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Improving Preventive Healthcare with an User-centric Mobile Tele-monitoring Model

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Abstract

Chronic diseases are an important field to tackle due to increasing healthcare risk factors, including population nutritional habits, lack of physical exercise, and population aging. Diabetes mellitus, hypertension, and obesity currently affect millions of people, and this statistic grows every year and is responsible for numerous deaths everyday. Many of those deaths could be delayed by following a steady monitoring strategy over such a population, which would prevent vital signs from reaching critical stages and providing knowledge for these patients about their health. This paper introduces Mobilicare, a mobile health promotion system designed to: (i) monitor remotely a patient´s vital signs in real time; (ii) support a health service in a Healthcare Center; and (iii) allow self-awareness of the disease and improve motivation. Our approach was applied to two distinct chronic patient management programs. The results showed the commitment of elder patients and the contribution of Mobilicare to the maintenance of a patient´s health stability.

Keywords:

Chronic disease management; eHealth; mHealth; cloud computing; tele-vital signs; tele-homecare.

Introduction

Access to medical care is sometimes difficult for citizens living in distant and underserved areas. However, even citizens living in large cities in developed countries may find it hard to reach medical services. Not being able to access primary medical care when illness, injury, or potential health problems arise may lead to a late diagnosis, delay in treatment, and possible future consequences. The problem gets even more serious in developing countries, such as the BRICS countries (Brazil, Russia, India, China, and South Africa).

With the goal of eliminating distance barriers, telemedicine is a multidisciplinary research area that integrates not only several computer science fields, but also medicine and healthcare. Its aim is to improve health services and quality of life, as well as provide remote medical training. Recently, telemedicine has been helped by advances in mobile communication and the adoption of tablets and smartphones. For example, it is currently easier to reach older or homecare patients whose medical access could be hampered by physical constraints. For example, mobile communications and portable devices permit monitoring of vital signs, no matter the patient's location.

Targeting one of the most critical chronic diseases, in 1985, there was an estimated 30 million adults living with diabetes mellitus. This number grew to 135 million in 1995, and then to 173 million in 2002 [1]. Currently, there are more that 371 million people living with diabetes between the ages of 20 to 79 years. This number rises every year in practically all countries, and 50% of the people with diabetes do not even know their clinical condition [2]. About two-thirds of these people live in developing countries, where the epidemic has more intensity, and with a growing rate in younger citizens [1]. Nevertheless, people with diabetes mellitus are living longer due mainly to advances in medicine [3].

As a consequence, both public and private healthcare costs for treating these types of patients are increasing due to higher average lifetime expectations worldwide. Additionally, both the number of medical doctors and their geographical distributions cannot cope with the quickly growing number of patients with chronic diseases. Finally, patients unaware of their clinical condition are not treated preventively and endure worse consequences since diabetes can be considered a “silent sickness”. They usually show greater resistance in following correct treatment since it is for the rest of their lives and demands daily care.

In Brazil, private health care operators offer Chronic Patients Management Programs to monitor patient clinical condition, mainly due to the possibility of income taxes reduction. In order to keep operational costs low, however, most of these programs only contact the patient once a month, either at home or through a phone call. If the patient does not feel well, he/she can call a monitoring center usually during working hours and speak with specialized nurses and doctors. This scenario limits the notion of the patient’s clinical condition. For patients with Type 2 diabetes, the medical protocol can lead to a possibly incorrect idea that they are clinically stable most of the time.

We present a mobile system – called Mobilicare – that is used by patients at home to collect and transmit patient data (e.g., glucose measurements) at specific dates and times. Through the system, the health center can remotely monitor a patient’s condition and even contact them. The main goals are to provide: a) a remote just-in-time pro-active and preventive health service to the patient, based on vital signs; b) graphs and alarms when vital signs are out of threshold for the health center and also the patient; c) video conference with doctors and family; d) patient risk analysis; and e) educational videos about diseases, food, and exercise habits. We observed that these features impact the way the treatment is performed, from reactive to active (i.e., anticipating an event). In order to analyze system outcomes over different scenarios, two case studies were conducted – one related to diabetes, and another to health promotion.

Methods

The Mobilicare System

The Mobilicare system is composed of three main entities, as depicted in Figure 1: a) the mobile kit at the patient's home; b) cloud storage; c) the medical/health care center.

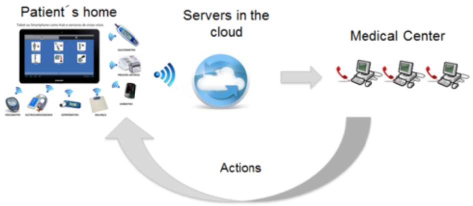

Figure 1- General view of Mobilicare.

The mobile kit in the patient's home

The mobile kit is composed of a 3G/Wi-Fi tablet and a number of vital monitoring medical devices according to their chronic diseases (Figure 2). Electrocardiograms, scales, blood pressure meters, oximeters, thermometers, glucometers, pedometers, and spirometers are connected via Bluetooth to a tablet or smartphone. This device transmits information over the network to a Cloud storage system in which a medical center has access and analyzes such data for decision-making. The most common sensors are Glucometer (for diabetes), Blood pressure (for hypertension), and Scale (for weight control).

Figure 2. Medical devices supported by Mobilicare.

Figure 3 (left) shows a glucometer attached to a device that convert the measurement to Bluetooth, sending it to the tablet. For instance, the interface is configured only for diabetes measurements. Figure 3 (right) shows a graph of the vital signs – in this case for glucose – in which patients can follow and verify the disease stability over time.

Figure 3- Use for the tele-glucose meter (left) and glucose graphics (right).

Figure 4 depicts the video conference interface that includes the following features: access to the healthcare center, health coach for remote training, family, and a social network for people with the same disease. The goal of the social media part is so that patients can exchange with and motivate one another.

Figure 4- Mobilicare video conferencing and social network modules.

Cloud Storage

Mobilicare works as a service, i.e., it follows the SaaS (Software as a Service) technology and business model. The Cloud is used to store all the information and allow transparent web access through the Internet using RESTful APIs. Over the Cloud, the system both receives and automatically compares the measurements against a set of thresholds (upper as well as lower limits) prescribed by the responsible physician. These limits are individualized for each patient according to different clinical profiles.

By using cloud computing, medical professionals can communicate with several medical centers if needed via Web services. They can also manually analyze the vital signs (visualized using Java applets), perform a diagnosis, send alerts to the tablet application, and even contact patients via teleconference - all of that using a web browser at the medical center. The goal is not to replace a medical consultation, but rather complement and expand the service, offering guidance and monitoring from a distance.

The Medical Center

The medical center aggregates all patient data. If there is an alarm on a patient, their data appear at the beginning of the list and a sound is generated, followed by a yellow message. If the patient does not perform a prescribed measurement, the call center gets a "non-measurement alarm" and follows a protocol to question the patient for reasons for this behavior. If the measurement exceeds either a higher or a lower limit of the associated clinical profile, the call center both receives a "clinical alarm" (e.g., emergency, urgency) and executes the medical protocol.

Figure 5 shows the health care real-time dashboard as patients performance charts, contact, contact of close people, name of physicians, medicines took, and visit records, among others.

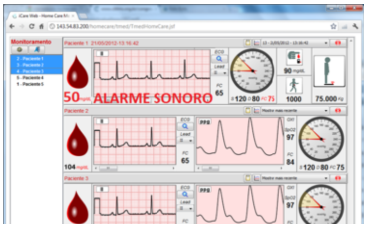

Figure 5- Mobilicare Medical Center dashboard.

Case study 1: 100 Diabetes participants over one year

Based on a Randomized Controlled Trial [7], 100 type two diabetes patients were classified into three distinct groups:

- GC (Control Group): received usual chronic disease management services only, which consisted of a call made by the health center attendant once a month to check patients' stability;

- GI1 (Intervention Group 1): used an offline glucose meter only, being managed by the patient himself;
- GI2 (Intervention Group 2): used a tablet with Android 4.0 and a glucose meter with a Bluetooth converter. These patients were monitored in real-time using Mobilicare by the healthcare provider.

Figure 6 shows the methodology workflow. First, 100 type two diabetes patients were selected from one of the largest home care providers in Brazil – Globalcare health center – and were chosen following the criteria of similar representation for all age groups and genders. Then, patients were randomized and distributed into the three subgroups (GC, GI1, and GI2). Eventually, a slight change was made among groups to keep a similar age distribution. Next, patients were asked to participate in the program (recruitment). In the case of a candidate refusing, another participant with a similar profile was chosen.

Once the set of patients were distributed into the three groups, a phase called "Intervention" took place. In this phase, patients had glycated hemoglobin collected for future comparisons. Afterward, the Follow-up, Data Collection, Data Processing, and Statistical Analysis phases were deployed (details in next section). The pilot lasted from October 2013 to September 2014.

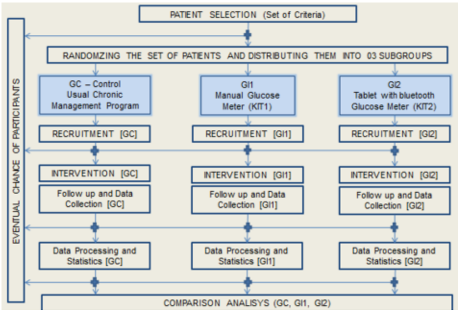

Figure 6- RCT – Randomized Control Trial Workflow.

Results

Diabetes

Figure 7 shows the monthly average levels of glucose measurements for the set of patients in GI2. It is possible to observe that the levels dropped from 118 to 111 using Mobilicare. For the other groups, there is no such a measure since they do not send their glucose levels to the health center. However, with the glycated hemoglobin levels reported, it was possible to verify the same behavior before the intervention.

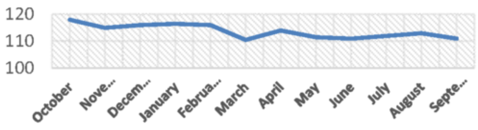

Figure 7- Mean value of glucose levels for GI2.

The number of "clinical alarms" among GI2 patients was around 62. Most alarms were triggered during typical vacation months, in which people often do not follow the specified diet. After a "clinical alarm", the average number of measurements to a GI2 patient to come back to an acceptable blood glucose level was 1.16, or a little more than two days. This quick return to a normal condition was a consequence of the medical protocols triggered by the alarms. For the other groups, they rarely reported an anomaly during the center calls.

Figure 8 shows the mean number of measurements for GI2. In the first months, there was instability due to system patient adaptability, which generated a high number of "non-measurement" alarms. Later, measurements became regular and stable with each patient performing about six measurements a week.

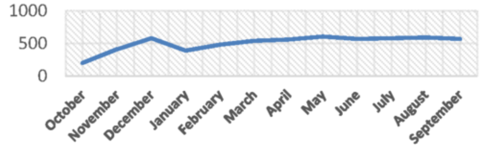

Figure 8- GI2 mean number of measurements per month.

The age average of the GI2 group is 69 years old, however this fact seems to have little influence in their adherence to the program, regardless of previous experience in using a tablet.

Also, one important result concerning the other two groups (GI1 and GC) is that less than 3% of the expected measurements were spontaneously reported to the "call center". This result can drive an assumption that these people could be under-watched and need a higher consciousness of the disease, as was provided for the patients of GI2.

Table 1 shows that the number of GI2 patients who went to the emergency room was 80% less when compared to GC patients in the same period. Also, GI1 patients were hospitalized 25% more times than GI2 patients and GC patients 50% more than GI2. The Unitcare Medical Services has details of the protocols, including ethical aprovement and agreement terms of patients.

Table 1: Emergency and hospitalization numbers.

	GI2	GI1	GC
Emergency Room	1	3	5
Hospitalization	4	5	6

Case Study 2: Health Promotion

This observational study intended to verify the Mobilicare performance for health promotion, i.e., the improvement of quality of life. This study has been carried out during a 4-week period, involving three people with different profiles:

- Patient 1: 56 years old, male, overweight and acquired diabetes type 2;
- Patient 2: 67 years old, male, overweight and Parkinson;
- Patient 3: 60 years old, female, overweight and hypertension.

During the first visit to the patient, a caregiver performed a training and also measurements for weight, blood pressure, and glucose. The results allowed the professional to get some indexes of the patients, like body mass index, body fat percentage, and waist to hip ratio. We also made an interview about their eating habits and physical activities during the last four weeks to better understand how the system could influence them.

After four weeks, the caregiver repeated the initial measurements and performed a final interview. After six months, another visit was made to verify self-health stability, without the Mobilicare influence. It is important to note that for statistical validation, this case study needs further investigation due to a restricted sample, but the preliminary results work as an indication of the system usability [15].

Health promotion

The patients in this study had to walk at least 5,000 steps daily and send the data, or else the system would show a “non-measurement” alarm to the health center. Figure 9 depicts the mean glucose and blood pressure variation of the patients. The glucose levels were high at the beginning of the experiments, and decreased to normal levels while the blood pressure levels, which were normal, remained normal. At the beginning of the experiment the glucose levels were about 120 in average, and at the end of the experiment they were about 100 in average, with a reduction of around 20%.

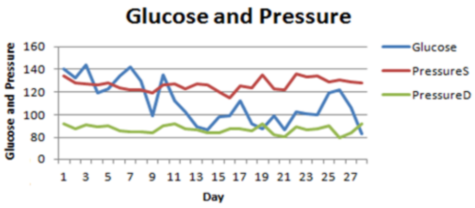

Figure 9- Patients mean glucose and pressure levels.

At the end of the experiment, the set of measurements was repeated. Table 2 presents the results for weight. All patients reduced their total weight, and additionally some of them increased in lean weight, reducing their percentage of body fat further. Fat weight and lean weight provide valuable information since they show that the intervention was probably producing significant results.

Table 2- Weight results.

	Total weight	Fat weight	Lean body weight	Body Fat (%)
P1_ini	85.00	16.14	68.86	18,99
P1_final	82.70	14.70	68.00	17.72
P2_ini	83.50	20.79	62.71	24.90
P2_final	82.00	16.50	65.50	20.12
P3_ini	73.10	25.56	47.54	34.96
P3_final	71.10	21.58	49.52	30.35

Other monitored results were the main corporal indexes, shown in Table 3: BMI (Body Mass Index), WHR (Waist to Hip Ratio) and BAI (Body Adiposity Index). The results showed a reduction the indexes for all patients. However, it is important to note that all participants still need to keep lowering most of their indexes in order to reach international health standards [4, 5, 6].

However, it is very hard to identify whether the benefits came from their motivation to adhere to the health program, and they internalized the learning, or by the pressure caused by the technology system itself. In order to minimize the error, the participants were contacted and measured again after six months of the experiment. Two of them had diminished the weight (6 kg and 2,3 kg), and the third was steady, with the diabetes controlled. The sample was only 3 participants, but the results are considered very promising.

Table 3- Main corporal indexes

	BMI	WHR	BAI
P1_ini	30.11	1.04	27.46
P1_final	29.30	1.01	26.54
P2_ini	29.94	1.00	29.72
P2_final	29.40	0.96	29.63
P3_ini	27.17	0.74	34.37
P3_final	26.43	0.74	33.51

Discussion

This paper presented Mobilicare – a new mobile monitoring for health promotion system. The front-end module works on any browser, being suitable for a variety of platforms, like computers, tablets, and mobile devices. One important goal was to encourage prevention and health promotion through the patient's interaction with advanced technological tools. In line with the concept of social networks, the developed tele-homecare model lets patients interact with other people who have similar medical situations, encouraging information exchange and commitment to self-care. Patients are encouraged to take an active role in their healthcare. For example, a diabetic patient could periodically check his blood sugar and adjust his or her behavior, such as in the case of an excessive intake of sugar. Additionally, the patient can optionally subscribe to an exclusive social network offered by the solution/health provider. There, patients can interact, post disease educational videos or materials for common access, discuss their health problems, and even compete with each other as they post their measurements and the disease remains stabilized over time.

Though it is still too early to be conclusive, we have collected significant evidence that remote measurement of vital signals, when integrated with awareness and healthcare support, might help leverage quality of life in the short term and delay the undesired side effects of chronic diseases like diabetes. Not only can the patient can get benefits using Mobilicare or similar systems, but also health care operators will probably be able to reduce emergency and therefore hospital costs.

We conducted two case studies, one for diabetes, and another focusing on health promotion. Related to the diabetes study, only 17% of GI2 patients have left the program after the end of the one-year experiment. Here, we observed that remote regular monitoring led to the earlier identification of more serious changes in glucose levels and also to an earlier reaction by health care personnel. As a consequence, patients’ measurements were brought back to acceptable levels sooner. Related to the health promotion study, from the first day it was clear that motivation increased. Being constantly monitored brought a new mood to the participants. The system changed the routine of these people, and they worked out much more when compared to the time prior to monitoring. Now they had goals to reach, and someone to help them with their doubts and questions.

Results in both cases showed that a monitoring and educational system can improve the health of the monitored people. Moreover, we detected a real improvement in the knowledge of the patients about their health situation and what to do in order to grow old in a healthy way.

As counter-intuitive as it might be, elderly people can learn to use new technologies relatively quickly, and for a significant number of them the access to their measurement curves resulted in a positive feedback and led to greater adherence to the healthcare program. In this sense, the use of technologies that improve the quality of preventive health and reduce medical costs has become a necessity since the costs of secondary and tertiary care are very high and constantly growing. In BRICS countries, where there is significant heterogeneity in access to and quality of offered medical services, this market is expected to reach $418.4 million in 2014. In Brazil, it is estimated that less than 5% of hospitals are providing telemedicine services, indicating a high potential for expanded use of telemedicine solutions in healthcare.

Conclusion

Of course, data interoperability, security considerations, and privacy issues remain. Health information must be protected by the standard transmission protocols (Continua Health Alliance: http://www.continuaalliance.org) and security layers of the cloud provider to not only prohibit unauthorized access to patient records, but also to guarantee data integrity and make sure that transmitted data are not maliciously modified. Finally, privacy is addressed by the management system, which assures that data is only accessed by the physician and related medical team of the patient provided by the patient's permission.

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