Remote Monitoring of Diabetic Patients Using Wireless Mobile Technologies
Seguimiento Remoto de Pacientes Diabéticos Mediante Tecnologías Móviles Inalámbricas

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ABSTRACT

Diabetes is one of the leading causes of death in the world, which is often attributed to lack of prompt treatment or patient neglect, a situation that, in addition to hospitalization, requires regular follow-up. This study involves developing a mobile health system (mHealth) that allows remote monitoring of diabetic patients using wireless mobile technologies to improve the quality of life of people with this condition. The monitoring system consists of a glucometer from which the data is taken and entered into the Android application installed on the patient's smartphone. Clinical data is stored and sent through the mobile phone network to a web server in the cloud for the physician to access through its application and make observations of the patient in real-time.

Keywords: Type II diabetes Mellitus; chronic disease management; m-health; follow-up; e-health

RESUMEN

La diabetes es una de las principales causas de muerte en el mundo, lo cual puede atribuirse a la falta de tratamiento o a la negligencia del paciente, situación que, además de la hospitalización, requiere un seguimiento regular. Este estudio consiste en desarrollar un sistema que permita el seguimiento remoto de

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pacientes diabéticos utilizando tecnologías móviles inalámbricas para mejorar la calidad de vida de las personas con esta condición. El sistema de monitorización consta de un glucómetro del que se toman los datos y se introducen en la aplicación Android instalada en el Smartphone del paciente. Los datos clínicos se almacenan y envían a través de la red de telefonía móvil a un servidor web en la nube para que el médico acceda a través de su aplicación y realice observaciones del paciente en tiempo real.

Palabras claves: Diabetes mellitus tipo II; manejo de enfermedades crónicas; m-salud ;seguimiento;e-salud

1. INTRODUCTION

Diabetes is a condition with a growing morbidity and mortality burden. The World Health Organization (WHO) estimates that 422 million people worldwide have diabetes, where approximately 7.5% (31.6 million) of patients that were diagnosed with diabetes live in Latin America [1]. Diabetes is a general term for heterogeneous metabolism disturbances characterized by elevated glucose levels in the blood. It is caused either by the absence of insulin secretion from the pancreas, the decreasing amount of insulin production, or the weakened effect of insulin [2]. Once diabetes is diagnosed, self-care and self–monitoring are essential for glycemic control who suffer from it. Diabetes self-care includes changing patients' daily lifestyle habits, physical activity, weight control, blood glucose monitoring, and medication are crucial for preventing and controlling diabetes complications [3].

In the daily routine of diabetes mellitus type II, the patient needs to frequently monitor blood glucose levels by means portable glucometer and to keep a record of glycemia's measurements to perform actions, make decisions, and to assess the adequacy of pharmacological and non-pharmacological treatment. For instance, insulin dosing depends on the time of day, the amount of food eaten, the momentary glycemia, the physical activity, among others. As a result, there is a difficulty for the patient to adequately monitor and follow up all the information related to the treatment of his disease in a timely manner.

Furthermore, care costs for chronic disease such as diabetes are immense. Several studies evidenced that the costs associated with diabetes complication and management can be reduced by supporting the self-management capabilities of patients [4]. With the rapid adoption of smartphones in developing countries, patients have an opportunity to use mobile applications (apps) to track, monitor, and access health information and services for a health-specific condition at a low cost.

The use of mobile health (m-health) technology can benefit the health care system in multiple ways. First, from the patient's perspective, they can make self-care more confidently, improve independence and adherence to the treatment plan. Second, from a professional perspective, they can increase coordination and communication between physicians and clinical staff. Lastly, this can lead to improved continuity of treatment, as well as increased patient safety and quality of care.

Developing mobile applications for health management has been rapid over the past years. Diabetes care can benefit from the use of mHealth applications and SMS-message-based solutions. Diabetes is a chronic condition that needs constant monitoring and communication with a health care expert. These apps can allow the patient to record aspects of their health in a possibly simpler way and get feedback on their results. This can support and increase the self-management and motivation to regulate their condition [5], [6].

The proposed work envisages in its objective the development of a monitoring system with a glucometer, from where the data is taken and entered into the application installed on the patient's Smartphone, whose data will be transmitted to a web server, where they are processed and sent over the wireless network to the mobile device of the health specialist, which also has an application on Android, which shall give relevant recommendations to the patient through this means.

The developed application provides significant contributions to the healthcare management of diabetic patients by enabling real-time monitoring from home, thereby facilitating continuous control of their condition. Furthermore, it fosters direct interaction with healthcare specialists through the platform, enhancing communication and personalized care. Lastly, the historical recording of glycemia measurements allows for detailed tracking of the patient's progress, supporting timely and evidence-based clinical decision-making.

2. METHODS

The process of implementing the mobile application consists of i) requirement analysis with physicians and patients with diabetes to identify needs and relevant functionalities, ii) design and development of the app, and iii) data transmission and . The remote monitoring system is shown in figure 1.

The initial phase involves the use of the digital glucometer by the diabetic patient, from where the data is taken. Here the patient has the supervision of a nurse who validates the value of glycemia to enter.

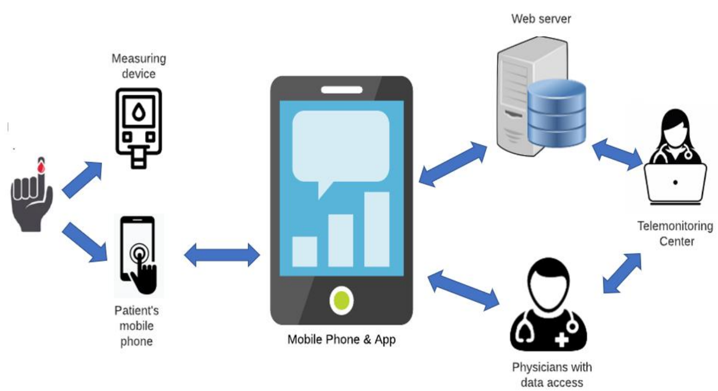

Figure 1. The flowchart of the monitoring system.

The second phase is when the patient accesses the Android application installed on their mobile phone in which the data is registered, stored, and sent over the mobile telephone network to a database administrator who has a MySQL database manager [7]. To access this web administrator, for safety, the patient had a username and an access code. Data encryption techniques and security mechanisms were used to protect the patient's information.

The third phase involves access by means of a URL to the measurement or other patient data through an Android application installed on the physician's Smartphone. The fourth phase is when the physician feeds the patient back on blood glucose levels and suggests the relevant actions to be taken.

3. RESULTS

A total of four patients(50% women) who were diagnosed with diabetes used the mobile application proposed. Glucose measurements were carried out twice a day for two weeks and recorded in the system.

The results obtained at the application's development stage are shown in Android Studio 1.0 Lollipop version 5.0 for the patient and medical roles. In both cases, work was on developing the application's graphical interface [8], designing and locating the components: buttons, texts, and images, among others, so that users interact appropriately with the application and find it eye-catching.

After the application creation process, called AppGluco, some of the components are displayed. When accessing, diabetic patients find a drop-down side menu (menu drawer) with options: start, measurement, notification, clinical history, and recommendation.

Pressing "Start" displays a text and image related to the study's goals. At the bottom, there are two buttons: a "Panic Button," that when pressed, gives the option to send the physician or medical staff an alert message about the severity of their health status, and the "Siren Button", whose purpose is to notify the relatives of the patient that the patient has an emergency (see figure 2).

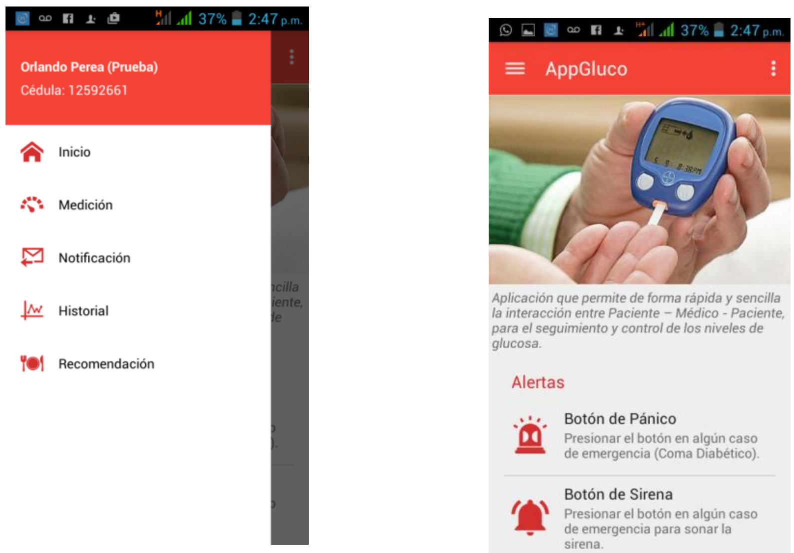

Figure 2. Mobile application. Left: AppGluco menu, Right: Option to Start AppGluco.

In the "measurement" component, two buttons are located: one for the option to enter the data thrown by the digital glucometer in a "Manual" way and the "Bluetooth" option for the patient to connect to a glucometer that has a Bluetooth accessory that in turn automatically connects to the mobile device so that the application receives the sent data (see figure 3).

AppGluco has a bar that changes color when the data is entered: if the data is equal to or less than 70 mg/dl, the bar goes from white to yellow, indicating that the patient has a hypoglycemic state. Now, when that value is greater than 70mg/dl and less than or equal to 130 mg/dl, the bar goes from white to green, indicating that the patient is normoglycemic. Nevertheless, if the result is greater than 130 mg/dL, the bar changes from white to red, indicating that the patient is hyperglycemic. At the end of this component, the patient in the "Observation" part has the freedom to write some concerns to the physician and then end with the save option.

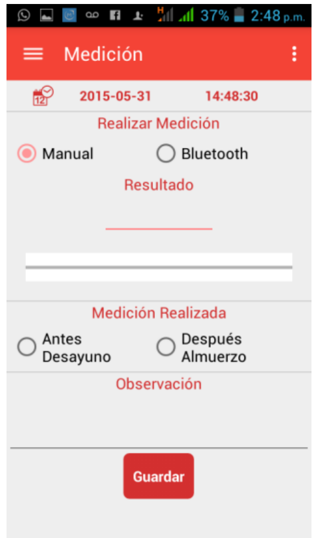

Figure 3. Measurement component in AppGluco.

In the "Notification" component of the AppGluco application, the patient, after entering the data, has the option to display the information entered in the "Measurement" component. In the "Observation" space, the patient can read the message that the physician sends him/her over a wireless mobile network. This component is shown in figure 4.

Figure 4. Notification component in AppGluco

"History" in AppGluco is an essential component for the patient and the physician, as it reflects the behavior of blood glucose levels in diabetic patients. This graph shows the last three (3) days of measurement on the horizontal axis and the vertical axis, the blood glucose concentration in mg/dL.

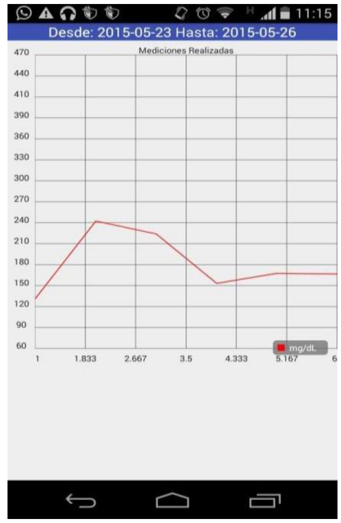

Figure 5. History component in AppGluco.

Furthermore, a component to highlight in AppGluco is the so-called "Recommendation," where the patient has the option to select one day of the week and immediately appears the diet proposed by experts that includes breakfast, lunch, and dinner.

On the other hand, we have the " Physician" Login designed for the professional who monitors patients, where the elements appear to access it.

Figure 6. Login to the app.

When the physician enters the AppGluco app, the "Patient List" component immediately appears on a screen, where each appears with their record of the last measurement highlighted with a color indicating their condition. If it appears in yellow, its status is hypoglycemia, green normoglycemia, and red hyperglycemia, as shown in figure 7.

Figure 7. List of patients in the Physician App.

By pressing the patient's name on the list, the physician will access his most relevant data such as sex, body mass and height, supplemented by information about the medications you are consuming and the observations sent; In addition, you can visualize the last result in glycaemia, as well as the patient's history.

When it came to Web Manager [9], located in the cloud, it is accessed through the URL: appgluco.texet.co. When the entry requirements are met, a table appears with patient identification numbers, supplemented by glycaemia results, among others. This server designed under the MySQL database manager exchanges information with the patient app and doctor's app via FTP protocol [10].

These results were complemented by those obtained in a survey with eight satisfaction indicators applied to the physician (n=5) and patients (n=5). Indicators 1 through 7 have the same intentionality for study participants. Indicator 1, as shown in Figure 8, reflects disciplined access to patient and medical applications. Indicator 2 shows that participants rated well the guidance related to navigation procedures in the application. Indicator 3, physicians and patients gave the highest score to the services provided by the developed app. Indicator 4 shows that the app significantly favored the decrease in glycemic levels in patients.

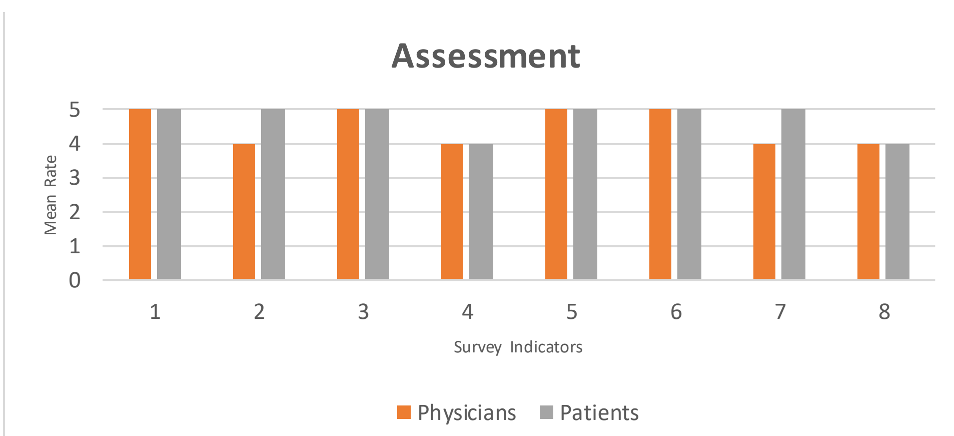

Figure 8. Results of the satisfaction survey for patients (n=5) and physicians (n=5) of the AppGluco App.

As for indicators 5 and 6, participants agree that the app has been developed attractively and interactively, facilitating its use. Indicator 7 is highly valued in the sense that the app is a technological innovation that provides in solving health-related problems.

Finally, indicator 8 reflected that both patients and physicians value the quality of feedback as good. The doctor emphasized that patient messages were concrete and timely, while patients mainly were attentive and understanding of the health specialist's observations.

4. DISCUSSION

Remote monitoring of diabetic patients has been showing relevant results in the control of diabetic patients. The development of mobile applications has allowed both the doctor and the patient to interact dynamically; facts that could be validated in the study and showed that the application designed in Android Studio: AppGluco provided and installed to participants on their Smartphones by the authors, has advantages in the design of its graphical interface, manipulation and costs concerning other commercial applications. The app developed can be a helpful engineering solution for health systems to improve the quality of monitoring of affected patients [11].

Based on the results of the surveys administered to users and physicians, the most relevant performance indicators identified were overall satisfaction, ease of use, and the perceived impact on patients' quality of life or health. From the users' perspective, these indicators reflect the acceptance of the service, its technological accessibility, and its perceived effectiveness. From the physicians' standpoint, the quality of communication with patients and the operational utility of the application also stand out, enabling a comprehensive assessment of its contribution to clinical practice and patient care interactions

5. CONCLUSION AND FUTURE WORK

It was possible to demonstrate that the use of apps in monitoring diabetic patients favors that in real time the doctor, through an Android application on his Smartphone, can make observations of the patient.

Through the remote monitoring system implemented, it was possible to send the patient's glycemic data from the patient's Android app to a web manager in the cloud, from which the doctor remotely receives it through his application on Android. The system described could prevent situations of risk to patients' health and shows its efficiency by promoting proper follow-up.

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