MOBILE PERSONAL HEALTH APPLICATION FOR EMPOWERING DIABETIC PATIENTS

Ilias Lamprinos Dr Eng[1], Chrysa Papadaki Dipl Inf[1], Hans-Holger Schmuhl Dipl Inf[2], Hans Demski Dipl Ing[2], Claudia Hildebrand[2], Manuela Plößnig Dipl Ing MSc[3]

[1]Intracom Telecom, Telco Software Department, 19.7 km Markopoulou Ave. GR-19002 Peania, Athens, Greece
[2]Helmholtz Zentrum München, Institute for Biological and Medical Imaging, Laboratory for Medical Information Systems, Munich, Germany
[3]Salzburg Research Forschungsgesellschaft, Salzburg, Austria

Abstract

In this paper we present the features of a Mobile Personal Health Application that aims to empower Type 1 and Type 2 diabetic patients by facilitating self-management of their disease. The application supports the collection of observations of daily living i.e., vital signs, diet, quality and quantity of sleep, physical parameters such as weight, mental parameters such as self-assessment of quality of life, level of mood and stress, and physical activity related information. The application can operate in stand-alone mode as a consumer health application running in smartphones and tablets. However, the full range of its functionality is available when integrated with a server based patient empowerment framework that further facilitates diabetes management with the active involvement of healthcare professionals, the exploitation of inclusive knowledge from clinical guidelines, and the incorporation of comprehensive information material.

Keywords: diabetes mellitus; self-management; mobile application; personal health record.

Introduction

Health related mobile applications have the potential to offer tremendous value in monitoring chronic conditions by supporting clinician intervention without a brick and mortar patient visit.[1] The collection and analysis of patient-driven observations of daily living (ODLs) can help healthcare professionals monitor compliance with treatment regimens and identify effective and ineffective treatments and medications. ODLs represent “patterns and realities of daily life” including but not limited to “diet, physical activity, quality and quantity of sleep, pain episodes and mood”.[2]

Chomutare et al. compared the features of approximately 290 mobile applications for diabetes care and assessed the offered functionality ranging from logging of vital signs to synchronization with Personal Health Record systems (PHR-S) and integration with social media.[3] It was found that the most prevalent features of these applications were logging of vital signs, data export, and synchronization with Web applications, while less prevalent features were access to information material, logging of physical activity, diet and weight, and integration with PHR-S. The study revealed that although there are many diabetes-related mobile applications that offer a plethora of features, there are still gaps between the evidence-based clinical recommendations for diabetes management and the typical functionality found in related mobile applications. Furthermore, personalized education and access to information material was confirmed as an underrepresented feature in those applications.

The EMPOWER project aimed at developing a modular and standards-based patient empowerment framework, which facilitates self-management of diabetic patients, based on PHR-S and on context-aware, personalized services delivered through Web and mobile applications.[4] The supported functionality related to self-management opens the possibility for patients not only to contribute to their own healthcare but also to be more in control of their disease. While adopting a patient-centric perspective in EMPOWER, healthcare professionals are still an essential part of the disease management cycle as they can constantly guide their patients in managing their disease, whilst staying informed about their progress.

For the specification of the EMPOWER framework, end users (i.e., healthcare professionals and patients) and ICT professionals who form the EMPOWER project consortium, collaborated in an activity that included the exploration and assessment of the established diabetes care processes (in particular in Germany and in Turkey), and the specification of two detailed storyboards (reflecting the cases of Type I and II diabetes patients) that broke down diabetes treatment into logical steps, each of which should be mirrored to a functional feature of the EMPOWER system.

In the following sections we provide an overview of the EMPOWER framework, followed by a detailed description of the EMPOWER mobile application. In the final section, we provide an assessment of the currently supported functionality and present ideas and plans for future work.

The EMPOWER framework

The EMPOWER Framework aims at supporting self-management of diabetes patients, in particular changing behavioural patterns and self-control compliance with diabetes treatment. The framework provides disease management recommendations to the healthcare professionals, taking into account relevant clinical guidelines. The recommendations are validated and approved by the professionals and subsequently serve as a basis for specifying individual goals for the patient via a Web portal. Based on these goals, relevant information and their preferences, patients can specify their individual diabetes-specific actions. Recommendations, goals, and actions can be updated iteratively according to needs and preferences.

The patient portal features functionality for the collection of ODLs for disease self-monitoring and self-control. ODLs are also collected via a mobile application as described in more detail below. All data recorded by the patient are evaluated on a weekly basis, giving the patient feedback on how successfully s/he is meeting the personalized self-management goals and actions and hence, the treatment goals prescribed by the physician.

From a technical perspective, the EMPOWER framework semantically integrates multiple information sources (EHR/PHR-S, clinical guidelines for diabetes, applications for collecting ODLs) into a shared knowledge model. On the data exchange interoperability level, IHE profiles are implemented, as defined in the IT Infrastructure Technical Framework and the Patient Care Coordination Technical Framework.[5] On the semantic interoperability level – in order to process EHR and PHR data safely and consistently,[6] ISO 13606,[7] and openEHR[8] information models are utilized.

The EMPOWER mobile application

The application enables end-users to collect ODLs by leveraging various sensors embedded in modern smartphones and tablets, and by communicating with high-end consumer medical devices. It also allows visualisation of valuable information in a way that helps diabetics to assess their long-term performance and adapt their lifestyles.

Vital signs ODLs

The implemented application enables the user to record a set of vital signs (blood glucose concentration, blood pressure, heart rate and weight) that are meaningful for diabetes management. The patient can insert a new measurement either by typing or dictating it in a user-friendly submit-form or automatically, provided that the medical device supports proper communication features (Figure 1).

Whenever a new vital sign measurement is being logged, the user is prompted to input information related to mental parameters such as self-assessment of quality of life, and anticipated levels of mood and stress. This applies to all the ODLs.

The flexibility in logging vital signs measurements (manually or automatically) renders the application independent from medical device vendors and markets, thus making it suitable for larger end-user communities. For demonstration purposes, the first prototype of the application supports automatic communication with BodyTel's GlucoTel™ glucose meter, Omron's 705IT blood pressure meter, and Nonin's Onyx® pulse oximeter.

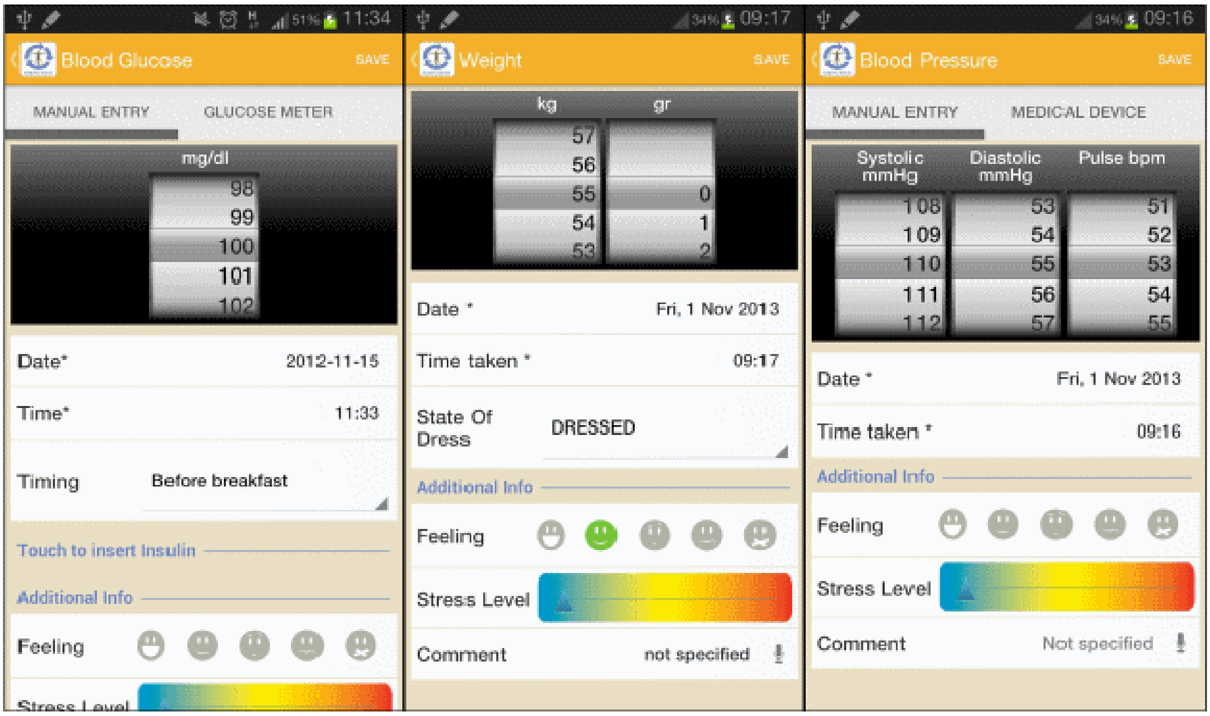

Figure 1. Screen shots of the ODL collection for vital signs.

Medication ODL

Patients with Type 1 diabetes require, in general, insulin therapy while treatment for Type 2 diabetes may include various medications to help control blood sugar. In both cases, the application enables the user to keep a medication diary and to collect the corresponding medication changes.

For drug intake, the application provides an extensive list of medications for selection. Additionally, patients using insulin can record their insulin intake; in this case the user edits date, time, units and type of insulin dosage.

Physical activity ODL

In agreement with the fundamental needs of diabetics, the application supports indoor and outdoor physical activity monitoring. From a functional perspective, the application supports both manual and automatic recording of the user's physical activity. It provides detailed real-time feedback regarding the duration, distance, speed, pace, and altitude of the activity, as well as calories consumed by the subject. In addition, the application supports the option of marking a followed route as a favourite for future reference. It also embeds a media player with access to the smartphone's music library, which the user can control while exercising, while the application keeps monitoring physical activity in the background.

A user-motivating feature of the application is the option of setting a workout goal before starting a physical activity session and monitoring performance during execution, while also getting real-time voice feedback on the physical activity progress. The workout goal is usually related to total activity duration, distance to be covered, calories to be consumed or maximum speed (Figure 2). Regarding indoor activity monitoring such as exercise at a gymnasium, the patient is able to manually log an entry, including all the attributive information (date, time, number of sets, intensity, duration, speed, calories, etc.).

From a technical perspective, the application utilizes the GPS sensor and Android’s Network Location Provider to acquire the user’s location and provide a real-time route-tracking map during a physical activity session. Although GPS is mostly

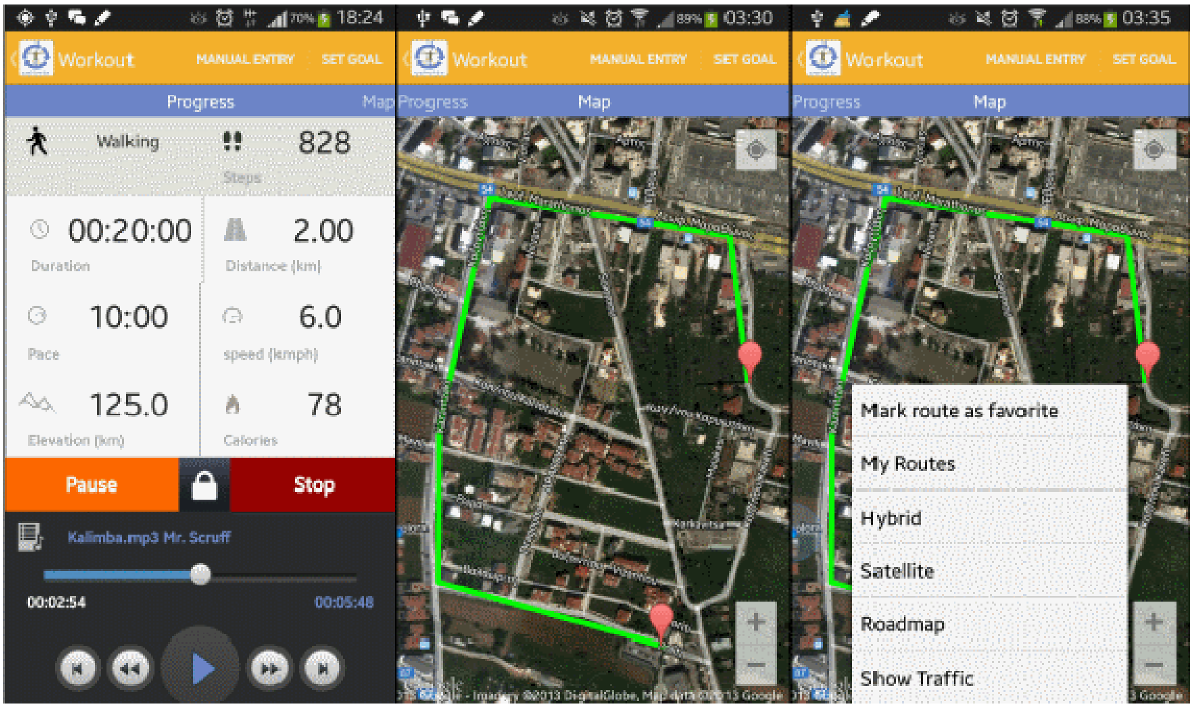

Figure 2. Screen shots of the ODL collection for physical activity.

accurate, it only works properly outdoors, rapidly consumes battery power, and does not return the location quickly enough to provide real-time feedback. On the other hand, Android's Network Location Provider determines the user's location using connection details from the mobile operator's base-station and surrounding Wi-Fi signals, providing location information in a way that works both indoors and outdoors, uses less battery power, and responds faster. In the context of EMPOWER, we defined and adjusted a model that makes use of both technologies, achieving better application performance in terms of positioning accuracy and energy efficiency.

Diet ODL

The application provides a tool that enables the user to log their nutrition information and eventually manage their diet. The user is able to evaluate the nutritional values of meals using a food search engine embedded in the application as well as the locally stored United States Department of Agriculture (USDA) nutrient database.[9] While the user records the details of the meal, the application calculates and presents the maximum values for a set of food and drink indices, such as glycaemic index, calories, fat, proteins, carbohydrates, and fibre.

If a desired food item is not found within the embedded nutrient database, the user can insert a new food item by filling in a form that prompts for nutrient details. Also, the user can mark a food item as a favourite and easily re-use it to create a meal. The application automatically provides a list of frequently used food items so as to facilitate the user's data entry.

Sleep ODL

Several studies provide evidence that not sleeping well can increase the risk of developing diabetes, while diabetes can cause sleep loss.[10,11] By recording and analyzing movements during sleep it is possible to determine sleep quality and irregular sleeping patterns. The mobile application leverages the smartphone's inertial sensors to assess the subject's sleep pattern, to record the fall asleep and wake up episodes, and to calculate and store the duration of each sleep session.

Specically, the application uses the smartphone's embedded tri-axis accelerometer to measure the intensity of the body movement of the subject during sleep. For this to happen, the device must be placed on the mattress. The applied algorithm records the values of each axis and computes the absolute acceleration, which is an implicit indication of movement instances of interest (Figure 3). Based on this information, the mobile application assesses the sleep phases and the overall sleep quality (e.g., deep, light).

A calibration function is used to enable the algorithm to take into consideration the mattress material and eliminate the sensor noise that varies depending on the mobile device, improving its accuracy. Calibration is required when using the sleep monitoring feature for the first time. A series of experiments was conducted using several Android-powered devices to determine the optimal position of the device on the mattress. No serious constraint regarding the placement of the smartphone on the bed was found.

Further related functionality has to do with sleep session scheduling. For example, the user can set up a weekly sleep schedule by defining reusable sleep session items (go to sleep and wake up time, repetitions, activity monitoring, ringtone, vibration).

The user also has access to a range of relaxing sounds to assist in falling asleep and may also access music stored in the music library of the smartphone.

Journals

The patient's Web portal has an electronic diary that allows the user to view the recorded ODLs in daily, weekly, and monthly views - the EMPOWER Journals. The Journals page is also part of the mobile application (Figure 4).

In addition, the application presents an overview of the diabetes management related actions, as edited by the user via the Web portal, on the basis of self-management goals and of the physician's recommendations. In the same context, users can monitor their progress by checking in the application the status of the scheduled actions (future, pending, accomplished, etc.).

Patient information material

Education and access to informational material are important to people who are newly diagnosed with diabetes or who want to enrich their knowledge on diabetes to better understand and manage their disease. The application provides access to information material related to diabetes management and provides tips on how to efficiently handle this condition. Short

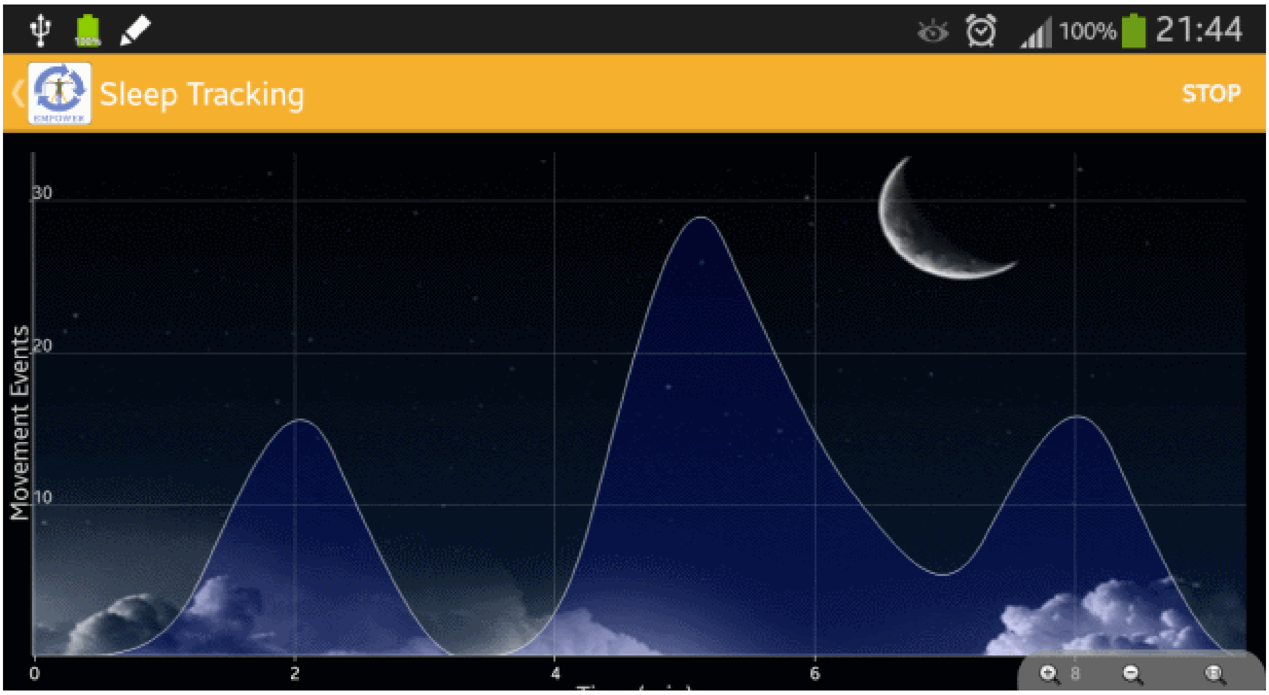

Figure 3. Screen shot of subject's movements monitored during a sleep session.

texts are provided within the mobile application, while for further information the user is redirected to the EMPOWER information material wiki page and other Web resources.

User interface multimodality

The mobile application provides multimodal interaction, combining visual, haptic, and voice modalities. When entering data, the user can fill in text fields by either using the smartphone's soft keyboard or a voice recording mechanism. Voice commands are also used to enable the user to easily navigate through the application and execute actions such as insertion or deletion of a new ODL or set up of a reminder. The Journals page presents a visual representation of the recorded ODLs and also provides a detailed voice output of the recordings. Real-time verbal feedback is also part of the physical activity monitoring function, while informative voice messages are issued in case of incorrect actions or when undertaking crucial steps (application logout, delete of recordings).

Data handling

The application can operate in stand-alone mode as a consumer health application allowing users to log their disease related ODLs or with a server based patient empowerment infrastructure (the EMPOWER framework). This approach facilitates diabetes management, through active involvement of healthcare professionals, use of clinical guidelines, and the incorporation of comprehensive information material related to the disease.

With this in mind, data are handled in two ways in the application. First the collected data are stored locally on the smartphone, assuring availability at any time. Second, for those users who are registered with the EMPOWER framework, the mobile application is synchronized with the EMPOWER PHR-S database through available IP networks. In addition, by utilizing core Android functionality the user can share entries with third parties by email or store them as a text-based file on cloud storage platforms such as Dropbox™ or Google Drive™. In such cases, the user is made aware of the related privacy and security issues that might occur by frivolously utilizing third party data transfer services.

Visualization of self-monitoring data

A wide variety of diabetes related data are collected through the ODLs. These ODLs can serve as a rich pool of data for thorough analysis by the research

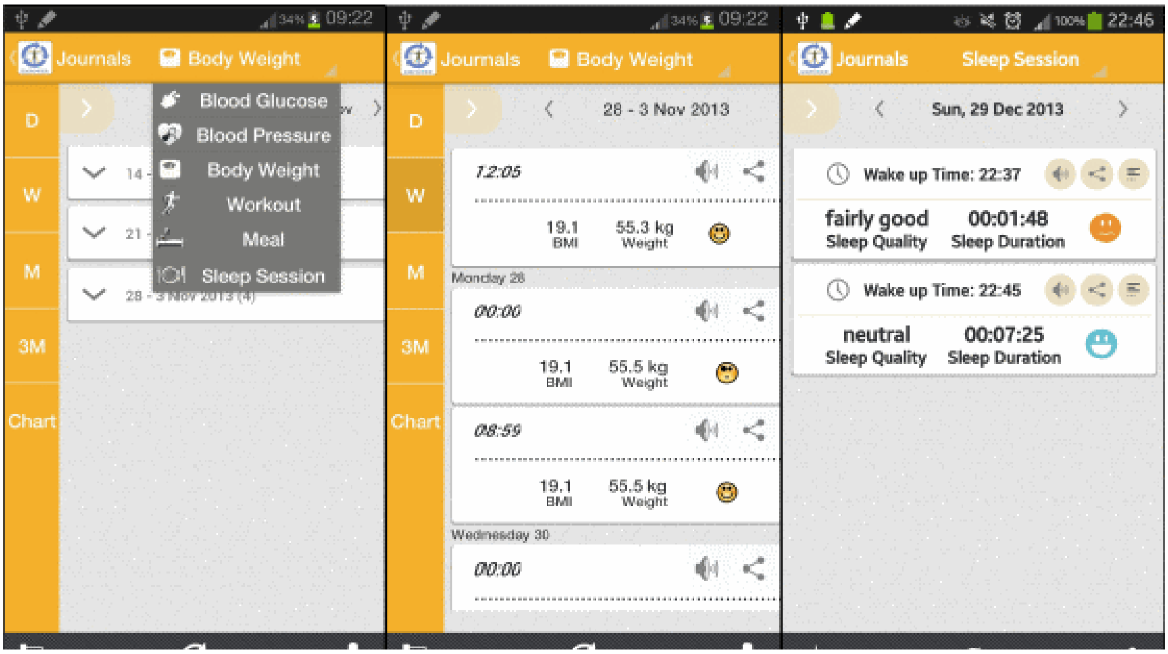

Figure 4. Screen shots of Journal pages summarising ODLs over time.

community in order to gain insights related to diabetes disease management. For the end users, the diabetic patients, it is important to have access to simple yet efficient reports that summarize trends of the monitored ODLs over time. The application provides them with relevant graphs as for example indicated in Figure 5.

largest markets, while also being the leader in China, the world's largest smartphone market.[12] Android has the highest number of installations among any mobile platform and keeps growing fast.

The application was developed in Java and runs on devices with Android v2.3 or later. The choice of compatibility with the particular versions of the Android platform was based on assessment of the distribution of the Android versions, which shows that earlier versions (Android 2.2 or earlier) are obsolete and run on a limited number of devices.[13] Based on this assessment the EMPOWER mobile application is able to run on approximately 97.8% of all active Android devices.

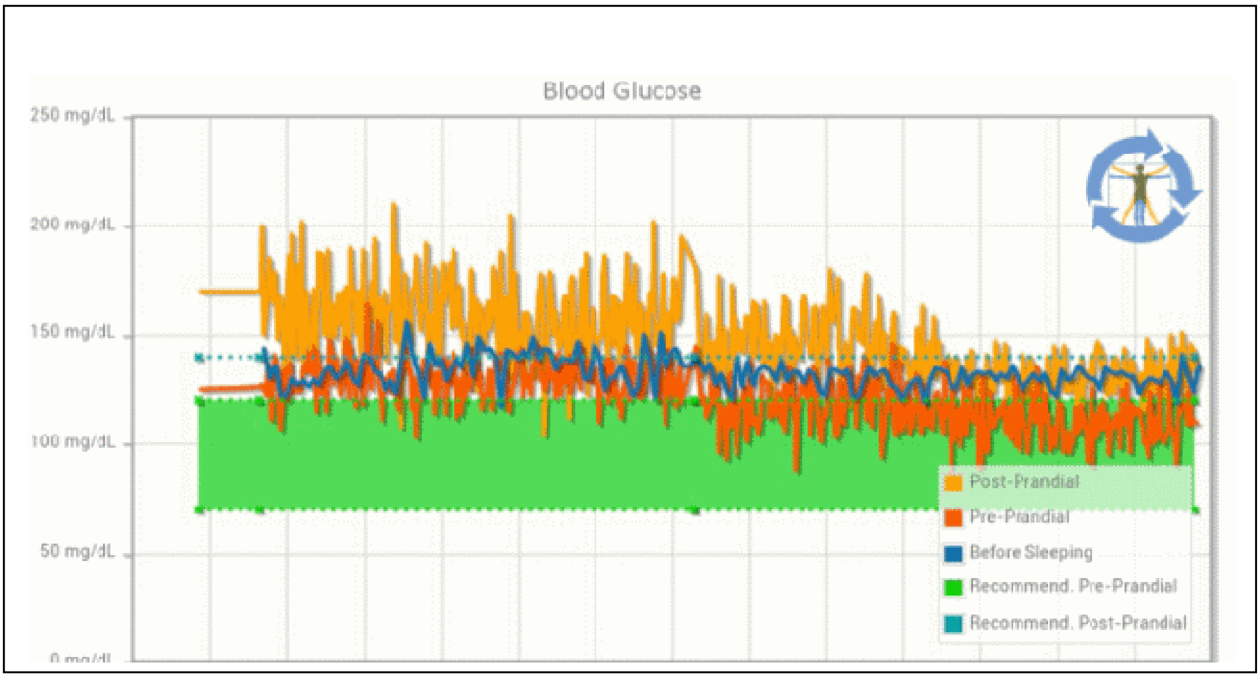

Figure 5. Screen shot of charts and trends presented in the EMPOWER mobile application.

Depending on their level of digital literacy, users are provided with different on-demand graphs or predefined weekly reports that summarize the evolution of the monitored ODLs. The graphed data enables users to check data trends, recognize correlations between specific parameters and constantly keep track of the outcome of their behavioural attempts.

EMPOWER application development environment

The first release of the application (January 2014) is designed for Android powered devices while iOS and Windows Mobile versions are to follow. The selection of Android as the platform to start with, was based on its global penetration in the smartphone's market. Android exceeded 70% of market share of smartphones sold during 2Q 2013 in Europe's five

Discussion

The work presented in this paper focuses on the description of the main functional features of a mobile application designed to empower diabetic patients in the management of their disease. It is based on the growing use and acceptance of smartphones in everyday life to communicate, consume content, and access the Web.

By offering diabetes management services in the form of a mobile personal health application rather than on a personal computer, we anticipate that disease self-management will be easier to achieve. We intend to further exploit inherent features of modern smartphones to enhance users' experience in disease self-management.

Another area of research is use of the information collected by the mobile application to monitor progression of the disease, and its impact on the patient's lifestyle. For example, if a patient records the essential ODLs on a regular basis, the application could potentially automatically correlate insulin dosage with blood glucose, blood pressure, physical activity, and carbohydrate intake, which would comprise a first step towards insulin dosage calculation. Personalized recommendations regarding behavioural attitude and lifestyle changes would also assist in better management of the disease.

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Conflict of Interest: The authors declare no conflicts of interest.

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Corresponding Author:

I. Lamprinos
Intracom Telecom,
Telco Software Department,
labil@intracom-telecom.com
19.7 km Markopoulou Ave. GR-19002 Peania,
Athens,
Greece

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