthermore, the articles were also excluded on the following benchmarks: a) if the article gave reviews without original study data, b) if the article gave reports that only introduced mobile phone technologies, c) if the articles focused on other diseases with diabetes, d) if the articles are written as reports, e) if the articles centred only on the clinical professionals and not on the patient's side.

Moreover, data was extracted from the articles according to the study design, application devices, individuals taking part in the application such as patients and family members and health care providers; input of data by patients and the data record techniques, targeted population, roles of the application, techniques used to analyse acceptability, feasibility and effectiveness, techniques and the outcome of experimental results review if presented, and the exploration outcomes. Figure 2.5 shows the study search strategy and review process.

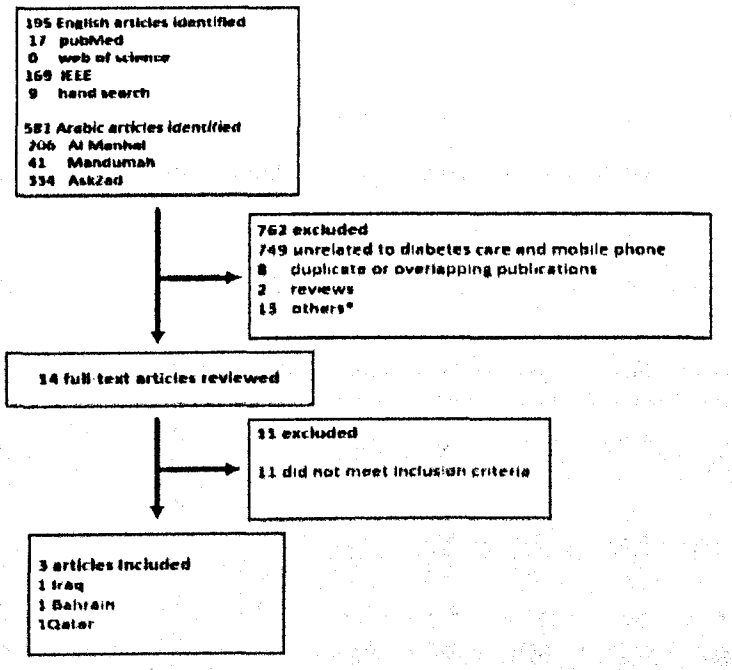

Figure 2-5 The Study Search Strategy and Review Process

2.5.3. Results

In the first stage of selection, 195 English articles were and 581 Arabic articles were identified. Among the English articles, 17 were from Pub Med, non from Web of Science, 169 from IEEE Xplorer and 9 from hand search. On the other hand, among the Arabic articles identified 206 were from Al Manhal, 41 from Mandumah and 334 from AskZad. In the second phase of the selection of the data sources, 762 articles were excluded and only 14 articles were full text peer-reviewed articles. The 762 articles either gave evaluations short of creative study data, gave hearsays that merely gave introductions of cell phone technologies or focused on other diseases with diabetes. Of the 14 selected articles, only 3 of these met the exclusion and inclusion criteria. The three articles identified included 1 Iraq article, 1 Bahrain

article and 1 Qatar article. The summaries of these studies are presented in table 2.5. The 11 articles not selected did not meet the criteria for inclusion and exclusion.

In a study conducted by Hussein et al. in 2011, in Bahrain, the impact of using the short message services on type 2 diabetes mellitus management was assessed. 34 patients were selected for the trial, out of which the intervention group had 12 patients and the control group had 22 patients [82]. The control group received usual care. The intervention group patients received two mobile numbers, one for the physician, and the other for diabetic educator. The patients can send unlimited SMS to the two numbers for support, information and any queries. The study lasted for three months, and the total messages received were 633. Majority of the messages (64.7%) were concerning the review of the glucose readings, 7% regarding the dietary and food related queries, 6% were regarding the help in hyperglycaemia situations, and 4% regarding the medication. Interestingly more messages were sent to diabetic educator than the physician. However, the amount of messages sent in the first month was high, and in the next two months, the number of messages received decreased. The results of the study were interesting, as both groups had a significant reduction in HbA1c levels. The reduction of HbA1c levels in the intervention group was 2.76%, which is 1.16% lower than in the control group. The study conducted by Mulvanet et al. reveals the initiatives taken in implementing the e-health and m-health applications in Iraq, where the DeLPHE-Iraq project was discussed [83]. Two m-health pilot studies were planned and implemented in Baghdad and Basrah, which include: a) feasibility and acceptability of SMS service for pregnant woman identified with gestational diabetes of their healthcare in Baghdad; and b) feasibility of mobile phone text messaging to support type 2 diabetes management in Basrah [84].

The first study involving pregnant women had two groups: intervention group with 146 pregnant women, and control group with 97 pregnant women. A mobile phone is given to the patients in the intervention group, where they can use the mobile phone for SMS service for obtaining information related to the study, or any other health related issues. The results of the study have shown an increase in the number of visits, with a median of four in the intervention group and two in the control group. The second study concerning the type 2 diabetes management included 50 patients. The patients were asked to fill a questionnaire at the start and end of the study to assess their knowledge in health related aspects. During the period of study, educational SMS were sent to the patients mobiles. The results were

impressive, as there is a significant increase in the knowledge of patients from a score of 8.57 to 9.85. In addition, during the period of study, significant reductions in the HbA1c levels of the patients were observed (from 9.33 to 8.56).

The study presented by Alhazbi and colleagues presents a mobile application that aims to assist diabetic people in Qatar to manage such chronic disease through glucose monitoring and diet management [85]. Besides helping patients to log their data of glucose level and transmit them wirelessly to health care centres, more importantly, the application supports patients to manage their food consumption by providing them with advices about food items and their appropriateness to their personal conditions. The recommended mobile application utilizes concept of ontology to represent Qatari food items and their nutrition. The information is shared between the three components which include mobile application on patients that sends and receives data from Food ontology database; mobile application or system at healthcare operators that sends and receives data from Food ontology database; and the Food ontology database.

In general, from this review study, there is no much evidence of systems, trials, or studies conducted in this region in the aspect of m-health in general and mobile diabetes management in particularly in Saudi Arabia.

Table 2-5 Summary of Mobile Diabetes Management System Embedding Social Networking Platform in Gulf Region

No.	Author, Year	Mean Sample Age	Sample Population	Duration	Study Location	Study Design	Diabetes Type	Data Input Methods & Functions	Result	Comments
1	Hussein et al. 2011 [82]	46.33 ± 7.22 (Interventional group), 47.59 ± 7.10 (Control group)	34 patients with type 2 diabetes 12 in Intervention group, and 22 in control group	3 months	Bahrain	RCT	Type 2	SMS	The reduction of HbA1c levels in the intervention group was 2.76%, which is 1.16% lower than in the control group.	Mobile phone interventions can help in reducing the HbA1c levels, and also increase the knowledge of the patients in health related aspects.
2	Mulvanet et al. 2012 [83]	N/A	**Study 1** Intervention group (146 Pregnant women) Control group (97 Pregnant Women) **Study 2** 50 type 2 diabetes patients	N/A	Baghdad Basrah	RCT N/A	Gestational diabetes Type 2	SMS SMS	**Study 1:** Increase in the number of visits, with a median of four in the intervention group and two in the control group. **Study 2:** increase in the knowledge of patients from a score of 8.57 to 9.85, and significant reductions in the HbA1c levels of the patients were observed (from 9.33 to 8.56).	Use of SMS service intervention can have a great impact on increasing the awareness of the diabetes, and also the knowledge among the people in Gulf region.
3	Alhazbi et al. 2012[85]	N/A	N/A	N/A	Qatar	N/A	Type 1 & Type2	Automatically	Higher satisfaction levels towards m-health intervention in Qatar.	This mobile system was implemented in Qatar, where the prevalence of diabetes is significantly high

2.6 Social Networking for Healthcare

In recent years, social networking for different healthcare domains and services has been increasingly used. In USA, nearly 72% of adults living with chronic disease conditions use such type of this technology[86].The total number of social networking users using in Saudi Arabia reached around 7.8 million Facebook's users, 1 million LinkedIn users and more than 5 million Twitter users at the end of 2013[22]. In this section, we describe the general architecture of social networking. We then describe some of the social networking systems targeting to different healthcare domains and services. Finally, we describes the importance of social networking for diabetes management.

2.6.1 General Architecture of Social Networking

One of the key definition of social networking is " A social network in a social science context is a social structure made up of a set of actors (such as individuals or organizations) and the dyadic ties between these actors"[87]. Therefore, figure 2.6 illustrates the general architecture of social network applications. The details of the social networking architecture are described elsewhere[88]. However, we will describe briefly these building blocks for completeness.

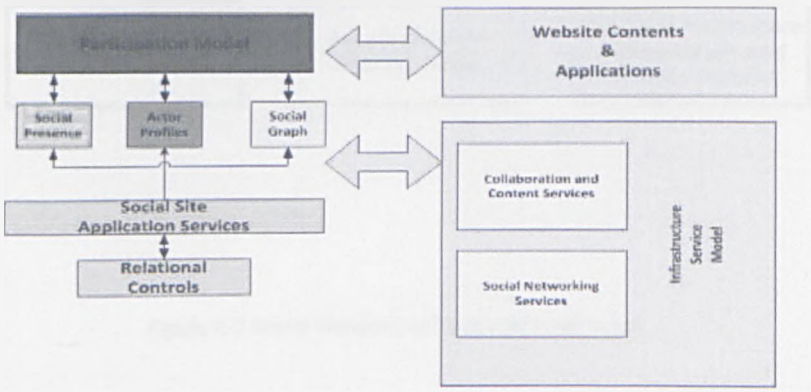

Figure 2-6 General Social Networking Architecture [88]

- Social networking graph: "is a structure that used for the representation and implementation of a social network"[89].
- User profiles: are well known as actor profiles of the general social network.

- Social presence: is a quite new model in a social network framework. In the old social networking, social presence was basically being connected and available. However, nowadays it is well known as user's "current status", which is a description of a user's activity.

- User participation tools: provides techniques for users' to communication, interaction, and participation with other users such as instant messaging, and message boards.

- Relation controls: defines the relationship types that can users create with each other[88][89].

2.6.2 Social Networking Types for Healthcare

In general, there are three types of social networking for healthcare as shown in figure 2.7. These are described briefly below.

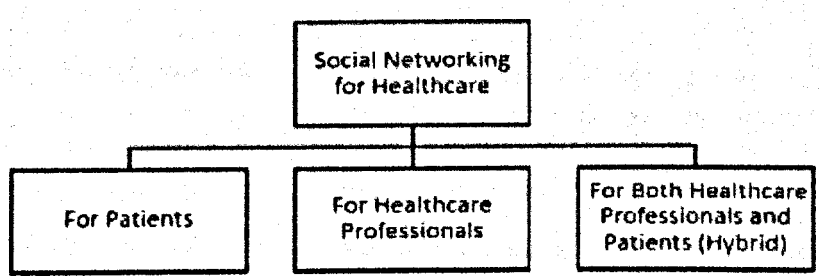

Figure 2-7 Social Networking Types for Healthcare

a) Social Networking for Patients

In this type of social networking, the patients are the key focus of the users. According to the social networking architecture, the social graph of this type is only patients to the patients users. Therefore, this type of social networking is a platform only for patients to communicate with each other. An example of this type is PatientsLikeMe [90]. The main benefits of patients

social networking is that patients and their families appreciate and benefit from contact with others who are experiencing similar conditions and treatments. It is not always possible or practical for families to travel to visit support groups but it is much easier to make contact over the social networking and find all kinds of useful and reliable information, as well as friendly discussion groups.

b) Social Networking for Healthcare Professionals

In this type of social networking, the healthcare professionals are the key focus of the users. According to the social networking architecture, the social graph of this type is only healthcare professionals to healthcare professionals. Therefore, social networking for healthcare professionals is a platform only for healthcare professionals to communicate with each other. An example of this type is Sermo.com [91]. There are significant advantages are discovering how practices vary in different locations, and experts can consult each other on difficult cases by sharing data and commenting to each other confidentially over the social networking.

c) Hybrid Social Networking for both Healthcare Professionals and Patients

In this type of social networking, the healthcare professionals and patients are the key focus of the users. According to the social networking architecture, the social graph of this type is healthcare professionals to patients, healthcare professionals to healthcare professionals and patients to patients. Therefore, hybrid social networking is a platform for both healthcare professionals and patients to communicate with each other. An example of this type is TuDiabetes.org[92]. This type of social networking can support the healthcare distribution process by allowing written follow-up clues, test results, a means for patients to easily contact their physician, as well as, share opinions and medical information every time and everywhere by offering to physicians an opportunity to improve, the awareness of patient's health conditions and enhance their satisfaction.

2.6.3 Social Networking Applications for Diabetes Management

In this section, the applications of social networking for diabetes management are reviewed. We have divided these applications into the following three categories: a) a public social networking, which is designed for a public use and general purpose and it could be used by diabetic patients; b) a general social networking for healthcare, which is tailored for many different conditions and diseases ; c) social networking for diabetes disease which is specifically tailored for diabetes condition.

Facebook previously invented and considered as public social networking application. More recently, Facebook service allows users to access and use it via a cell phone or mobile. Users can upload videos and images and update or exchange ideas, suggestions, and profile status on wall posts via text messages and much more. Moreover, Facebook is extensible, as applications can be added to make it more functional and loaded with new features[93]. Similarly, Facebook mobile is also extensible, as users can add various applications for added functionality. Moreover, a calendar and other mobile applications can also be integrated with Facebook mobile for an interactive exchange of information[93]. In the context of health care services, there are large numbers of pages in Facebook such as private pages for hospitals and clinics, and many groups that can be activated for a specific purpose or disease. A diabetes self-management group is one well-known group on Facebook[94].

Twitter is also a social networking platform [95] just like Facebook; however the communication modes are slightly different. It is an online social networking application, which allows the users to send short messages called tweets. It can be accessed by wen interface, or SMS, or by using mobile application. Usually much of the conversation on twitter happens as soon as the tweet is posted and lasts for few hours, whereas on Facebook it is likely to go on for longer durations. Therefore, twitter is more like a real time communication platform whereas Facebook is like ongoing communication platform. Twitter allows users to follow important topics, participate in tweeting or in conversations which are relevant or important or a point of interest for them. Therefore, it is easy for the users to interact and get the updates which are of interest to them.

Within the diabetes condition context, the diabetes patients can follow different users on twitter, where there is a continuous tweets on sharing the information related to diabetes management, and other related health topics. There are many twitter accounts that share the

diabetes related information like '@managediabetes', '@diabetesUK', '@diabetesdaily', '@diabetes_sanofi', which provide tweets on diabetes management. The users can get real time information, and can also participate in conversation by posting tweets, which not only increases their knowledge but also increases their social presence, which can be a new and interesting approach for dealing with diabetes self-management.

PatientsLikeMe [90] is the most social networking application for health care that assists its users to examine their medical condition, medicine routines and symptoms. PatientsLikeMe can only resolve for about 16 health related issues and helps to support the patients emotionally[96]. The user of PatientsLikeMe share their own views, experiences and recommendations that can help other patients improve their daily routine[97]. Furthermore, PatientsLikeMe enables the patients to view statistical values and graphs illustrating their health condition along with the tracking of prescribed drug doses. Moreover, chronic disease patients, for instance, diabetic patients can utilize this service to review their glucose levels that are displayed on trends in graphs identifying increase and decrease of sugar levels in the blood[96].

In addition, several patients interacting via PatientsLikeMe are notified for giving contribution of information if required for clinical trials .The integration of online health tracking and clinical trials facilitate and advise patients to submit an experienced feedback and suggestions along with response to drugs .Moreover, clinical trials are considered to be more effective, as they operate on a large database associated with the health history of patients. The huge amount of data available in databases will facilitate and provide a path for understanding situations and conditions in a better way. Moreover, the information collected from PatientsLikeMe will benefit pharmaceutical laboratories, research facilities and educational institutes and will aid in their research in finding better cures for diseases [98] [96].

One of another popular healthcare social networking application is CureTogether[99]. CureTogether provides an emotional support and information sharing service as, it is considered the basic service provided to the patients. For example, CureTogether users can share their personal information and can track their own medical condition namelessly while highlighting the main cause i.e. an emotional support [100]. Furthermore, CureTogether provides options for self-tracking as well. This option provides an interactive interface for data entry from the patients. Patients can update health conditions, symptoms, treatment or cure and other related medical information. Patients or groups can view rich graphical screens.

Moreover, the service also facilitates patients to review their medical details in analytical mode[96].

MedHelp [101] is a popular social networking application for healthcare that interconnects common patients with medical experts in facilitating medical advice and support[102]. Therefore, MedHelp enables patients to manage and review their health condition.

mCare is a well-known as wireless mobile social networking system for general healthcare purpose [89] . The proposed social network module for mCare is demonstrated as following: *a)* "Users have the ability to share questions and answers with friends, b) Users have the ability to recommend physicians to friends, c) Users have the ability to ask physicians questions, d) Users have the ability to view their own questions, e) Users have the ability to view favourite questions, and f) Users have the ability to have access to their Google Health records."[89]

There are general and specific diabetes-related social networking available now. One of the biggest online communities is TuDiabetes.org [92] but there are others such as dLife [103]. Both of these applications offer information for patients and all kinds of supportive advice on how to live well with diabetes. Patients who use these communities generally do better than others who have no such support, and this reduces the cost of health care while at the same time increasing benefits for the patient. Further individual blogs, diaries and wikis are emerging all the time, offering tips, daily nutrition guides, and newsletters as well as the usual information on symptoms and treatments.

In general, it can conclude from the above studies that, social networking is not a replacement for clinicians or doctor; however, they are best suitable for answering questions that people consider too insignificant to ask their health professional and also help in overcoming the information inequality that exists between patients and physicians. Furthermore, the previous studies have not dealt with any type of mobile diabetes management and behavioural change intervention. While a wide variety of mobile applications appear to be available for people with diabetes, we found that there are no such studies and applications on social networks for diabetes self-management concepts on mobile devices for Saudi dietetic patients, and their potential remains largely unexplored. Table 2.6 presents the analyses concept of some of those systems based on the general architecture of the social networking and mobile diabetes management tools.

Table 2-6 Summary Analysing of Social Networking Applications for Diabetes Management

Social Networking System	**Social Networking Graph**	**User Profiles**	**User Social Presence**	**User Participation Tools**	**User Relation Controls**	**Diabetes Management Tools**
Facebook	Many	Many	Current status	Private messaging Instant messaging and other	Friendship	Using the participation tools only for managing their diabetes condition, such as patients can write their status using this tool.
PatientsLikeMe	Patients	Patients	Current status	Private messaging Forum Instant messaging	Follow me	Diabetic patients can utilize this service to review their glucose levels and display graphs trends identifying increase and decrease of sugar levels in the blood.
mCare	Patients & Doctor	Patients & Doctor	Current status	Private messaging Ask Doctor	Friendship	N/A
TuDiabetes	Patients & Doctor	Patients & Doctor	Current status	Private messaging Instant messaging and other	Friendship	N/A, but this social networking was intergraded with other platform called Diabetes Analyses

2.6.4 Potential Effects of Social Networking for Diabetes Management

As described earlier, social networking can provide a superior and more efficient diabetes management for patients. Recent research studies have shown that using such social interaction can decrease the incidence of diabetes adverse symptoms, improve health behaviors and reduce utilization of health care resources. However, up to date there is study that addresses the effectiveness of using social networking on diabetes management. The benefits of social networking for diabetes management can be summarized as following:

a) Improves and changes patient's health behaviours

Social networking for healthcare can be a method to change patient behaviour. This fact supports that behavioural change through increased awareness and inclination to exchange ideas and experiences has been supported through online networking applications. Another example that, the American Academy of Family Physicians (AAFP) has registered through Facebook, one of the most famous social networking applications, to provide an open discussion for people with health-related concerns[104]. The ease of access, convenience and 24/7 support services offered by social networking applications enable patients to manifest behavioural changes as advised and supported by various authoritative medical groups and sources.

b) Increases interactions between patients and medical staff

By using the tool of social networking on diabetes management, the way of the communication between patients and medical staff can move from the traditional way, for example, contact can occur during clinical visits only, to the smart one, which will overcome the drawback of geographical location.

c) Reduces utilization of health care resources

Improving quality of care, self-efficacy, health state and provide the healthcare services in the way which is remotely that could be affecting the diabetic patients positively, which will lead to reduce the risk and complications of diabetes for a short and long term. As a result of that, the healthcare resource will be saved in terms of, but not limited, financial and time expenses.

d) Delivers sensible suggestions due to frequent communication

The huge amount of information exchange and communication that is more frequent will facilitate and provide the medical staff a path for understanding situations and conditions

in a better way. Moreover, these will benefit research facilities and educational institutes and will aid in their research in finding better cures for diseases[98].

2.7 Conclusion

In this chapter, an overview of diabetes condition and diabetes prevalence and its challenging in Saudi Arabia are presented. The previous work on the use of mobile diabetes management system is reviewed and analysed. The key and most popular smart phone application for diabetes management is also presented . Furthermore, the current statue of mobile diabetes management system embedding social networking is also reported. A review of social networking in healthcare in general and diabetes specifically is also presented.

From this review chapter, the key outcomes of these reviewed studies are summarised as follows:

1) The key outcomes of these review papers shows that there is a clear evidence and significant improvement in HbA1c, self-efficacy and diabetes knowledge among those using mobile diabetes systems.

2) The trials and studies of mobile diabetes management system in Gulf region are very limited, which brings out a clear need to focus on the design, development, and deployment of m-health system specific to this region particularly in Saudi Arabia, so that all the other aspects like lifestyles, dietary requirements, ethnicity etc. are taken in to account in conducting the studies and trials.

3) The previous studies have not dealt with any type of mobile diabetes management and behavioural change intervention. Moreover, this technology is very new, and as yet not very much research on its impact on patients who have diabetes condition. While a wide variety of mobile applications appear to be available for people with diabetes, we found that there are no such studies and applications on social networks and behavioural change with diabetes management concepts on mobile devices for Saudi dietetic patients, and their potential remains largely unexplored

4) In parallel and with the explosion use of smart mobile phone technologies, there is an increase in using social networking in the kingdom especially in the educated and younger population. Thus, there is an urgent needed for innovative

strategies for the KSA to deliver healthcare services and medical educations particularly to diabetic patients by relying on these technologies; and in particular for enhancing diabetes management by using a diary management system, as well as providing emotional support and health education using the social networking concept.

5) To date, there has not been a study conducted to date on the impact and evaluation of mobile diabetes management systems integrated with social networking and behavioural change in the kingdom. It is very essential that trial needed to be conducted and a system needs to be designed specifically for this region. The more details of health behavioural change issues for diabetes management will be discussed in the next chapter.

Chapter 3 : Cognitive Behavioural Therapy for Diabetes Management

3.1 Introduction

In this chapter, we present the general behavioural change models for healthcare and the focus on the most relevant research study to this work, namely Cognitive Behavioural Therapy (CBT) for diabetes management.

3.2 Behavioural Change Models for Healthcare

Behavioural change theories would help people in gaining insight in to their health related issues influenced by their behavioural aspects, and suggest methods to modify/ change their behaviour to lead a healthy lifestyle [105]. In this process of encouraging individuals to maintain healthy lifestyle by changing their behaviour, different models have been developed to implement such change in their healthcare setting. The major models concerned with health behavioural changes are discussed next.

3.2.1. Health Belief Model

Health Belief Model (HBM) is a socio – psychological model that explains and predicts health behaviour, focusing on the aspect, why individuals may accept or reject preventive healthcare services or adopt healthy behaviours [106]. The model works with a principle of how an individual's perceives and believes of a negative health condition, which is influenced by modifying factors to achieve a likelihood of action by the individuals [105].

As explained by Gochman et al. [107], the HBM model works with the concepts of perceived susceptibility, which defines an individual's assessment of getting a condition; perceived severity, which defines an individual's assessment of the seriousness and the consequences of a condition; perceived Benefits which defines an individual's assessment of positive outcomes of adapting a behavioural change; perceived barriers, which is an individual's assessment of influences which discourages or stops from adopting the behavioural change; The influences from external environment in promoting the behavioural

change (Cues to Action); and Self-Efficacy, which is an individual's assessment of confidence in adopting the behavioural change.

There advantages of health belief model include: easy to implement, and promotes research in developing preventive models in healthcare; and it can also predict variety of health actions and provide insights into its complexity and status [107]. However there are few drawbacks of this model, mainly, firstly, as a psychological model it does not take into consideration other factors, such as environmental or economic factors, that may influence health behaviours, and secondly, it does not incorporate the influence of social norms and peer influences on people's decisions regarding their health behaviours. Most of the HBM-based research has incorporated only selected components of the HBM, thereby not testing the model as a whole [107].

3.2.2. The Protection Motivation Theory

The Protection Motivation Theory (PMT) is a theory of persuasion; guided by the process of guiding oneself or another towards the adoption of an idea, attitude, or an action by rational and symbolic means. It proposes two appraisals; a process of threat appraisal, and a process of coping appraisal, in which the behavioural options to diminish the threat are evaluated [107]. The appraisal of health threat results in adaptive responses or protection motivation in order to diminish the threat, or maladaptive responses leading to negative consequences as a result of non-participation in adapting the behavioural change [108].

The major components of the Protection Motivation Theory as explained by Boer & Seydel [107] include susceptibility /vulnerability, severity, threat, response efficacy (the individual's expectancy that carrying out recommendations can remove the threat), self-efficacy (the belief in one's ability to execute the recommend courses of action successfully), Coping efficacy (estimation of response efficacy and self-efficacy), and Protection motivation, which is a mediating variable whose function is to arouse, sustain and direct protective health behaviour.

The response efficacy variable is an important factor, which is considered in PMT, and HBM, but not in other theories. There are many advantages of using this theory. Firstly, it is useful in making predictions which can be tested. Secondly, it is easy to use and apply when compared with HBM. However there are few drawbacks, as it is comprehensive in

nature; and it does not explain behaviour completely. Another drawback with PMT is that, motives for behaviour other than health are not considered for explaining behaviour.

3.2.3. Theory of Reasoned Action and Theory of Planned Behaviour

In an attempt to provide consistency between the behaviour and attitudes, the theory of reasoned action (TRA) was formulated in [109] . The main assumption of TRA and Theory of Planned Behaviour (TPB) is that the individuals are rational in considering their actions and the implications of their actions; and it is assumed that decisions are made under uncertainty (Rational Decision Making) [110]. It works with a principle that in assessing the specific behaviour, specific attitudes must be assessed in reference to the target, context, and time[111]. Attitudes and Subjective norms are used in assessing the behavioural intentions in TRA; extending it further, by using Perceived behavioural control (how easily a specific behaviour will be performed) along with attitudes and subjective norms in assessing behavioural intentions, TPB was developed[112].

The major difference and one of the special features of this model when compared with HBM and PMT is that this model considers Social norm as an important variable in explaining social behaviour. In addition, other advantages include: the problems like limitations of the TRA including the inability of the theory, due to its individualistic approach, to consider the role of environmental and structural issues and the linearity of the theory components are answered in TPB. It also covers the choosing behaviour of the individuals, which is not covered in TRA, and provides with improved predictability of intentions. The relationship between the Actual behaviour and Behavioural intention can be assessed in TPB. However the major disadvantage of this model is that, the emotional factors like fear, threat, mood etc., are not considered in assessing the intention, and it provides poor predictability as per the evidences[113].

3.2.4. Information - Motivation – Strategy Model

Information motivation strategy model works with a principle covering the aspects of information, motivation, and strategy in achieving health behavioural change or adherence. Information in this model defines that an individual must know what change is necessary, and other information related to the condition, and the individual should have / be supported with

the desire to change (motivation). Then, the necessary tools are to be implemented to achieve, and manage the change (Strategy)[114].Unlike the other models, it is simplified, and easy to use, as shown in figure 3.1:

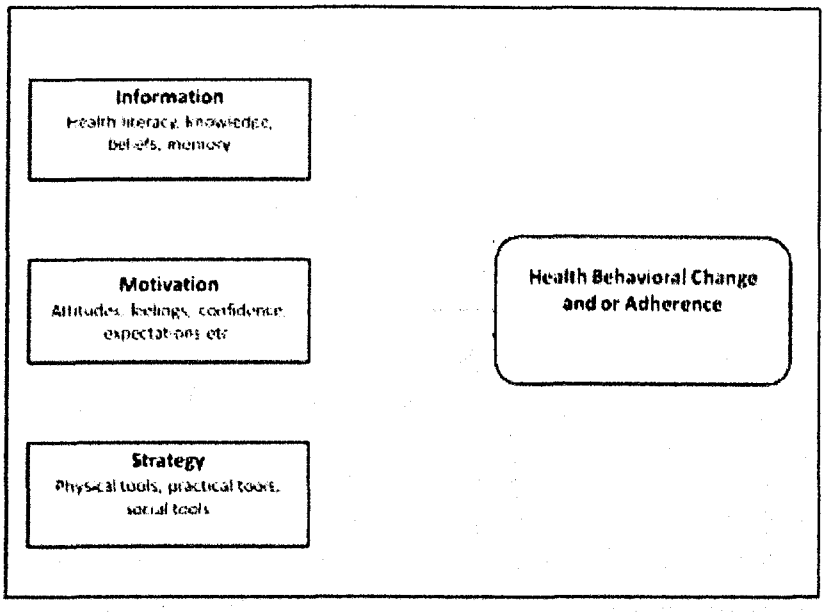

Figure 3-1 Information - Motivation – Strategy Model [114]

There are many advantages of this model. Firstly, it is simple and easy to use, as it is flexible nature for incorporating new techniques and strategies. Secondly, it considers emotional factors like fear, mood, threat etc., and is consistent with other theories and models, and has flexibility for adopting changes. However there are few drawbacks to this theory, as it requires continuous updating according to the changing behaviours and social factors in the society. Other drawbacks include problems in managing Information flow and rapid changing technologies are few drawbacks in the model which can result in poor outcomes. In addition lack of technology support can affect the process of achieving behavioural changes[114].

3.2.5. Social Cognitive Theory

Social Cognitive Theory (SCT) explains how people acquire and maintain certain behavioural patterns, while also providing the basis for intervention strategies. In this process, the human behaviour is explained in terms of a triadic, dynamic, and reciprocal model in which behaviour, personal factors, and environmental influences all interact. An

individual's behaviour is uniquely determined by these interactions [115]. Figure 3.2 shows the basic principles of SCT.

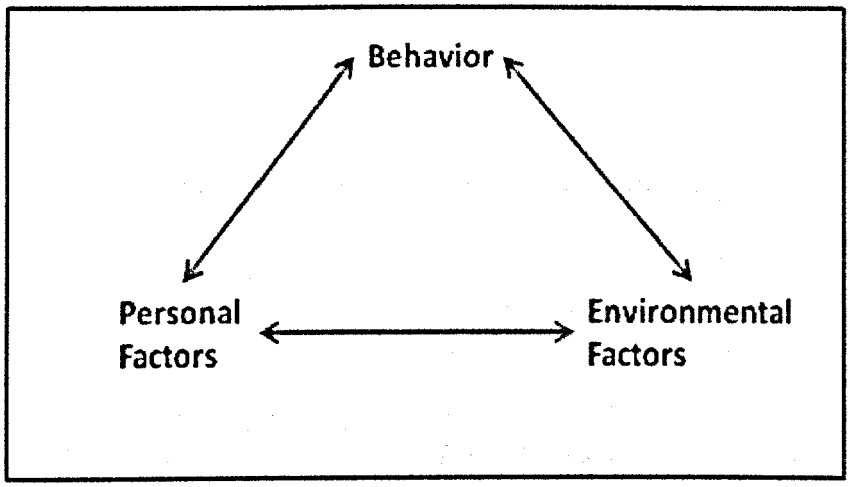

Figure 3-2 Social Cognitive Theory (SCT) [14]

There are several advantages of this model. Firstly, it can be applied in wide range of areas along with healthcare, and the concepts such as self-efficacy, observational learning and reciprocal determinism are easily applicable to real-world implementation. Secondly, it allows cross-cultural analysis, and emphasizes the dynamic composition of individuals, rather than treating individuals as self-contained rational subjects. However there are few drawbacks, as it has multiple concepts and is difficult to implement in an intervention. Other drawbacks include minimizing emotional responses, ignoring biological differences and hormonal responses, and not easy to implement on smart phones.

3.2.6. Cognitive Behavioural Therapy

Cognitive Behavioural Therapy (CBT) is a psychotherapeutic approach addressing problems such as maladaptive behaviours, health condition etc. Talking and changing your behaviour can change how you think (cognitive) and what you do (behaviour). Computerized CBT (CCBT) is one of the most popular examples used these days. As CCBT is a software programs for individuals to manage their problems by changing the ways they think and behave [116]. There are different models, and approaches of CBT used for different health conditions. However, thoughts, feelings, and actions/ behaviour are the main factors considered in CBT, which are interconnected as shown in figure 3.3:

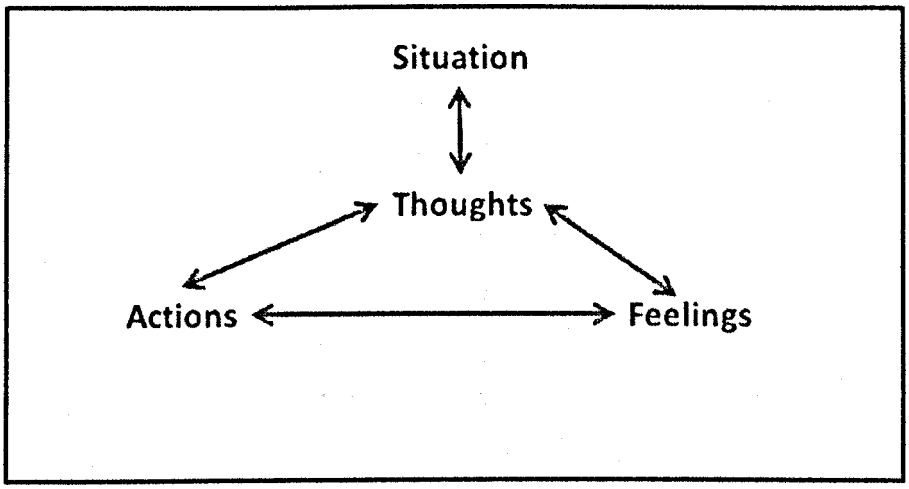

Figure 3-3 Cognitive Behavioural Therapy (CBT) [15]

CBT has major strengths points as it can be used as effective tool for health changing behavior and it can be completed in short periods of time. Therefore, CBT has more flexibility for having different structured formats such as group, self, computerized formats as it would result in better outcomes. Finally, skills learned through CBT are useful knowledge resources which can be practiced in everyday life.

In general, this theory is considered in this study for diabetes management system. The reasons for selecting this approach since it has several advantages over other theoretical aspect particularly for diabetes management. Table 3.1 presents the comparatives summary of the key advantage and disadvantage of each of the theories presented earlier. From this table, it can be seen that the CBT offers compatible characteristics and functionalities required for the current application:

1) This theory can be achieved in shorter time compared to the other theories
2) This theory is easy to implement on smart phones and easy to measure the main components of this theory.
3) This theory is more flexibility for having different structured formats such as group.

Table 3-1 The Comparatives Summary of The Key Advantage and Disadvantage Each Approach

Theory name	Advantages	Disadvantages
Health Belief Model (HBM)	• It is easy to implement, and promotes research in developing preventive models in healthcare. • It can also predict variety of health actions and provide insights into its complexity and status.	• It does not take into consideration other factors, such as environmental or economic factors, that may influence health behaviours. • It does not incorporate the influence of social norms and peer influences on people's decisions regarding their health behaviours. Most of the HBM-based research has incorporated only selected components of the HBM, thereby not testing the model as a whole • Lack of technology support
The Protection Motivation Theory (PMT)	• It is useful in making predictions, which can be tested. • It is easy to use and apply when compared with HBM.	• As it is comprehensive in nature; and it does not explain behaviour completely. • Motives for behaviour other than health are not considered for explaining behaviour. • Lack of technology support
Theory of Reasoned Action and Theory of Planned Behaviour	• This model considers Social norm as an important variable in explaining social behaviour.	• The emotional factors like fear, threat, mood etc., are not considered in assessing the intention, and it provides poor predictability as per the evidences.
Information - Motivation – Strategy Model	• It is simple and easy to use, as it is flexible nature for incorporating new techniques and strategies. • It considers emotional factors like fear, mood, threat etc., and is consistent with other theories and models, and has flexibility for adopting changes.	• It requires continuous updating according to the changing behaviours and social factors in the society. • Problems in managing Information flow and rapid changing technologies are few drawbacks in the model, which can result in poor outcomes. • Lack of technology support can affect the process of achieving behavioural changes.
Social Cognitive Theory	• It can be applied in wide range of areas along with healthcare, and the concepts such as self-efficacy, observational learning and reciprocal determinism are easily applicable to real-world implementation. • It allows cross-cultural analysis, and emphasizes the dynamic composition of individuals, rather than treating individuals as self-contained rational subjects.	• It has multiple concepts and is difficult to implement in an intervention, and Non-linear relationships are not considered. • Minimizing emotional responses, and ignoring biological differences and hormonal responses. • It is difficult to be completed in short time.
Cognitive Behavioural Therapy	• It can be completed in short period of time • It is more flexibility for having different structured formats such as group; and skills learned through CBT are useful knowledge resources which can be practiced in everyday life • It is easy to implement and easy to measure the main components	• It does not take into consideration other factors, such as economic factors, that may influence health behaviours.

3.3 Cognitive Behavioural Therapy for Diabetes Management

This section discusses the recent studies on CBT with diabetes management. Two recent systematic reviews studies were reviewed[117][118], focusing on CBT interventions in improving glycaemic control in type 1 and type 2 diabetic patients respectively. Other studies were also reviewed. The summary of these studies are given in table 3.2.

The first study focused on the systematic review and meta-analysis of psychological therapies to assess their effectiveness in improving glycaemic control in type 2 diabetes. Studies included in MEDLINE, PsychINFO, EMBASE, and the Cochrane Central Register of controlled trials were examined and 25 trials were found to be eligible for the study. From these 25 trials, the study focused on analysing the long-term glycaemic control measured by percentage of glycated haemoglobin; measuring blood glucose concentration, weight, and psychological distress by using the pooled standardised effect for calculating the sizes. The study distinguishes education and psychological therapy as different approaches in dealing with diabetes which can co-exist. The aim of the study was to carry out a systematic review and meta-analysis of randomised controlled trials assessing the effectiveness of psychological therapies in improving glycaemic control in adults with type 2 diabetes and in reducing psychological distress and bodyweight.

The major findings from the study include: the mean percentage of glycated haemoglobin covering 12 trials with 522 patients was lower (Pooled mean difference= -0.32) in people assigned a psychological intervention than in the control group; the pooled mean difference of -0.11 was calculated in blood glucose concentration covering 8 trials with 314 patients; the pooled mean difference of 0.37 was calculated in weight gain aspect covering 9 trials with 455 patients; the pooled mean difference of -0.58 was calculated in psychological distress aspect covering 5 trials with 197 patients.

Out of the 25 trials, 12 trials resulted using psychological therapies resulted in significantly better glycaemic control approximating to an absolute difference of 0.76% in glycated haemoglobin. Study of other trials revealed that psychological therapy was associated with a reduction in psychological distress but did not appear to affect weight control or blood glucose concentration. As there was no significant results achieved in weight loss it was stated that the psychological therapies would encourage long term lifestyle changes, which might result in slow weight reduction process. As most of the studies were

having small sample, the outcomes of the studies in the review were considered to be of moderate to poor quality.

The second study focused on the systematic review and meta-analysis of psychological therapies to assess their effectiveness in improving glycaemic control in type 1 diabetes associated with children and adolescents, and adults. Studies included in MEDLINE, PsychINFO, EMBASE, and the Cochrane Central Register of controlled trials were examined and 29 trials were found to be eligible for systematic review and 21 for meta-analysis. From these 29 trials, only 21 trials (10 for children and adolescents, and 11 for adults) were studied which focused on analysing the glycaemic control measured by percentage of glycated haemoglobin; and psychological distress by using the pooled standardised effect for calculating the sizes. The aim of the study was to carry out a systematic review and meta-analysis of randomised controlled trials assessing the effectiveness of psychological therapies in improving glycaemic control in children and adolescents, and adults with type 1 diabetes and in reducing psychological distress.

The key findings from the study include: the mean percentage of glycated haemoglobin covering 10 trials was lower (Pooled mean difference= -0.35) in children and adolescents assigned a psychological intervention than in the control group; the mean percentage of glycated haemoglobin covering 10 trials was lower (Pooled mean difference= -0.26) in adults assigned a psychological intervention than in the control group; the pooled mean difference of -0.46 was calculated in psychological distress aspect in children and adolescents; the pooled mean difference of -0.35 was calculated in psychological distress aspect in children and adolescents.

The study has found that psychological therapy was associated with a significant improvement in glycaemic control in the 10 studies in children and adolescents, with a pooled absolute reduction in glycated haemoglobin of 0.5%. But in the 11 studies in adults in the meta-analysis this association was smaller and not significant. Psychological distress was found to be significantly lower in the intervention groups in children and adolescents but not in adults. The study has found weak evidence for the effectiveness of psychological treatments in improving glycaemic control in children and adolescents but not in adults. These two studies have found that there is an impact of psychological therapies in diabetes management. However, the findings are varied accordingly with type 1 and type 2 diabetes groups.

In a 48-weeks randomised trial conducted by Amsberg and colleagues[119] to analyse the impact of CBT on type-1 diabetes, the results has shown the greater improvements in all outcomes including diabetes-related distress, frequency of blood glucose testing, avoidance of hypoglycemia, perceived stress, anxiety and depression in the intervention group than in the control group. A significant difference ($P<0.05$) was registered with respect to non-severe hypoglycemia, which yielded a higher score in the intervention group. The study has concluded that CBT-based intervention appears to be a promising approach to diabetes self-management, and improves glucose control and psychological factors in patients with type 1 diabetes.

In the study conducted by Ven et.al. [120] in assessing Short-term effects of cognitive behavioural group training (CBGT) in adult Type 1 diabetes patients in prolonged poor glycaemic control, it was found that CBGT was successful in improving self-efficacy, diabetes-related distress and mood at 3 months' follow-up, but not in improving glycaemic control. Glycaemic control (HbA1c), diabetes-specific self-efficacy (CIDS), diabetes-related distress (PAID) and depressive symptoms (CES-D), were assessed in this study. However, the dropout rate was high in CBGT group, and the study was assessed at three intervals 3 months preceding the trial (T1), at base line (T2), and three months after (T3). The study showed that CBT had little effect in managing glucose levels in short term treatment.

In the study conducted by Snoek et.al [121] in comparing CBT with blood glucose awareness training (BGAT) in poorly controlled Type 1 diabetic patients, it was found that CBT can effectively help Type 1 diabetic patients with co-morbid depression achieve and maintain better glycaemic outcomes. The primary outcome of the study was HbA1c control, and the secondary outcomes were: self-care, diabetes-related distress, diabetes self-efficacy, and depressive symptoms. Neither CBT nor BGAT had a significant impact on HbA1c at 6 and 12 months' follow-up. Both interventions resulted in lower depressive symptoms up to 12 months, but only CBT was effective in lowering HbA1c in patients with high baseline depression scores up to 1 year of follow-up. This study reflects that CBT can achieve good results in long term management of diabetes.

In the study conducted by Ismail et.al [122] it was found that CBT aims to enable the patient to identify and modify unhelpful cognitions and behaviours and is effective in the treatment of a range of psychological problems, but limited evidence in improving glycaemic control. In regards to this aspect, Motivational Enhancement Therapy (MET) was used along with CBT in a randomised controlled trial with type-1 diabetes. The results proved that the

combined MET and CBT approach may be useful in individuals with persistent sub-optimally controlled diabetes, but MET appeared to be less effective than MET+CBT approach. This reflects that adding MET to CBT approach in dealing with type-1 diabetes can achieve good results.

Table 3-2 Summary of Cognitive Behavioural Therapy for Diabetes Management

No	Author, year	Sample	Duration	No of Studies	Study Design	Diabetes type	Results
1	Khalida et al., 2004[117]	N/A		25	N/A	Type 2 diabetes	There are improvements in long-term glycaemic control and psychological distress but not in weight control or blood glucose concentration in people who receive psychological therapies.
2	Winkley et al., 2006[118]	N/A		29	N/A	Type 1 diabetes	Psychological treatments can slightly improve glycaemic control in children and adolescents with diabetes but have no effect in adults.
3	Amsberg et al., 2009 [119]	94 patients	48 weeks	N/A	RCT, two studies with 3 months follow up, and 12 months follow up	Type 1	There is a significant impact on HbA1c
4	Ven et al., 2005 [19]	107 patients	3 months	N/A	RCT, three studies were assessed at baseline, directly before and 3 months after the intervention.	Type 1	CBGT was successful in improving self-efficacy, diabetes-related distress and mood at 3 months' follow-up, but not in improving glycaemic control.
5	Snoek et al., 2008 [20]	86 patients	12 months	N/A	RCT, two studies with 6 months follow up, and 12 months follow up	Type 1	CBT can effectively help Type 1 diabetic patients with co-morbid depression achieve and maintain better glycaemic outcomes.
6	Ismail et al., 2010[122]	344 patients MET+CBT (N=106), MET (N=117), usual care (n=121)	12 months	N/A	RCT, the patients were divided in to three groups usual care group, MET group, and MET+CBT group	Type 1	MET+CBT approach can deliver good results in diabetic management

From the mobile application perspective, more recently, CBT has been applied to mobile platforms. Furthermore, there are no studies found in the literature review linking the CBT and mobile application in managing diabetes. However, there are few commercial mobile applications available, which are concerned with CBT in general, but not in specific to diabetes management. These are discussed in the next.

'Thought diary pro' is one such mobile application that uses CBT in resolving a wide range of emotional and behavioural problems [123]. This smart phone application is designed to help people record and change the thoughts that cause emotional and psychological distress. It allows the identification of thinking errors (cognitive distortions), and the modification of our unhelpful thoughts into more productive ways of thinking. 'My thoughts' is another such similar application which is designed to control the thoughts. This application is a fun little program to keep your mind focused on your true potential. Every time you start it up, you are greeted with a positive, life-changing affirmation that helps in having positive thoughts [124].

There are other applications that use the same concept of CBT, but in different formats. 'MoodPanda' is one such application that is used for tracking the mood. The benefit of this process is that once you start to track your daily mood it sets a seed in your mind and you can start to concisely think of things that will make you happier and avoiding thing's that won't[125]. 'Cognitive Diary CBT Self-help' is another such application that helps in challenging the irrational thinking which causes many psychological and emotional problems. This application provides a simple way of doing this by reviewing the history of your recorded events [126].

3.4 Conclusion

In this chapter, the main behavioural change models for healthcare were presented. The key aspect of each theoretical models was also analysed in this chapter. This chapter also presented a detailed review of Cognitive Behavioural Therapy for diabetes management followed by discussions on this theory. The key outcomes of this reviewed chapter was that the Cognitive Behavioural Therapy was more effected on diabetes management and considered in this thesis for SANAD system

Chapter 4 : Saudi Arabia Networking for Aiding Diabetes (SANAD)

4.1 Introduction

This chapter presents the detailed design and implementation of SANAD system. These include:

1) The system overview of SANAD system.
2) The development process of the SANAD system.
3) A preliminary study on perception of managing diabetes mellitus through social networking in the kingdom of Saudi Arabia as user requirements.
4) The design and implementation of SANAD system.

4.2 SANAD System in Corporation with Cognitive Behavioural Therapy Approach

Figure 4.1 shows the general blocked diagram of the SANAD system developed in this work. It can be seen that the structured of SANAD consist of three building blocks:

1) Mobile diabetes management services: SANAD mobile diabetes management module will be designed to provide the basic functions of m-health such as add blood glucose reading by transferring it wirelessly and display the reading in a smart graphical chart.
2) Social networking services : SANAD social networking module will be designed to provide such social networking service as engage with diabetic patients, messaging and videos, as it will be mainly based on their clinical requirements and need (on one above).

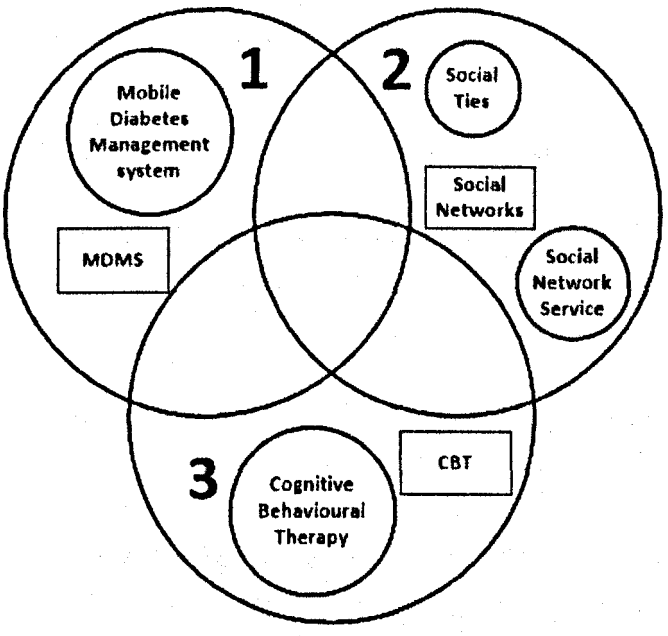

Figure 4-1 The Main Components of SANAD System

3) Apply a behavioural change method for improving and changing patient's health behaviour by using CBT model. SANAD behavioural change module will be designed to provide this technique.

Figure 4.2 shows the relationship and the theoretical framework among SANAD system modules. This figure also shows the potential impact and effect on diabetes management. In general, it shows integrated these three modules together into one system that could be improved self-efficacy, then improved glycaemic control, and enhanced diabetes management. The details and implementation of each of this building block will be described in details in the next chapter of this thesis.

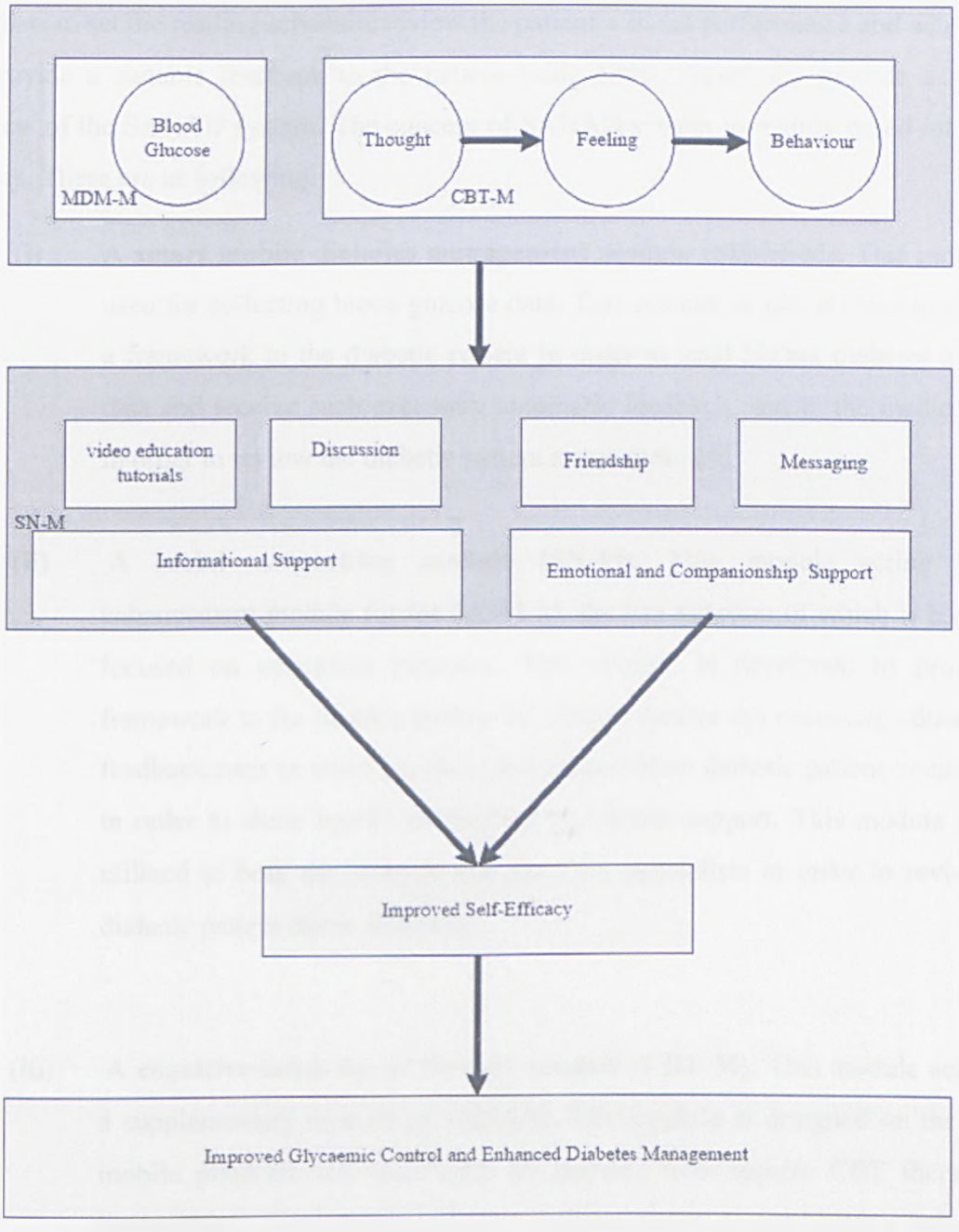

Figure 4-2 The Relationship and Theoretical Framework of SANAD System Modules and Their Potential Impact.

4.3 SANAD System Overview

The SANAD system comprises two main components. First, the patient end that comprises of SANAD smart app. The second is remote web portal hosted in a hospital. The mobile application facilitates sending, receiving and reviewing patient's diabetic data whereas the web portal application provide a framework to the diabetic and the CBT

specialists to set the reading schedule, review the patient's statue performance and adherence, and provide a suitable feedback to the patient using SMS. Figure 4.3 provide a general overview of the SANAD system. The concept of SANAD system in mainly based into three modules. These are as following:

(i) **A smart mobile diabetes management module (MDM-M).** This module is used for collecting blood glucose data. This module is also utilized to provide a framework to the diabetic patient in order to send his/her diabetes medical data and receive such necessary automatic feedback, and to the medical staff in order to review the diabetic patient statue remotely

(ii) **A social networking module (SN-M).** This module acting as an enhancement module for the MDM-M, the key function of which is currently focused on education purposes. This module is developed to provide a framework to the diabetic patient in order to receive the necessary educational feedback such as video tutorials, and contact other diabetic patient or caregiver in order to share health information and better support. This module is also utilized to both the diabetic and the CBT specialists in order to review the diabetic patient statue remotely.

(iii) **A cognitive behavioural therapy module (CBT-M).** This module acting as a supplementary module to MDM-M. This module is designed on the smart mobile platform and used only by patients who require CBT therapeutic intervention. This module is allows diabetic patient to send his/her behavioral change data and retrieve CBT specialties feedback on patient thought, feeling and behavioural. This module also allows the CBT specialties to review the behavioural change of the diabetic patient remotely. This module will completes the proposed SANAD diabetes management cycle.

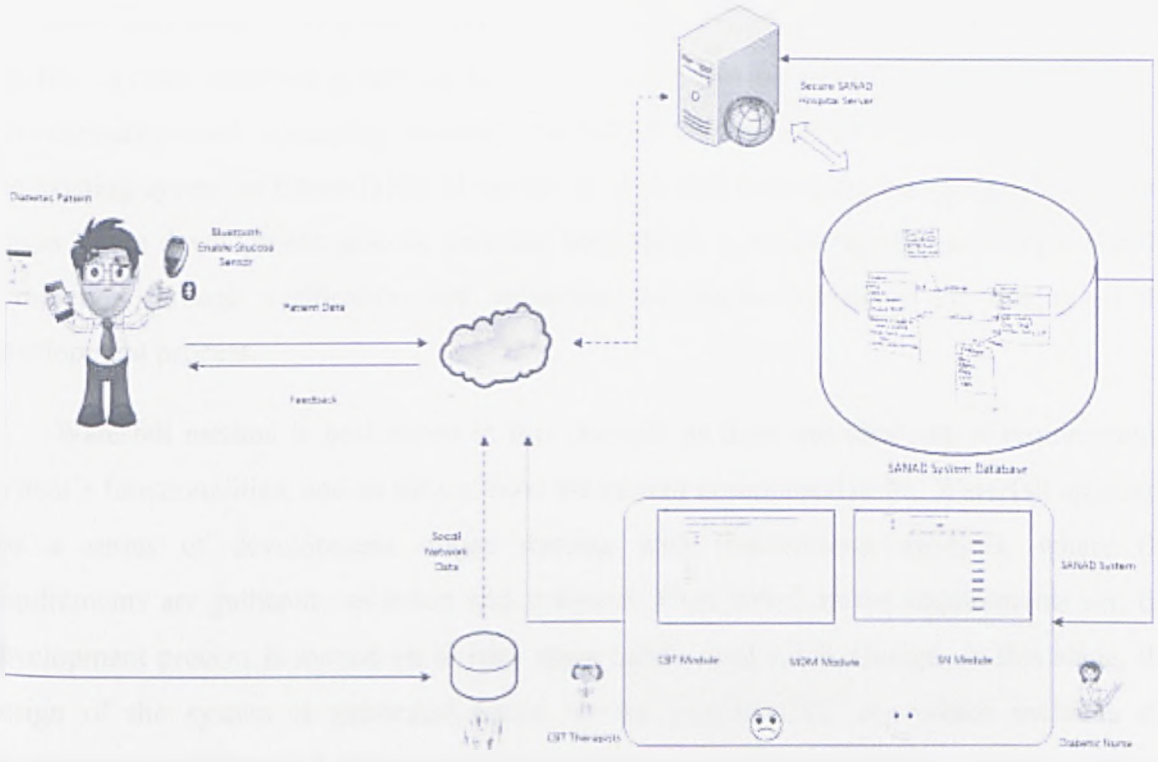

Figure 4-3 SANAD System

4.4 SANAD Development Method

Software development typically involves several phases [127][128]; specification, design, implementation, validation, and evolution. Different methodologies in software engineering can be used to manage the software development process, however due to the exploratory nature of the project, there is a need for using the method which is effective and flexible in adapting the changes during the development process. The study conducted in this thesis and the system development process can be complex as the requirements are assessed from different users' perspectives. Thus, the development methodology of this research is mainly based on top down approach / waterfall method.

Waterfall method is a sequential development process involving different stages, where each preceding stage has to be effectively reviewed and completed before moving to the next stage[129]. It is like the downward flow of development process, where each stage is systematically arranged to ensure the quality and efficiency of the system to be developed. Waterfall method is simple to use and has a linear and sequential development stages, which

is a major advantage. Unlike other development methods, the clients using waterfall approach can have a clear estimates or idea on the timeline, cost, and the size of the project. The strong documentation used in waterfall method would allow the enhancements and improvements to the existing system in future [130]. However, as it is very hard to fix the changes in the later stages of the development process, care has been taken in reviewing the each stage after its completion through verification and validation techniques to ensure the quality in the development process.

Waterfall method is best suited in this research as there are clear set of requirements, system's functionalities, and an idea of how the system is supposed to be. Waterfall approach has a series of development stages starting with requirements analysis, where the requirements are gathered, reviewed and analysed. Then based on the requirements set, the development process is moved on to next stage called Analysis & Design. In this stage, the design of the system is generated based on the requirements set, which includes the development of different designs using the concepts of Unified Modelling Language (UML). After completing the design phase, the development process is moved on to the next stage called implementation, where the actual system is developed. In the next stage, the developed system is validated and evaluated. If the system meets the specified requirements then it is deployed and maintained. These concepts are embedded in to the research developmental work, which is represented using the SANAD development method, as shown in the following figure 4.4:

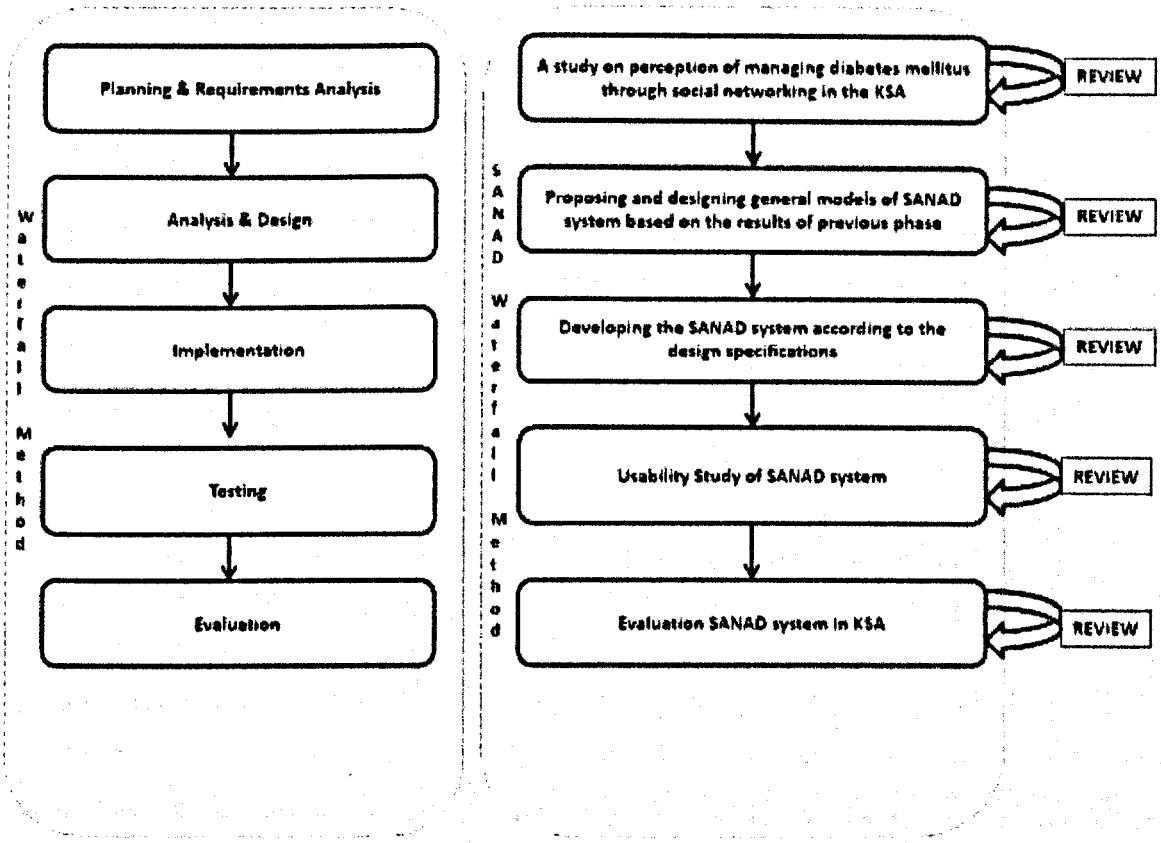

Figure 4-4 The General Waterfall Method and SANAD Waterfall Method

4.5 SANAD Requirements Analysis

4.5.1 Method

In order to explore clinical requirements and needs of SANAD system, a preliminary study on social networking was carried out both in the KSA and the UK. The study was divided into two phases: (1) Initial interview with diabetic specialist clinician from the KSA and the UK to understand the need for smart mobile management and social networking for diabetes management, and (2) a follow-up questionnaire designed to understand and identify the key social-networking elements required from a diabetic patient's perspective in the KSA. Two senior clinicians from the UK and the KSA participated in this initial phase that included a total of 30 diabetic patients. Clinical staff recruited patients during an office visit or by sending an SMS message.

There were two research instruments used in this study, i) an interview program contained 10 in-depth questions about the need for social networking tools, diabetes

management tools, and the main concern of the clinician, ii) a study survey based on the mobile diabetes management system of an earlier work was used [131]. The questionnaire was chosen because it matches the areas addressed in this work both diabetes management and social networking issues. The questionnaire used in this study is divided into four sections: basic information, diabetes management, social networking with social support, and a Saudi Arabia social network for diabetics. It was also translated into Arabic. The questionnaire structure as shown in Figure 4.5 is a sample snapshot of the online questionnaire used in this study. The design of questionnaire based on multiple choices and open questions.

The questionnaire was then published and posted online to a Saudi diabetic-patient group in the Dammam region using Google forms. All of the diabetic patients were informed that the information given would be kept confidential. A summary of the project is given at the top of the questionnaire, followed by a description of its importance and a notification that information gathered will be used for research purposes. Study participants completed a total of 30 questionnaires.

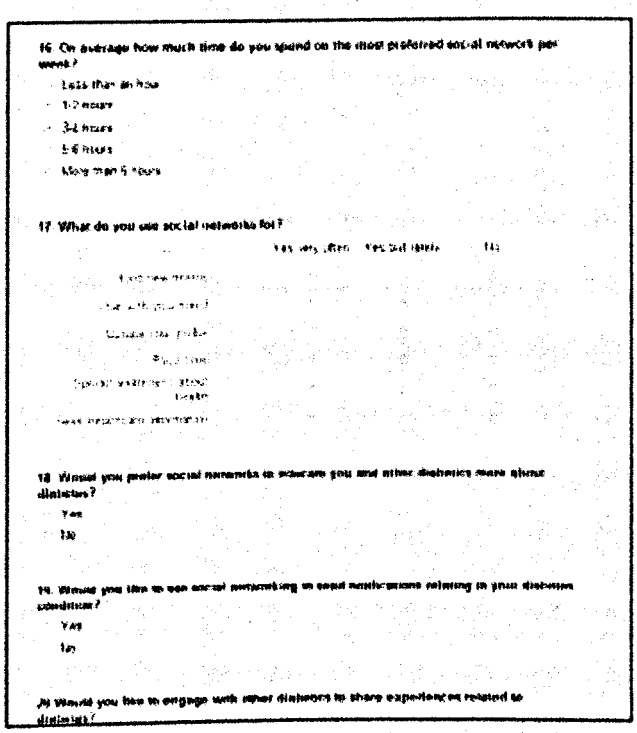

Figure 4-5 A Sample Snapshot of The Online Questionnaire Used In This Study

4.5.2 Results

Table 4.1 shows an overview of the demographics of patients used in this study. Participating patients (N=30) were predominantly male (n=21, 70%). The majority of the participants were between 18-40 years (n = 22, 73%). Almost all participants (n = 23, 77%) consulted a diabetes specialist at least once a month.

We also measured the way of accessing internet (n = 29, 97%) of respondents who had access the internet using PCs, laptops, and smart phones. All participants were engaged with online social network such as Facebook and Twitter (n = 30, 100%). The majority of the participants spent more than 6 hours weekly (n = 24, 80%) on social networks, 63% of mobile phone users use the iPhone as the most popular smart phone followed by HTC mobile type at 23%. Most of participants preferred to engage with a private social network tailored to Saudi diabetic patients (n = 24, 80%).

Table 4-1 : Study Patients' Demographics

General characteristics		*N*	*%*
Gender	Male	21	(70)
	Female	9	(30)
Age group	18-40	22	(73)
	41-50	8	(27)
	51-65	0	(0)
Diabetes specialist consultation	More than once	23	(77)
	Once a month	5	(17)
	Other	2	(7)
Computerized characteristics			
Internet access	PC/Labtop	29	(97)
	Smartphone	29	(97)
Smart phone type	iPhone	19	(63)
	Blackberry	4	(13)
	HTC	7	(23)
	Nokia	0	(0)
	Other	0	(0)

General characteristics		N	%
Engaged with web social network	Yes	30	(100)
	No	0	(0)
Average time spending on social network	Less than an hour	0	(0)
	1-2 hours	0	(0)
	3-4 hours	0	(0)
	5-6 hours	6	(20)
	More than 6 hours	24	(80)
Prefer to use private social network for Saudi diabetics	Yes	24	(80)
	No	6	(20)

From the patient's requirements and needs perspectives, the following results were the most significant outcomes and proposed design decisions were made based upon them:

i. A total number of diabetic patient participating (n=30) prefer the following social networking functionalities to be incorporated in the proposed system which are: (i) ask a doctor (n = 30, 100%), (ii) messaging (n =30, 100%), (iii) blogs (n = 27, 90%), (iv) video education tutorials on diabetes (n =20, 67%). Figure 4.6 shows a graphical chart presented those functionalities.

ii. A total of (n=30,100%) and (n=23, 77%) of respondents prefer to receive real-time feedback by SMS and E-mail respectively.

iii. A total of (n=22, 73%) of respondents prefer to manage their diabetic condition by using a social networking system.

iv. A total of (n=27, 87%) of respondents would like to share experiences of their diabetic condition with other diabetics friends and relatives by using social networking system.

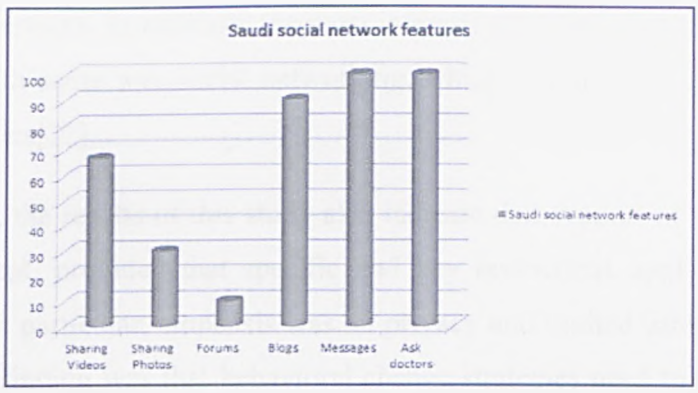

Figure 4-6 Patients Preference for Social-Networking Functionalities in The Proposed System

From the clinician requirements and recommendations perspectives, the summary of the outcomes from the UK and the KSA clinician surveyed in this study indicated the following requirements:

i. The system should include an emphasis on privacy and limited information exchange due to the social and religious issues in the KSA.
ii. The system should include social-networking elements and diabetes self-management elements for enhanced diabetes management in the KSA.
iii. The system should contain a reminder element delivered via either SMS, e-mail, or a private message.
iv. The system should have a simple mechanism for interactivity between patients and clinicians.
v. The system should include behavioral change strategies based on such health behavioral change theory.

4.5.3 Study Summary

The results of this preliminary study can conclude that the acceptance of Saudi patients for using social networking as a tool for better managements of their diabetes is relatively high. This acceptance is specifically high in younger population (18 – 40 years), whom preferred the use of a private Saudi social networking tool for managing their condition. Another important finding was that the preferred social-networking functionalities —such as ask a doctor, messaging, blogs and video tutorials, had the highest percentages of suggested functionalities. It is interesting to note that most of the patients prefer to have a real-time

feedback via SMS services. In addition, the most interesting finding was that all of the Saudi patients engaged with some web social networking, which is consistent with other research outcomes and statistics[22].

Furthermore, the results of this study also indicate that support of the KSA specialist for such new concept, provided that specific and key restrictions apply to any proposed network structure. In particular, emphasis was on privacy and limited information exchange. Another interesting finding was that behavioral change strategies need to be included in the proposed system to assist patients in changing their behaviour as part of the management cycle. In conclusion, there is substantial support for the adoption of social networking in enhancing healthcare awareness in the KSA.

4.6 SANAD System Analysis and Design

In this section, we describe the SANAD system design including, SANAD functions and non-functions requirements, uses cases and the building block of SANAD system.

4.6.1 Function Requirements

In general, terms, the system requirements with respect to the SANAD system are mainly classified in to functional and non-functional requirements. The functional requirements defines the behaviour of the system or what a system must do, while the non-functional requirements defines or elaborates the performance characteristics of the system or how the system shall be [132][133]. These requirements of the SANAD system are mainly drawn from the problem statement, literature reviews, KSA and UK medical collaborators and from the preliminary user requirements study discussed earlier.

As shown in figure 4.1, the system has mainly three modules, and therefore the functional requirements of the system are specified from the SANAD modules perspectives, which are summarised below:

a) Mobile Diabetes Management Module Requirements

- Providing a customised page that allows the diabetes medical staff to register the patient in the system.

- Transmitting the blood glucose levels from the glucometer to the mobile device using the medical sensor, and then to the server.
- Providing automated feedbacks regarding the current diabetes management status of the patient, especially relating to the blood glucose levels.
- Providing a customised page that allows the patients to review his/her health data over a period of time in a graphical user interface such as charts and tables.
- Providing a customised page that allows the diabetes medical staff to record the patient's health data in the system.
- Providing a customised page that allows the diabetes medical staff to schedule the timings related to the collection of patients' readings.
- Providing a customised page that allows diabetes medical staff to review the patient's health data over a period of time using graphical user interface such as charts and tables.
- Providing a customised page that allows the diabetes medical staff to send feedbacks to the patients regarding their diabetes management status.

b) **Social Networking Module Requirements**

- Providing a customised page that allows the patients to find friends and add them to his/her friends list.
- Providing a customised page that allows the patient to share health related information (educational) with other diabetic patients.
- Providing a customised page that allows the patient to communicate and send private messages to other users in the SANAD system.
- Providing a customised page that allows the patient to view and watch educational videos and tutorials.
- Providing a customised page that allows the diabetes medical staff to communicate with other diabetic patients.
- Providing a customised page that allows the diabetes medical staff to post educational videos and tutorials.

- Providing a customised page that allows the CBT therapist to post behavioural change videos and tutorials.

c) Cognitive Behavioural Therapy Module Requirement

- Collecting behavioural change data (thought, mood and action).
- Providing a customised page that allows the patient to review his/her behavioural change data over a period of time using graphical user interface such as charts and tables.
- Providing an automated feedback regarding the current behavioural change status of the patient.
- Providing a customised page that allows the CBT therapist to record the patient's behavioural change data in the system.
- Providing a customised page that allows the CBT therapist to set the classification algorithm regarding the behavioural change process.
- Providing a customised page that allows the CBT therapist to set the messaging box regarding the behavioural change process.
- Providing a customised page that allows CBT therapist to review the patient's behavioural change data over a period of time using graphical user interface such as charts and tables.
- Providing a customised page that allows the CBT therapist to send feedbacks to the patients regarding their behavioural change process.

4.6.2 Non-Functional Requirements

- Extensibility: As the changes occur in the areas of technology and healthcare delivery, the system must be able to integrate the new modules or components in to its architecture.
- Maintainability: After the implementation, the system must support in adapting both malignant and the benign changes focused on improving the quality attributes, and also in updating the components and features.
- Privacy: The personal data in the system must be accessed only by the authorized users of the systems or devices.

- Usability: As the users and patients of the system may be new to this kind of treatment, the system must be easy to use with attractive graphical user interface, processing speed, and in providing support in using the devices.
- Reliability: The system must be reliable, as the diagnosis and treatment processes are controlled remotely, and the patients are completely dependent on the system in managing their blood glucose levels.
- Portability: The system must be portable, as it can be implemented in other similar locations or regions, where it is possible.

4.6.3 SANAD System Uses Cases

A Use Case diagram depicts the interactions between the actors and the system. It can also depict the overall view of the system's functioning; therefore it can also be considered as the blueprint of the system [134]. Basically it has four major elements, which include 1) the actors with which the system interacts (represented as stick figures), 2) the use cases, or services which are performed by the system (represented as ellipses), 3) the system itself, and 4) the lines that represent the relationships between these elements[135][136].

The use case diagram of the SANAD System is shown in Figure 4.7 .The diagram depicts three users/ actors that include the diabetes patients, the diabetes medical staff, and the CBT Specialist. The MDM-M use case extends the relationship to the three use cases, which include historical record, reminders, and schedule reading time. This module is accessed by the patients to view their historical data, reminders; and the diabetes medical staff uses this module to view the historical data and readings, and for scheduling the reading time.

The CBT-M element includes relationship to three use cases that include classification algorithm, data record, and feedback. This module is accessed by the CBT Specialist to update the classification algorithm according to the health data record, and to provide feedback; and by the diabetes patients to update their behavioural data and to view the information in their CBT therapy. The SN-M use case includes the relationship to four use cases, mainly messages, search and find friend, educational material, and post comments.

The SN-M functionality is used by the diabetes medical staff and the patients to chat with other actors and to share health related information, as shown in the included use cases.

The data collection use case extends the relationship to two other use cases that include health diabetes data, and behavioural change data. Health diabetes data use case further extends the relationship to the four use cases including HbA1C, BMI, BG, and length. This module is only focused with the function of collecting the diabetes related information. The behavioural change data use case further extends the relationship to the three use cases that include thought, mood, and behaviour. This module includes the function of collecting the behavioural data of the patients. All the three actors are associated with the data collection use case as the diabetes patients provides the data, and the other actors including the diabetes medical staff, and the CBT therapist can access this data.

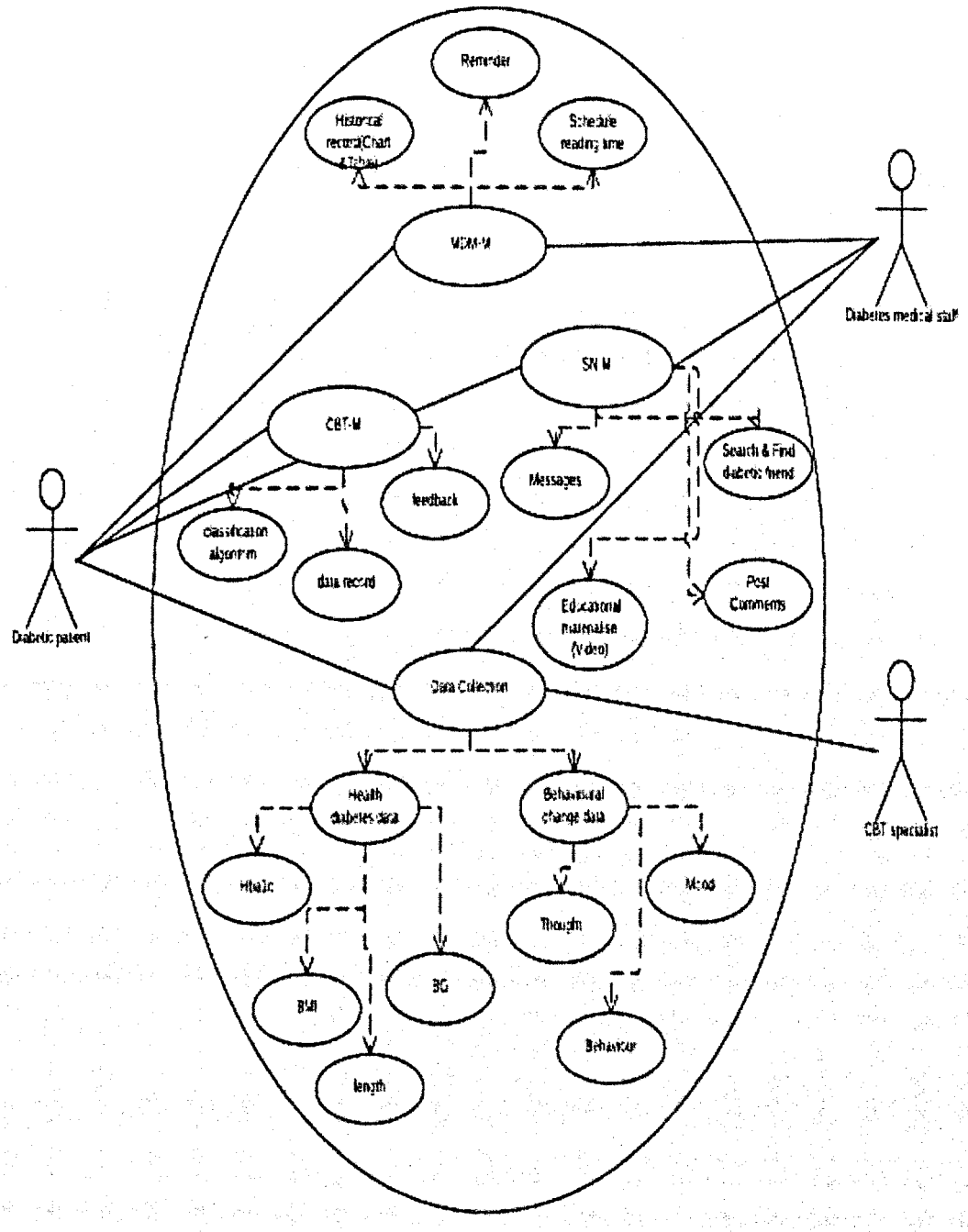

Figure 4-7 SANAD System Use Case Diagram

4.6.4 Building Blocks of SANAD System

The general building blocks of the social networking system includes relationship control, social graph, actor profiles, social presence, participation model, website contents and application, and infrastructure services model. Considering this architecture, the major building blocks of SANAD system are developed, as shown in the figure 4.8, and explained in the following points.

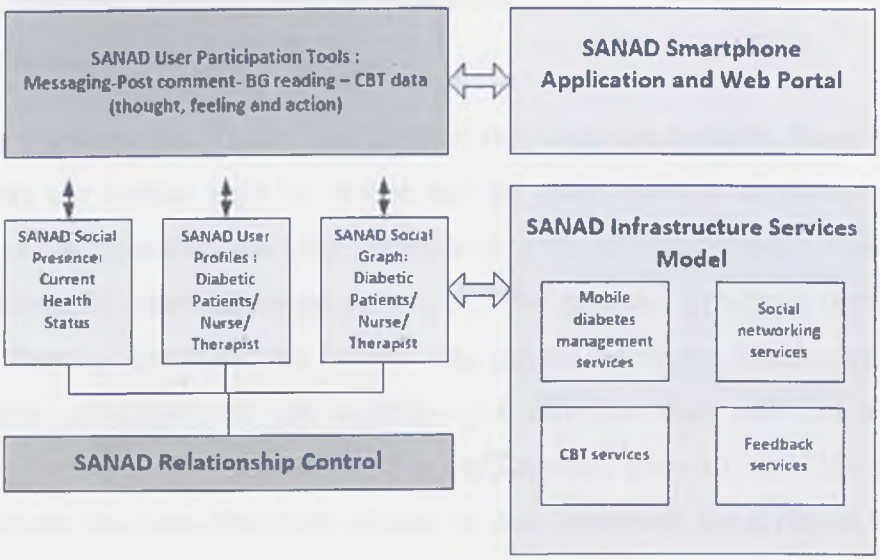

Figure 4-8 Building Blocks of the SANAD System

SANAD Relationship Control: The relationship control in SANAD system is a friend relationship with diabetic patients ,diabetic nurses and CBT therapist.

SANAD Social Graph: The social graph of SANAD is signified by the following type of friendship relationships: diabetic patients to diabetic patients, diabetic patients to diabetic nurses, diabetic patients to CBT therapist.

SANAD User Profiles: The user profile represents the personal information of a person. These profiles can include different types of information based on the needs and the requirements of a system. A user profile can also be digitally represented on a system. The users can also be specified as actors. There are mainly three types of actors in the SANAD system: diabetic patients, diabetic nurse, and CBT therapist.

SANAD Social Presence : Social presence is the degree of salience (quality or state of being there) between two communicators using a communication medium [137]. This feature is quite a new model in a social network framework. The type of media used plays an important role in the social presence theory. For example, face to face video or mobile calls have higher social presence than other media. Mediums with high social presence are sociable, warm, and personal; and mediums with low social presence are less personal. With the social networking context, the social presence nowadays is known as the user's current status, which reflects the description of the users' activity. The Social presence in the SANAD System is well known as current health status.

SANAD User Participation Tools: User participation tools are basically those tools, using which the users can interact with the system and the other users of the system. There are different types of user participation tools, as required by the different systems. For example, a group chat window in Facebook messenger is a tool that provides a platform for the users to participate in chatting. Similarly, the features like instant messaging, posting comments or messages, offline messaging etc. are available with different tools, and can improve the experience of the users in participation. The participation tools of SANAD system are messaging between the users, the ability of users to post comments, the ability of the diabetic patients to insert their reading information, and the ability of users to submit their therapeutic data.

SANAD Smartphone Application and Web Portal: The SANAD system comprises two main applications. First, mobile application, which is downloaded on the patient's smartphone. The second is web portal application, which is hosted on the hospital.

SANAD Infrastructure Services Model: In this model, the content and services of SANAD system are included as following: i) mobile diabetes management services, ii) social networking services, iii) CBT services, and iv) feedback services.

4.7 SANAD System Implementation

In this section, we present the implementation of SANAD system. The SANAD system comprises two main applications, which are smart mobile application and web petrol application, and these two applications are mainly based into three modules discussed earlier. Thus, this section is specified from the SANAD modules perspectives.

In general, a custom server PHP application is used to support remote log-in. This custom server is also used to review diabetic patient data, user settings, and provide such feedback by the medical staff. In addition to viewing patient data and assessment results, a key feature was allowing diabetic patients to access via the web rather than mobile use. Diabetic patient data was stored on a remote Microsoft MS-SQL secure database server portal. The mobile phone platform is implemented using Android OS and the JAVA SDK. The blood glucose sensor using Bluetooth (Polymap Wireless adaptor) is also used for transferring the data to the mobile app. GALAXY S III is used as the mobile phone, running Android 4.0 to send the clinical data in a real time to the server portal. For more details of the implementation tools used in this thesis, see appendix (A).

4.7.1 Mobile Diabetes Management Module

This module consist of two main components i) patient's mobile diabetes end, and ii) remote server and web portal interface for diabetic staff end. The patient end consists of an Android based smart phone equipped with a special (myDiabetes) smart App developed for this purpose. The myDiabetes App was linked wirelessly via a Bluetooth adaptor (Polymap Wireless) linked to the patient's blood glucose monitor (OneTouch Ultra 2 blood glucose monitor (LifeScan Inc., Milpitas, CA). The patient glucose level measurements and medical data were sent wirelessly to the remote server using local HSXPA (3.5G or 4G) cellular and internet network connectivity. The patient was able to display their blood glucose data in graphical presentation such as table and chart. The remote server and web portal interface for diabetic staff end consist of the SANAD health information and management system, which assists the medical staff to schedule the reading time and date and send such feedback and observe the statue of the panties remotely. Apart from the web and internet technology, text

messaging was also used to improve the diabetes management, by acting as a medium of communication.

4.7.2 Social Networking Module

The key function of this module is to provide the necessary social information required for the SANAD system. This module consist of patient's mobile social networking end (mySocial), which provides to the patient: i) a simple mechanism for interactivity between the patients and the clinicians; and ii) display a video education tutorials on diabetes; and web portal medical staff end, which assists them to interact with patients and post educational videos, tutorials and useful information.

4.7.3 Cognitive Behavioural Therapy Module

. This module consists of a patient's mobile CBT component (myThought). This module assists the patient in providing his/her CBT data remotely via the smartphone App. It will also display the patient's CBT (thought, mood, and action) in graphical presentation, such as in formats of tables or charts, linked with a web-portal CBT specialist component; this will assist the therapist in sending feedback and observing the state of the patient's behavioural changes remotely. This module will aid in CBT intervention by applying a specific classification algorithm to decide whether or not to trigger an intervention via SMS message, instructing the patient to submit his or her CBT data. The CBT cycle in SANAD system is shown in figure 4.9.

The CBT-M cycle starts from the event in which high blood glucose levels of the patients are recorded or observed from the diabetes management system. In such an event, and based on the classification algorithm, detailed in the next section, the system will automatically send an SMS to the patient, requesting the submission of his or her CBT data. The patient will then submit the CBT data, which comprises thought, mood, and action. The patient is required to select the appropriate options, which define the thought, mood, and action at the point of time when the list is displayed on their mobile screens and when accessing the CBT-M module application. These actions are discussed in detail in the following section, which completes the CBT-M cycle.

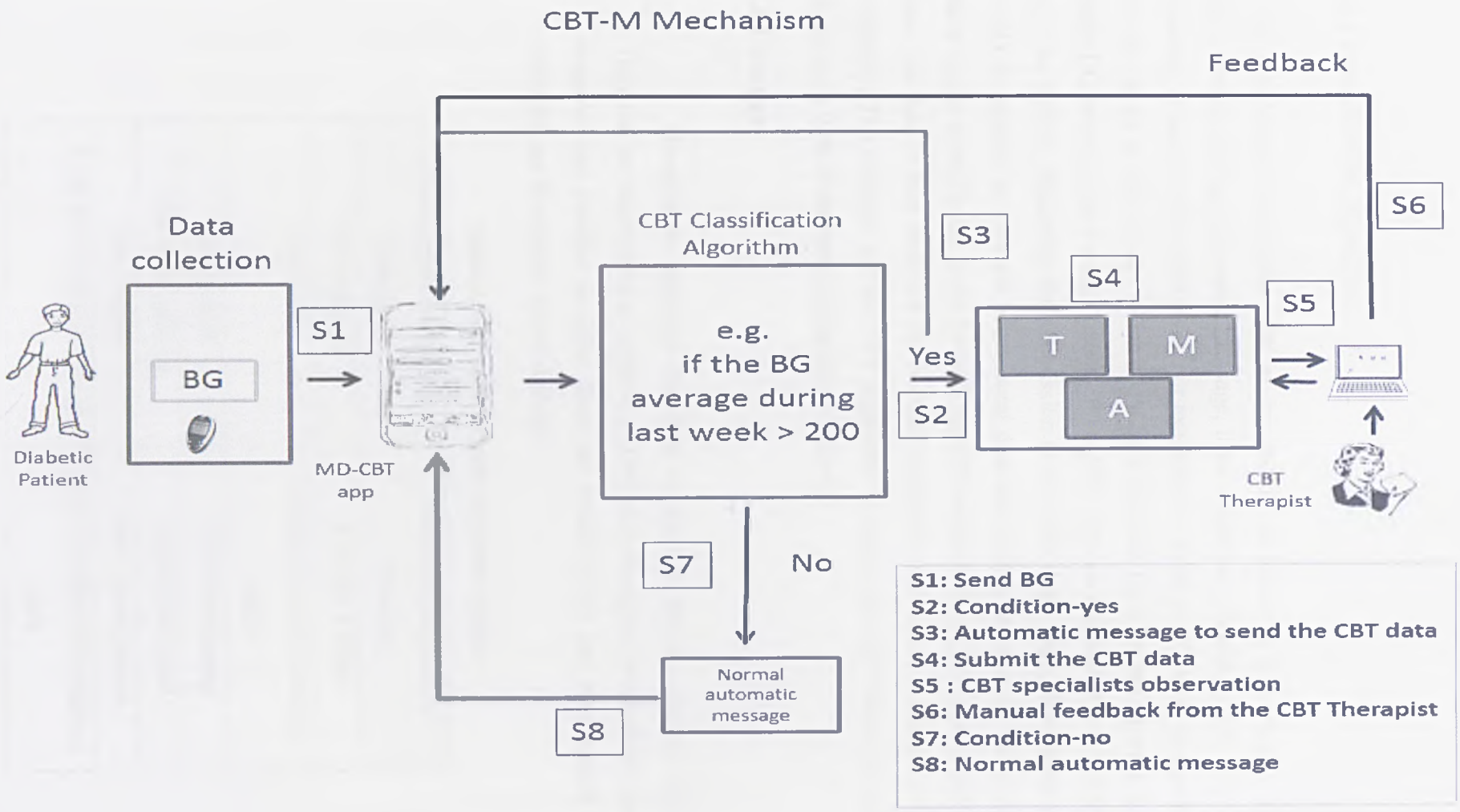

Figure 4-9 CBT-M cycle

4.7.3.1 Classification Algorithm

The classification algorithm used in this unit is the software that triggers the CBT-M therapy module and the automated message, if the specified criterion is met. The criterion is the reading of the blood glucose level. For example, the average BG level of a patient for one week can be set at 200 mg/dL, which could be a criterion for a patient. In case the patient's average BG level during a week crosses 200 mg/dL, then an automated text message will be sent to the patient, requesting the submission of the CBT data. Then, the patient will access the CBT-M module to load the behavioural data and submit the data by selecting the most suitable option from the list given for each specific component, including thought, mood, and action. The data is then analysed by the CBT therapist, who sends feedback to the patient accordingly. The criterion for the CBT algorithm is set by the CBT therapist, based on the each patient's type of diabetes and health condition.

4.7.3.2 Thought

Thoughts are basically the ideas or opinions that are derived from thinking. They can be categorized as positive and negative thoughts. Some of the most popular negative and positive thoughts from the review [138] and consultation with CBT specialist are developed, which include:

Table 4-2 Most Popular Negative and Positive Thoughts

Most popular negative thoughts	Most popular positive thoughts
I am confused	I can do it better
I am afraid	I will learn to love and be happy
I am scared	Life is interesting
I have no patience	I really feel good
I am stupid	I am a good person
I am not capable of loving	I really handled this situation well

My hopes have vanished	I like people
I will never be able to change	I will find strength to solve any difficulty
I have no enthusiasm for anything	I am honest
Everything is my fault	I am very responsible
I am inferior to others	I am important to my family
Life isn't worth it	I am lucky
I am not as good as others	I am intelligent.

The patients can choose their thoughts from the table and move on to the next step, where they can define their mood.

4.7.3.3 Mood

Mood is the temporary state of mind or a feeling that is presented in a person at a certain point of time. The mood can be different in different time periods. However, the mood can be categorized into different sets of feelings and can be numbered in order to analyse the changes in the mood of a person [139]. This process can be reflected on a mood scale. The patients can select their mood as shown in the table 4.3, and move on to the next step, where they can define their action.

Table 4-3 Mood scale

Mood scale	Scale weight
The best	9
Much better	8
Better	7
Better than regular	6
Regular	5
Worse than regular	4
Worse	3
Much worse	2
The worst	1

4.7.3.4 Action

Action is the process of doing something, and it defines the patients' behaviour. Therefore, an action list is developed for this purpose[138], where the patients can choose the actions they have done. The list is shown in the following table.

Table 4-4 Most Popular Actions

Most popular actions
Wear clothes I like
Watch or participate in sports
Help groups I respect (NGO/ local community)
Buy things
Talk to my friends
Read books, magazines, and newspapers
Drive a car
Do my job
Sing
Watch nature
Give gifts
Take pictures
Listen to jokes
Pray

After filling the action part, the patients can submit their selection data remotely. This data will be reviewed by the CBT therapist, and will send the suggestions and feedback to the patients as required.

4.7.4 Feedback Mechanism and Messaging Box Module

The key function of this module is to provide the necessary gate for the medical staff and the CBT therapist to set and send automated and manual feedback to the diabetic patients. The following points are the main features of this module:

1) Automated feedback: The system will send automated text messages to the diabetes patients, which may include reminders, feedbacks, acknowledgements etc.
2) Diabetes status feedback: Based on the readings, the diabetes nurse will use the web-based portal to design customised manual messages and feedback and then send it to the patients.
3) Behavioural status feedback: Based on the readings, the CBT Therapist will use the web-based portal to design customised manual messages and feedback and then send it to the patients.
4) Messaging box: The system will have a messaging box, where all the messages are saved and can be used for reference. A sample of theses messaging is shown in table 4.5.

Table 4-5 Examples of SANAD Text Messages

Message categories	Example messages
Reminder	Could you please submit your blood glucose level
General Automated Feedback	Could please have a look to diabetes Video in the social networking module
Acknowledgement	Your thought has been sent. Thank you
Diabetes Status Feedback	Your blood glucose level was normal during the last week.
Behavioural Status Feedback	We have noticed that your mood level was up to normal last month.in this case, we need to talk more via the social networking module

4.7.5 Database Module

The data used in the system functioning is stored in the SQL database server. The database is designed using the tables with different attributes. The data is stored in these tables and can be retrieved, updated, edited, inserted according to the requirements of the users while using the system. There are 11 tables in the SANAD System database which include schedule, reading, healthdata, messagingbox, thought, user, video, video_categories, messages, messages_conversations, and search tables.

4.8 Hierarchical Structure of SANAD System

The GUI and the hierarchical structure of the system running on the mobile devices and webserver are presented in figures 4.10 and 4.11.

(a) (b) (c)

(d) (e) (f)

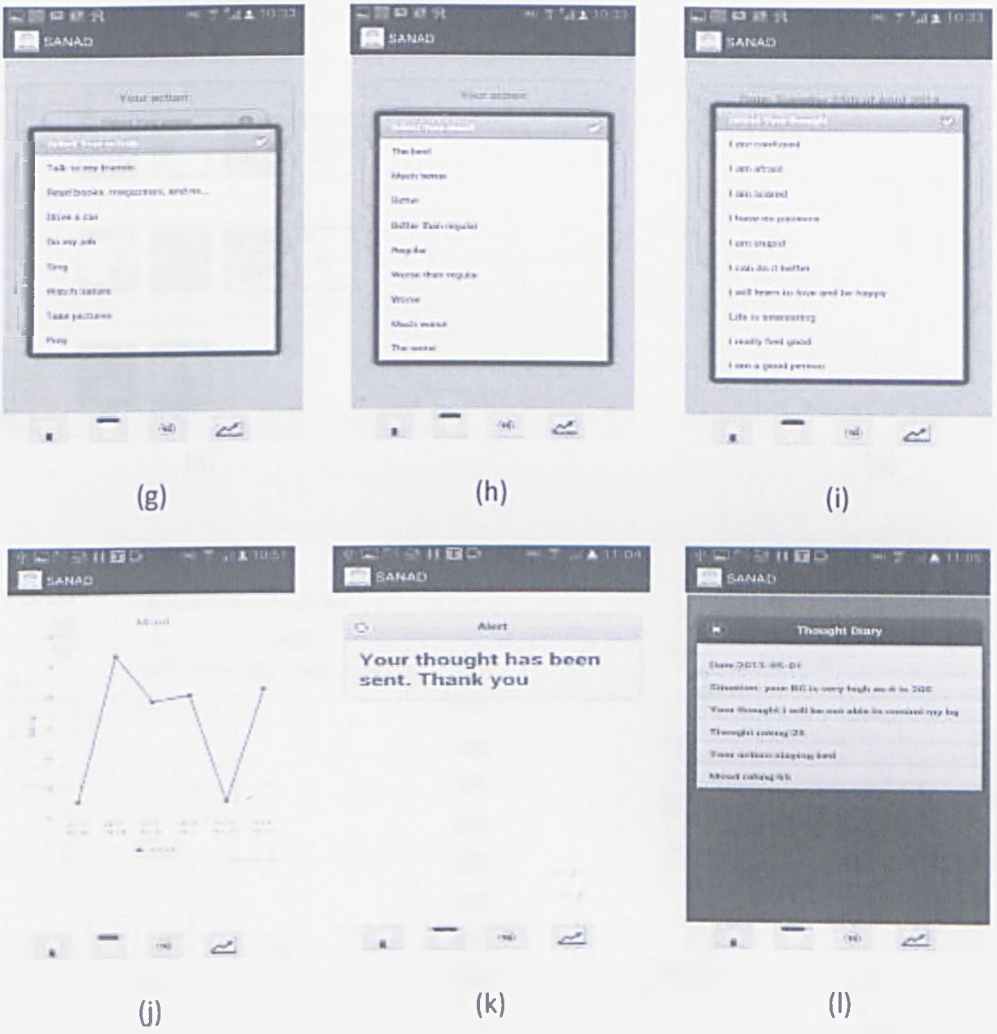

Figure 4-10 Snapshots of The Diabetic Patient Smart Phone Interfaces in SANAD System

(a) (b)

(c) (d)

Figure 4-11 (a,b) Snapshots of The Diabetic Nurse Portal Interface End, (c,d) Snapshots of CBT Therapist's Portal Interface End in SANAD System

4.9 Conclusion

In this chapter, we presented the general design and implementation of SANAD system. In particularly, we presented the details of :

1) The preliminary study on the perceptions with the aim of Saudi diabetic patients and medical staff requirements and needs for mobile diabetes management conducted in KSA.
2) The design and development of a new mobile diabetes management system embedding social network and behavioural change intervention modules tailored for Saudi diabetic patients.
3) The relevant modules and their functionality of SANAD system.

Chapter 5 : Usability Study of SANAD System

5.1 Introduction

As described in chapter 4, the development process of SANAD system includes usability evaluation study. This chapter presents the usability study results of SANAD system among Saudi Type 2 diabetes patients. The aim of this usability study was to assess the usability factors that have influenced the design of the SANAD system, to identify perceptions of its usability factors among Saudi type 2 diabetic patients in Saudi Arabia. In this chapter, we also presents an overview of the importance of usability factors with mobile health particularity in SANAD system, the study design and method used in the usability study and the preliminary results of this study and discussion.

5.2 Usability for m-Health System

The usability feature in mobile smartphone applications is gaining importance, as there is tremendous growth in the usage of mobile devices and applications across the globe. The usability of mobile applications in m-health aspect, is also gaining importance, as there are many research studies being carried out, and there are many procedures being implemented in the delivery of healthcare such as SMS (Short Message Service), mobile applications, video conferencing and being a part of tele-monitoring and tele-diagnosis[74]. The benefits of usability testing of mobile health applications include reducing measurement error, and respondent burden. The trend for mobile phone users to purchase smartphones is on the rise[140] . This means that health users, such as diabetes patients, will have more choice as new applications are developed, increasing the competition and demand for high performance systems. The usability of a system, such as a smartphone mobile health application is guided by Human-Computer-Interaction (HCI), which is the interface between the system and the user. The overall idea behind defining system usability relates to the effectiveness and efficiency of that system in achieving the specified goals, and the satisfaction levels of its users. The term usability is defined variously as the efficacy and efficiency of the interface and users reactions to the interface [141]; as user acceptance,

including a combination of both practical acceptability (e.g., system functionalities such as speed, reliability, compatibility, usefulness (i.e., achieving its specified objectives in terms of utility and usability)), which mediates the system's social acceptability [142]. Utility and usability refer to identifying if a system is doing what it is supposed to do; and how well users are able to use the system, respectively, including itslearnability, efficiency, memorability, error preventability and process control, and user satisfaction [143]. Shackel defined four aspects of system usability including effectiveness, learnability, flexibility, and attitude [144]. Similarly, Rubin and Chisnell defined system usability asits usefulness, effectiveness, learnability, and attitudes [145]. Smith and Mayes (cited in Carvalho, 2001) defined usability as: easy to learn, easy to use and user satisfaction levels [141]. As there is no consistent definition or model of system usability, the present study has operationalized the usability of the SANAD system as five constructs: overall reaction; screen factors; terminology and system information; learning factors; and system capabilities.

5.3 SANAD Usability Study

5.3.1 Methods

5.3.1.1 Study Setting and Participants

A preliminary evaluation study of the SANAD system was carried out in the Dammam region in KSA in collaboration with the medical school in the region. The main objective of the study was to investigate the usability aspects of the SANAD system among the Saudi diabetes patients. The participants constituted of 33 type 2 diabetic patients (17 male, 16 female). The study was conducted in the Dammam region of Saudi Arabia. Patients were recruited by clinical staff during an office visit or by sending an SMS message.

Three tasks are designed, based on the three functional of the system which are carried out using the SANAD system. Care was taken to ensure that the tasks were simple and met the purpose of the application. These tasks include the following:

1) Perception toward the SANAD mobile diabetes management module: measuring blood glucose level by using this module and sending it to the SANAD server;

2) Perception toward the SANAD social networking module services: sending a private message to the nurse or other friend, watching videos, searching and finding a friend;

3) Perception toward the SANAD CBT module: submitting his/her CBT data to the server, and the system displaying the data in chart and tables.

5.3.1.2 Measurement Tools

Questionnaire for User Interaction Satisfaction (QUIS) was used in this research for designing the questionnaires for the survey. QUIS was developed by Shneiderman, and is based on OAI (Object-Action Interface) model [146]. The assessment of the satisfaction levels of the users is subjective and a complex question, and to overcome this, QUIS was used as it gauges the satisfaction aspect of software usability in a standard, reliable, and valid way. QUIS was first implemented using a nine point Likert scale rating on a standard paper and pencil form. It focuses on the analysis of usability features based on six aspects, which include overall reaction to the system, screen factors, terminology and system feedback, learning factors, system capabilities[142].

By using QUIS version 7.0, the questionnaire is arranged in a hierarchical format which includes:

1) Demographic questionnaire,
2) Six scales for measuring overall reaction ratings of the system including terrible / wonderful, difficult / easy, frustrating / satisfying, inadequate power / adequate power, dull / stimulating and rigid / flexible.
3) Four measures including screen factors, terminology and system feedback, learning factors, system capabilities, for analysing interface aspects.

Each item in the QUIS questionnaire is rated on a scale of 1 to 9, and an additional option 'N/A (Not applicable), is also provided, in case the users feels that the questionnaire is not applicable to them. [147].

Statistical data visualisation tools like bar charts, and box plots are used to display and analyse the survey results. Bar charts were used to represent the difference between mean of an item and the selected criterion. Means and standard deviation for each item in the questionnaire and diagnostic tests [148] were carried out in this research. Overall means are calculated in each section for indicating if the mean of an item is above or below the

criterion. To determine the reliability of the mean, 95% upper and lower confidence intervals at the 0.05 level of significance are plotted during the analysis of results.

5.3.2 Results and Discussion

5.3.2.1 Patient's Demographics

Thirty-three patients with type 2 diabetes, who were recruited from the outpatient clinic in Naval Technical Institute Clinic, completed the study. The demographic and clinical characteristics of the study groups are summarised in Table 5.1. The participants were both men and women (17 male, 16 female), the large majority were aged 41-50 years, and the majority had a diagnosis of diabetes for five years or less.

Table 5-1: Patients Demographics

General characteristics		Type 2 n	Type 2 %
Gender	Male	17	(48.5)
	Female	16	(51.5)
Age group	18-40	14	(42.4)
	41-50	18	(45.5)
	51-65	1	(3)
level of education	Secondary	16	(48.5)
	Diploma	7	(21.2)
	University or more	10	(30.3)
marital status	Married	12	(36.4)
	Widowed/Divorced	12	(36.4)
	Never married	9	(27.3)
diagnosed with diabetes long	≤ 5 years	13	(39.4)
	6-10 years	8	(24.2)
	11-15 years	5	(15.2)
	> 15 years	7	(21.2)

5.3.2.2 Saudi Type 2 Diabetes Patients Group

Table 5.2 presents the means and standard deviations of each item in 95% Confidence Intervals for each items in QUIS of SANAD study

Table 5-2: Means, Standard Deviations and 95% Confidence Intervals for items in QUIS and related to SANAD

No	Overall	Mean	SD	95 %	
				Lower	Upper
1	Terrible / Wonderful	6.79	1.24	6.35	7.23
2	Difficult / Easy	6.33	0.92	6.01	6.66
3	Frustrating / Satisfying	6.64	1.32	6.17	7.10
4	Inadequate power / Adequate power	6.24	1.30	5.78	6.70
5	Dull / Stimulating	6.39	1.14	5.99	6.80
6	Rigid / Flexible	6.00	0.97	5.66	6.34
	Screen	M=6.40			
1	Characters on the mobile screen	6.45	1.06	6.08	6.83
2	Highlighting on the screen	6.36	1.14	5.96	6.77
3	Screen layouts were helpful	6.03	0.98	5.68	6.38
4	Sequence of screens	6.67	1.22	6.24	7.10
	Terminology & System Information	M=6.38			
1	Use of terminology throughout system	6.58	1.12	6.18	6.97
2	Terminology relates well to the work you are doing.	6.55	1.18	6.13	6.96
3	Messages which appear on screen (inconsistent/consistent)	6.21	1.05	5.84	6.59
4	Messages which appear on screen (confusing/clear)	6.09	1.07	5.71	6.47
5	Mobile keeps you informed about what it is doing	6.27	1.10	5.88	6.66
6	Error messages	6.15	1.20	5.73	6.58
	Learning factors	M=6.31			
1	Learning to operate the system	6.76	1.25	6.31	7.20
2	Exploration of features by trial and error	6.12	1.14	5.72	6.53
3	Remembering names and use of commands	6.58	1.20	6.15	7.00
4	Tasks can be performed in a straight-forward manner	5.91	0.84	5.61	6.21
	System Capabilities	M=6.34			
1	System speed	6.39	1.14	5.99	6.80
2	The system is reliable	5.97	1.07	5.59	6.35
3	System tends to be	6.97	1.29	6.51	7.43
4	Correcting your mistakes	6.27	1.18	5.85	6.69
5	Ease of operation depends on your level of experience	6.15	1.15	5.74	6.56
		M=6.35			

5.3.2.2.1 Overall Reaction Ratings

Out of the six items, four were rated lower than the mean response (m = 6.40). These items were ease-of-use, perceived powerfulness, level of stimulation and flexibility, which indicates a need for additional scrutiny. The other two items (impression and satisfaction) were rated higher than the mean response. Depending on these results, it can be concluded that the system indeed has a positive impact on diabetes patients, but the overall impression and the satisfaction in using the system received a good response. Figure 5.1 depicts the reliability of the items in the overall reaction ratings part. By using the mean of 6.40, and the 95% confidence interval plotted, it was reflected that the mean ratings of individual items are not very different from the overall mean of 6.40 at the 0.05 significance level.

Figure 5-1: Distribution of six items that measure overall reactions of SANAD system relative to overall mean of 6.40 (flat horizontal line), and 95% upper and lower confidence intervals. Items reflect item numbers in Table 5.2.

The results indicate that the mean concern for impression, ease of use, satisfaction, being stimulated and perceived powerfulness were significantly greater than the mean concern of flexibility. The mean difference was 0.79 between two 9 point Likert ratings for impression and flexibility; 0.33 between two 9 point Likert ratings for ease of use and flexibility; 0.64 between two 9 point Likert ratings for satisfaction and flexibility; 0.24

between two 9 point Likert ratings for perceived powerfulness and flexibility; 0.39 between two 9 point Likert ratings for being stimulated and flexibility.

5.3.2.2.2 Screen factors

Out of the four items, two items were rated below the mean response (m = 6.38): 'highlighting on the screen', and 'screen layouts were helpful'. The other two items, 'characters on the screen' and 'sequence of screens' were rated higher than the mean response. The result reflects that the screen-related factors, particularly highlighting and screen layouts, need be improved for users to make the best use of the system. A bar chart is created to represent the reliability of the items in the screen factors part as shown in Figure 5.2. By using the overall mean of 6.38 and the 95% confidence interval plotted, the mean ratings of individual items are shown to be not much different from the overall mean of 6.38 at the 0.05 level of significance.

Figure 5-2 : Distribution of screen related factor item ratings for the SANAD system, including overall mean (flat horizontal line) and 95% upper and lower confidence intervals. Items reflect item numbers in Table 5.2

The results indicate that the mean concern for 'highlighting on the screen', 'sequence of screens', and 'characters on the screen' were significantly greater than the mean concern of 'screen layouts were helpful'. The mean difference was 0.33 between two 9 point Likert ratings for 'highlighting on the screen' and 'screen layouts were helpful'; 0.64 between two 9

point Likert ratings for 'sequence of screens' and 'screen layouts were helpful'; 0.42 between two 9 point Likert ratings for 'characters on the mobile screen' and 'screen layouts were helpful'.

5.3.2.2.3 Terminology & System Information

Out of the six items, four were rated below the mean response (m = 6.31): 'clarity in messages appearing on the screen', 'error messages', 'consistency in messages appearing on the screen', and 'system informing the users on what is being done'. The other two items, 'terminology throughout the screen' and 'terminology relating to the work being done', were rated higher than the mean response. This result reflects that consistency and clarity among the messages and system features for informing its users on the work being carried out need to be improved. Figure 5.3 represents the reliability of the items in the terminology and system information section. By using the overall mean of 6.31 and the 95% confidence interval plotted, the mean ratings of individual items are found to be not very different from the overall mean of 6.31 at the 0.05 level of significance.

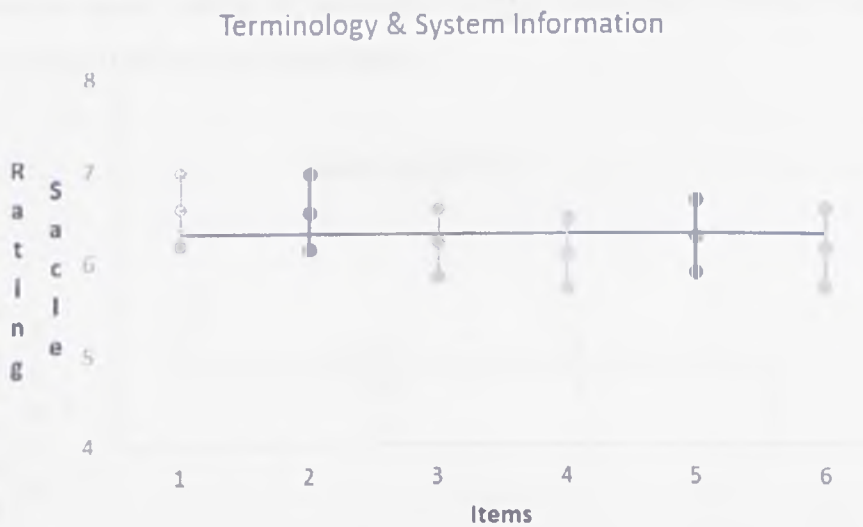

Figure 5-3: Distribution of Terminology and System information factors of the SANAD system, including overall mean (flat horizontal line) and 95% upper and lower confidence intervals. Items reflect item numbers in Table 5.2

The results indicate that the mean concern for 'terminology throughout the screen' and 'terminology relating to the work being done' are significantly greater than the mean concern of 'clarity in the messages appearing on screen'. The mean difference was 0.49

between two 9 point Likert ratings for 'terminology throughout the screen' and 'clarity in the messages appearing on screen'; 0.46 between two 9 point Likert ratings for 'terminology relating to the work being done' and 'clarity in the messages appearing on screen'.

5.3.2.2.4 Learning factors

Out of the four items, two were rated lower than the mean response (m = 6.34), which include exploring the features by trial and error and being able to perform the tasks in a straightforward manner. The other two items include learning to operate the mobile system and remembering the names and use of commands that were rated higher than the mean response. The results show that it is easy to learn the mobile system and for users to remember the names and the commands. However, the users did not find trial and error useful in exploring the system's features, and it was difficult to complete the tasks as easily as the users had expected. These areas need to be improved so that users can explore the system and perform tasks. Figure 5.4 depicts the reliability of the items in the learning factors section. By using the overall mean of 6.34 and the 95% confidence interval plotted, it is reflected that the mean ratings of individual items are not very different from the overall mean of 6.34 at the 0.05 level of significance.

Figure 5-4: Distribution of learning factor items of the SANAD system, including overall mean (flat horizontal line) and 95% upper and lower confidence intervals. Items reflect item numbers in Table 5.2

The results indicate that the mean concern for 'learning to operate the mobile system', 'exploration of features by trial and error method', and 'remembering the names and use of commands' were significantly greater than the mean concern of 'tasks can be performed in a straightforward manner'. The mean difference was 0.85 between two 9 point Likert ratings for 'learning to operate the mobile system' and 'tasks can be performed in a straightforward manner'; 0.21 between two 9 point Likert ratings for 'exploration of features by trial and error method' and 'the tasks can be performed in a straightforward manner'; 0.67 between two 9 point Likert ratings for' remembering the names and use of commands' and the 'tasks can be performed in a straightforward manner'.

5.3.2.2.5 System Capabilities

Out of the five items, three were rated lower than the mean response (m = 6.35): 'reliability', 'auto correction capabilities', and 'ease of operations on the system'. Depending on these results, the users or the participants were happy only with the speed and noise of the system. Reliability is the only factor, which received the lowest average rating. Therefore, additional developments are needed in order to improve the reliability of the system and thereby increase the user's trust in the system. Figure 5.5 represents the reliability of the items in the system capabilities section. By using the overall mean of 6.35 and the 95% confidence interval plotted, the mean ratings of individual items are shown to not be very different from the overall mean of 6.35 at the 0.05 level of significance.

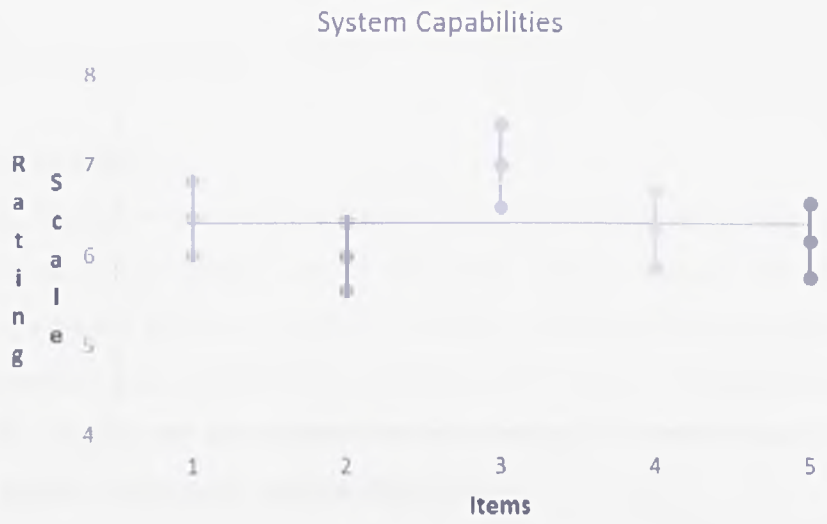

Figure 5-5: Distribution of five scales that measure system capabilities of the SANAD system, including overall mean (flat horizontal line) and 95% upper and lower confidence intervals. Items reflect item numbers in Table 5.2

The results indicate that the mean concern for speed, noise levels, and correcting mistakes were significantly greater than the mean concern of reliability. The mean difference was 0.42 between two 9 point Likert ratings for 'speed' and 'reliability'; 1.00 between two 9 point Likert ratings for 'noise levels' and 'reliability'; 0.30 between two 9 point Likert ratings for 'correcting your mistakes' and 'reliability'.

5.4 Conclusion

In this chapter, we present a usability study of mobile social networking system tailored for patients with diabetes in the KSA (SANAD). A questionnaire was designed based on the OUIS for the purpose of this usability evaluation study. The outcome of the study concludes that the users of the system provided good ratings in the overall reaction categories. In particular, the patients reported a higher satisfaction with the overall impression, and satisfaction including screen, learning, and capabilities aspects of the system. However, poor ratings were obtained in aspects relating to terminology and system information and learning factors. This indicates that these factors should be improved in order to increase the users' satisfaction. As result, these factors of the system functions have been taken into account and improved in the version two of the system. In general, the outcome of this study indicated that the concept of SANAD is considered acceptable tool in patients with Type 2 diabetes. The main limitations of the study are the sample selected and the fact that the research was conducted in only one region of the KSA.

Chapter 6 : Clinical Study of SANAD System

6.1 Introduction

In this chapter, we present the clinical study of SANAD system among Saudi Type 2 diabetes patients. . The primary aim of this study was to evaluate the effect of SANAD system on: 1) improve glycaemic control; 2) improve health awareness; and 3) enhance self-efficacy. Secondary aims qualitatively evaluated the content of communication in SANAD system. In this chapter, we also present the study design and method used in this study, the preliminary results of this study, and the discussion.

6.2 Study Design and Methods

6.2.1 Study Setting and Participants

Participants constituted 20 type 2 diabetic patients (15 male, 5 female). The study design was a randomized controlled trial (RCT) with two groups, intervention group (using SANAD system) and control group as shown in figure 6.1. Patient records were reviewed for the following eligibility criteria: duration of type 2 diabetes > 1 year, HbA1c < 12 % and age <=50 years at the time of enrolment. Exclusion criteria was currently pregnant. In the intervention group, the diabetic patients used SANAD system, and they were taught in how to operate and run the blood glucose device to transmit measurements using SANAD smartphone app, how to use the social networking services and how to apply the CBT intervention and when, in one group sessions lasting 30-45 minutes. The patient in the control group were receive the normal care and management entirely from the general practitioner and/or practice nurse in the medical centre. The study was conducted in Dammam region of Saudi Arabia. Patients were recruited by clinical staff during an office visit or by sending an SMS message. Written informed consent was obtained from all patients before entry. Ethical approval was obtained as the standard for clinical research studies in KSA and UK. Ethical approval for this study was granted by the ethical committee of Naval Technical Institute Clinic, KSA and Kingston University, UK.

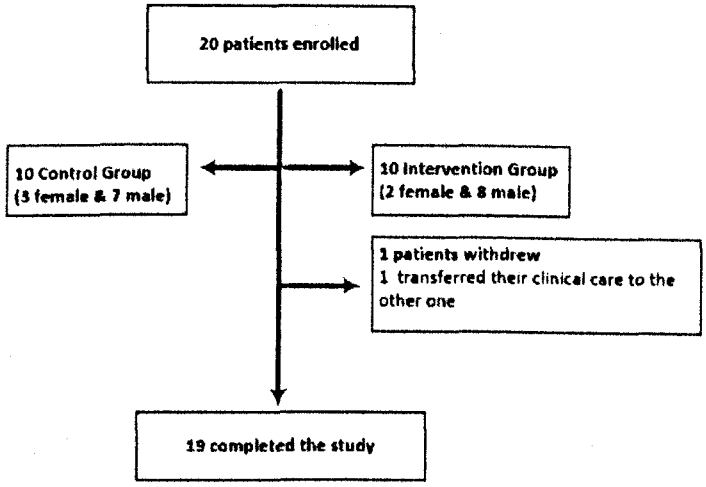

Figure 6-1 Study Design and Patient Sample Selected

6.2.2 Primary and Secondary Outcomes

The primary outcome measure was glycaemic control assessed by HbA1c . The second outcome measures were health awareness measured by Diabetes Knowledge Test and behavioural change measured by Self-efficacy Scale. A brief description of these outcomes are summarized as following:

Glycemic Control: HbA1c was collected using an aqueous finger stick 3-μL blood sample collection kit. The HbA1c method used for this study used a multi method sample screening via high-performance liquid chromatography-ion exchange for detecting possible interference followed by high-performance liquid chromatography-bioassay analysis to determine the percent HbA1c. HbA1c was collected using this method at enrolment and 6-month intervals for every participant for the duration of the study.

Diabetes Knowledge Test (DKT): The DKT was used to measure patient diabetes management-related knowledge [149]. The DKT is a 24-item test developed by the Starr County, Texas, Diabetes Education Study and is a shortened version of the original 60- item survey from Villagomez et al. [150]. Possible answers to each question are yes, no, and I do not know. The items were scored with one point given for a correct answer and zero points given for an incorrect answer or an I do not know response. The DKT was collected at Baseline and Month 6. (See the appendices)

Diabetes Management Self-efficacy Scale (DMSES): The 20-item Dutch/US DMSES measures the individual's efficacy expectations for engaging in 20 type 2 diabetes

self-management activities, for example, taking daily exercise, keeping to a healthy eating plan when away from home [151]. The scale is scored according to a 1–10 point numerical scale indicating the level of efficacy expectation the respondent has for each item with higher scores indicating greater levels of self-efficacy. The DMSES was collected at Baseline and Month 6. (See the appendices).

6.2.3 Statistical and Qualitative Analysis

The pre-post control-intervention data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21. Statistical significance was defined as probability (p) < .05 [152]. Power calculations were performed using GPower 3.1. The primary outcome measures were HbA1c (%), total diabetes knowledge, and average self-efficacy. Ten participants were evaluated in each group. Power calculation indicated that 10 participants per group had 60% power (two-sided, large effect size, p-value = 0.05) for the paired samples t-test to compare the pre and post data at baseline and 6 months. The assumption of normality was met, with all skewness values close to 1 [153]. The main hypothesis testing differences between the control and intervention groups over time was calculated using mixed analysis of variance (ANOVA), and paired t-tests. To assess the amount of change from baseline to 6 months, change scores were calculated for each outcome measure using the formula [time2–time 1]; and percentage change was calculated for each outcome measure using the formula [((time2-time1/time1)*100)]. Independent samples t-test and linear regression were then used to assess the impact of the intervention on mean using the change scores for each outcome measure. For the linear regression analyses, the independent variable was condition (dummy coded as: 0=control, 1=intervention group), and the three dependent variables were the HbA1c (%), diabetes knowledge, and self-efficacy change scores. Pearson correlations compared pre and post HbA1c (%), diabetes knowledge and self-efficacy scores. All qualitative data collected will be analyzed by thematic analysis using the method of content analysis, developed descriptive codes based on broad themes in the data [154].

6.3 Results

6.3.1 Clinical Outcomes

The baseline demographic and clinical characteristics of the study groups are summarised in Table 6.1. Chi-square and independent samples t-tests revealed there were no significant differences between control and intervention group in demographic or clinical characteristics, except for education, which was higher in the intervention group ($X2(2)=6.79$, $p<.05$). The participants were mainly men, the large majority were aged 18-40 years, and were married, and the majority had a diagnosis of diabetes for five years or less. On average, participants scored 8-9 for HbA1c (%), 12-12.50 for diabetes knowledge, and 5 for self-efficacy scores.

Table 6.2 shows the baseline and post-intervention scores with regard to the main hypothesis, and paired t-test results. Table 6.3 shows the Independent samples t-test comparing mean post - pre change scores for each outcome measure between study groups. Table 6.4 shows the Pearson correlations between pre and post HbA1c, diabetes knowledge and self-efficacy.

Table 6-1 Baseline Demographic and Clinical Characteristics of Study Groups

Variable	Category	Control group	Intervention group	Test of Group Difference	*p*-value
n (%)		10	10		
Gender	Male	7 (70%)	8 (80%)	χ2 = .267	1.000
	Female	3 (30%)	2 (20%)		
Age Group	18-40 years	8 (80%)	9 (90%)	χ2 =.392	1.000
	41-50 years	2 (20%)	1 (10%)		
Education	≤ Secondary	5 (50%)	0 (0%)	χ2 = 6.79*	.034
	Diploma	2 (20%)	5 (50%)		
	≥ University	3 (30%)	5 (50%)		
Marital Status	Never Married	3 (30%)	3 (30%)	χ2 =.000	1.000
	Married	7 (70%)	7 (70%)		
Duration of	<=5 years	10 (100%)	8 (80%)	χ2 = 2.22	.474
	6-10 years	0 (0%)	2 (20%)		
HbA1c (%)		8.84 ± 1.16	8.21 ± 1.15	*t* = 1.22	.238
Diabetes Knowledge		12.50 ± 0.97	12.10 ± 1.97	*t* =.576	.572
Self-Efficacy		5.21 ± 0.36	5.19 ± 0.43	*t* =.114	.911

Note. Data are *n* (%), means ± SD. X2 = Chi-Square test result; *t* = independent samples t-test result.

Table 6-2 Paired T-Test Comparing Pre-Post HbA1c (%), Diabetes Knowledge, and Self-Efficacy

Group	Pair	Outcome Measure	Mean	SD	Mean Change	SE M	*t*-value	*p*-value
Intervention group	Pair 1	Pre HbA1c (%)	8.14	1.20	.600	.102	5.84***	.000
		Post HbA1c (%)	7.54	.96				
	Pair 2	Pre Knowledge	12.11	2.09	-2.44	.530	-4.61**	.002
		Post Knowledge	14.56	1.59				
	Pair 3	Pre Self Efficacy	5.17	.45	-.994	.192	-5.16***	.001
		Post Self Efficacy	6.17	.39				
Control group	Pair 1	Pre HbA1c (%)	8.84	1.16	.050	.109	.455	.660
		Post HbA1c (%)	8.79	1.10				
	Pair 2	Pre Knowledge	12.50	.972	-1.00	1.52	-.208	.840
		Post Knowledge	12.60	1.84				
	Pair 3	Pre Self Efficacy	5.21	.36	.035	.251	.440	.671
		Post Self Efficacy	5.17	.49				

Note. SD = standard deviation, SE M = standard error of the mean. **p<.01, ***p<.001.

Table 6-3 Independent T-Test Comparing Mean Post-Pre Change Scores between Study Groups

Outcome Measure	Study Group	N	Mean Change	SD	SE M	*t*-value	*p*-value
HbA1c (%)	Control	10	-.050	.347	.110	3.63**	.002
Change Score	Intervention	9	-.600	.308	.103		
Diabetes Knowledge	Control	10	.100	1.52	.482	-3.28**	.004
Change Score	Intervention	9	2.44	1.59	.530		
Self-Efficacy	Control	10	-.035	.252	.080	-4.94***	.000
Change Score	Intervention	9	.994	.578	.193		

Note. SD=standard deviation, SE M=standard error of the mean. **p<.01, ***p<.001.

Table 6-4 Pearson Correlations between Pre and Post Hba1c (%), Self-Efficacy and Diabetes Knowledge Scores

Group		Mean	SD	Pre HbA1c (%)	Post HbA1c (%)	Pre Diabetes Knowledge	Post Diabetes Knowledge	Pre Self-Efficacy	Post Self-Efficacy
Control group	Pre HbA1c (%)	8.84	1.16	-					
	Post HbA1c (%)	8.79	1.10	.954**	-				
	Pre Diabetes Knowledge	12.50	.9718	.326	.339	-			
	Post Diabetes Knowledge	12.60	1.84	.343	.174	.560	-		
	Pre Self-Efficacy	5.21	0.356	-.280	-.337	.361	.555	-	
	Post Self-Efficacy	5.17	0.492	-.193	-.258	.128	.403	.872**	-
Intervention group	Pre HbA1c	8.21	1.15	-					
	Post HbA1c (%)	7.54	.9645	.983**	-				
	Pre Diabetes Knowledge	12.10	1.97	-.315	-.313	-			
	Post Diabetes Knowledge	14.56	1.59	-.755*	-.711*	.657^	-		
	Pre Self-Efficacy	5.19	0.426	-.127	-.085	.307	.260	-	
	Post Self-Efficacy	6.17	0.386	-.425	-.478	-.041	.512	.050	-

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

^. Correlation approached significance (p = .055).

HbA1c: Mean baseline HbA1c (%) was 8.14 (SD 1.20) and decreased to 7.54 (SD 0.96) after the SANAD intervention (mean [SE] decrease .600 [.103]). A paired-samples t-test showed this change to be significant ($p = .001$) (see Table 6.2). Linear regression analysed each study group separately, and revealed that age significantly predicted change in HbA1c (%) in the intervention group, with older age (i.e., 41-50 years) associated with higher HbA1c (%) at six months, as compared with baseline values ($\beta = .865$, $t = 3.67$, $p<.05$). Gender and educational level did not predict the change in HbA1c (%). In the control group, education level predicted the change in HbA1c (%) ($\beta = -.714$, $t = 4.94$, $p<.05$), with lower education associated with higher HbA1c (%) at six months, as compared with baseline values. Baseline and 6-month HbA1c values were positively and strongly correlated for both intervention and control group ($r(9) = .983$, $p<.01$; and $r(10) = .954$, $p<.01$, respectively) (see Table 6.4). An independent samples t-test compared mean change in HbA1c (%) scores between the control and intervention group, and revealed that HbA1c (%) decreased by .600 points in the intervention group, but decreased by only .050 points in the control group, and this difference was significant, $t(17) = 3.63$, $p<.01$ (see Table 6.3).

Diabetes Knowledge: The mean diabetes knowledge score prior to the intervention (baseline) was 12.11 (SD 2.09), which rose to 14.56 (SD 1.59) afterward. This increase (mean [SE], 2.44 [0.530]) was shown to be significant using the paired-samples t-test ($p = 0.002$) (see Table 6.2). Linear regression demonstrated that age, gender, and educational level were not related to increased diabetes knowledge in each study group. Correlation between diabetes knowledge scores before and after the SANAD intervention approached significance ($r(9) = .657$, $p = .055$) (see Table 6.4). An independent samples t-test revealed that diabetes knowledge significantly increased in the intervention group by 2.44 points, and increased by .100 points in the control group, $t(17) = -3.28$, $p<.01$ (see Table 6.3).

Self-Efficacy: The mean self-efficacy score prior to the intervention (baseline) was 5.17 (SD 0.45), which rose to 6.17 (SD 0.39) afterward. This increase (mean [SE], .944 [0.192]) was shown to be significant using the paired-samples t-test ($p = .001$) (see Table 6.2). Linear regression demonstrated that age, gender, and educational level were not related to increased self-efficacy in each study group. There was no correlation between self-efficacy scores before and after the SANAD intervention ($r(9) = .050$, $p = .899$) (see Table 6.4). An independent samples t-test indicated that self-efficacy significantly increased in the intervention group by .994 points, but decreased in the control group by .035 points, $t(17) = -4.94$, $p<.001$) (see Table 6.3).

6.3.2 Social Interactions Outcomes

The other aim of the study is to assess and qualitatively evaluate the content of communication in SANAD. After collecting six months' worth of social networking activity in the system, there was a total of 654 posts for analysis. The posts were then coded based on the type of content they referred to expedite classification and further scrutiny. In the end, the posts fell into eight different categories: information provision, information requesting, advice provision, greeting, diabetes status, positive mood and feeling, negative mood and feeling, and irrelevant posts. Note that relevance was assessed based on whether the posts fell within the purview of the goals and aims of the system. Moreover, the posts were originally in Arabic and have been translated into English for this discussion.

By carrying out a thematic analysis on the data that has been gathered, the various categories of posts can be distilled into three themes: information sharing, emotional expression, and community formation. The quantitative breakdown of the various themes is shown in Figure 6.2.

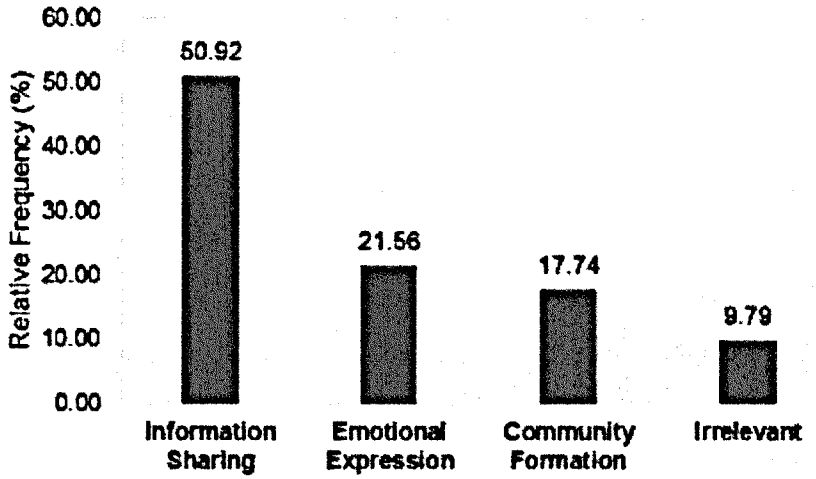

Figure 6-2 Relative Frequencies of Themes of Posts as a Percentage of The Total Number of Posts

Information Sharing

Majority of the posts (50.92%) that were posted in the SANAD system focused on the relay of information, which emphasises how diabetic patients are keen towards the need to gain more information to better manage their disease [155]. Among the posts that fell within this theme, there were more posts providing information and advice compared to those posts asking for information. These posts that endeavoured to introduce new tips to others who are afflicted with diabetes were about symptoms, dietary considerations, physical activity, and medications. One particular poster, noted the most common symptoms for diabetes in the hope of making people more aware of its onset:

من اعراض مرض السكر 1-عطش شديد وجفاف بالفم 2-تبول متكرر 3-ارهاق شديد 4-جوع مستمر 5-نقص مفاجئ بالوزن 6-الالتهابات متكررة 7-عدم وضوح الرؤية

> Symptoms of diabetes: 1 - extreme thirst, dry mouth, 2 - frequent urination 3 - severe fatigue 4 -constant hunger 5- lack of sudden weight 6 - frequent infections 7- blurred vision.

Much of the information that was shared, however, was focused on dietary tips and reminders and this indicates that the greatest challenge that diabetics have to overcome is the need to better manage the food that they eat. Many of the posts regarding such dietary tips fell in the same thread as these particular posts:

الإبل اصاله سياحه لحم شهي وفوائد علاجيه حيث يساعد حليب الإبل على تخفيض معدل السكر ب الدم وب التالي مقاومة مرض السكري

Camel meat is delicious, and the therapeutic benefits of camel milk helps to reduce the level of blood sugar and resistance diabetes.

الرغيف الاسمر مفيد
انصح بالتفاح للسكري
انصح بالبرتقال للسكري
انصح في الاكل قليل الدهون
يجب علينا المحافظة على اقدامنا
يجب علينا المحافظة على صحتنا
يجب علينا المحافظة على مستوى النظر لدينا

Please be advised that brown bread is very useful for us. Orange and apple are also very helpful and please do try to eat low fat food. Additionally, we must keep our foot clean, our eyes well, and our health safe.

Another type of information sharing tweet pertained to the kind of physical activity that is required of diabetic patients. These were often written with a sense of urgency in light of the fact that many diabetics are led to their condition due to a sedentary lifestyle [156]. More so, the onset of diabetes is also viewed as a hindrance to pursuing a more active life, which is why many diabetics continue to have low levels of physical activity [157]. In many cases, these posts on physical activity were intertwined with those on dietary advice as they are both needed for weight management. One example of this is the following:

علاج مرض السكري بالعسل مفيد جدا
تجنب السكريات
تجنب الرز
انصح بالمشويات
لتخفيف السمنة ممارسه الرياضة يوميا واقل حد لها 15 دقيقه

Please be advised that the honey is a good substitute for other sweets and chocolates for diabetics. Grilled food is also very good for the diabetic patient. Finally, to become less obese, please increase your level of physical activity by exercising for at least for 15 minutes a day.

Medication was also among the information that was given; however, it was provided less than the dietary and lifestyle tips given above. This could be due to the fact that the SANAD system provided an avenue for the participants to go beyond the usual and common advice provided by health practitioners. One of the posts that provided medication information was as follows:

دراسات فتامين دال يساعد في علاج الاكتئاب واللام الاعصاب عند مريضات النوع الثاني من مرض السكر

Studies showed that Vitamin D helps in the treatment of depression and neuropathic pain female patients with type 2 diabetes.

In terms of the questions asked in the system, they were very direct and with little context due to the character limitations of twitter. Most of the questions were dietary in nature as the participants either inquired about whether eating a particular food was okay or whether substitutes of a particular food type was available. Shown below are some of these posts:

أحب الاكل لكن ماذا تنصحوني؟

I love to eat, but could you please advise me what type of food that is good for diabetic patients?

ممكن اعطائي معلومات عن فائدة التمر للسكري

Could you please give more information about the main benefits of Dates for diabetes?

In summary, therefore, the questions and information that was moved around in the SANAD system focused on informal pieces of knowledge that are rarely asked in the hospital setting. In this way, the system provided a more casual point of interface for the participants to learn more about the disease and the means through which they could better manage it.

Emotional Expression

The social media component of the SANAD System was also used by many of the participants as an outlet for emotional expression, most of which were expressions of frustration over their current state of health and the limitations that constantly hamper them. One particular participant lamented over the changes in life disposition that diabetes can bring to a person's life and this was expressed in the post:

ولاكن عندما تصاب بالسكر ينقص هذا الامل والتفاول

When you are diagnosed with diabetes, it means that your hope and optimism towards life will suffer greatly.

This sentiment needs particular emphasis because it presents a notable opportunity for counsellors and other healthcare professionals to address the fears and problems of the patients. Much of the frustration, however, seems to draw from the inability to fully enjoy the pleasures of being able to eat what they wanted to eat. This is shown in the posts of some participants:

لدي خوف شديد من أي قطع حلوى انها ترفع السكر لدي

I am feeling very fearful of any piece of sweet because I believe that eating them will increase my blood glucose level.

اضطراب الاكل يجعلني اغضب من الجوع

The eating limitations that are posed by diabetes makes me angry when I am hungry.

Nevertheless, amidst these numerous statements of frustration, there were still some who were positive about their condition. Many of the positive posts emerged after an implied realisation that the limitations brought about by diabetes do not necessarily mean that one will live a less meaningful life. Many initiatives of care providers have been geared to illustrate that inasmuch as diabetes makes certain choices less possible, there are still many opportunities for diabetic patients to live a full life[158]. This is encapsulated in one of the posts:

قبل كنت أفكر ان الحياة ستصبح تعيسة لاكن يوم بعد يوم تفاؤلي يزداد

In the past, just after I was diagnosed, I thought that my life would become miserable, but as each day passes, I begin to realize that it isn't so bad and because of this, my optimism is growing.

In this sense, emotional expression becomes a matter of perspective. Those individuals who are able to see beyond the limits of their condition are able to develop an enthusiasm regardless of the diabetes. Moreover, based on the honest and candid nature of the emotional expression that is demonstrated by the participants of the SANAD system, it shows that the particular system was able to develop a notable connection with the participants, allowing them to freely express themselves. Studies have shown the affective dimension of a

disease is also important to consider to make sure that one has a positive health-related quality of life[159].

Community Formation

The final theme that emerged in the posts of the participants to the social media component of the SANAD system was community formation. These posts were basically efforts of direct interaction where people greeted one another, gave advice on how to deal with diabetes, or talked about their current status. The development of rapport is important in fostering genuineness and promoting freer self-disclosure, both of which are integral in any support group [160].

In terms of the advice that was provided by the various members of the community, they were mostly medical or dietary in nature. They were often phrased as urgent reminders such as the case of one poster who implored that the rest of the participants constantly attend regular check-ups with their doctors to make sure that everything is well and good. The provision of such advice allows for the building of trust because the participants realise that they are starting to look out for one another.

Another aspect of community formation was self-disclosure through the form of revealing one's diabetes status. On one hand, this can constitute an emotional catharsis because it allows the individual to completely recognise his or her condition but, on the other hand, it also empowering to others because it gives the individual's fellow participants the licence to do the same thing. Some of the posts on diabetes status were the following:

تناولت حبة السكر باكرا قبل العشا ونزل معدل السكر

I have eaten my diabetes tablets a little bit early before the diner and then I felt that my blood glucose level was going low.

اثناء جلوسي مع اطفالي ومناقشتنا العائلية ينزل معدل السكر لدي

When I stay with my family and discuss our issue, my blood glucose level is going low.

لم افطر اليوم جيدا وزوجتي تأخرت بالغداء ونزل سكري

I do not eat very well at the breakfast time and my wife was doing our lunch too late, as result, my blood glucose level was going low today.

The final set of posts falling within the theme of community formation were greetings by the participants. These were basically recognitions of the social nature of the system; that is, the participants fully acknowledge that there are other people who are trying to manage diabetes better along with them.

6.4 Discussion

This feasibility study, which is the first evaluation of SANAD for diabetes type 2 patients in Saudi Arabia, provides evidence that SANAD has a positive impact on promoting knowledge of diabetes in individuals living with type 2 diabetes, and reflects the generally positive outcomes of reducing glycated hemoglobin control (HbA1c (%), and increasing self-efficacy. This is also the first study to analyse the content of diabetes patient's posts on the SANAD private social networking module. This study offers preliminary support for the proposed public health benefits of social networking for type 2 diabetes management.

Our pre-post randomised controlled trial revealed that participants' level of diabetes knowledge in the intervention group increased significantly following the intervention, which is consistent with the findings of Haddad et al., who found a mean pre-post increase of 1.29 points in diabetes knowledge[84]. Our study found an even larger mean increase of 2.44 points in knowledge ($p<.05$). Further trials and clinical observation are required to determine whether this increase in diabetes knowledge is clinically sufficient. A limitation of our randomised control trial is that the intervention group were more highly educated, than the control group. This may have facilitated their information processing and retention of diabetes information, over and above effects of the SANAD intervention. In addition, mean glycemic control in our intervention group achieved a significant mean decrease of .600 points from baseline levels ($p<.01$); whereas mean HbA1c concentration in controls decreased only .05 points from baseline levels. This finding suggests that the SANAD system is comparably effective to SMS text messaging for glycemic control, as Haddad et al. [84] found a significant change in HbA1c levels ($p<.001$) with a mean decrease of 8.6 (%) in type 2 diabetes patients; and is as effective as the similar Sweet Talk device which decreased intervention patients HbA1c concentration by 9.2 points ($p<.001$), which did not change

significantly in controls from baseline levels. Self-efficacy improved significantly in our SANAD intervention patients by .994 points from baseline scores ($p<.001$), which is comparable to the Sweet Talk associated improvement in self-efficacy in their treatment group, which improved by 62.5% ($p<.01$) [77]. In summary, the SANAD application combines the advantages for improving mean glycemic control and diabetes knowledge, found by Haddad et al. using SMS; and the improvements in self-efficacy found by Franklin et al. using Sweet Talk, a mobile phone text messaging support network. In addition, SANAD features includes videos and communication between patients and physicians, making it a more efficient system for improving all three target outcomes. A previous usability study found SANAD system is well received by diabetes patients in Saudi Arabia, but as a first development, obviously requires some upgrade to increase satisfaction [161].

This study has revealed notable strengths of the SANAD system and the present study. For example, it is the first mobile diabetes management system to be developed and tailored for Saudi diabetes type 2 adult patients, to enhance their diabetes type 2 management, including improving glycemic control, diabetes knowledge, and self-efficacy for behavioural change, based on cognitive behaviour therapy (CBT). It was easy to recruit type 2 diabetes patients from one healthcare clinic in Dammam, Saudi Arabia. This study is also the first randomised clinical controlled trial, in the Gulf area, particularly in Saudi Arabia to evaluate the effectiveness of SANAD for adult type 2 diabetes. A recent usability study [161]provides evidence that the SANAD system is easy to use.

Limitations of this study that may affect internal and external validity include the small sample size (N=20), which was due to limited funding. Additional limitations are that there was 1 patient dropout in the intervention group due to transferring him to another clinical. Recruiting from one small healthcare clinic in one region (Dammam), reduced the generalizability of results, however this is an exploratory pilot RCT; therefore it was not intended to generalise results to this population.

Ethical approval from Saudi government sector was difficult to obtain in terms of time (a very slow process). It was also difficult to gain ethical approval from Kingston University London for this study. The issue of using self-report tools (e.g., to measure self-efficacy, is associated with common method bias (e.g., mood bias, socially desirable responding). It is possible that intervention participants may have felt grateful for receiving a top branded smartphone, and felt obligated to report better self-efficacy. The finding that

change in self-efficacy and glycemic control was uncorrelated among intervention participants adds some validity to the limitation of self-report findings.

6.5 Conclusion

In this chapter, we present both a clinical study of SANAD system among Saudi type 2 diabetes and qualitative evaluation the content of communication in SANAD system. The key outcomes of the SANAD clinical study concludes that SANAD has a positive impact on promoting knowledge of diabetes in individuals living with type 2 diabetes, and reflects the generally positive outcomes of reducing glycated hemoglobin control (HbA1c (%), and increasing self-efficacy. In addition, the social networking aspect of the SANAD system was assessed by analysing the posts of the participants via the social networking module. It was found that there were three prominent themes in the posts and these were information provision, emotional expression, and community formation. The various posts within each theme demonstrated how the system was able to effectively foster a community among the participants as they were shown to be actively communicative and helpful with one another.

Chapter 7 : Conclusions and Future Work

7.1 Conclusion

The primary aims and contributions of this thesis are the design, implementation, and evaluation of the next generation of mobile social diabetes management for Saudi patients (SANAD). The work, which was carried out to achieve these aims, as well as the results of the work, was reported in the previous chapters of this thesis. In this section, the achievements and conclusions which have been previously drawn will be summarized as follows.

(i) Comprehensive Study and Review of Mobile Diabetes Management and Social Networking System.

A comprehensive study was carried out to understand the procedure of traditional and current diabetes management procedures by searching and studying extensive documents from Saudi diabetes framework and National Institute for Health and Clinical Excellence (NICE) and other sources cited in the thesis.

A comprehensive review on state of art of mobile diabetes management and social networking systems was performed. This review involved studying past and existing research projects, and examined their advantages and shortcomings, and identify the current status and potential impact of using mobile diabetes management system by embedding social networking in the Gulf region and particularly in the kingdom of Saudi Arabia (KSA).

(ii) Comprehensive Review of Health Behavioural Change Theories

A comprehensive study was carried out to identify the most relevant health behavioural change theories for diabetes management. This review involved studying these theories, examined their advantages and shortcomings, and identify the suitable theory that can be used on mobile diabetes management system by embedding social networking. From this review,

the Cognitive Behavioural Therapy (CBT) was chosen. Thus, from these two reviews, the initial architecture of SANAD system was proposed.

(iii) Design and Implementation of the SANAD system

The complete architecture of SANAD system on the three modules, mobile diabetes management module, social networking module and CBT modules together with relevant software and hardware options of the system were presented. The SANAD system was designed and developed based on the previous work in this area and the preliminary study conducted with the aim of collecting the Saudi diabetic patients and medical staff requirements and needs.

(iv) A Preliminary Usability Evaluation Study of SANAD System.

The thesis also presents the preliminary usability study with the aim of evaluating the SANAD system in the KSA and in analysing the aspects of user satisfaction and interaction. In this study, a Questionnaire for User Interaction Satisfaction (QUIS) was used and a total of 33 users with type 2 diabetic patients participated in this study. The preliminary results of the usability study indicated general acceptance of the patients in using the system with higher usability rating in type 2 diabetic patients. In general, the study concluded that the concept of SANAD system is considered acceptable tool in patients with Type 2 diabetes.

(v) Pilot and Preliminary Clinical Study of SANAD System

The thesis also presents a pilot clinical study with aim of evaluating the SANAD System in collaboration with medical collaborators in the KSA and in analysing the aspects of user clinical outcomes (HbA1c), self-efficacy and diabetes knowledge, and a qualitatively evaluation study of the content of communication in SANAD. A total of 20 subjects with type 2 diabetic (15 male, 5 female) participated in this study. The study design was a randomized controlled trial (RCT) with two groups, intervention group (using SANAD system) and control group. The key preliminary results of this study provided an evidence that SANAD has a positive impact on promoting knowledge of diabetes in individuals living with type 2 diabetes, and reflects the generally positive outcomes of reducing glycated hemoglobin control (HbA1c (%), and increasing self-efficacy. Furthermore, the content of communication in SANAD system was assessed by analysing the posts of the participants in

the SANAD social networking module. It was found that there were three prominent themes in the posts and these were information provision, emotional expression, and community formation. The various posts within each theme demonstrated how the system was able to effectively foster a community among the participants as they were shown to be actively communicative and helpful with one another.

7.2 Future Work

The area of mobile diabetes management system is considered as an emerging field of modern healthcare in the Gulf region. Significant technical and clinical progress and advanced technologies can be utilized to enhance the performance and ubiquity of such systems. In this section, we give suggestions about how the work presented in this thesis can be carried out further. The future work which can presently be seen in this field may be classified into a number of categories.

The first category for future research is related to the fact that the current system does not has a specific diabetes education programme content. This can be achieved by designing and developing a tailored diabetes education programme for Saudi patients that suitable and fit for mobile diabetes management system usages. This programme can be developed by using intervention mapping (IM) methodology.

The second category is related to the intelligent strategies for SANAD system. The research area that can be contributing to future work is the application and integration of Data Mining techniques for behavioural change issue. This gives the system the ability to suggest to the user of the SANAD behavioural change module extra feedback to his/her diabetes management status, based on the patterns of previous behavioural. For example, when a diabetic patient submit his/her behavioural change data to the health provider server, the system would automatically suggest to him/her the best way for improving and managing diabetes condition.

The third category is related to the design of SANAD system. As the SANAD system was mainly designed for type 2 diabetic patient. Design and development a tailored mobile systems for type 1 and elderly diabetic patients can be considered in future work by designing and adding a gamification concept for type 1 diabetic patients and an easy icons, and functionalities for elderly diabetic patients.

The final category is related to the clinical study. A power calculation recommended 19 participants to produce paired t-test results (one-tailed) with 95% power (based on a large effect size, d = .8; and recommended 35 participants per group to produce independent samples t-test results (one-tailed) with 95% power, based on a large effect size, to compare change between control and intervention groups in future SANAD trials). This larger sample would be feasible in a national study to replicate this study in central, east, west, north and south Saudi Arabia. To improve external validity, a more sophisticated random sampling strategy is also recommended in future trials, such as multi-stage cluster random sampling within each region, recruiting diabetes patients from primary health centres as the sampling frame. This study should then be replicated in national studies of Bahrain, UAE, Iraq, and Egypt. Validation is then recommended SANAD for use in English-speaking countries, to further validate and widen the marketability of SANAD to help patients self-manage their diabetes, and share knowledge and support with their peers. Importantly, SANAD is currently available exclusively on Samsung' android operating system. Therefore, Samsung should be approached to fund part of the costs of a future national feasibility study, including supply of Galaxy smartphone and associated charges for participants. The SANAD system is currently being configured for use on IOS (iPhone), which should significantly broaden its usage and appeal to the larger market of diabetes patients across the world, and this will also require RCTs and usability studies.

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Appendices

Appendix – A

Implementation Tools and Technology

Tools Name	Brief Description
PHP	PHP is known as hypertext pre-processor, which is basically a scripting language used for web development, and also used for general programming. It can be embedded in to the HTML source code directly, which improves and simplifies the process of web designing and development. In SANAD System, a custom server PHP application is used to support remote log-in. It is also use to review of the diabetic patient data, control user settings and in providing feedback by the medical staff. In addition, viewing patient data and assessing the results, a key feature developed using PHP, to allow the diabetic patients to access via the web rather than mobiles.
SQL data base	Structured Query Language is a programming language used for managing the data in the relational database management systems. Different data management options like edit, copy, insert, save, update etc. can be easily used with SQL. It allows to use different expressions like 'when', 'else', '=', '>'. '<' etc., and makes it easy to extract the required information from the database like reports of readings over a period of time. The SQL database is used in the SANAD System for managing the data by the different users.
Social engine	Social engine is a PHP community software used for building customised social network website or application. Any user can create a personalised social network website according to his/her requirements, and use it for different purposes. Different templates can also be used in improving the graphical user interface of the website. This software is used for developing the customised social network for SANAD System involving the participants, diabetes patients, diabetes nurse, and the CBT therapist.

	Different features like messaging, posting an educational video and tutorials etc. are added to the system using the social engine.
Android	Android is a mobile operating system based on the Linux Kernel, mainly developed for smartphones. The graphical user interface of the Android uses different manipulation techniques closely related to real world actions like swiping, touching, pinching, tapping etc. Android based mobiles are used in the SANAD System, for transmitting the data related to blood glucose levels, behavioural aspects, and other information from the diabetes patients to the SQL Server.
JAVA SDK	Java Software Development Kit is a platform for developing different software applications on different operating systems like Mac, Windows, Linux etc. It has many components and functionalities which help in developing effective and efficient applications which run on Java platform, and can be used on different devices. Java SDK is used for developing the mobile application to be used by the diabetes patients in accessing, submitting, viewing the health related information.
Platform eclipse	It is an Integrated Development Environment (IDE), and possess the workspace and plugins options for improving the developing environment. It is used for developing different applications, and mostly written in Java. Platform eclipse is used in developing the mobile applications for SANAD System.
SMS text local	SMS text local provides services in delivering text messages as per the customised requirements. Instant text messaging, automated text message delivery, group text messaging, online text messaging, text to email etc. are few major features of this system. SMS text local services have been used in the SANAD System to send automated text messages, feedbacks, and alerts to the diabetes patients. It is also used for sending customised messages to individual patients like information regarding their treatment, medication, readings etc., by the diabetic nurses.
Cron job	The cron job is job scheduling software which is used to perform certain

	actions at specified time intervals. The tasks can be automated using the cron job, if they are specified to run at specific times. The tasks can be run only once or multiple times at specified intervals. The Cron Job is used in the SANAD System to send automated SMS alerts, automated recording of the readings at specified time intervals, and also to develop weekly reports, and assessments.
GALAXY S III	Galaxy S3 is a smartphone developed by the Samsung which has wide range of features and applications. It uses Android operating system, and can be operated purely on touch screen. It has a 4.8" wide screen with HD output, and 1.5Ghz processor, and possess different connectivity features like Bluetooth, wi-fi, mobile data networking etc. and can use 3G network. These advanced features and medium price of the mobile are the key factors in using this mobile in the SANAD System. The Galaxy S3 mobiles are used by the diabetes patients to transmit their health related data to the server, and to interact with the other users in the system.
BGM	Blood Glucose Monitoring is one of the important processes in the SANAD System. Daily monitoring of blood glucose levels of the patients data is an important function of the system. Glucometers attached with Bluetooth sensor are used in collecting the readings. The Glucometers used in SANAD system is LifeScan OneTouch/ Ultra 2. The Bluetooth wireless adopter used in SANAD system is Polymap one.
Xml	Extensible Markup Language is a markup language used for structuring,. storing and transporting the data, with a focus on what a data is. It is easy to use own tags are created by the users which can be read by the machines and humans. It helps in simplifying the process of data management during the application changes, system updating etc. XML is used in the SANAD System for managing the data by creating xml files which can be accessed and managed easily.
JavaScript	JavaScript is a dynamic programming language used in designing the web pages. It is the part of web browsers which allows the client side

	scripts to interact with the user. Different functions can be prescribed in the scripts and the scripts can be then embedded in to the HTML pages. The script loads along with the web pages, and the functions are executed. It helps in building more effective web pages according to the requirements of the users. Java Script is used in developing the web pages in the SANAD System which are then embedded in to HTML Pages.
CSS3	The Cascading Style Sheets are used for designing the web pages to make them more effective while browsing. CSS is designed primarily to enable the separation of document content from document presentation, including elements such as the layout, colours, and fonts. This separation can improve content accessibility, provide more flexibility and control in the specification of presentation characteristics, enable multiple pages to share formatting, and reduce complexity and repetition in the structural content. CSS is used in the SANAD System while developing the web pages in order to differentiate the data and the design, and also for providing an effective design of web pages.

Appendix – B

Research Questionnaire

Diabetes Knowledge Test (DKT): * Please answer the following questions by ticking the correct box?

	Questions	Yes	No	Don't Know
1	Eating too much sugar and other sweet foods is a cause of diabetes.			
2	The usual cause of diabetes is lack of effective insulin in the body.			
3	Diabetes is caused by failure of the kidneys to keep sugar out of the urine.			
4	Kidneys produce insulin.			
5	In untreated diabetes, the amount of sugar in the blood usually increases.			
6	If I am diabetic, my children have a higher chance of being diabetic.			
7	Diabetes can be cured.			
8	A fasting blood sugar level of 210 is too high.			
9	The best way to check my diabetes is by testing my urine.			
10	Regular exercise will increase the need for insulin or other diabetic medication.			
11	There are two main types of diabetes: Type 1 (insulin-dependent) and Type 2 (non-insulin dependent).			
12	An insulin reaction is caused by too much food.			
13	Medication is more important than diet and exercise to control my diabetes.			
14	Diabetes often causes poor circulation.			
15	Cuts and abrasions on diabetes heal more slowly.			
16	Diabetics should take extra care when cutting their toenails.			
17	A person with diabetes should cleanse a cut with iodine and alcohol.			
18	The way I prepare my food is as important as the foods I eat.			
19	Diabetes can damage my kidneys.			
20	Diabetes can cause loss of feeling in my hands, fingers and feet.			
21	Shaking and sweating are signs of high blood sugar.			
22	Frequent urination and thirst are signs of low blood sugar.			
23	Tight elastic hose or socks are not bad for diabetics.			
24	A diabetic diet consists mostly of special foods.			

Diabetes Management Self-efficacy Scale (DMSES): Below is a list of activities your may have to perform to manage your diabetes. Please read each one and then circle the number that best describes how confident you usually are that you could carry out that activity. For example, if you are completely confident that you are able to check your blood sugar levels when necessary, circle 10. If you feel that most of the time you could not do it, circle 1 or 2. If you feel that all of the time you could not do it, circle 0

	Questions
1	I am able to check my blood/urine sugar if necessary
2	I am able to correct my blood sugar when the sugar level is too high
3	I am able to correct my blood sugar when the blood sugar level is too low
4	I am able to choose the correct food
5	I am able to choose different foods and stick to a healthy eating pattern
6	I am able to keep my weight under control
7	I am able to examine my feet for cuts
8	I am able to take enough exercise, for example, walking the dog or riding a bicycle
9	I am able to adjust my eating plan when ill
10	I am able to follow a healthy eating pattern most of the time
11	I am able to take more exercise if the doctor advises me to
12	When taking more exercise I am able to adjust my eating plan
13	I am able to follow a healthy eating pattern when I am away from home
14	I am able to adjust my eating plan when I am away from home
15	I am able to follow a healthy eating pattern when I am on holiday
16	I am able to follow a healthy eating pattern when I am eating out or at a party
17	I am able to adjust my eating plan when I am feeling stressed or anxious
18	I am able to visit my doctor once a year to monitor my diabetes
19	I am able to take my medication as prescribed
20	I am able to adjust my medication when I am ill

Questionnaire for User Interaction Satisfaction (QUIS):

PART 1: Overall User Reactions

Please circle the numbers which most appropriately reflect your impressions about using this computer system.

Not Applicable = NA.

1.1 Overall reactions to the system:	terrible wonderful 1 2 3 4 5 6 7 8 9	NA
1.2	frustrating satisfying 1 2 3 4 5 6 7 8 9	NA
1.3	dull stimulating 1 2 3 4 5 6 7 8 9	NA
1.4	difficult easy 1 2 3 4 5 6 7 8 9	NA
1.5	inadequate power adequate power 1 2 3 4 5 6 7 8 9	NA
1.6	rigid flexible 1 2 3 4 5 6 7 8 9	NA

PART 2: Screen

2.1 Characters on the computer screen — hard to read / easy to read

1 2 3 4 5 6 7 8 9 NA

2.2 Highlighting on the screen — unhelpful / helpful

1 2 3 4 5 6 7 8 9 NA

2.3 Screen layouts were helpful — never / always

1 2 3 4 5 6 7 8 9 NA

2.4 Sequence of screens — confusing / clear

1 2 3 4 5 6 7 8 9 NA

PART 3: Terminology and System Information

3.1 Use of terminology throughout system — inconsistent / consistent

1 2 3 4 5 6 7 8 9 NA

3.2 Terminology relates well to the work you are doing? — never / always

1 2 3 4 5 6 7 8 9 NA

3.3 Messages which appear on screen — inconsistent / consistent

1 2 3 4 5 6 7 8 9 NA

3.4 Messages which appear on screen — confusing / clear

1 2 3 4 5 6 7 8 9 NA

3.5 Computer keeps you informed about what it is doing — never always

1 2 3 4 5 6 7 8 9 NA

3.6 Error messages — unhelpful helpful

1 2 3 4 5 6 7 8 9 NA

PART 4: Learning

4.1 Learning to operate the system — difficult easy

1 2 3 4 5 6 7 8 9 NA

4.2 Exploration of features by trial and error — discouraging encouraging

1 2 3 4 5 6 7 8 9 NA

4.3 Remembering names and use of commands — difficult easy

1 2 3 4 5 6 7 8 9 NA

4.4 Tasks can be performed in a straight-forward manner — never always

1 2 3 4 5 6 7 8 9 NA

PART 5: System Capabilities

5.1 System speed — too slow fast enough

1 2 3 4 5 6 7 8 9 NA

5.2 The system is reliable — never always

1 2 3 4 5 6 7 8 9 NA

5.3	System tends to be	noisy quiet	
		1 2 3 4 5 6 7 8 9	NA
5.4	Correcting your mistakes	difficult easy	
		1 2 3 4 5 6 7 8 9	NA
5.5	Ease of operation depends on your level of experience	never always	
		1 2 3 4 5 6 7 8 9	NA