Chapter 7
A PHR-Based System for Monitoring Diabetes in Mobile Environment

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Abstract Currently, people are more concerned about their health and diseases. Therefore, their interests in health and diseases have increased tremendously in the last decade. Till date, medical industries developed several programs and services to promote the health-related issues such as awareness programs regarding HIV, diabetes, dengue, overweight, etc. Due to increased concern for ubiquitous health services, it incorporates the advantage of information technology which can lead to design a preventive management system for various types of disease and health conditions. Further, the technological advancement is also favorable to the management of chronic diseases. In this work, a personal health record (PHR)-based decision support model is proposed for monitoring diabetes using mobile environment. In order to facilitate the people, a graphical user interface is incorporated into the PHR-based model for analyzing their lifestyles.

7.1 Introduction

In the world, more than 40 million people die of various noncommunicable diseases like cancer, cardiovascular diseases, diabetes, heart failure, chronic obstructive diseases, etc. [1]. The majority of people belong to low- and middle-income countries. But, these diseases are also responsible for mortality in high-income countries. This can be prevented by adopting healthy behaviors and also decrease the mortality rate worldwide. A study on smoking habits presents that the risk oflung

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cancer is reduced up to half for a person who has stopped smoking since the last 10 years in comparison to those who continued smoking [2]. From this study, it is observed that the risk of cardiovascular disease is similar to the risks of a person who has stopped smoking since the last 15 years and a person who never smoked. The risk of HIV can be reduced by adopting safe sexual practices and awareness about this disease [3]. In high- and middle-income countries, most people suffer with overweight problem due to unhealthy eating habits and lack of exercise and it can lead to the risk of diabetes. Further, it is reported that the risk of onset of retinopathy and nephropathy can increase due to diabetes, and these risks can be reduced up to half and two-third levels, respectively, by controlling diabetes [4, 5]. The main function of healthcare services is to inspire and support the people to adopt healthy behaviors and self-manage the chronic diseases [6]. But, the main obstacle regarding this is the way through which information can be propagated. The main sources to propagate the information are consultations, existing service infrastructure, and through traditional media, but these sources can be used in a limited way. Due to advancement in mobile telephone technology, the numbers of mobile users are increasing day by day. A variety of mobile phones and mobile service providers are available in the market. The invention and advancement in mobile phones changes the traditional communication system and entertainment industry and also affects the life of people [7]. The dependency of human beings on the mobile phone is increasing day by day, especially of the youth. The mobile technology includes a variety of mobile phones such as personal digital assistants (PDAs) and PDA phones (BlackBerry and Palm Pilot), smartphones (iPhone), enterprise digital assistants (EDAs), etc. These devices have a variety of services and functions such as SMS, MMS, WWW, multimedia access, and application software. These features and functions of mobile technologies also encourage the scientists and researchers to explore the capability of mobile phones for providing individual-level support to patients in the healthcare domain [8]. Few examples are to send a text message to avoid smoking habits, awareness message regarding HIV, weight loss programs' message, diabetic disease-related message, asthma patients access information regarding exacerbation of asthma, etc. Due to incremental growth and deployment of mobile devices into private devices such as smartphones, tablets, pads, etc., large numbers of applications regarding medical treatment are available on mobile application stores and half of applications are related to daily health tips and disease information [9–13]. The trend of self-healthcare can increase exponentially to meet the demand of patients.

7.1.1 Objective of the Chapter

This chapter proposes a personal health record (PHR)-based health index mobile service using a decision support model. This PHR can enable medical staff to inquire and manage health- and medical-related information of patients. Further, this information can analyze information in different situations and extracts pattern

of behaviors of patients which are not explored. The aim of the PHR-based decision support system is to improve the lifestyle of patients and also to overcome the risk of chronic diseases. In addition to it, a user interface is developed for the users such that it can communicate in the optimized mobile environment. This decision support system is available for users at all times and provides the status of their health. The objectives of the proposed chapter are as follows:

- To design a PHR-based diabetes monitoring system to monitor the health of users
- To develop the user interface for the proposed monitoring system
- To incorporate the proposed model into mobile environment
- To analyze the information of the patients and give suggestions

7.2 Related Works

This section describes the related work in the direction of e-health monitoring system and usability of mobile phones to monitor the health of mobile users.

7.2.1 E-Health Model

Recently, the applicability of mobile devices has increased rapidly in health services. In the present era, the growth of mobile users is exponential, and it can act as an important tool regarding health communication. It is also a good medium for the low literacy and low-income populations to get information regarding health issues. The aim of the e-health is to monitor the health of the individual person. It includes a variety of fields such as monitoring individual bio-signals, area of telemedicine, analyzing signals, and customized health and medical services [9, 10]. In bio-signal monitoring, several sensors are combined together to obtain the sample output using some predefined procedure [12]. It also provides a graphical user interface to enter the information through patients. These types of monitoring systems are available in the market, which transmit the information regarding heart rate, blood pressure (BP), and body temperature of patients. Some of applications that can be used in this process are wireless communication terminals, Bluetooth, near-field communication (NFC), wireless local area networks (WLANs), and service providers are delivering processed healthcare information to users. On the other side, telemedicine is a remote treatment process carried through video conferencing and analyzes the collected PHRs for rehabilitation training. The aim of the e-health model is to mine the gathered information and predict the occurrence of disease. Due to the increase in interest of mobile phones in healthcare, several applications have been developed to monitor the health of mobile users.

7.2.2 PHR-Based Health Management

The personal health record can be defined as to store and manage the health record of a person throughout their life [13, 14]. Due to technological revolution, it is possible to measure the activity related to PHR data, such as amount of exercise, blood pressure, diabetes index, and so on. Hence, the demand of customized health management services is increased in present scenario due to the availability of health-related data. Further, it is also conceivable to cure the chronic diseases via PHR. The PHR of individuals can be used for continuous health management and health promotion activities. The other reason is that such type of health management can improve the health of persons [13, 15, 16]. For, continuous individual health management, it is necessary that personal health record of a person can be collected continually and, in this direction, mobile phones are the appropriate medium to collect that health data. Further, the more the PHR data are collected, the greater the usefulness and utilization, and patient-oriented environment is developed rather than hospital-oriented environment. In addition, patients can obtain accurate health information due to the various types of information integrated with PHR. This can lead to the prevention of disease and controlling the health of an individual. In literature, it is noticed that large numbers of health-based monitoring and management systems are reported. Some of these are listed as. Zhu et al. [17] have proposed a cardiac monitoring system to label the electrocardiogram (ECG) data. The proposed system integrates the mobile end of the system with a back-end annotation system for reviewing and scoring the quality of an ECG signal. In the proposed system, crowdsourcing methodology has been used to determine the ECG annotations from a set of experts including doctors, trainees, and automated algorithms. It is observed that the proposed system gives diagnosis accuracy equivalent to experts with reduced cost. Benharref and Serhani have proposed Service Oriented Architecture (SOA) and cloud-based framework for e-health monitoring [18]. The aim of the proposed framework is to collect real-time data from patients, provide nonintrusive monitoring, and provide medical and lifestyle management activities. In this framework, the mobile technologies are incorporated to collect and communicate data from a patient. The effectiveness and usability of the proposed framework are investigated using a case study, and it is observed that the proposed framework provides promising results. Xu et al. have developed an m-Health monitoring system based on cloud computing platform (Cloud-MHMS) and mobile network for implementing pervasive health monitoring [19]. In the proposed system, data storage, data processing, and data analysis processes are carried out using cloud storage and multiple tenants' access control layer, healthcare data annotation layer, and healthcare data analysis layer. Further, it is observed that the usability of the proposed monitoring system is tested on antimicrobial drug usage. It is reported that the proposed system provides better results for personal health care analysis. To determine the impact of the lifestyle and environmental parameters on the seminal quality and fertility rate, especially in man, a seminal quality prediction model is presented in [20]. To determine symptom trajectories of depression, a mobile-

based monitoring system is presented in [21]. The proposed mobile-based system is used to classify the depression severity. The performance of the proposed system is evaluated on 344 primary care patients with depression. The depression symptoms are measured weekly through interactive voice response (IVR) calls using the patient health questionnaire. Further, it is noticed that multivariate linear regression is applied to predict the trajectories. To efficiently and accurately determine the light exposure, mood, and activity levels of individual people, McNamara and Ngai have designed a personal mobile sensing system [22]. The proposed system explores the technologies embedded into smartphones. The functionality and performance of the proposed system is evaluated through various users up to a time period of 2 years. The authors claimed that the proposed system can estimate accurate light exposure and also predicted well both personal light exposure and general seasonal trends. A rule-based classification system has been designed for the diagnosis of different types of liver disease [23]. In this work, a rule base is constructed for effective diagnosis and prediction of liver diseases. The rule base consists of 20 rules to classify the liver disease. It is noticed that the proposed rule-based system provides better results in terms of classification of liver diseases. Hossain has developed an elderly monitoring system to continuously monitor the health of older adults and support them with various services like emergency detection and alarm, information and media service access, and interaction and communication [24]. The performance of the proposed system is evaluated using ten elder adults of the age group of 60–70 years. It is reported that the proposed system gives better results in terms of efficiency, effectiveness, and user satisfaction. Santos et al. [25] have proposed IoT-based mobile gateway for mobile health (m-Health) scenarios. The proposed gateway is applied to collect the information of patient-like location, heart rate, and possible fall detection. The objective of the proposed system is to forward the collected information to a caretaker, and it will manage a set of actions and alarms appropriately. It is observed that the proposed mobile gateway act as an effective communication channel. The usability and applicability of the different predictions and monitoring systems have been presented in [26]. For earlier prediction and diagnosis of dengue disease, a PSO-ANN-based diagnostic model is reported in [27]. In the proposed model, PSO is applied to optimize the parameters of the ANN. The results report that the proposed model effectively predicts the occurrence of the dengue disease. A systematic review on the diabetic personal health record is reported in [28]. A diabetes electronic health record for effective diabetes management is presented in [29]. Some diagnostic systems for predicting diseases using machine learning approaches are described in [20, 23, 30].

7.3 PHR-Based Diabetic Monitoring System

This section describes the proposed PHR-based diabetes monitoring system. A PHR can be described as a software tool which permits the patient to enter the desired information regarding the disease and provides the possible solution for

the disease. Further, patients can manage their health information using the PHR system and can access the medical information anytime round the clock. This system also associates the patient's information with the medical institutes, hospitals, consultation, doctor's appointments, etc. and can be accessed easily whatever is needed. As the medical awareness among people is increasing day by day, such types of systems are in demand and can also improve the lifestyle of people. But, the effectiveness and utilization of these systems are highly dependent on the medical data; as more and more medical data are gathered, these systems can be utilized effectively. Further, the aim of the PHR system is to covert the hospital-centered medical environment into the patient-centered one. Hence, in this work, a PHR-based diabetes monitoring system is developed for effective management and diagnosis of the diabetes disease. Diabetes is one of the metabolic diseases that can occur due to nonconversion of glucose into energy by body cells. It can be classified into two types such as type-1 diabetes and type-2 diabetes. It is reported that only 10% patients of the total diabetes population suffer from type-1 diabetes and rest of them suffer from type-2 diabetes. In type-1 diabetes, insulin is not produced by the human body, and for the treatment of this type of diabetes, insulin can be given to the patients. Type-2 diabetes can occur due to genetic factors, stress, obesity, and lack of exercise. The effects of type-1 diabetes are quite complicated, such as they are responsible for heart disease, limb disease, blindness, kidney failure, etc. while lifestyle factors are more responsible for type-2 diabetes. Highly obese and overweight people have more chances for type-2 diabetes. It is observed that type-2 diabetes can be controlled by changing lifestyle, weight loss, diet control, and exercise. In this work, a Personal Health Record (PHR)-based model is proposed for accurate diagnosis and effective management of diabetes. Further, this model will help and make the people aware regarding diabetes. Figure 7.1 illustrates the proposed PHR-based diabetes monitoring system. The proposed system is divided into three phases, such as, user information, PHR-based diabetic monitoring system, and clinical information. To identify the people with diabetes, some diagnosis standard is considered for the prescreening of diabetes. The descriptions of these standards are mentioned in Table 7.1. The diagnosis standards considered for the prescreening of diabetes are body mass index (BMI), blood pressure (BP), cholesterol levels, history of heart disease, sedentary lifestyle, prenatal history, and age. Further, blood pressure is divided into three categories, such as, healthy BP, early high BP, and high BP. Similarly, cholesterol level is also categorized into three classes, such as, low-density lipoproteins (LDL), high-density lipoproteins (HDL), and triglycerides. Tables 7.2 and 7.3 give information regarding the categories of blood pressure and cholesterol-level diagnosis standards. The above-mentioned diagnosis standards are applied to diagnose whether a person has diabetes or not. Further, diabetes is classified into two types, such as, Type-1 and Type-2. Tables 7.4 and 7.5 present the diagnosis standard to identify the patients affected with either Type-1 diabetes or Type-2 diabetes. In case of Type-1 diabetes, it is recommended that some insulin dose will be considered for the patients. But for Type-2 diabetes, it is suggested that patients can take a healthy diet as well as go for daily workouts.

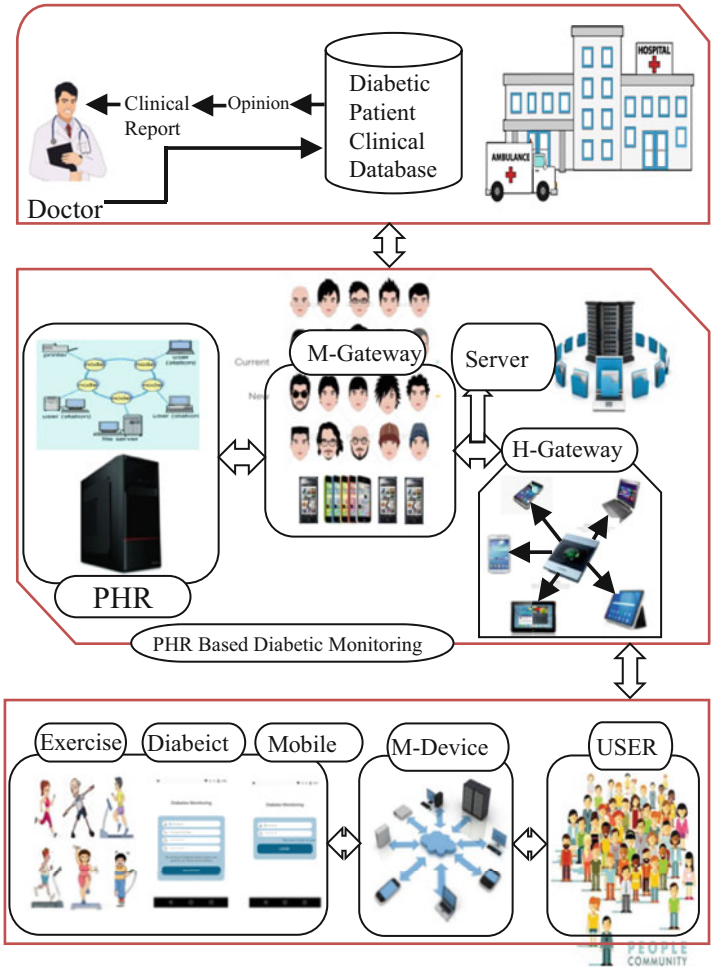

Fig. 7.1 Proposed PHR-based diabetes monitoring system

Table 7.1 Diagnostic standard for classification of prediabetic screening

Sr. no.	Diagnosis standard	Range
1	Body Mass Index (BMI)	Higher than 25 kg/m^2
2	Blood pressure	Higher than 120/80 mmHg
3	Cholesterol level	Higher/Lower
4	History of heart disease	Yes/No
5	Sedentary lifestyle	Yes/No
6	Prenatal history	Yes/No
7	Age	More than 40 years

Table 7.2 Classification of the cholesterol diagnostic standard

Standard	Classification	Range
Cholesterol	LDL	Higher than 100 mg/dl
	HDL	Less than 40 mg/dl
	Triglycerides	Higher than 150 mg.dl

Table 7.3 Classification of the blood pressure diagnostic standard

Standard	Classification	Range
Blood pressure	Healthy BP	120/80 mmHg
	Early high BP	In between 120/80–140/90 mmHg
	High BP	Higher than 140/90 mmHg

Table 7.4 Classification of type-1 diabetes

Diabetes classification	Standard diagnosis	Range
Type-1	Random blood sugar test	Higher than 6.4 mg/dl
	Fasting blood sugar test	Higher than 126 mg/dl
	Glycated hemoglobin	Higher than 6.4

Table 7.5 Classification of type-2 diabetes

Diabetes classification	Standard diagnosis	Range
Type-2	Two-hour postprandial test	Higher than 7.0 mmol/L
	Oral glucose tolerance test	More than 200 mg/dL

7.4 Implementation Details, Results, and Discussion

In this work, a mobile-based application is developed to monitor the diabetes. In the proposed system, a user can enter the medical details regarding diabetes through a mobile application; then, this information is analyzed using the PHR-based system. This analyzed information is used for monitoring the diabetes-affected person through a mobile app. The main task of the proposed app is to classify the person as normal, prediabetic, having type-1 diabetes, and type-2 diabetes. Further, this app also provides some suggestions to overcome the diabetes like life health index, exercise therapy, health information, and dietary nutrient information. The proposed system considers the body mass index (BMI), blood pressure (BP), cholesterol levels, history of heart disease, sedentary lifestyle, prenatal history, age, and some clinical features for effective diagnosis of the diabetes. The proposed PHR-based diabetes monitoring system is developed using Android Studio 1.1.0in environment on window-based operation system having Intel(R) Xeon(R) processor, CPU E5–1620 v2, 3.7 GHz, and 8 GB RAM. The process of identification of diabetes is mentioned in Fig. 7.2. Figure 7.3 illustrates the login screen of the proposed

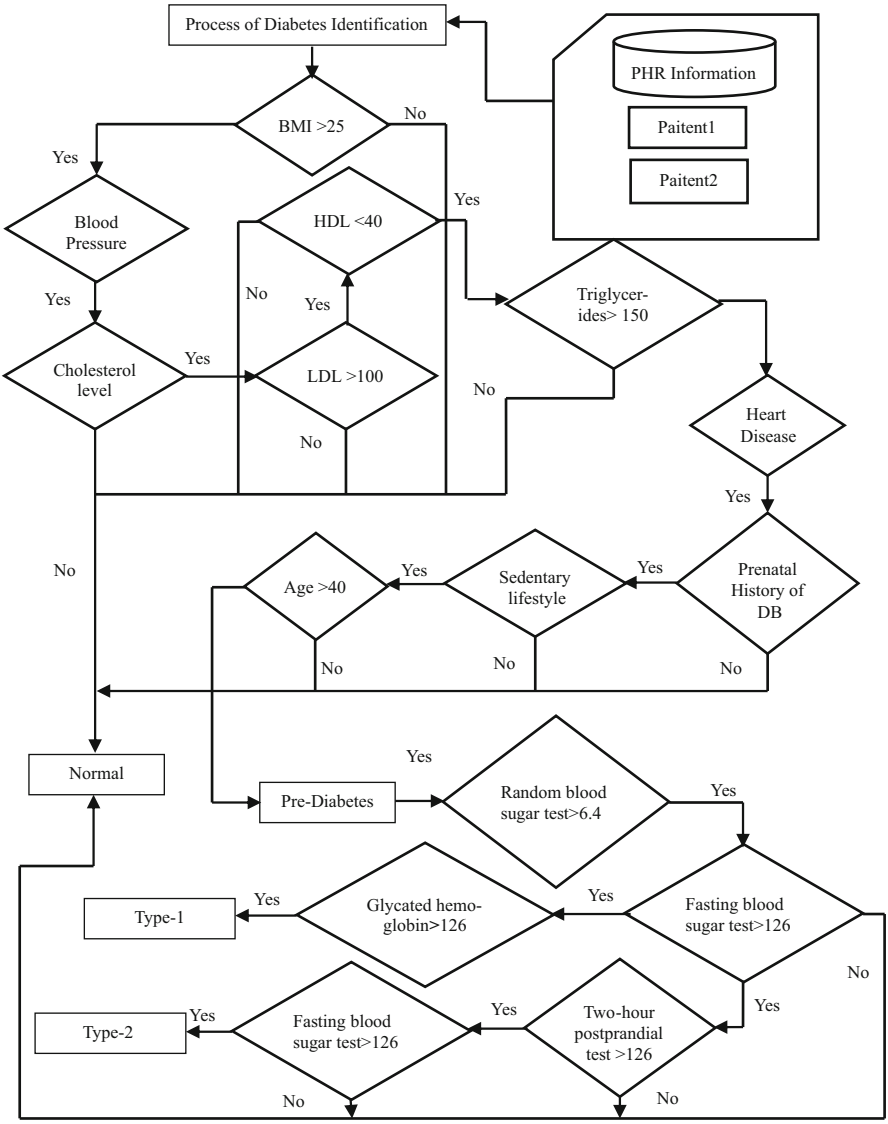

Fig. 7.2 Diabetes identification rule base process

diabetes monitoring app. If the user is already registered with the app, then it will login into the system using the user name (refer Figs. 7.4 and 7.5). Otherwise, users can initially register with the app using create account option. Figure 7.4 shows the user registration process interface of the proposed app. After registration process, an account of user is created and unique user name and password is given to every user for further processing. Figure 7.5 shows the interface of the pre

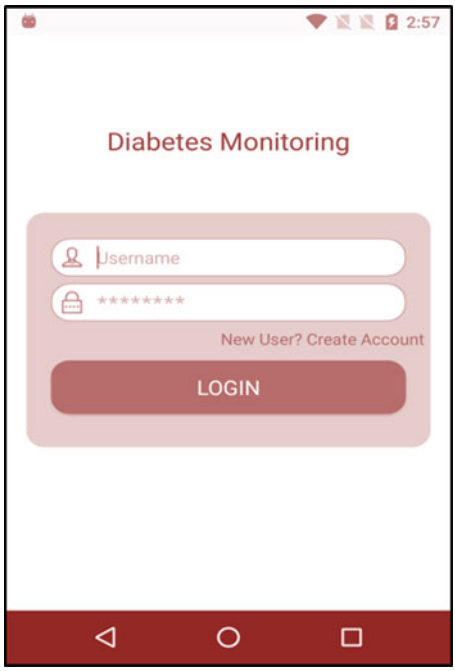

Fig. 7.3 LOGIN screen

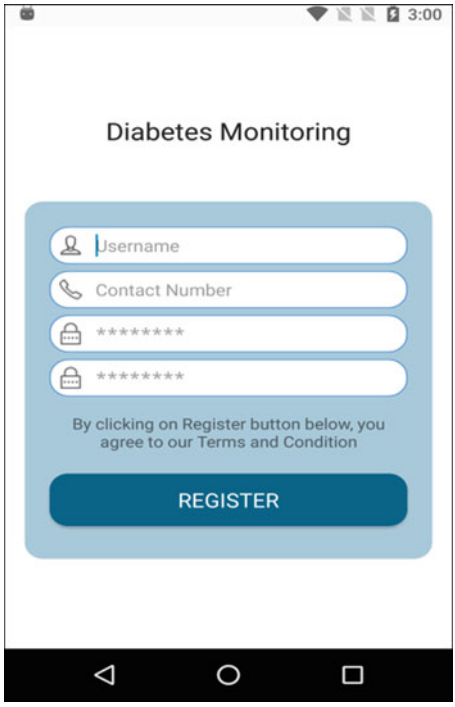

Fig. 7.4 Registration interface

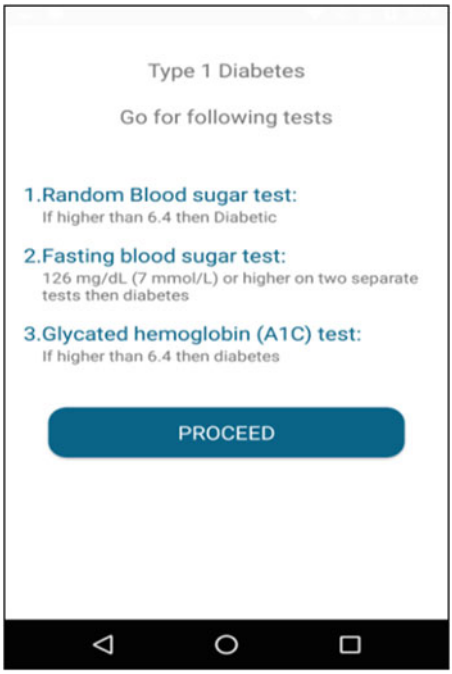

Fig. 7.5 Prediabetic screening interface

diabetes screening. This interface requires information like BMI, BP, cholesterol level, heart disease history, life style information, and parental history of diabetes for successful diagnosis of a person either pre-diabetic or normal. If a person has high BP, high BMI score and also having parental history of diabetes, then the person has maximum chance of pre-diabetes and further, it is suggested that to control the BP and BMI to reduce the chance of pre-diabetes.

Figure 7.6 describes the nonclinical parameters for diagnosing and monitoring type-1 diabetes. These parameters include excessive thirst, high level of urination, weight loss, tiredness, and blurring of vision. If such symptoms occur, then definitely the possibility of diabetes exists, and it is recommended that the person undergoes some clinical tests. Figure 7.7 illustrates the diagnostic tests which are used for the confirmation of diabetes.

These tests include random blood sugar test, fasting blood sugar test, and glycated hemoglobin test. These tests clearly notify the presence of type-1 diabetes. Figure 7.8 shows the list of suggestions that can be taken after diagnosis of the diabetes. It is suggested that in case of type-1 diabetes, the patient should take the insulin dose as per recommendation. Further, it is advisable that the patient should go for regular monitoring of the diabetes and also improve eating habits. The nonclinical parameters for diagnosing and monitoring type-2 diabetes are reported in Fig. 7.9. These parameters include being unwell, eating too much, and ineffective diabetes medication. Further, it is suggested that if these symptoms occur, then some clinical tests are recommended for identifying the presence of diabetes. These

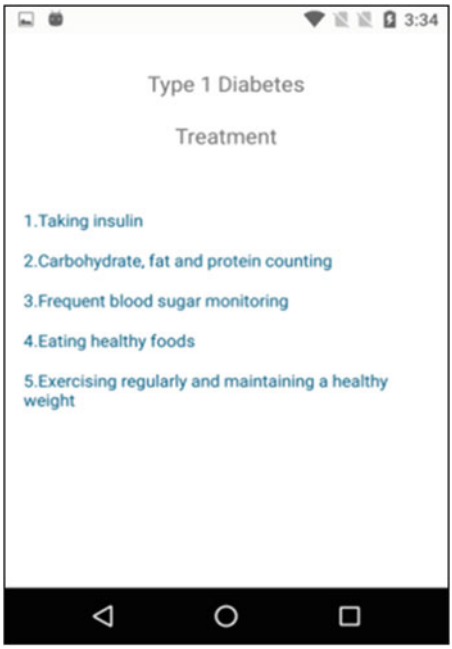

Fig. 7.6 Nonclinical symptoms of type-1 diabetes

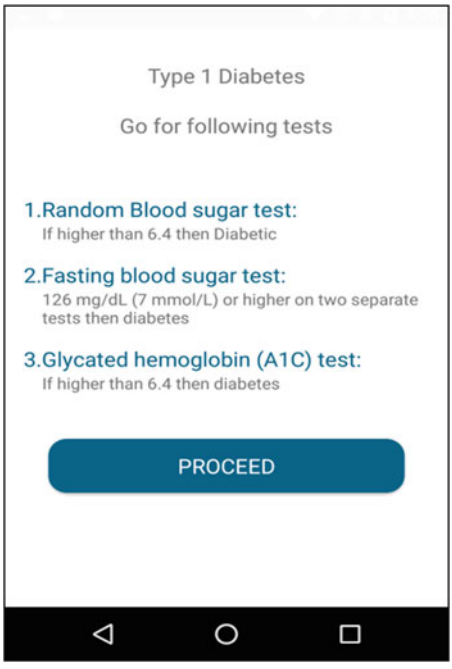

Fig. 7.7 Clinical symptoms of type-1 diabetes

Fig. 7.8 Lifestyle improvements to reduce type-1 diabetes

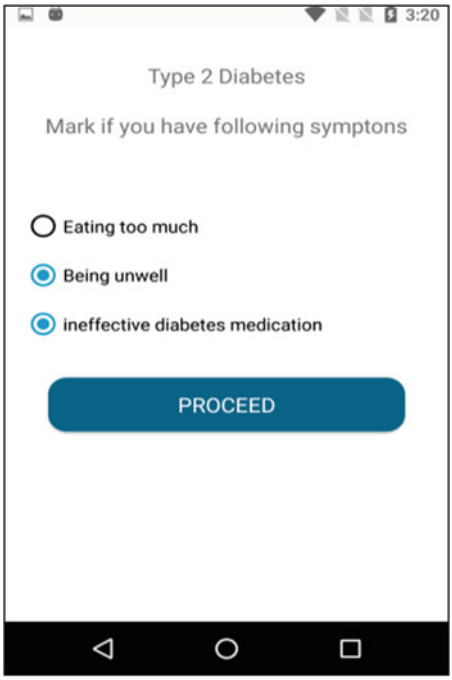

Fig. 7.9 Non-clinical symptoms of type-2 diabetes

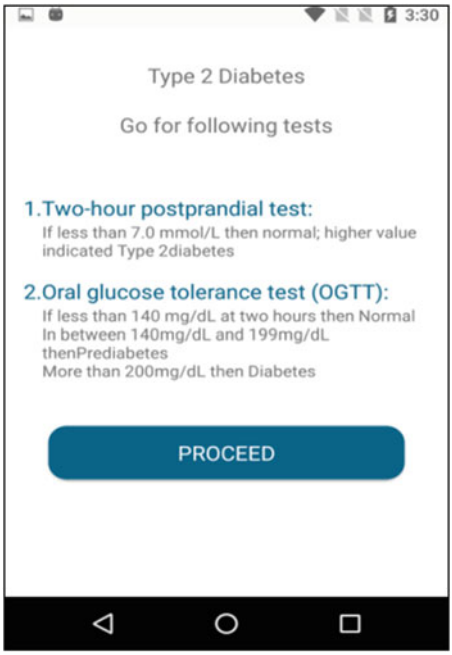

Fig. 7.10 Clinical symptoms of type-2 diabetes

Fig. 7.11 Lifestyle improvements

tests are 2 h postpyramidal tests and oral glucose tolerance test (OGTT) which are described in Fig. 7.10. If the results of these tests are positive, then the patient is affected with type-2 diabetes. Figure 7.11 illustrates the precaution taken in case of type-2 diabetes. In most cases, type-2 diabetes is reduced by adopting habits such as

healthy eating, daily exercise, reducing the intake of Bailey fat, and so on. In some cases, the insulin dose is also given to maintain the sugar level in the body. Further, it is advised that the patient should go for the regular monitoring of diabetes and control the sugar level by adopting healthy habits.

7.5 Conclusions

Currently, people are more concerned and conscious regarding their health. Moreover, large numbers of medical services and devices have been developed to automate the medical facilities. The concept of M@M, IoT, and smart health has become widely popular among human beings, and people want to collect more and more information on health issues. Further, it is noticed that chronic diseases increase due to eating habits, obesity, lack of exercise, late-night sleep, excessive smoking and drinking, unmanaged lifestyle, etc. Hence, due to advancement in medical technology and increased convergence, it is possible that the patient can control himself to avoid some chronic diseases like diabetes and obesity by using the PHR platform. In this paper, the PHR-based diabetes monitoring system is proposed that performs the real-time monitoring of the diabetes user. In this system, the real-time data are collected through mobile phones, and these mobile phones are connected with the PHR server for monitoring and diagnosis of diabetes of the individual user. Further, the PHR server is connected with the hospitals in case of emergency service and also for consultation with doctors.

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