

Design and Development of Smart application for Diabetes Awareness, Prevention and Management

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Abstract

Worldwide the number of diabetes patient is increasing and the rate is alarming in countries with low and middle income. Management of a diabetes are still costly which leads to high mortality rate in low and middle income countries. Considering the fact that diabetes is a non-curable disease, prevention and management is the only option to deal with. However, proper lifestyle management requires awareness, knowledge and care. Utilization of Information and Communication technology based tools can make life easier to manage diabetes. Smartphone applications are also becoming more popular as it is convenience and easy to use. Sharing knowledge, creating awareness, disease management and even diagnosis is possible using smartphone applications. Cloud based system can also bring benefits in this regard as it can be accessed from anywhere and anytime. With the existing infrastructure it can be used as a tool to create awareness, share knowledge and it can also help people to manage their lifestyle effectively. In this thesis we have reviewed ICT enabled services and articles for diabetes awareness, prevention and management, and proposed a cloud based framework that can be used for screening diabetes and educating people about it. This cloud based framework can also be used for preventing and managing diabetes. We have also explored possible solution of diabetes prevention and management through mobile application. We also presented a smart application, DiaHealth for diabetes management. For complete diabetes lifestyle management, DiaHealth is designed with all necessary advanced and some unique features, which includes Digital Log Book with Graph and Statistics, Intelligent Suggestions, Support for two different Languages and BMI Calculation with visual representation. Other necessary features like Blood Pressure and Blood Glucose Monitoring, Quick Help, Food Value and Physical Exercise List are also included. To complete the thesis work, we added recent trends of diabetes management using cloud services and mobile applications and compared our work with other existing services. We piloted our application and obtained user feedback, accordingly made recommendation for future improvement. With the technological advancement, we believe our work will shed light to diabetes patients to manage their health and life style, consequently it will prevent health consequence and reduce healthcare cost.

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Terminology

ICT	Information and Communication Technology
IT	Information Technology
AI	Artificial Intelligent
GPS	Global Positioning System
App	Application
PDA	Personal Digital Assistant
SMS	Short Message Service
PC	Personal Computer
DM	Diabetes Mellitus
DM2	Diabetes Mellitus Type 2
BMI	Body Mass Index
HbA1c	Haemoglobin A1c (Glycated Haemoglobin)
WHO	World Health Organization
WDD	World Diabetes Day
SEAR	South-East Asian Region
IDF	International Diabetes Federation
NCD	Non-Communicable Disease
USA	United States of America
NIDDK	National Institute of Diabetes and Digestive and Kidney Diseases
NIH	National Institutes of Health
ADA	American Diabetes Association
AADE	American Association of Diabetes Educators
JDRF	Juvenile Diabetes Research Foundation International
ACE	Angiotensin-Converting Enzyme
ARB	Angiotensin Receptor Blockers

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Chapter 1

Introduction

This chapter introduces the background, motivation and objectives of this thesis. The challenges and contributions of this research are summarized in this chapter. In the last section of this chapter, organization of the thesis is summarized.

1.1 Background

Diabetes Mellitus (DM) is a chronic disease and occurs if the pancreas cannot produce required amount of insulin or the body cannot use insulin effectively. Type 1 and Type 2 are two different types of diabetes among which Type 1 diabetes is more severe. Type 2 diabetes leads to Type 1 diabetes if left untreated and not properly controlled. Gestational diabetes is another kind of diabetes that occurs during the time of pregnancy [1].

According to World Health Organization (WHO), 8.5% of adults who are at least 18 years old had diabetes in the year 2014. In the year 2012, 1.5 million people died because of diabetes and 2.2 million people died because of high distribution of fasting plasma glucose in blood. It is the projection of WHO that, in 2030 diabetes will become the 7th major cause of death [2].

According to Global Report on diabetes, Geneva, 2016 by WHO, the number of diabetes patient has increased dramatically 108 million to 422 million from the year 1980 to 2014 which is almost four times higher. For both Men and Women highest number of deaths occurred in the age of 50 To 69. The prevalence of diabetes is also increasing rapidly. In 1980 world-wide prevalence of diabetes was 4.7%. However, it increased to the number 8.5% in the year 2014 which is almost double compared to the 1980 [3]. The details of diabetes prevalence categorized by countries with different income group are shown in Figure 1.1.

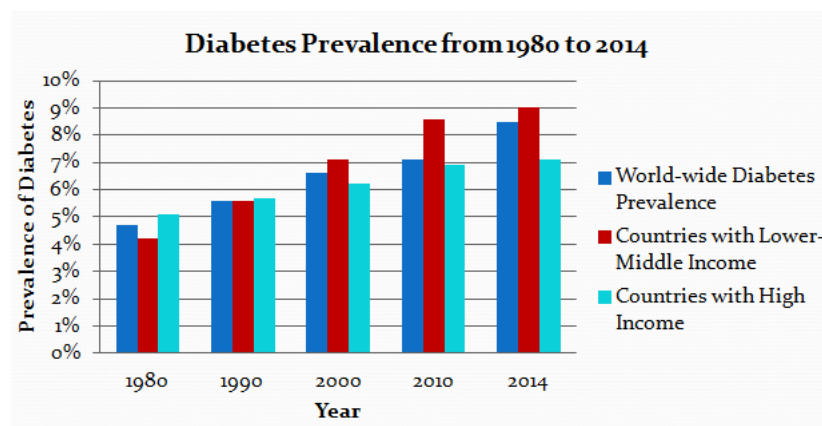


Figure 1.1: Prevalence of Diabetes from 1980 to 2014 categorized by countries with different income group.

To prevent the complexity of diabetes which leads to deaths, blood glucose level should be controlled and life style should be managed properly. The treatment of this type of disease through medicine proves lower improvement of patient's health. Failure in proper diagnosis also causes health problems, complications and finally deaths. This indicates a cost effective solution is required. This solution can be the self-management and use of ICT, a present day infrastructure to promote knowledge of diabetes prevention and management and to shape lifestyle of a diabetes patient.

To overcome the present day crisis of diabetes and to help patients to manage their lifestyle more effectively, mobile applications can be made and used [4] as well as websites can be made with necessary features to screen diabetes, to help communicate with doctors more effectively and sharing knowledge to help them to manage their lifestyle effectively. In this research we have discussed about present day scenario of diabetes management. We have also discussed the role of ICT in this context. We then, proposed a cloud based architecture for diabetes awareness, prevention and management. We have also presented our smart mobile application DiaHealth which is helpful for complete diabetes lifestyle management.

1.2 Motivation

Diabetes is a growing concern and number of diabetes patient is increasing worldwide. Diabetes is a lifelong disease and once occurred, there is no escape from this. However, prevention is big deal for Type 2 diabetes which actually leads to Type 1 diabetes. Type 2 diabetes can be prevented by taking regular exercise, eating healthy food and by checking risk overall, by modifying life style. This life style modification can prevent Type 2 diabetes by 50% [5]. However, these preventing measures can be performed effectively by the people who are properly educated with the knowledge of diabetes. This diabetes education can be performed in various ways. ICT can be the right tool and also a media to perform knowledge education and share knowledge about diabetes.

Diabetes causes complication which leads to death in a long term. Proper life style management is the key to control this disease. Treatment of diabetes is costly and complication caused by diabetes requires additional treatment. In developing countries, the situation is even worse. To address this problem, an innovative and cost effective solution is required which will prevent diabetes and helps patient to modify their life-style.

Cloud based architecture can be very fruitful in this regard as it can be accessed from anywhere with IT enabled devices. With the existing infrastructure it can be used as a tool to create awareness, share knowledge and it can also help people to manage their life-style effectively. Interactive cloud based platform can be used to show tips, diet measurement information and generate preventive measures.

Along with cloud based architecture, mobile application based solutions can also play an important role. Steps which can be taken to prevent and manage diabetes with the help of ICT are SMS based mobile awareness, internet based health monitoring systems, Information Technology for creating awareness, use of Mobile Health (mHealth) technology and using application services (Mobile app.). In this research we have studied mobile applications based and cloud based solutions to address this alarming issue. We have presented our smart app DiaHealth for complete diabetes lifestyle management and proposed a cloud based solution to screen diabetes and help patient to manage their lifestyle more effectively.

1.3 Objectives

The objective of this research is to analyze ICT enabled services, articles to promote ICT in an effective way for diabetes awareness, prevention and management. To promote ICT in this context, we have discussed possible solutions and we proposed a cloud based framework for screening diabetes patient and help them to manage diabetes effectively. We have also presented our smart app DiaHealth which provides complete solution for diabetes lifestyle management.

Our goal is to prevent diabetes and help patient to manage the disease through ICT. For this reason, our objectives were:

- To study recent trends of web based services for diabetes awareness, prevention and management.
- To identify necessary features to be covered by cloud based solutions to effective diabetes management.
- To define features for screening diabetes using cloud based services.
- To propose a cloud based framework that covers necessary aspects to cover the services for diabetes awareness, prevention and management.
- To define necessary features for developing smart mobile application for diabetes lifestyle management.
- To develop a smart app for complete diabetes lifestyle management which will include the features,
 - Blood glucose monitor
 - Medication suggestion
 - Diet plan
 - Physical activity/exercise plan
 - Automated transfer of blood glucose data
 - Secondary features may include:
 - SMS based service/notification
 - Data entry and record (blood glucose/sugar, blood pressure, HBA1c, cholesterol, weight etc.)
 - Nutrition information
 - Communication with healthcare team
 - Education
 - Weight management
 - Blood pressure monitoring

Finally, it can be said that, if we succeed in implementing our solution in real life, prevention and management of diabetes will be easily possible and people of rural areas will also find it useful to manage this disease effectively.

1.4 Challenges

Diabetes is a lifelong illness and it is a global concern. People of developing countries are facing more challenges to manage diabetes as cost of diabetes treatment is costly. Even in

developed world it is a big challenge to address this issue. The goal of this thesis is to provide cost effective solutions using ICT which is an integral part of our life. Along with this we have faced several challenges while doing this thesis work. These challenges include both experimental design and development studies. Challenges that are faced are given below:

- Studying websites that covers diabetes care.
- Identifying necessary features for the cloud based architecture.
- Defining parameters and techniques to screen diabetes remotely.
- Defining unique features that is yet to be provided by any cloud based solutions.
- Identifying all necessary features to develop DiaHealth was really a challenge.
- Making DiaHealth a unique and complete app among all healthcare related apps (around 30,000 apps are available).
- Developing the app with user-friendly and easy UI (User Interface).
- Developing the app with both languages (English and Bengali).

It is good news that, we have successfully overcome all the challenges and completed the thesis work with desired outcomes.

1.5 Contribution made to knowledge and Publications

In this thesis work we have several contributions to the existing knowledge. We have made two publications in two International Conferences. Details are given in sections below.

1.5.1 Contribution

Diabetes is a global concern. More people are engaging as diabetes patient day by day and the prevalence of diabetes is increasing very rapidly in both developing and developed countries. The cost of treatment of this disease is still very costly and cost effective solution is hard to find (Details of present day diabetes scenario is given in Chapter 2). Prevention of diabetes is big deal to address the issue. Lifestyle modification is required to live a healthy life and to control this disease. Information and Communication technology (ICT) is now an integral part of our life. Our contribution is to find one or more cost effective solutions for preventing diabetes and help diabetes patient to manage this disease properly. To do this, we have analyzed recent cloud based solutions and mobile application based solutions for diabetes awareness, prevention and management. Then, we have proposed a cost effective cloud based solution and presented a smart app DiaHealth. Our cloud based solution has necessary features to prevent diabetes by creating awareness through knowledge sharing. It can also be used to screen diabetes remotely. If we implement this successfully, diabetes patient will be able to communicate with desired doctor, even he/she stays far away, especially in rural areas. SMS, Email based reminder and alarm services are also integrated in this system. Our smart app DiaHealth has some unique and all necessary features for a complete lifestyle management. With the help of this app diabetes patient can easily monitor his/her month-long and even yearlong health status. Most necessary features provided by DiaHealth are digital log book, Diet Planning and suggestion, BMI calculation, Food value of different foods, exercise lists with calorie burn chart and other necessary features. If we can implement these two solutions in real life it will be easier for diabetes patient to control the disease through lifestyle modification.

1.5.2 Publications

During the period of my M.Sc. thesis, the research work performed in this thesis has been published and accepted in two international conferences (One is already published and another is accepted). A list of publications of this research work is included in *Appendix A*.

1.6 Organization of the Thesis

This thesis is organized into six Chapters. Chapters 2 and 3 contain background materials, chapters 4 and 5 mainly describe the research specifics of this thesis, in which Chapter 4 describes a proposed cloud based architecture and 5 describes the research work on smart app DiaHealth. Chapter 6 draws the conclusion of the thesis. The contents of each chapter are listed in the following.

- Chapter 1 introduces the background, motivation and focus of this thesis. The challenges and contributions of this research are summarized.
- Chapter 2 gives review of current practices of diabetes management. At first present state of diabetes management of developing countries then developed countries are given. Then, challenges and problems of developing countries to manage diabetes are given. The present day scenario of this disease is also discussed in this chapter.
- Chapter 3 gives detail overview of diabetes management using Information and Communication Technology (ICT). At first ICT based solutions are discussed, then mobile app based solutions are also given.
- Chapter 4 presents a proposed cloud based system for diabetes awareness, prevention and management. In the beginning of this chapter we discussed about available cloud based services for diabetes management. Available features are also summarized in a table. Then, we have discussed our proposed system with a flowchart. The features of the proposed system are also discussed in the later section of this chapter.
- Chapter 5 presents DiaHealth: A smart app for complete diabetes lifestyle management. In this chapter at first, we compared features of DiaHealth with some popular available apps. Then detail features are discussed. After that, the application of this app in Bangladesh is given. Some user feedback is summarized later in this chapter.
- Chapter 6 presents discussion, critical analysis, conclusion and future work of this research.

Chapter 2

Current Practices of Diabetes Management

In this chapter, we have presented present situation of diabetes management in both developing and developed countries. At first, present scenario of diabetes management in developing countries and then developed countries are provided. After that, challenges of developing countries to manage diabetes are given.

2.1 Introduction

Diabetes is a growing concern and has become a major socio-economic challenge. People are suffering from diabetes both in developing and developed countries [6, 7]. Genetic, environmental and lifestyle management factors play a great role in developing diabetes [8]. Diabetes occur when the body cannot produce required amount of insulin or the body cannot use insulin effectively. Because of total or relative lack of insulin, body fails to metabolize sugar effectively. Fat, protein and glycogen are then broken down in order to produce sugar which results high sugar level in blood [9].

Thirst, sudden weight loss, blurred vision, polyuria may present as characteristic symptoms of diabetes [10].

The effects of diabetes are very severe. In long term it may cause damage and dysfunctions of various organs [10]. Type 1 diabetes mellitus encompasses the majority of diabetes, which are primarily due to pancreatic islet beta cell destruction and are prone to ketoacidosis [11]. If diabetes is not well-controlled, complications will follow. These complications include kidney, heart, eye disease, mental disorder etc. Moreover, treatment of these complications is expensive and it puts severe economic burden to the poor people. In developing countries, the situation will become worse as non-communicable diseases like diabetes are evolving rapidly in this region [3]. Diabetes prevalence is also high in this region. Despite this high prevalence, the quality of care is still very low in developing countries [12]. Diabetes is becoming epidemic in both developing and developed countries and for this reason it has become the cause of serious public health problem and clinical concern [13].

Both developing and developed countries struggling to manage diabetes. In developed countries, people are trying to manage this disease through medication, lifestyle management and through other expensive solutions. The situation is no good here. The cost is still very high. However, the situation is worse in developing countries, as people do not want to spend much money on any disease. For this reason, complications of diabetes are increasing and people are suffering more.

2.2 Present State of Diabetes Management in Developing Countries

Diabetes has become major health problem. In 2013 it affected 382 million people and deaths caused by diabetes were 5.3 million in that year [14]. It is estimated that around 592

million people will be affected by diabetes in the year 2035 [14]. Among all these diabetes patients around 80% diabetes patient live low and middle income countries [14]. In south-Asian region diabetes has become seventh major attributable risk factor for burden of disease [15]. Previously, diabetes was considered to be a disease of rich people, but now it is causing serious health problem in people of middle and low income countries [6-8], particularly affecting more South-Asians [16]. The health system of low and middle income countries is still fragile. The socio-economic burden of diabetes has put an enormous pressure in the health system in these countries. In South Asian region, it is found that, Bangladesh has the second largest number of adult diabetic patients (5.1 million adults, 6.31%) [14].

According to IDF (International Diabetes Federation), around half of the population living with diabetes in South-Asian region were unaware about their condition in 2013 [14].

There are several causes behind obesity and developing diabetes in developing countries. Current lifestyle with better economic development, increased income and urbanization have caused diet change and less physical activity. Lifestyle management through physical activity and diet plan is the most important thing to control diabetes. Unfortunately, people of developing countries are less aware about these factors. In developing Type 2 diabetes diet and lifestyle play key role. However, genetics also play a great role in developing Type 2 diabetes. Although, obesity plays an important factor in the diabetes epidemic, it does not alone explain the vast increase in prevalence of diabetes especially in the developing countries [17].

In the last few years, diabetes has become a serious health problem in low and middle income countries and has been found in a wide variety of atypical forms. Its socio-economic burden is huge in developing countries, people of these countries lack basic means of diagnosis and much knowledge how to control or prevent this disease. Another major issue is that, in developing countries there are low number of healthcare providers who have requisite knowledge, experience and expertise for the care of diabetes patient. Diabetes care in these countries needs to address some specific criteria which includes background of the patient population, patient's need and their medical problem [18].

The situation is worse in sub-Saharan Africa as 33 of the 50 poorest countries in the world situated here [19]. These huge population lack knowledge, medication and other means of diabetes care.

There is an issue in collecting information about diabetes management in low and middle income countries, as these countries are hospital based and data that is found is only on patients who visit hospitals regularly [13]. More epidemiological survey is required to get real data on diabetes management in these countries and it has become urgent as both Type 1 and Type 2 diabetes mellitus is increasing rapidly [14].

According to a recent study, it is found that the number of diabetes patient is increasing in Bangladesh [14]. However, the treatment and control of this disease is still substantially low. There are a lot of reasons for variation of treatment and awareness among people of developing countries like Bangladesh. Access to care depends on socio-economic status of a family and it affects awareness and treatment. It also found that, people of Bangladesh has less capacity to spend money on healthcare [14]. Moreover, proper management of diabetes mostly rely on the health system's ability to provide diagnosis, care and other

services with affordable cost to the general people. A recent study showed that, in Bangladesh around 12% people sell household assets or borrow money to pay healthcare costs which are related to chronic disease [20]. Although government is subsidizing public health services, they fail to provide affordable healthcare to the poor population [20]. This factor implies that, for this subpopulation this subsidized program may not work properly. For this reason, poor population of Bangladesh skip taking medication and refrain accessing other health care services to avoid financial burden. Despite this socio-economic burden, subsidized healthcare system is highly restricted to child health programs and some communicable diseases [22]. It is also found that, NCD management receives less attention especially for diabetes and hypertension [14]. To overcome these situation, health policies, programs in Bangladesh should be scaled up according to current situation and predicted disease burden. Figure 2.1 shows age-specific and age-standardized prevalence of diabetes and prediabetes in Bangladeshi adults aged 35 years or older [14].

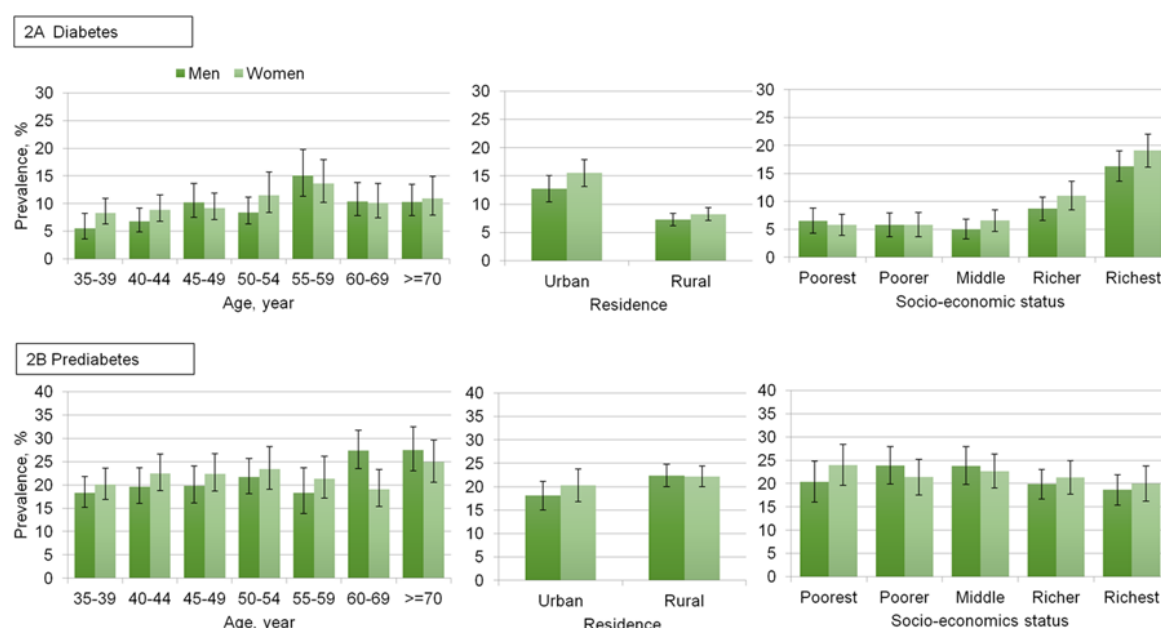


Figure 2.1: Age-specific and age-standardized prevalence of diabetes and prediabetes in Bangladeshi adults aged 35 years or older [14].

2.3 Present State of Diabetes Management in Developed Countries

Diabetes is serious health concern and the prevalence of diabetes is increasing rapidly. The situation is not less serious in developed countries. Around 8.2 million (6.3 percent) people of United States have diabetes. However, diagnosis rate is high and people get good healthcare services in developed countries like US, compared to developing countries. Among 18 million of diabetes patient of US, around 13 million are diagnosed and around 5.2 million are still to diagnose [23].

Diabetes is still major problem in rural areas of developed countries. In US, the incidence of diabetes in rural areas is around 17% higher than in cities. The people of rural areas have less access to the advance healthcare system and many of them are poor and less interested to spend for the treatment. In rural US, between 28% and 45% of diabetes patient is left untreated [24].

A Research team from the Department of Pharmaceutical and Administrative Sciences, Presbyterian College School of Pharmacy, Clinton, South Carolina have published their research work in the Journal of Pain Research which reviews data collected from a free, pharmacist led diabetes education clinic. In that research, they have found that, the majority of diabetes patients who were treated for diabetic neuropathy, never received guideline directed care [24].

Another research has found that, around 60% diabetic patients with neuropathy were undiagnosed and even undocumented. That research also indicates that, in those rural areas men are likely to develop diabetic neuropathy more than women. Patients with diabetic neuropathy are found around 12 kilograms lighter than those who have not developed diabetic neuropathy [24].

Compared to developing countries a lot more research organizations, institutions conduct research on diabetes and other non-communicable diseases. NIDDK (National Institute of Diabetes and Digestive and Kidney Disease) of USA is one those institutes. It has its own research laboratory where it conducts research and provide supports to basic and clinical research in the medical centers and hospitals of United States. NIDDK also gathers data and analyzes statistics about diabetes. NIH (National Institute of Health) is another institute that conduct research about diabetes related complications and provide support for the heart and vascular complications, eye disease and dental problems [23].

In developed countries, there are many other organization outside government to provide diabetes education and provide support for diabetes research. American Association of Diabetes Educators (AADE), the Juvenile Diabetes Research Foundation International (JDRF) and American Diabetes Association (ADA) are such organizations.

In developed countries, research on diabetes has increased in recent years and advanced research on this field led better ways of treating and managing diabetes and its complications. The output of these advanced research includes better ways of monitoring blood glucose level, long acting and quick acting insulins and development of non-invasive methods to monitor blood glucose level [23]. According to NIDDK, some key findings in this aspect are given below,

- Invention of outer insulin pump to supply insulin. Now, it is not required to have regular injections.
- Laser technology for eye disease caused by diabetes. This technology prevents the risk of blindness.
- Successful pancreas and kidney transplantation in those diabetic patients whose kidney fails because of this disease.
- Better drugs for the treatment of Type 2 diabetes and better ways to control weight for managing diabetes effectively.
- Preventing development of diabetes complications through intensive management of blood glucose level.
- Researched to find out that, two types of antihypertensive drugs, Angiotensin-Converting Enzyme (ACE) inhibitors and Angiotensin Receptor Blockers (ARB) are more effective compared to other antihypertensive drugs to reduce decline in kidney function in diabetes patients.

- Successful islet transplantation for people with Type 1 diabetes. This promising result is achieved by researcher of University of Alberta in Canada.

It is clear that, developed countries have more resources and educated personal to research on diabetes management and help people with promising results. However, diabetes is still big concern worldwide including developed countries and for this reason more research is still required in this field.

2.4 Main challenges of managing diabetes in developing countries

2.4.1. Ignorance

Ignorance plays a great role in developing diabetes and its complications. People of developing countries are less aware of this disease. Due to this ignorance, people with diabetes are lately diagnosed even after arising diabetic complications. For people with diabetes living in rural areas in this region it is not high priority to spend to prevent diabetic complications. Like buying footwear is luxurious to some people which may prevent foot complications and a lot of people in rural areas are found who walks in barefoot [25].

2.4.2. Economic and cost of management of diabetes

The management of diabetes is complex and multidisciplinary, hence expensive for the people of low income countries where most of the people live below a dollar per day [13]. There are three broad categories of economic costs.

- Direct healthcare costs:** Direct healthcare costs include costs on purchase of medicine, glucometers and other necessary things for those who can afford it. This costs also include cost on visiting hospitals and other healthcare facilities, to see professionals and specialists and also money spent for hospitalization for diabetes and its complications [17].
- Indirect cost on healthcare:** Indirect healthcare costs include costs of nursing homes and informal care provided by relatives and healthcare professionals. Societal expectations for appropriate place for professional and informal healthcare certainly have economic consequences [17]. Friends and relatives may lose productive hours which is important for their work or business while caring for their patients.
- Productivity costs:** Productivity costs includes earning loss from morbidity and mortality when time is taken by economic individuals to treat their condition and disability associated with its complication [17]. In developing countries, with the help of scare resource, some effective programs are still possible to put in place. Some patients, mainly in rural areas travel a great distance to seek medical care. This means people need more money in order to get medical checkups and to visit healthcare professionals. This discourages diabetic patients from seeking early diagnosis which may reduce healthcare costs in future [17].

Diabetes mellitus is a growing problem. This problem will have significant impact on individual and national economics. Diabetes will create serious burden on health problem

also. These direct and indirect costs will be increased as more and more people with income source are getting affected [26]. However, good data on direct and indirect medical costs of diabetes are not available in most of the developing countries [26].

2.4.3. Poverty

In developing countries, health condition is poor and a lot of people live below poverty line [19]. Healthcare services are limited and people cannot get all services because of their poor living condition. The number of healthcare provider with requisite expertise, experience and knowledge are very low in these countries. In healthcare facilities there is a lack of diagnosis and monitoring tools and supply of insulin is also irregular. In many parts of developing countries insulin is still not always available [18].

2.5 Conclusion

In conclusion, it can be said that, people living in urban areas with higher socio-economic status have more access to healthcare services compared to the people living in rural areas. Both in developing and developed countries people of rural areas are suffering more from diabetes and its complications. However, the rate of diabetes is still high among people who live in urban areas and have good socio-economic status [14]. To assist diabetic people in developing countries, proper diabetes detection is needed and valid treatment is required. To attain this, government should give top priority to Non-Communicable Diseases (NCDs), especially to diabetes and disease related to diabetes complications. The health system is needed to be reformed based on disease burden. Universal health insurance is needed to be implemented or other financial services needed to be established in order to ensure that, people from aspects, rich or poor will have proper healthcare services. People are also needed to be educated more about diabetes awareness, prevention and management through lifestyle modification and dietary habits.

Chapter 3

ICT-based Diabetes Lifestyle Management System

In this chapter, we have provided detail overview of diabetes management using ICT and Mobile Apps. To do this we have analyzed current research works, existing mobile apps and ICT based other solutions that are available to support diabetes patient. At first ICT based solutions are discussed, then mobile app based solutions are discussed.

3.1 Introduction

Diabetes is a non-curable disease and it causes serious complications if it is left untreated which eventually causes death [27, 28]. More people are affecting by this disease and the rate is increasing alarmingly [28]. This is an everlasting disease till death. The good news here is, this disease can be controlled and it requires proper lifestyle management. All kinds of diabetes require proper patient care including diet management, exercise, medication, awareness, sufficient knowledge on this disease and strict discipline in the lifestyle. The main key to control this disease is self-management. But, this is a challenge to most diabetes patients as it requires a lot of change in day to day habitual activities. In developing countries most people are ignorant and unaware about diabetes. For this reason, diabetes remains unnoticed and in long run causes deaths. For this reason, main challenge for middle and low income countries is to aware people about diabetes and its complications. For people who are already victims of diabetes, their main challenge is to lifestyle modification to control diabetes and further complications caused by diabetes.

Recently, in a very short span of time, ICT (Information and Communication Technology) has emerged significantly and become an integral part of our life [29]. Due to the recent evaluation of ICT, world is now in our hand grip and information can be found more easily with a touch of a finger. It has been found that, in developed countries around 80% people own a mobile phone and in developing countries it is around 50% [30]. Among all these mobile phones, a lot are smartphones. Smartphones are the latest inclusion and it offers functionalities like a computer, still remain hand or inside a pocket [31]. Besides, smartphone and PC (personal computer) users have increased significantly. Smartphones, PDAs (Personal Digital Assistant) and PCs are now facilitating advanced operating systems which enable better data storage, web browsing, access to internet, social networking and many more [32]. In many cases, these ICT enabled devices eases up complicacies of our life. In healthcare, ICT enabled services are providing enormous contribution [33, 34]. Mobile and IT (Information Technology) based services are spreading fast and offering a lot supports to patients which include education, self-management options, counselling, information etc. [28, 35]. All these features are very helpful to keep control over diabetes as a success of self-management depends on the glycemic control by monitoring blood glucose in a proportionate rate [36].

In this chapter, we have analyzed articles, existing mobile apps and ICT based other solutions that are currently available to support diabetes patient. Based on the analysis and discussion of this chapter we designed a cloud based framework and a mobile application

with necessary features to support diabetes patient in both developing and developed countries. The details will be followed in next chapter.

3.2 ICT based Solutions for Diabetes Prevention and Management

Diabetes is non-curable but preventable disease. Creating awareness is the first step to prevent diabetes. To create awareness, we need to spread the knowledge about preventive measures of this disease. World Diabetes Day (WDD) is celebrated yearly on November 14 to aware people about diabetes and to show them the means of prevention. This campaign is supported by International Diabetes Federation (IDF) and corresponding member associations. Other ways those are followed to create awareness are organizing flash mob, speaking in schools and colleges, spreading leaf lets, handbooks, banner, making news on newspapers [37]. However, as we live in an age of technology, we can aware people more effectively by using information and communication technologies. Nowadays, almost all kinds of people including children and aged old peoples use some kind of communication devices [38].

The number of mobile phone has increased dramatically and a related study showed that, the number of messages sent tripled globally between the year 2007 and 2010. Being low cost and instant transmission mobile messaging has become well accepted among people of all status. For this reason, mobile phone messaging (SMS) can be used to send educational advice as well as motivational messages to change lifestyle for preventing diabetes [5]. In a recent study, it has been found that, worldwide the number of smartphone user is more than 1 billion. It has also been found that, around 30,000 healthcare based mobile applications are available [39]. For these reasons, we can develop an application to promote healthy lifestyle which will help people to prevent diabetes and manage the disease effectively. Moreover, patient can find it interesting and easy to maintain diabetes through such modern technologies. The following Figure (Figure 3.1) shows available android applications for health and fitness available at “Google Play Store” [40].

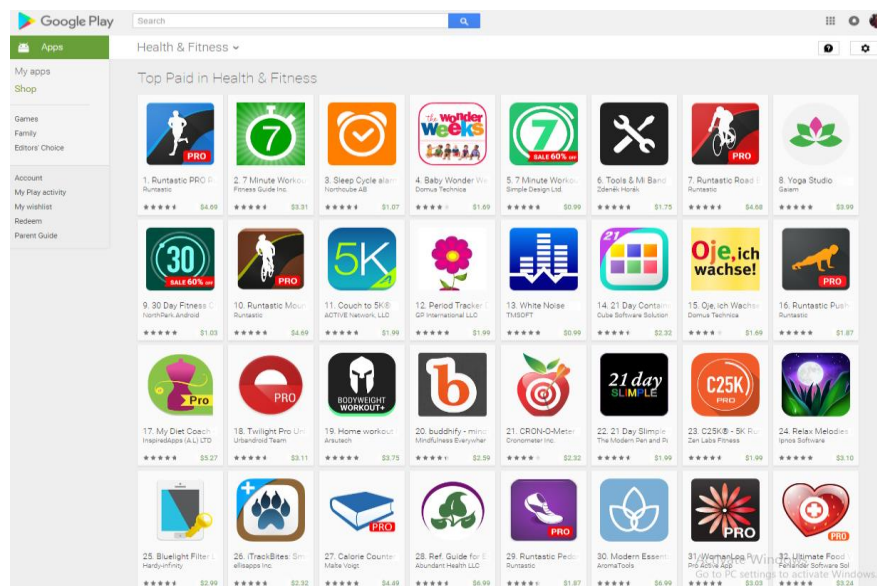


Figure 3.1: Screenshot of Google Play Marketplace, showing some of the health and healthcare-related apps that are currently available for downloading.

Smartphone, Personal Computers (PC), Notebooks or Tablets are found even with peoples in developing countries. With the help of internet all these devices can be used as a tool or communication media to share news about the prevention of diabetes which will actually aware people [41]. Another important sector that can be considered is Social Media. Social media has become an important part of our life. More people are engaging in social media every day. Social Media can be used as an easy, cost-effective solution to reach millions of people across worldwide. This platform can be used to share online resources. Web pages, statistics, medication and a lot of information can be shared in social media to raise awareness. Health promotion is also possible through internet based social media which include Facebook, Twitter, Myspace, blogs, messaging application like Viber and WhatsApp [42].

Websites are becoming more popular day by day not only for accessing information but also to share knowledge, storing information and communication purposes. A recent study showed that, in rural China a smart web aid helped people to identify and diagnose diabetes a way that was never been possible before. The name of their system is “Smart Web Aid for Preventing Type 2 Diabetes (SWAP-DM2)”. Using SWAP-DM2, around 2219 patients identified with diabetes risk and within 6 months 113 diabetes diagnosis was possible [43]. For this reason, it is now feasible to take help from internet based websites to prevent diabetes and also control this disease by educating people through online.

3.3 App based Solutions for Diabetes Lifestyle Management

Mobile phones are becoming more popular and it has become an essential part of our daily life. According to different statistics in different countries, it has been found that around 80% people uses mobile in developed countries, in developing countries it is around 60% and 50% in least developed countries [30, 44, 45]. If we consider families then, around 89% families own at least one mobile phone in the world [30]. It is being predicted that, globally the number of mobile phone user will cross 90% very soon [44]. The number of smartphone users are low compared to the mobile phone users, but it is estimated that in next 5 to 10 years around 80% to 90% people will use smartphone [44]. For this reason, it can be a revolution to use smartphone application for lifestyle management of diabetes patients.

In our review of diabetes lifestyle management through mobile applications, we found that, there are almost same number of mobile applications are available for both Android and iOS. Android applications are less expensive, more user friendly compared to iOS and also available for various types of devices like tablets, phones etc. [30, 32, 45]. From various online app store, it is also found that, Android applications are more popular compared to other platforms especially in low and middle income countries.

App can be bought from online app store. There are also free apps to use. The user ratings and features do not significantly differ between paid apps and free apps [34]. However, a lot of free apps are also found which lack quality features and usability. Being cost free, free apps are more popular in low and middle income countries as people of these countries are not eager to spend their valuable money on mobile apps.

Table 3.1: Summary of the Features of the Apps

Name	Features										
	Medication	Glucose Monitor	Diet Plan	Auto Data Input	Exercise	Blood Pressure Monitor	Communication	Weight	Detail Log Book	Differentiate between types of Diabetes	Education
Sugar Sense	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓
Diabetes Tracker	✓	✓	✓	×	✓	✓	✓	×	✓	✓	×
Diabetes: M	✓	✓	✓	×	×	✓	✓	✓	✓	×	×
on Track	✓	✓	✓	×	✓	✓	✓	✓	✓	×	×
Diabetes PA	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×
Blood Sugar Manager	×	✓	×	×	×	×	×	×	×	×	×
Blood Glucose Tracker	✓	✓	×	×	✓	✓	✓	✓	✓	×	×
iHealth Gluco Smart	×	✓	×	✓	✓	×	✓	×	✓	✓	×
Glucose Buddy	✓	✓	×	×	×	✓	×	✓	✓	✓	×
Diabetes Glucose Diary	×	✓	×	×	×	×	×	×	×	×	×
BG Monitor Diabetes	×	✓	×	×	×	×	✓	×	✓	×	×
Diabetes Recorder	×	✓	×	×	×	✓	✓	✓	×	×	×
Diabetes Plus	✓	✓	×	×	✓	✓	✓	✓	✓	×	×
My Glycemia: Diabetes Tracker	×	✓	×	×	×	×	×	×	✓	×	×
Sugar Log	✓	✓	×	×	×	×	×	×	✓	×	×
Diabetes Diary Glucose Tracker	✓	✓	✓	×	×	×	✓	×	✓	×	×
Diabetes Tracker Mobiscreen	✓	✓	×	×	×	×	×	×	✓	×	×
Diabetes Connect	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×
Smart e-smbg Diabetes Lifelog	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
Diabetes Journal	×	✓	×	×	✓	×	✓	×	×	×	×
dbees.com Diabetes Management	✓	✓	✓	×	✓	✓	✓	×	✓	×	×
Glucool Diabetes	✓	✓	×	×	✓	✓	✓	✓	✓	×	×
SiDiary Diabetes Management	×	✓	×	×	×	✓	✓	✓	✓	×	×
Lifespan Measure	×	✓	✓	×	×	✓	✓	×	✓	×	×
Diabetes Diary	✓	✓	✓	×	✓	×	×	×	✓	×	×
Sweet Log	×	✓	×	×	×	×	×	×	×	✓	×
Diabetes UK Tracker	✓	✓	×	×	×	✓	✓	✓	✓	×	×
Glucose	×	✓	×	×	✓	×	✓	×	×	×	×
Gmate	×	✓	×	×	×	×	✓	×	×	×	×
Diabetes in Check	✓	✓	✓	×	✓	×	✓	×	✓	✓	✓
Mysugar Diabetes Log Book	✓	✓	×	✓	✓	×	✓	×	✓	✓	×
Glucose Wiz	✓	✓	✓	×	×	×	✓	✓	✓	×	×
Diabetes Pal App	✓	✓	✓	✓	✓	✓	×	✓	✓	×	×
Diabetes Pedometer	✓	✓	✓	×	✓	✓	✓	✓	×	×	×
Diabetes Kit Blood Glucose Logbook	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓

Glucose Companion	×	✓	×	×	×	×	✓	✓	✓	✓	×
Easy Diabetes	×	✓	×	×	×	×	×	×	✓	×	×
Glooko	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×
Diabetik	✓	✓	×	×	✓	×	✓	×	✓	×	×
Diaguard	×	✓	×	×	✓	×	×	✓	✓	×	×
Diabetes in Check	✓	✓	✓	×	✓	×	✓	×	✓	✓	✓
Glicontrol	×	✓	✓	×	×	×	✓	×	×	×	×
Diabetes App Blood Glucose Tracker	×	✓	×	✓	✓	×	✓	×	✓	×	×

There are a lot of mobile applications as well as cloud based solutions to enhance diabetes lifestyle management. However, automation is not present everywhere especially in low and middle income countries. For this reason, diabetes patient can be automated in lifestyle management, but physicians may lag behind or vice versa. But, this is a starting effort to use mobile technology for human health and it's going to have good impact on our society. We reviewed diabetes related mobile applications and sorted out all necessary features for diabetes lifestyle management.

In our review, we carefully selected applications with an extensive search. Our reviewed apps consist of both paid and free apps. These apps and their features are summarized in Table 3.1. Total 43 apps are compared here. Among these 43 apps, 32 apps are free and rest of the apps are paid with a price range of 2.86 USD to 9.99 USD. In terms of features, usability and functionality free apps did not differ much from the paid apps. From this table, it is clearly visible that, no app is complete in terms of lifestyle management as every app misses more than one necessary features. From this review, we collected essential features for diabetes lifestyle management and later we developed a smart app DiaHealth with all necessary features for complete diabetes lifestyle management (discussed in Chapter 5).

3.4 Conclusion

The potential use of Information and Communication Technology encourages wide variety of mobile applications and ICT based solutions in healthcare. A lot of diseases do not require self-monitoring and lifestyle management. Diabetes is non-communicable but not curable disease and it requires awareness and lifestyle management to control this disease. To achieve glycemic control, continuous monitoring is required especially for the child and old people. Timely notification is also required for these diabetes patients. All these put a heavy challenge in diabetes self-management. ICT based solutions are easier to use and people of all ages are getting used to it. For this reason, healthcare related services focused on diabetes are now widely available. All these services are important for diabetes prevention and management. The fact here is that, no single service is completed for complete diabetes care. There are still fields left for research and develop more significant and complete services.

Chapter 4

Proposed Architecture for Diabetes Awareness, Prevention and Management

In this chapter, we have presented a proposed cloud based architecture for diabetes awareness, prevention and management. In the beginning of this chapter we discussed about available cloud based services for diabetes management. Available features are also summarized in a table. Then, we discussed our proposed system with a flowchart. The features of the proposed system is also discussed in the later section of this chapter.

4.1 Introduction

Diabetes is complex hormonal disorder. Worldwide, more than three hundred million people are affected by diabetes and the number of diabetes patient is increasing. According to WHO, around 347 million people are victim of diabetes. It is being predicted that the number of diabetes patient will be doubled by 2030 [46, 47]. Prevention and early diagnosis can reduce this burden. To maintain a good quality of life, several therapies have been proposed along with lifestyle management. There are four keystones for diabetes self-management which are diet, physical activity, controlling blood glucose and insulin level [47].

To reduce the occurrence of this disease we need to create awareness and take preventive steps as much as possible. To reduce the deaths caused by the diabetes, proper life-style management is required. Present day healthcare system is not well-equipped to face this crisis of diabetes even in developed countries [48]. The situation is worse in developing countries. According to WHO, the diabetes increase rate is alarming in South-East Asian Region (SEAR) and total of all diabetes patient, more than 20% will be found in this region. Currently, around 7 million cases of diabetes are available in Bangladesh and the number of diabetes patients is increasing by the rate of 5-6% in a year [49]. To overcome this crisis self-care activity is required in addition to existing healthcare programs and medical interventions. AADE (American Association of Diabetes Education) has a guideline supported by American Diabetes Association for self-care educations. A set of activities are defined in that guideline. Most important of them are performing exercise, taking healthy foods, medication and self-monitoring. All these activities are hard to follow for a diabetes patient. However, the use of ICT can be very helpful for a patient in this context [50]. The use of ICT can enhance patient's self-care activity. Moreover, patient can find it interesting and easy to maintain diabetes through modern technologies like mobile apps and websites.

In this chapter, we have analyzed cloud based services, articles to promote ICT in an effective way for diabetes awareness, prevention and management. To promote ICT in this context, we have discussed possible solutions and we proposed a framework for screening diabetes patient and help them to manage diabetes effectively.

4.3 Related Work

There are lots of websites available for diabetes education and support. Some of these websites also offer diabetes risk test for Type 2 diabetes. American Diabetes Association has its own website. They provide important features which includes risk test for Type 2 diabetes, medication guideline, diet plan and BMI check. However, there is no option available for Blood glucose monitoring, SMS/Email notifications [51]. There are other websites also available with similar features. However, in an extensive search there is no cloud based system found which supports diabetes prevention, management and screening in a single platform. Our proposed framework can screen diabetes based on the input of user, suggest medication, provide diabetes education for all kinds of user, and provide support by assigning a doctor. Table 4.1 shows the summary of some mostly used websites for diabetes management and prevention.

In this summary we have added basic features for diabetes awareness, prevention and management. Limitation is added to visualize the strength of a particular web. The country in which the website is developed also added. It is matter of sorrow that no interactive website is found developed and used in Bangladesh. Bangladesh Diabetes Association has its website only provide diabetes information.

Table 4.1: Summary of Some Mostly Used Websites for Diabetes Management and Prevention

Name	Address	Features											Developed in	Limitations
		Diabetes Education	Test for Diabetes	Glucose Monitoring	Medication Guideline	Diet Plan	Exercise	Blood Pressure Monitoring	BMI Checking	Communication(Online/Offline)	Support	SMS/Email Notifications		
American diabetes Association	http://www.diabetes.org/	✓	DM2*	×	✓	✓	✓	×	✓	✓	✓	×	USA	No active blood glucose, Blood pressure monitoring options available. Diabetes screening is not also available.
Diabetes Self-Management	http://www.diabetesselfmanagement.com/	✓	×	×	✓	✓	✓	×	×	✓	✓	✓	Not found	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.
Sanofi Diabetes India	http://www.sanofidiabetes.in/	✓	×	×	✓	✓	✓	×	×	×	×	×	India	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.
Diabetes Australia	https://www.diabetesaustralia.com.au/	✓	DM2*	×	✓	✓	✓	×	×	✓	✓	×	Australia	No active blood glucose, Blood pressure monitoring options available. Diabetes screening is not also available.

The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)	http://www.niddk.nih.gov/Pages/default.aspx	✓	✗	✗	✓	✓	✓	✗	✗	✓	✓	✓	USA	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.
Lilly Diabetes	http://www.lillydiabetes.com/	✓	✗	✗	✓	✓	✓	✗	✗	✓	✗	✗	USA	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.
Fit2Me	http://www.fit2me.com/	✓	✗	✗	✓	✓	✓	✗	✗	✓	✓	✗	USA	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.
Canadian Diabetes Association	http://www.diabetes.ca/	✓	✗	✗	✓	✓	✓	✗	✓	✓	✓	✓	Canada	No active blood glucose, Blood pressure monitoring options available. No BMI checking and Diabetes testing options available either. Diabetes screening is not also available.

* Diabetes Mellitus Type 2 (Type 2 Diabetes). Only Type 2 diabetes test option is available in that particular website with user data input.

4.3 Diabetes Screening and Management: A Proposed System

To identify diabetes patient and manage the disease we propose a cloud based architecture where diabetes screening will be performed automatically based on user input. The process follows given steps;

- At first, user has to create his account by giving necessary information to identify a person. Creation of account will be done through email/cellphone verification.
- Then, system will generate some questions regarding diabetes symptoms for rapid assessment which will include BMI (Body Mass Index), diet and exercise pattern, obesity, previous diabetes record in any other family members and other assessments.
- If diabetes risk is detected, then system will ask for blood glucose test.
- If there is no risk detected then, system will provide (electronic media) some basic knowledge and preventive steps of diabetes. After that, system will update its database and end the procedure.
- User with diabetes risk need to perform blood glucose test. Then, a user needs to input his result in the system. System will then identify whether the user has diabetes, prediabetes or normal condition.
- If no diabetes found (fasting glucose < 5.6 mmol/L) then system will follow steps designed for user without diabetes risk. If prediabetes found (fasting glucose is 5.6 to 6.9 mmol/L), then system will generate basic treatment guideline and preventive steps, provide diet plan and required exercise pattern. It will also set a reminder for checking in next 30 days. The reminder message can be sent to registered email address/cellphone number. In the end system will update its database for this particular patient.

- However, if the value of fasting glucose is greater than 7.0 mmol/L, then system will undergo a weeklong observation for the user. In this time, the system will check user's BMI level, diet pattern, blood glucose level, obesity and some other necessary parameters.
- If the user proved as normal or in prediabetes state, the system will follow steps of a user who have prediabetes.
- If diabetes is confirmed, then system will engage the user as patient. It will also subscribe the user to daily feed which is email/SMS based. This feed will provide necessary information about controlling diabetes and also motivational messages to change life-style. System will also generate a diet plan according to patient's condition, BMI level and required exercise pattern.
- Then, a doctor will be assigned for the patient depending on his/her geographical area.
- At the end, system will update the database with new information about the patient.

These steps are for new users. If the user is not new and also is not a patient then system will start its steps from rapid assessment. If the user is a patient then system will generate his/her statistics considering his/her diabetes condition. Then system will start steps from measuring blood glucose level. Figure 4.1 shows the flowchart of the proposed framework. Figure 4.2 shows the architecture of the framework.

4.4 Features of the Proposed System

ICT is already an important part of our life and the use of ICT in the healthcare sector is promising. Cloud based services are the most widespread sector of ICT. With almost all kinds of IT enabled devices a website can be viewed and service can be taken. Considering this fact, we proposed this our frame with required feature for diabetes awareness, prevention and management. With these features it will be easier to screen the disease, monitor health and spread awareness as well. Features of proposed system summarized below:

1. SMS based reminder and Knowledge sharing.
2. Engagement of more people and aware them on Social Media.
3. Sharing knowledge about preventive steps on social media in a regular basis.
4. Interactive website to keep track on diabetes patient as well as to aware them about the disease.
5. Use of Telemedicine/mHealth/eHealth facilities (if exist) to spread knowledge, awareness and life style management information which can be very fruitful in preventing the disease.
6. It can also be used as a media for remote diagnosis of the disease and also it can help to identify diabetes patient by providing them the knowledge of diabetes symptoms and measurement procedures.
7. With the integration of GPS (Global Positioning System), it can be also used to track down nearest healthcare center in case of emergency.
8. Communication is possible with the assigned doctor in case of emergencies.
9. It can also help doctors to keep track on the patient which will reduce the need of physical meeting; a cost effective solution when patient and doctor live far away, especially in rural areas.

Overall, the use of ICT can be very fruitful for the management and prevention of diabetes disease. It is a disease that needs personal awareness and life style medication to control it. The use of ICT is a big deal in this context. As people use ICT regularly, it will be easy for them to take necessary steps through ICT.

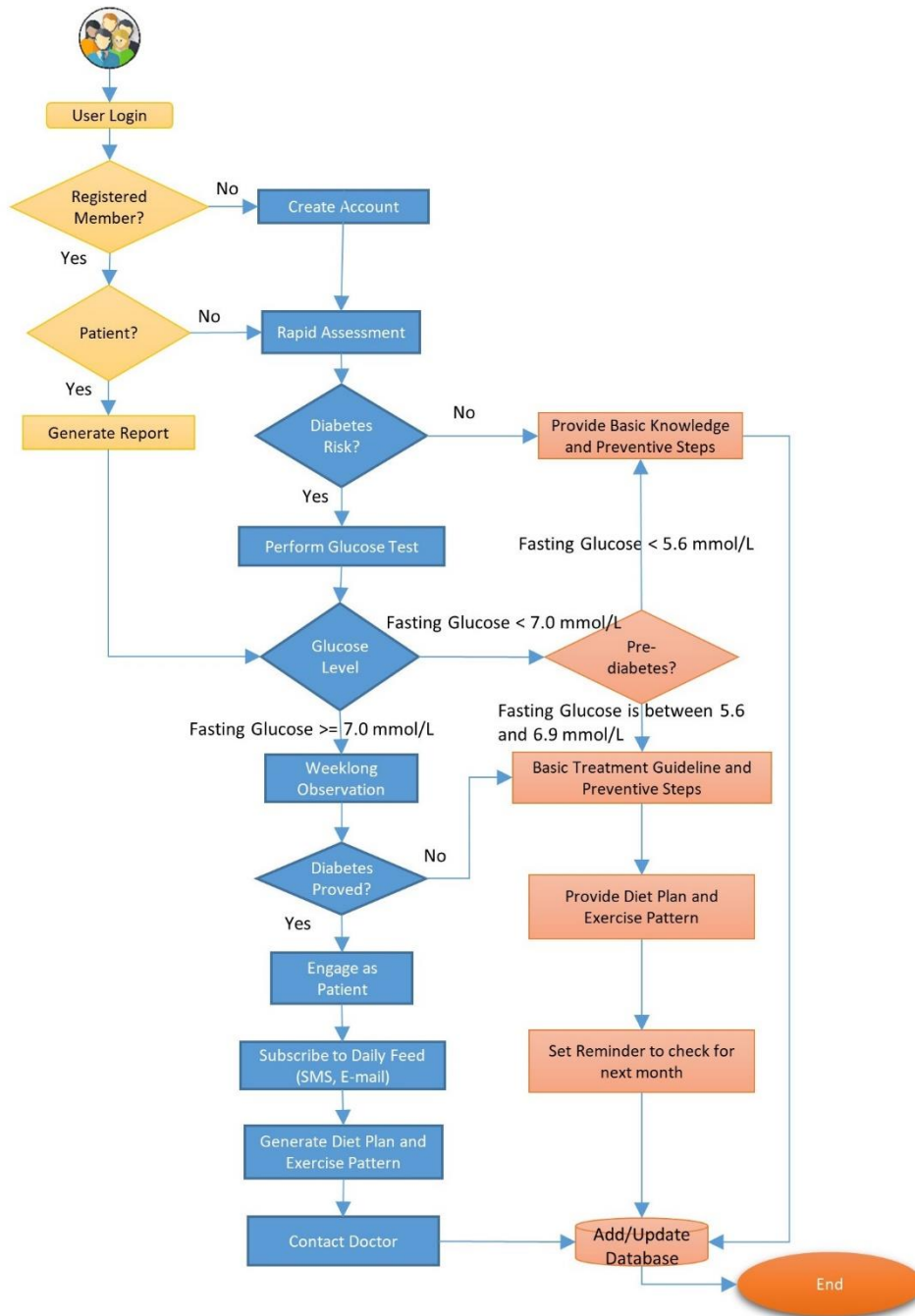


Figure 4.1: Flowchart of Cloud based smart diabetes screening and management system.

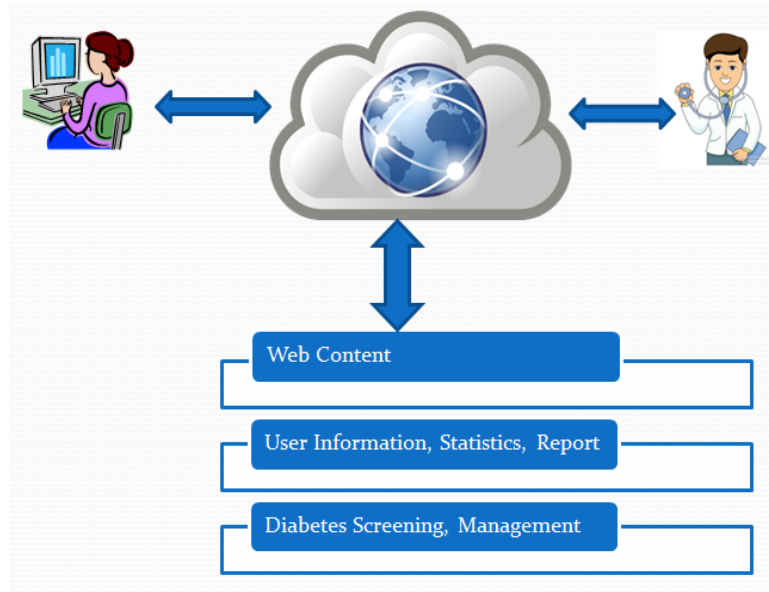


Figure 4.2: Architecture of cloud based smart diabetes screening and management system.

4.5 Conclusion

The number of diabetes patient is increasing rapidly and it is definitely a challenge to reduce the rate. To address this issue, preventive measures are needed to be taken. Creating awareness, sharing knowledge are the ways of preventing diabetes. There are also some challenges to resolve which include financial challenges. Implementation of web based platform can be very fruitful addressing all of these issues. Internet and web have its own infrastructure and it is already is an active part of our life. So, if we use this proposed web based infrastructure in a proper way it will be cost-effective, easy and user friendly solution for diabetes awareness, prevention and management.

To reach the goal and to successfully implement our research work and its feature there are still some steps needed to be taken. We need to develop the cloud based framework and to experiment it for further study and effectiveness of this type services. We need to collect user feedback to make it more perfect and user friendly. We need to consult with physicians as it is a service that concerns about human health.

Chapter 5

DiaHealth: A Smart App for Complete Diabetes Lifestyle

Management

In this chapter we have presented our smart app DiaHealth for complete diabetes lifestyle management. At first, we compared features of DiaHealth with some popular available apps. Then detail features are discussed. After that, the application of this app in Bangladesh is given. Some user feedback is also summarized later in this chapter.

5.1 Introduction

Diabetes is non-communicable but non-curable lifelong sickness. Diabetes patients need to maintain regular medication with lifestyle management. Self-management is required to prevent complications caused by diabetes and proper education is needed to perform self-management effectively [52].

In 2014, there were around 422 million people who were diabetes patient. In the year 2011, more than 4.5 million adult people died because of diabetes [3]. In that year, the cost of treatment of complexities caused by diabetes was more than 465 billion U.S. dollar [33].

According to the report of World Health Organization (2016 International Report on the disease diabetes, Geneva), maximum number of individuals died in developing countries because of high fasting plasma glucose level in blood and least amount of deaths occurred in poor and low income countries [33]. People who are aged between 50 and 69 were the primary victims of deaths caused by diabetes. From the year of 1980 to 2014, total number of diabetes patient raised to more than 420 million from 108 million which was almost four times higher [33]. Total amount of diabetes patient who are adult of different regions from the year 1980 and 2014 are depicted in the following graph (Figure 5.1).

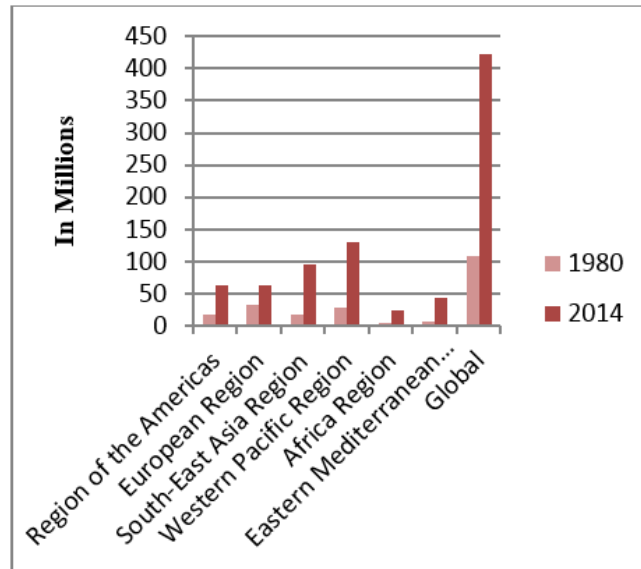


Figure 5.1: The amount of total diabetes patient who are adult of different regions of the world from the year 1980 and 2014.

A lot of complexities arises if diabetes is left untreated and it is not properly controlled. These complexities may cause deaths in a long term. To prevent these complexities, blood glucose level should be monitored and controlled through proper lifestyle management. Treatment of diabetes through medication proves lower improvement in diabetes patient. It is also found that, lack of accurate diagnosis causes health problems, complications and finally deaths [4]. All of these indicates that, a cost effective solution is required to assist patient with diabetes and to prevent this disease as well. This cost effective answers of this problem can be utilization of smartphone application, an ICT based solution for assisting self-management of diabetes management through sharing and promoting knowledge about effective life-style management, making reminder for medication, doctor's visit, alarming for high blood glucose level and many other ways. It can also be used for creating awareness among people and sharing knowledge about preventive steps of diabetes.

DiaHealth is complete and smart app that helps to screen and manage diabetes effectively. It can also prevent diabetes in means of sharing diabetes knowledge. In this chapter, we have discussed DiaHealth and its advanced features, the use of mobile application in diabetes lifestyle management, application of DiaHealth in Bangladesh and some user feedback of this app. We have also observed recent scenario of prevention and management of diabetes through mobile applications.

5.2 DiaHealth Compared to Recent Smartphone Apps

Mobile app is the recent inclusion in ICT. With its advanced features, smartphone applications can be used to prevent and control diabetes. Worldwide, there are around 1 billion smartphone users are available and 30,000 apps are available which are based on healthcare [39]. A recent study on diabetes management through mobile application has showed that, there are around 1004 diabetes related apps are available [49]. Some of these apps can perform multiple actions which include Diet Planning, features to use Digital Log Book, Blood Glucose Monitoring, Communication, Medication, Weight Statistics and Education Services [49]. Some apps are being researched and some are already available

which applied Augmented Reality for the visualization of protein, calorie and other food value in a particular food items [53]. All of these features of smartphone based apps are very much helpful in both preventing and managing diabetes in a same time.

It has been found that, in the end of the year 2011, more smartphone were sold worldwide than personal computers [54].

Google Play Store, Apple App Store, Microsoft App Store are market places of mobile applications. All these market places offer thousands of mobile apps. In most times, people find it difficult to select right application for their requirement from all of these apps. There are also some apps available which are poorly designed without scientific backgrounds. These apps become outdated and useless by time. However, it is easier to modify mobile apps compared to print materials and can be upgraded when needed. It has become common practice nowadays that, general people mostly use higher rated mobile apps without getting much information about that app. However, top ranked mobile apps are not always best mobile apps for real life use [49].

Before developing our smart mobile app DiaHealth, we studied and explored more than 70 reputed international conference papers and journals [49]. Our findings was published in 2015's IEEE International Conference on Computer and Information Technology (ICCIT), Dhaka, Bangladesh. While studying about mobile application based solutions for diabetes, we have seen that some common features exist in almost all apps. We have also found that, apps with higher ranks do not always offer best features and usefulness. In our study we found that, there are some features missing in almost every apps which guides us to develop DiaHealth, a smart and complete app with all required features for lifestyle management of a diabetes patient.

After carrying out systematic review, we have summarized the primary features of the apps for diabetes management. Those are:

- Monitoring Blood Glucose Level
- Diet Plan Suggestion
- Exercise Plan
- Medication Suggestion
- Measurement and/or entry option to digital log book for Blood Pressure, Weight, HbA1c, Cholesterol etc.
- Automated data transfer for blood glucose
- Nutrition Information
- Entry option for blood glucose and record of data
- Education
- Monitoring Blood Pressure
- Communication with physicians
- Weight Management

DiaHealth offers all essential and required features for diabetes lifestyle management. In Table 5.1, we have compared DiaHealth with some other mobile applications. In this Table, we have summarized only few top ranked and popular apps, as we showed detailed summary of currently available apps in our previous publication.

Table 5.1: Feature Comparison of few Top Rated and Popular Mobile Apps with DiaHealth

Name	Glucose Monitor	Weight	Exercise	Diet Plan	BMI Calculation	Auto Data Input	Blood Monitor	Summary view using chart/graph	Communication	Medication	Diabetes Education	Digital Log Book	Rating of the app (Out of 5.0)*
Diabetes: M	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	4.7
Sugar Sense	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	4.2
Glucose Buddy	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	No	Yes	4.4
Diabetes Tracker	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	4.0
Dr. Diabetes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	4.3
DiaHealth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A**

* Rating of the app was last checked in Google Play Store on October 15, 2016.

** Rating value of DiaHealth is not available right now, as we have not uploaded DiaHealth to Google Play Store yet.

5.3 Features of DiaHealth

DiaHealth is a complete and smart app which is designed to assist diabetes patient to manage their lifestyle effectively. This app is a complete mobile application for the lifestyle management of diabetes patient. It has all essential features of most used and popular smartphone applications and also offers additional but required features which include Auto Data Input, BMI Calculation and Tricks and Tips for diabetic people. To offer easier User Interface (UI) for better user experience, all features are categorized into various sections, user input are designed with easier options and more graphics (menu icon and images, graphs) are used for proper visualization. Figure 5.2 depicted the outlook of DiaHealth mobile app.

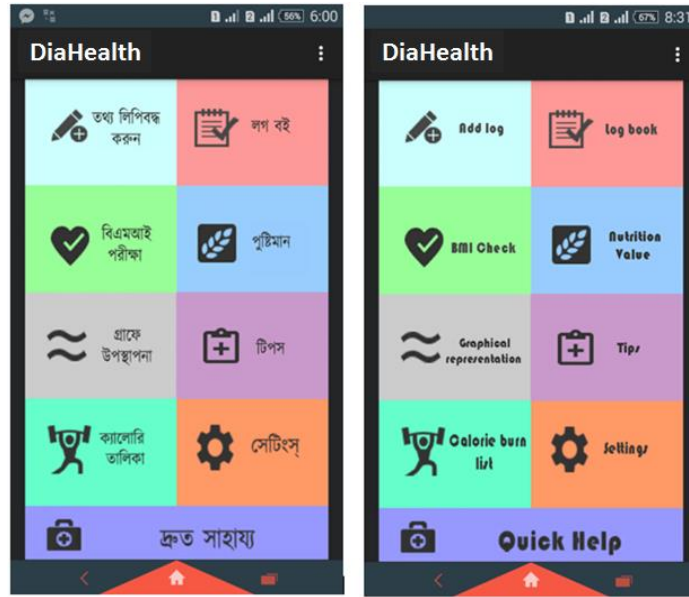


Figure 5.2: The outlook of mobile app DiaHealth in Both Bengali and English.

The features of DiaHealth are described in the following section.

Support for Two Languages:

The most important and fundamental feature of DiaHealth is two different language support. DiaHealth is developed and designed in Bangladesh and we consider the fact that, individuals for rural areas will utilize DiaHealth to monitor their health status, manage their lifestyle and to learn about diabetes. For this reason, DiaHealth has full support for Bengali language as every feature and functionality of this app are offered in Bengali. Now, individuals with less knowledge and learning of Bangladesh will be benefitted by using DiaHealth more effectively. People generally feel more comfortable to use an app if it is in their first language, mother tongue. Because of this, DiaHealth is developed with English and Bengali language support. Now, people of Bangladesh will feel more comfortable to use DiaHealth in managing Diabetes. All the features and functionalities of DiaHealth are properly interpreted in Bengali.

An App for Diabetes Screening:

According to the user input, DiaHealth can detect whether a person has diabetes or not. For this reason, DiaHealth can be used as a screening tool where diabetes screening is required. To get accurate information, all parameters and factors are used based on international standards. DiaHealth has an in-built feature to differentiate test outcomes based on the blood glucose measurement time. For this reason, it can determine if the result is for pre-meal (test before taking foods) or post meal (test before taking foods) and based on the outcome of the test it can decide if the person is diabetic or not.

Digital Log Book:

Lifestyle management is the single most significant thing to keep control over diabetes. To do this effectively, keeping records of certain health parameters and checking those in a regular basis is very important. Digital log book is very essential in this aspect. Diabetes patient can add records to this log book and can check anytime. It can show data from past months in ordered by time. Main features of this log book:

- Add record option for user's Blood Pressure
- Add record option for Blood Glucose level with time frame (Pre-meal, Fasting and Post-meal)
- Add record option for different types of Physical Exercise with Duration
- Add record option for Calorie Intake
- Add record option for Medication with Time

The User Interface (UI) of add records to log book of DiaHealth is shown in Figure 5.3.

Statistics with Graph Representation:

For a diabetes patient, it is required to monitor health status regularly. Blood glucose is essential to check regularly because diabetes patients need to maintain blood glucose level in danger free range. For accurate diagnosis, it is also required to keep information of blood pressure, food consumption and physical exercise [54]. In this regard, graph view of full statistics can be very useful and fruitful to monitor the status of health. It will also be useful for physicians to diagnosis their diabetes patients more effectively.

DiaHealth can generate different statistics of various health parameters based on the user entry. This statistics and parameters are also re-produced in graphs for better visualization of the health condition of diabetes patients. DiaHealth does not only provide digital log book for data entry but also offer visual output through graphs. In DiaHealth, the following graphs are shown;

- Graph view of user's Physical Exercise duration
- Graph view of user's Blood Glucose level
- Graph view of user's Blood Pressure
- Graph view of user's Calorie Intake

This is full graph presentation to monitor health of a diabetes patient and for this, it makes DiaHealth an essential and complete health status monitoring app. Figure 5.4 shows graph representation of health status of diabetes patient.

Figure 5.3: The User Interface (UI) of adding records to log book of DiaHealth.

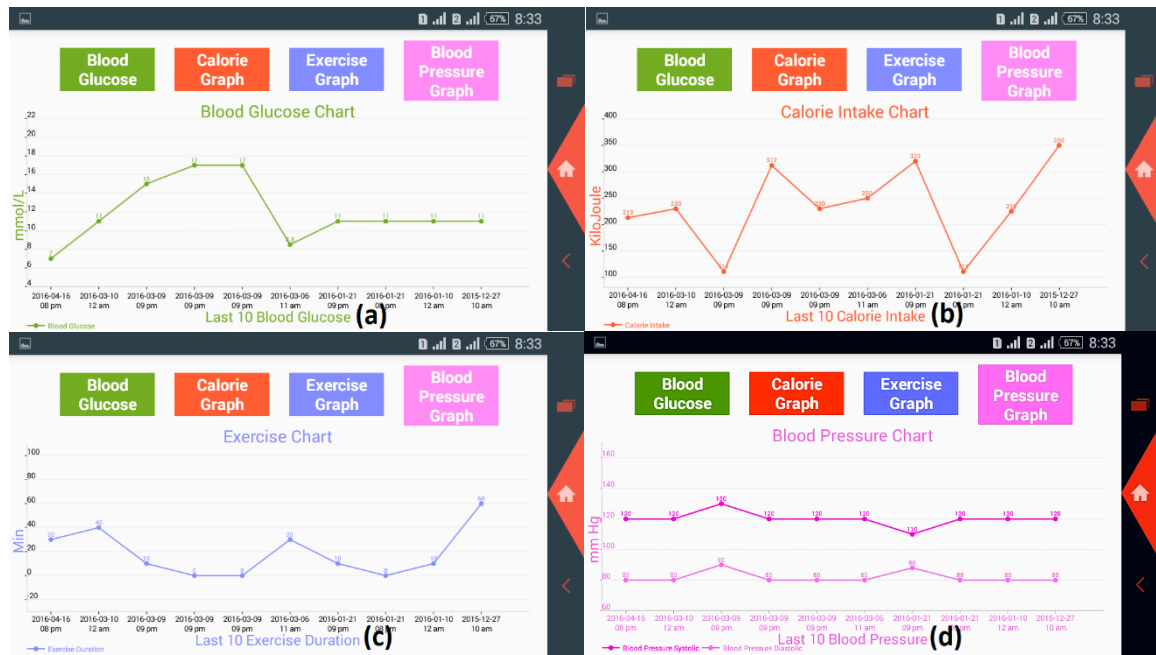


Figure 5.4: Graph representation of health status of diabetes patient. (a) Statistics in graph of blood glucose level, (b) Statistics in graph of blood pressure, (c) Statistics in graph of calorie intake, (d) Statistics in graph of Exercise.

Intelligent and Smart Suggestions:

DiaHealth can use user's health statistics to make suggestion about required action plans to guide diabetes patient, so that they can control diabetes in an effective way. Diet plan suggestion, medication intake, amount of physical activity to perform and other related measures are included in this Intelligent Suggestions to keep control over blood glucose level.

For making better and accurate suggestions, DiaHealth consider various health status which include blood glucose level, blood pressure, calorie intake, last time of medication and exercise with duration and type. All these parameters are required for effective suggestion, so that diabetes patient can lead a fit and healthy life.

Parameters which are considered with suggested actions are categorized as following;

- Is diabetes in under control or not? If diabetes is not under control, then what steps can be taken?
- How much one can eat?
- Is blood pressure unbalanced, low or high? Which measures are required to take?

The following image (Figure 5.5) depicts intelligent and smart suggestion of DiaHealth based on user's health statistic.

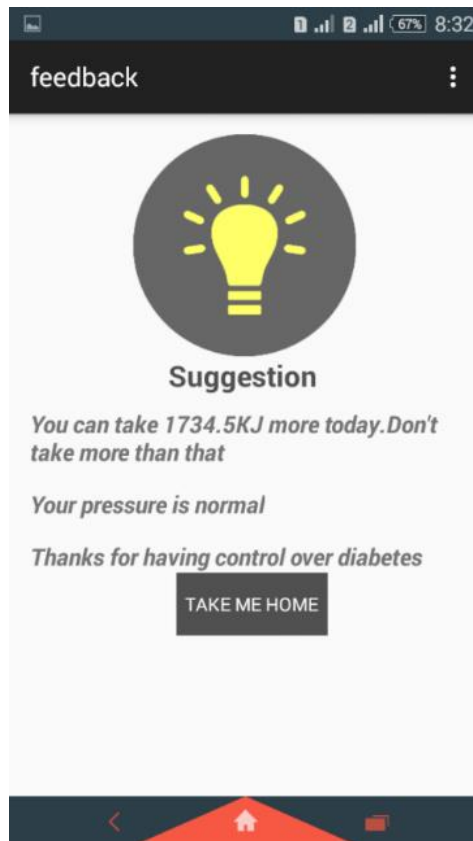


Figure 5.5: The intelligent suggestion of DiaHealth.

Result of BMI (Body Mass Index) Calculation with Visual Representation:

Unlike other mobile apps related to diabetes which only measure or store weight measurement, DiaHealth calculate information of Body Mass Index (BMI) and generate result based on it. The result of BMI is generated using a person's weight and height.

The equation is:

$$\text{BMI} = \text{kg/m}^2$$

Here, kg refers to person's weight in kilograms and m^2 refers to person's height in meters.

The healthy range of BMI for a person is 18.5 to 24.9. For this feature, a diabetes patient will be able know whether he is overweight, obese, underweight or in normal range.

However, calculation of BMI requires the measurement of height and weight and user need to input these parameters to know his/her BMI. In DiaHealth, BMI result is represented in numerical values with graphical representation. That means DiaHealth has a special feature to show image of human figure according to his/her BMI. Following image (Figure 5.6) shows calculation of Body Mass Index and outcome with visual representation.

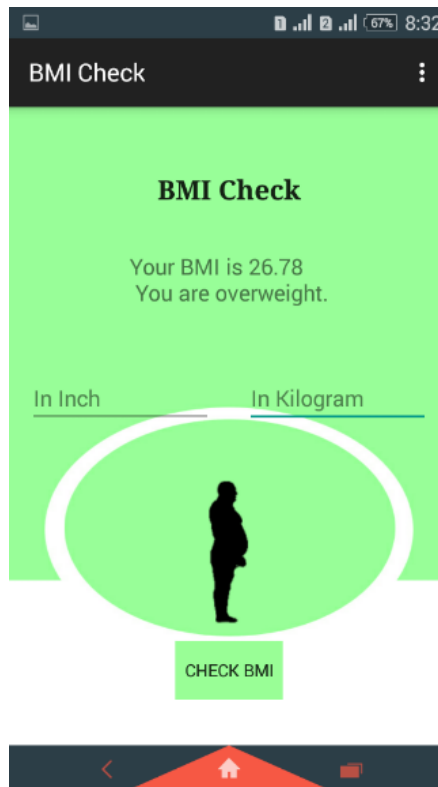


Figure 5.6: BMI Calculation with visual representation.

Food Values and Exercise with Calorie Burn List:

It is now proved that, lifestyle management is the single most important factor to manage and avert diabetes [54]. To modify lifestyle in an effective way, one need to take exercise regularly and control their food habit. For this reason, knowing the food value of foods we take and the amount of calorie burnt in a particular exercise is very important. These important features are included in DiaHealth. DiaHealth shows different foods with values per 100gm serving and amount of calorie burnt in a particular exercise. In the food value list, almost all available foods of Bangladesh are listed. Physical activity list includes backpacking, bicycling, aerobics, basketball etc. with time duration of 1 hour. The list is categorized into three different sections according to three different weights, which are;

1. How much calorie will be burnt if a person of 73 KG performs a certain exercise for time duration of an hour?
2. How much calorie will be burnt if a person of 91 KG performs a certain exercise for time duration of an hour?
3. How much calorie will be burnt if a person of 109 KG performs a certain exercise for time duration of an hour?

Figure 5.7 shows food value list and list of physical exercise. The left image shows different foods with values per 100 gm serving and right one shows different exercise with the amount calorie burnt in one hour.

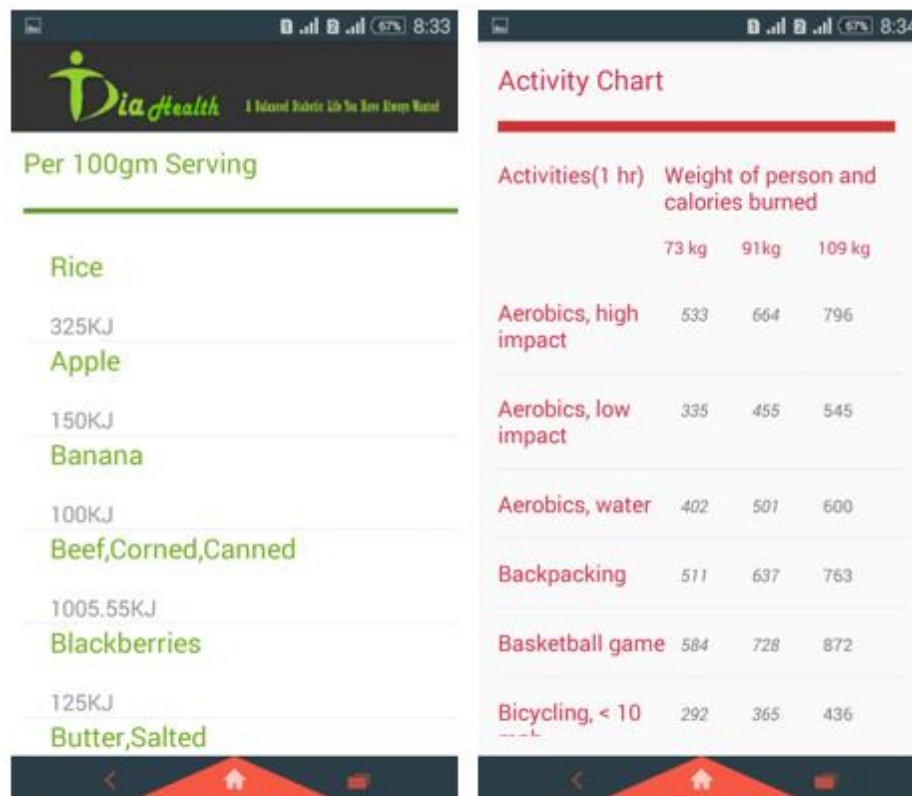


Figure 5.7: Food value list and list of physical exercise. Left one shows different foods with values per 100 gm serving and right one shows different exercise with the amount calorie burnt with the time duration of an hour.

Quick Help and Tips for Diabetes Patient:

DiaHealth is a complete app. To complete the services of DiaHealth, we added tips and quick help. Tips are useful as it provides interesting and new knowledge to prevent and manage diabetes. People also need quick help in emergency situations. With quick help at the right time life of patient can be saved.

Local Community:

Local Community is another interesting feature of DiaHealth. DiaHealth has options for finding relevant local communities. It might be interesting for a diabetes patient to join diabetes related local communities.

In a community, people gather knowledge through various discussions. Community also helps people in reducing mental stress. Local community “BD-Cyclist” is ideal for diabetes patient especially for younger ones as it inspire to perform more physical exercise by cycling.

DiaHealth has designed with features like this to find these kinds of local communities for the benefit of diabetes patients. Figure 5.8 shows tips and local community feature of DiaHealth. Left screenshot depicts tips and tricks for diabetes victims and right screenshot depicts link for joining communities.

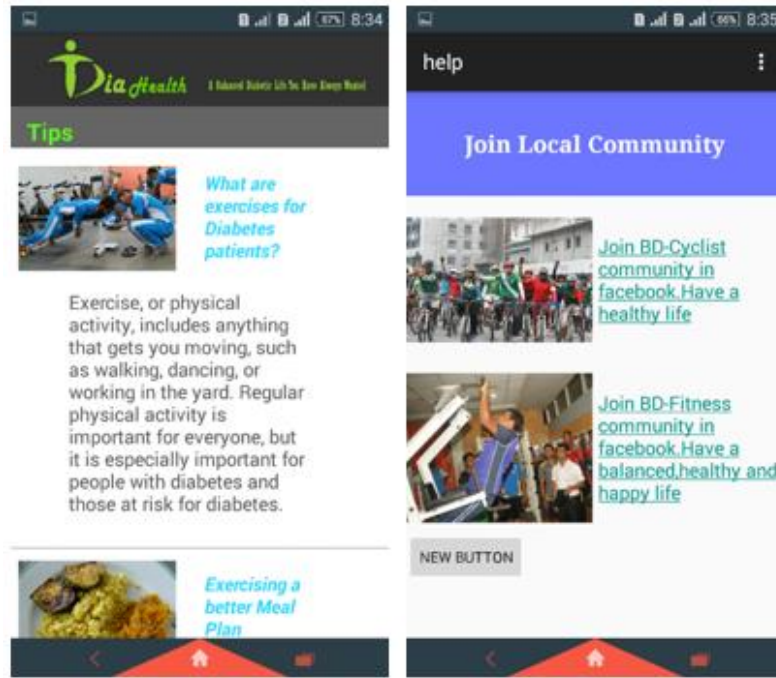


Figure 5.8: Tips and Local Community of DiaHealth. Left screenshot shows tips and tricks for diabetes victims and right screenshot shows link to join local communities.

5.4 Applications in Bangladesh

Bangladesh is a developing country. DiaHealth is designed in Bangladesh and it is an app made for this country. It supports Bengali language and also developed with simple User Interface (UI), so that general people of Bangladesh can easily use it. Smartphone technology is advancing day by day and price is lowering. In a recent news of a leading country newspaper it has been found that, in the first quarter of 2015 smartphone market of Bangladesh grew around 17% and it continues to grow [55]. Our primary target is to focus on this huge number of smartphone users of Bangladesh and provide these people with the perfect tool (mobile app) for helping and educating them to prevent and manage diabetes through lifestyle modification. For this reason, we have developed DiaHealth with both Bengali and English languages. All the features and functionalities of DiaHealth are available in these both languages. DiaHealth is also developed with scientific knowledge and background that makes it a very special mobile application in its category.

Diabetes prevalence is increasing in an alarming rate. The situation is worse in developing countries. Bangladesh is a developing country with population of 160 Million [56]. According to International Diabetes Foundation (IDF), in 2015, around 7.1 Million people were victims of diabetes in Bangladesh [54]. Because of this current situation, it is now our primary concern to reduce diabetes prevalence in this country. To do this, at first we have to screen diabetes patient properly. DiaHealth can help in this aspect, as it has in-built function to identify if a person is diabetic or not. It makes DiaHealth a perfect diabetes screening tool for Bangladesh. Moreover, tips and tricks, quick help option, digital log book, BMI calculation, list of physical activity with measurement of calorie burn, food value and intelligent based suggestion makes this app an all-day companion for the people with diabetes. The built in education system can also aware people to prevent diabetes as

well. DiaHealth is developed in Bangladesh and it can be our pride, if we make positive impacts in the society through DiaHealth. However, more testing and piloting of DiaHealth is still needed.

5.5 Benefits of DiaHealth

Modification of lifestyle is very essential for a diabetes patient as it is the most significant factor to control diabetes. In a recent study, it is found that, more improved and desired patient outcome can be achieved if patients integrate self-management support in their daily life [36, 54]. It is also found that, utilization of ICT and mobile apps can be useful and effective personal health care as well as in disease control [54]. DiaHealth is a complete and smart mobile app which offers necessary features to helps diabetes patient to manage their lifestyle effectively. Following benefits can be achieved with the proper use of DiaHealth.

- Support for multiple languages (Both English and Bengali)
- Blood pressure and blood glucose monitoring
- Digital log book to provide options for data entry, checking and storing
- Suggestion for diet plan, according to patient's present state
- Food list with food values
- BMI calculation with graphical representation
- Exercise list with the amount calorie burnt in one hour activity for three types of people of 73, 91 and 109 KG.
- Intelligent suggestion for various situation
- Graphical representation of blood pressure, calorie intake, exercise pattern and blood glucose level of previous months
- Health Parameters and reports generated from DiaHealth are accurate as we have used international parameters to define values and also talked healthcare professionals and compared our results for getting accurate values.

It is our believe that, the features and advantage that offer DiaHealth, can make positive influence in the society by managing and preventing diabetes.

5.6 User Feedback and Recommendations

We have not uploaded DiaHealth to Google Play Store yet. Because of this reason, large scale user feedback and review of DiaHealth is not available yet. However, to obtain review of this app, we distributed DiaHealth to small population group from where we collected their feedback. It is a good and excellent initiative from their point of view as no one have used any Bengali language supported app for diabetes management before. According to some of user's comment, DiaHealth is very useful and beneficial mobile application, because it can keep and track record on health status. They are intrigued to utilize this sorts of mobile applications. They have declared that, it will be their pleasure to utilize DiaHealth. However, around 10% of user mentioned that, they are not interested to use such kinds of mobile apps as it stores sensitive health related information. This is not unexpected as this is a developing country where people are still learning about the usefulness ICT.

Some recommendation and suggestion are also found in this small scale review of this app. According to the user point of view, there are still some features can be added. There are also some features which are needed to be improved. We have summarized user points in this aspect and made some recommendations which is given below;

- The number of local community linked to DiaHealth is limited. More local community is needed to be included.
- The number of tips are satisfactory. However, there are lot more tips and tricks out there and we need to update this section in a regular basis.
- Nutrition value is very important as it provides list of foods with their nutrition values. However, there are still some food items missing which we need to add.
- List of physical exercise with calorie burnt is satisfactory and very useful feature. However, the number of outdoor games are still limited here. We need to add more indoor and outdoor games here which are based on physical movements.
- The use of GPS (Global Positioning System) and Maps is missing in DiaHealth. This feature can help diabetes patient to find nearest healthcare centers.

If we address all of these recommendations, DiaHealth will be a perfect health companion. However, large scale piloting is still necessary to get more review for actual improvement of DiaHealth.

5.7 Conclusion

ICT has changed our life and become an essential part of our daily activities. The number of online resources are increasing more and more. In this age of science and information technology, it is not effective to carry notes and books on different disease and health problems. Nowadays, almost everyone poses mobile phone and a lot of them are smartphones. These smartphones are powerful enough to run various featured games and mobile apps. However, the number of apps which are developed with simple User Interface (UI), scientific knowledge and developed for a particular region so that people of that region can utilize the app without prior knowledge are limited. In Bangladesh, there is hardly any health related app is found which offers English and Bengali languages. We are proud to develop DiaHealth as it supports both of these languages. However, the feature of DiaHealth is not limited to two language support but also it has advanced features for preventing diabetes and managing lifestyle of diabetes victims as well. Nowadays, mobile phone is a daily companion in day to day life of general people. For this reason, it will be interesting for people to use an app which support Bengali language to get information about diabetes and suggestive techniques for lifestyle modification. DiaHealth has feature to screen diabetes and it can store health status and generate reports as well. We are optimistic that, if this app can be utilized in a large scale, there will be certain good impacts in the society in creating healthier nation with lower number of diabetes patient.

Chapter 6

Conclusion, Discussion and Future Work

In this chapter we have presented discussion and critical analysis. After that, conclusion and future work of this thesis is provided.

6.1 Discussion and Critical Analysis

Diabetes has become a global problem and the prevalence of diabetes is increasing rapidly in both developing and developed countries. In developing countries, most diabetes patients are aged between 45 and 65 years, but in developed countries most of the diabetes patients are older than 64 years. It is estimated that, by 2030 the number of diabetes patients who are older than 64 years will be 82 million in developing countries and 48 million in developed countries. However, it is expected that the greatest relative increase in prevalence will occur in sub-Saharan Africa, Middle East crescent and South-Asia (India, Bangladesh) [29]. In developing countries around 170 million people with diabetes are less than 30 years who will suffer from diabetes in their reproductive years of life [30]. In the year 2003, around 190 million people of age 20 to 79 years had diabetes in the developing countries which was almost three quarter of total diabetes population. It is also found that, almost one million people die each year because of diabetes. Among them two-third of diabetes patients die in developing countries. This growing problem will have significant impact on individual and national economy. However, actual impact is still difficult to determine [31]. Despite of increased research and effort, diabetes prevalence has continued to increase globally. In developing countries more patients are becoming victims of diabetes compared to developed countries [23, 33]. It is predicted that, diabetes prevalence will continue to increase in upcoming two decades and majority of victims of diabetes will be from developing countries [14]. In rural areas of developing countries, it is found that the prevalence of diabetes is around 1-2%, whereas in urban areas the prevalence is around 1-3% or more [14]. This increased prevalence will put serious burden on socio-economic development and health system of these countries.

According to a recent study, about one ten of adult population of Bangladesh had diabetes which was around 9.2% of all adult population. Many other studies from developing countries including Sri Lanka (8.0%), India (8.6%), China (9.6%) and Panama (9.5%) are consistent with this study [16]. According to 2013's estimates of IDF (International Diabetes Federation), diabetes prevalence of Bangladesh was 6.3% which was lower than the present estimate. Comparison of diabetes prevalence between and within countries are difficult because of several factors and hence avoided. Those factors include, inadequate sample size, different regional focus, varied sample design, lack of uniform diagnostic criteria, limited focus on both rural and urban population and different age distribution. In Bangladesh, increased prevalence of diabetes found in young, middle-aged and rich people. Among women, who live in urban areas and in rich households have higher prevalence of diabetes [16]. Reason behind increased prevalence of diabetes could be sedentary lifestyle, lack of physical activity and unhealthy dietary habits.

Management of diabetes is multidisciplinary and it is not always available with low resource settings. Lifestyle management is essential in the treatment and control of diabetes and it alone can be adequate to achieve therapeutical goals of normoglycaemia and normolipidaemia [21]. This lifestyle modification include change in diet plan and physical activity. The management of diabetes is complex and good control over this disease could prevent serious complications and death.

We are living in the age Science and technology, where ICT has changed our lives in many ways. Smartphone are now available and many people around the world are using smartphone both in developing and developed countries [39]. A recent study showed that, more smartphones are now sold than personal computers [54]. People are also getting help from cloud services. The main advantage of cloud based services is that, it can be accessed from anywhere, anytime with smartphones, PCs, Tabs and PDAs. Smartphone applications are also becoming popular. Apps related to healthcare are now easily found in various app stores [39]. For all this, we can use this existing ICT based infrastructure for diabetes awareness, prevention and management.

In this regard, traditional solutions are not enough. To get fruitful result we have to use present day ICT based infrastructure, both cloud based and app based solutions. If we can integrate ICT in this regard it will be easier for diabetes patient to manage their lifestyle effectively.

6.2 Conclusion

Worldwide, diabetes prevalence is increasing in an alarming rate and it has become a challenge to reduce the rate. To address this current situation, more preventive steps are needed to be taken. Sharing knowledge and creating awareness are the ways to prevent diabetes. Medication of diabetes is still costly and this leads to high mortality in low and middle income countries. Diabetes is non-communicable but non-curable disease, hence prevention and management are big deals. Proper lifestyle modification is required for managing diabetes. Information and communication technology (ICT) has made life easier and information can be found more easily. This ICT based technology can be used for diabetes awareness, prevention and management.

Our proposed cloud based architecture is ideal for diabetes prevention and management, especially for a country with low and middle income. It is proposed with features:

- It can screen diabetes and can keep records of diabetes patient.
- With its advanced features, diabetes patient can be able communicate with assigned doctors from anywhere, anytime.
- SMS, Email based reminder, knowledge sharing, suggestive medication and diet plan are very much helpful in preventing and managing diabetes.
- People from rural areas will also be highly benefited as they will no longer required to travel long distance to reach healthcare center.
- They can communicate with specialized physicians through this system.
- Features of the proposed cloud based architecture are complete and no other services are found yet that offer such usefulness.

If this cloud based architecture is developed and used widely, diabetes patient from both urban and rural will be highly benefitted.

Smartphone is another technology which has become our daily companion. Even in developing countries the number of smartphone users are increasing. Smartphones offer features like computer and can handle multiple apps and games. Apps are now widely used for health related purposes. DiaHealth is a smart app with advanced features for complete diabetes lifestyle management. Features of DiaHealth includes:

- Medication, diet plan, tips and tricks, blood glucose and blood pressure monitoring, BMI checking, food value checking and other necessary things can be done through DiaHealth.
- It supports two different languages including Bengali language. Now people of Bangladesh will be able to use this app more efficiently.
- It can also screen diabetes also as it has built in function to identify whether a person has diabetes or not.

DiaHealth is unique and complete app as it offers all necessary features for managing diabetes. With the proper use of DiaHealth, positive impact can be made in the society by helping people with diabetes to manage diabetes properly.

In our research, we have presented our two ICT based solutions for Diabetes awareness, prevention management. We have also discussed how we can use ICT to create awareness about diabetes and through awareness how we can prevent this disease. We are optimistic that, if our research work is implemented successfully, it will be easier to prevent this disease and people with diabetes will be able to manage diabetes more effectively with these ICT based solutions.

6.3 Future Work

To reach the goal and to successfully implement our research work and its features there are still some steps needed to be taken.

- At first, we need to develop our proposed cloud based architecture.
- While developing we need to communicate with healthcare professionals as this platform will be used for health related services.
- After successful development, testing of this kinds of services is required. After that, large scale user feedback will be required for further improvement.
- For DiaHealth, large scale piloting is required for necessary improvement.
- More user feedback is required for implementing this service in medical purposes.
- We also need address issues found in small scale user feedback
- More local communities are needed to be included. Tips and Tricks section is needed to be updated in a regular basis.
- There are still some food items missing in DiaHealth which we need to add. We need to add more indoor and outdoor games in exercise list.
- We are also eager to integrate GPS (Global Positioning System) and Maps, so that diabetes patient can find nearest healthcare center easily.
- More importantly we want to add cloud services to DiaHealth so that, its features can be more optimized and increased.

- For diabetes prediction we are eager to integrate AI (Artificial Intelligent) into DiaHealth which will be an advanced feature of DiaHealth and diabetes patient will be further benefitted.
- Moreover, time to time development of this app is also required to solve technical issues and integrate new features.

It is good news that, to make the app more robust and clinically an expert system and build a more reliable, smart cloud architecture we are collaboratively working with hospitals, doctors and professionals.

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APPENDIX A: Key Publications from this Research Work

Conference Papers:

1. M. A. Islam, H. N. Alvi, and K. A. Al Mamun, “DiaHealth: A smart app for complete diabetes lifestyle management,” *1st Int. Conf. Med. Eng. Heal. Informatics Technol. MediTec 2016 Dhaka*, 17-18 December, 2016.
2. M. A. Islam, S. A. Hossain, and K. A. Al Mamun, “A Proposed Web Based Architecture for Diabetes Awareness, Prevention and Management”, *International Conference on Emerging Technologies in Data Mining and Information Security, IEMIS 2018 Kolkata, India*, 23 - 25 February, 2018. (Accepted)