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MOBILE & WIRELESS HEALTH

An Interactive Mobile Phone–Website Platform to Facilitate Real-Time Management of Medication in Chronically ill Patients

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Abstract Poor adherence to medication is a prevalent issue that affects 50–60% of chronically ill patients. We present Medplan, a platform for patients/caregivers and healthcare professionals (HCPs) that aims to enhance adherence, increase patient medication knowledge, and facilitate communication between patients and HCPs. The Medplan platform was designed and developed by a multidisciplinary team composed of primary care and hospital physicians, pharmacists, patients, and developers. We questioned 62 patients in order to know their opinion about the different functions the app would incorporate and other possible features that should be taken into consideration. Medplan comprises a website for HCPs and an application (app) that is installed on the patient's phone. The app is available in Spanish, Catalan, and English. The patient's medication plan was introduced by the HCP and interfaced with the app. Each medicine is represented by an icon showing the indication of the treatment, the trade name, active ingredients, dose, and route of administration. Information about special requirements (e.g., need to take medication on an empty stomach), side effects, or lifestyle recommendations can also be provided. Additional functions include a medication reminder alarm system, by which patients can confirm whether or not they have taken the drug. Patients can self-track their adherence, and all data collected are sent automatically to the website for analysis by the HCP. Weekly motivation messages are sent to encourage adherence. A tool enabling interactive communication between patients and HCPs (primary care or hospital care) is also included. The app contains a feature enabling the HCP to verify the suitability of over-the-counter drugs. Medplan has the potential to significantly improve management of medication in chronically ill patients. A pilot study is being conducted to test whether Medplan is useful and effective.

Keywords Medication adherence · Chronic patients · Mobile phone · Mobile application

This article is part of the Topical Collection on *Mobile & Wireless Health*

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Introduction

Adherence to long-term therapy is mandatory for optimal disease control and management. However, many chronically ill patients find adherence difficult. It is estimated that 50% of chronically ill patients do not follow their recommended regimens, with the result that the patient's condition and quality of life deteriorate and health care resources are wasted [1, 2]. Non-adherence can be classed as intentional (e.g., non-adherence arising from the patient's beliefs) or unintentional (e.g., oversight because the

patient is too busy or absent minded). The most common patient-related reasons for non-adherence include oversight, poor knowledge, lack of motivation, and adverse events or fear of experiencing them. Consequently, adherence is a multidimensional phenomenon [3, 4]. Modern communication technologies can help to promote well-being and enable patients to monitor their health status. In fact, mobile phone technologies are rapidly becoming popular, even among older patients [5]. A recent study on the usability and usefulness of existing medication management applications (apps) for older adults, showed that adults aged 50 and over are capable of and interested in using mHealth apps to manage their medication [6]. Studies have shown that mHealth interventions can promote adherence to medication [7, 8], although the technology used was limited to short messages as medication reminders. Several medication reminder applications are currently available [9]. However, their availability in Spanish is restricted—most are in English—and the scientific evidence supporting their efficacy is negligible.

Therefore, we implemented a research and development program to investigate how evolving smartphone technology can enhance adherence to medication in chronically ill patients with a medication plan reviewed and validated by a healthcare professional (HCP), and improve communication between patients and their HCPs. The study comprised a design and development phase followed by an implementation stage, in which the platform was applied in chronically ill patients with human immunodeficiency virus (HIV) infection and in patients with hypertension/heart failure/dyslipidemia.

Materials and methods

The Medplan platform was planned as a joint program between physicians and pharmacists from hospitals and primary care, patients, and developers. It comprised a website and a mobile phone app that was developed in 4 steps:

2.1.1 *Platform requirements analysis*: A multidisciplinary team comprising 2 primary care physicians, 2 hospital specialists, 1 physician specialized in computer applications, and 3 hospital pharmacists was created to evaluate the platform requirements and to discuss the initial design. A systematic review of the literature was carried out to ascertain the state of the art in this field. Other areas addressed were information security network requirements, risk of medication errors, platform workflow, and findings of other studies. This step was repeated with developers. In addition, we questioned 62 patients (48 patients with hypertension/heart failure/dyslipidemia and 14 HIV-infected patients on treatment for these diseases) in order to know whether they considered the app to be potentially useful and to identify other possible features or comments we should consider before development. All patients surveyed owned a Smartphone device. Descriptive statistics were used to analyze the results.

2.1.2 *Development:* The platform was developed by a software company. A hospital pharmacist worked closely with the company in order to assess their work. During this phase, a patient joined the group to give his/her opinion on the feasibility and functionality of the app as an end user. The website design and functionality was assessed by the research team in order to avoid medication errors and ensure user-friendliness. The mobile phone app was developed for iOS and Android devices.

2.1.3. *Validation process:* Black box testing was used to validate functionalities in 5 fictitious patients in order to ensure that the platform worked perfectly. This method evaluates the inputs and its outcomes in the platform, without taking into account the inner workings of the program being tested. (e.g. if the HCP sends a message to a patient, that he received it). All the computer incidences detected were recorded in a standardize formulary which was then analyze by the software company who resolved them.

2.1.4. *Deployment phase*: The Medplan platform was installed on the hospital's server.

Results

Medplan comprises a website aimed at HCPs and a smartphone application installed on the patient's phone. Both are bidirectionally connected (Fig. 1). All data are encrypted in transit. The database is hosted in secure hospital servers to ensure compliance with Spanish data protection legislation.

Mean age of the patients surveyed was 56 years old (SD = 11.8), 78.6% were men, 57.1% had university studies and the mean number of diagnostics per patient was 3.3 (SD = 2.6). All of the patients surveyed expressed their interest in using a medication reminder app and in being able to communicate with their HCP, thus emphasizing the need for a user-friendly tool. Moreover, 8 patients were concerned about data storage and who would have access to it; 3 of 14 HIV-infected patients asked if the app was exclusively for patients with this disease, as they would not like to have it installed if it exposed their condition. One patient wanted the app to include information on healthy lifestyle, 2 patients wanted refill reminders, and 1 patient wanted to consult laboratory results. In contrast, HCPs wanted a time window in which patients could take the dose in order to avoid overdosing and stressed the importance of data confidentiality.

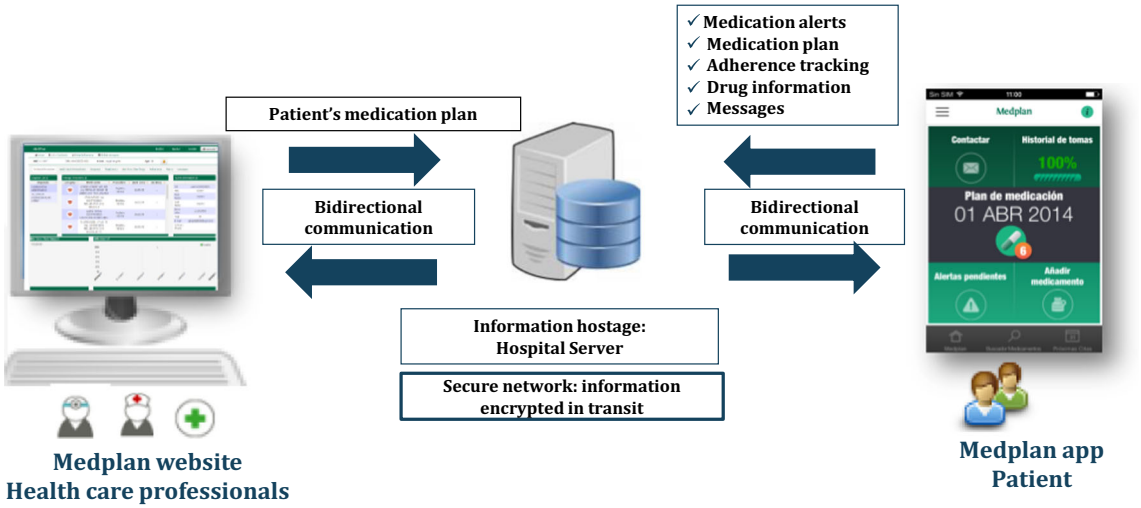

Fig. 1 Medplan platform flowchart

The platform is available in 3 languages (Spanish, Catalan, and English) for iOS and Android devices.

The patient's medication plan is introduced by the HCP and subsequently interfaced with the patient's mobile phone app. The different capabilities of the app and website are described below.

Smartphone application functionalities

1.1 Log in is by username and password. A recovery system is available in case the user forgets the password. Once the patient has logged in, the main menu is displayed (Fig. 2).

1.2 *Medication plan*: The center button enables users to access their medication plan. For each medicine, an icon indicating the aim of the treatment, the trade name, active ingredients, dose, and route of administration is displayed. Information can also be provided on special requirements (e.g., need to take medication on an empty stomach), on the drug itself (e.g., indication, storage instructions, side effects), and on healthy lifestyle (Fig. 2).

1.3 *Medication reminder alarm system:* A reminder appears when it is time to take medications. The name, dose, and route of administration are shown. Users can indicate whether they have taken the drug or not or wish to postpone intake. A maximum time limit for postponing intake is provided for each drug, according to its schedule, to avoid overlapping doses. The reminder can be set to coincide with breakfast, lunch, snacks, dinner, bedtime, or a specific time of day. Adherence is calculated according to the patient's selection in the medication reminder.

Users may customize the time of the alarm to take account of their daily routine and can choose whether they want it on or off. Different schedules for working days and holidays are also available. In order to avoid overlapping doses, a time limit is established for each meal (e.g., lunch 13:00–15:00). This aspect was requested by physicians, along with a time interval in which patients could confirm or delay the dose intake. This interval can be customized for each drug through the website. If the patient's normal routine does not fit with the Medplan schedule, an exact time can also be introduced by the HCP through the website (e.g., 15:45). Reminders are generated without connectivity.

1.4 *Pending reminders*: This option displays reminders for the current day that are not confirmed by the patient. The option can be used as a checklist, so that at the end of the day, the patient can ascertain whether they have taken the medication and confirm the dose in case they did not previously have the mobile phone with them.

1.5 *Add medicine*: Patients can inform their HCP about over-the-counter drugs (OTC) they take using a photograph or a text field. This information is automatically sent to the Medplan website so that the HCP can check suitability.

1.6 *Medication log*: The patient can self-track medication adherence over the previous day, week, month, or quarter at a glance. To incentivize patients to use the app, a game-like life bar displayed in the main menu refills and changes colour depending on the adherence rate: high adherence rate (>90%, green life bar); intermediate adherence rate (89–80%, yellow life bar); low adherence rate (<80%, red life bar). In addition, the patient receives weekly motivation messages, whose content varies depending on the adherence rate.

1.7 *Send medication plan*: Users are able to send the medication plan via email. In order to comply with Spanish data protection legislation, a website link is sent. When this link is selected, Medplan credentials are requested. Once introduced, users can download their medication plan.

1.8 *Contact:* A bidirectional communication tool is incorporated. Patients can send messages to their HCP

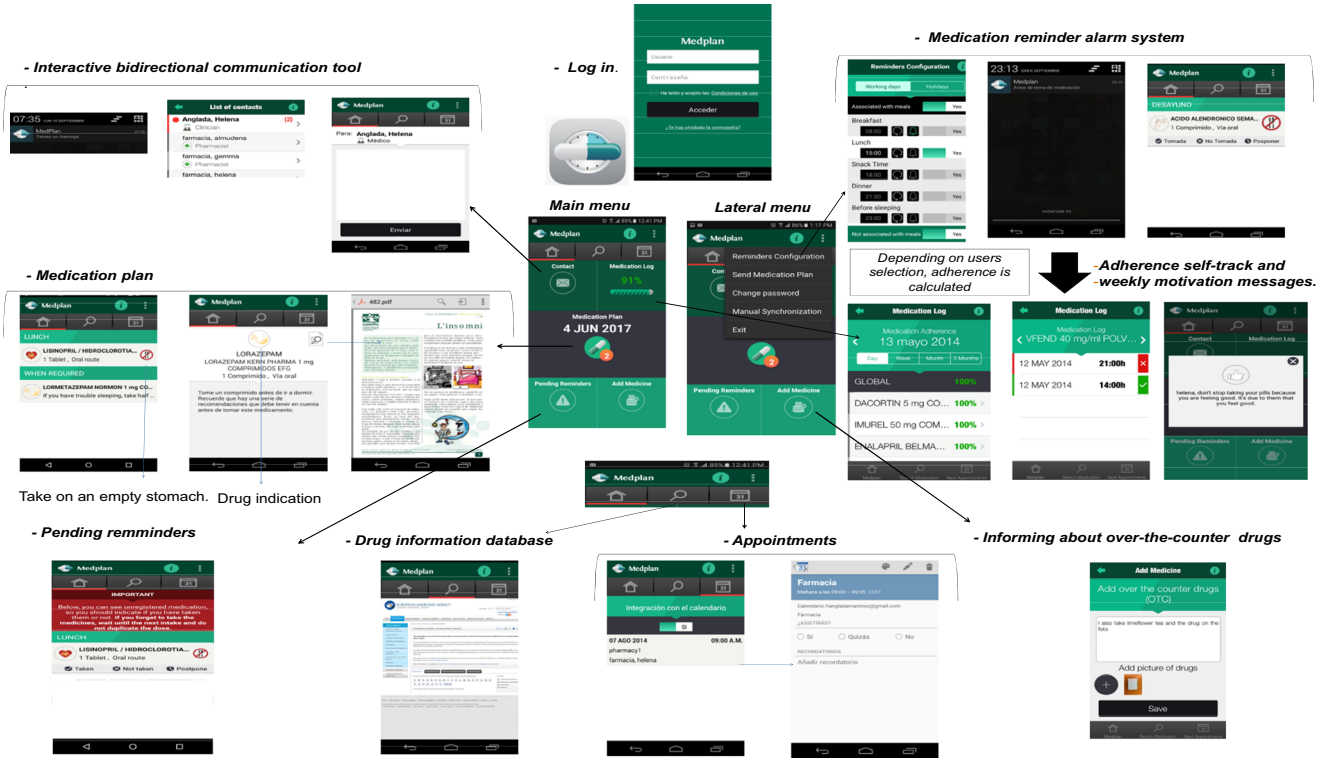

Fig. 2 Medplan app workflow

(physician, nurse, or pharmacist, independently of their care setting). HCPs can also send messages to the patient's phone. All data are encrypted to assure confidentiality.

1.9 *Appointments:* Patients can check their next appointment to pick up their medication at the hospital pharmacy. If they wish, they can integrate the appointment in the calendar app where it will be displayed as "pharmacy" on the day and at the time agreed.

1.10 *Manual synchronization:* This option forces communication between the app and the website. However, the patient's medication plan is automatically updated 3 times daily.

1.11 *Medicine search:* This option enables an automatic connection to 3 websites depending on the language (European Medicines Agency [English] [10]; Spanish Medicines Agency [Spanish] [11]; and the Catalan Medicines Information Centre [Catalan] [12]) so that the patient information leaflet or drug information can be consulted.

Website Functionalities

The website is aimed at HCPs. Four different profiles are created, 1 each for physicians, nurses, pharmacists, and administrators. The first 3 profiles make it possible to track adherence, consult the medication plan, make diagnoses, and send messages. The medication plan can be prescribed or modified by the physician (or other authorized HCPs) and the pharmacist profile incorporates an appointment manager option for the outpatient hospital pharmacy. The administrator profile is used to register users on the platform and to maintain the databases.

A username and password are needed to access the website. On the main site, the HCP can revise automatic messages, text messages or data on OTC drugs patients have sent to them, doses not taken, and whether patients have modified the alarm status (Fig. 3). In addition, HCPs can establish whether they want to receive an email with the list of patients with a specific adherence interval and its delivery frequency (e.g., weekly).

Users can search for a patient by introducing the name, surname, and clinical history number; alternatively, they can introduce the name of a specific drug to obtain the list of patients receiving that treatment. After selecting a patient, the data displayed are the patient's personal data, diagnosis, treatment, OTC medication, and an adherence graph (Fig. 4). Data for the alarm status and the time of the latest communication between the application and the website are also displayed. Diagnoses are coded based on the International Classification of Primary Care, Second Edition.

Drug data entry is shown in Fig. 5. The formulary of the Spanish Agency of Medicines and Medical Devices is used and automatically updated each month. However, the administrator profile can update the formulary when necessary. Depending on the Anatomic Therapeutic Chemical (ATC)

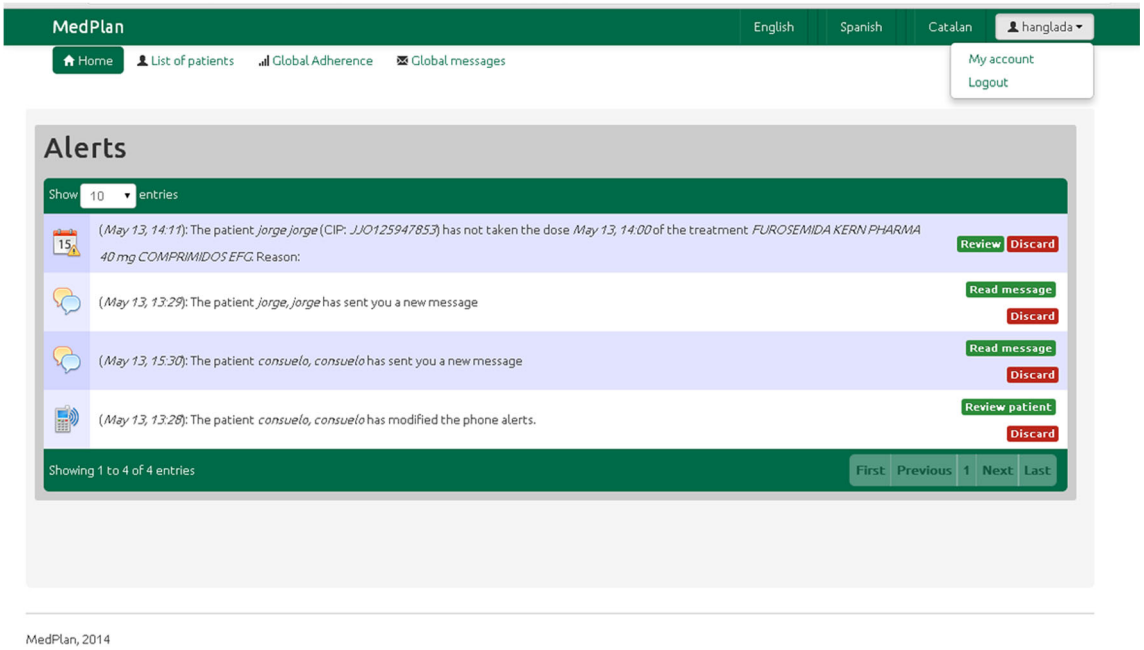

Fig. 3 Website: home page

classification code, an icon is automatically assigned to indicate the aim of the treatment. Nevertheless, if the HCP considers it appropriate, a photograph of the pill or package can also be included.

Data can also be entered on complex medication regimens (e.g., monthly administration or tapering doses) or the maximum time period a dose can be postponed. Medication regimens may be associated with a specific meal (breakfast, lunch, dinner, or

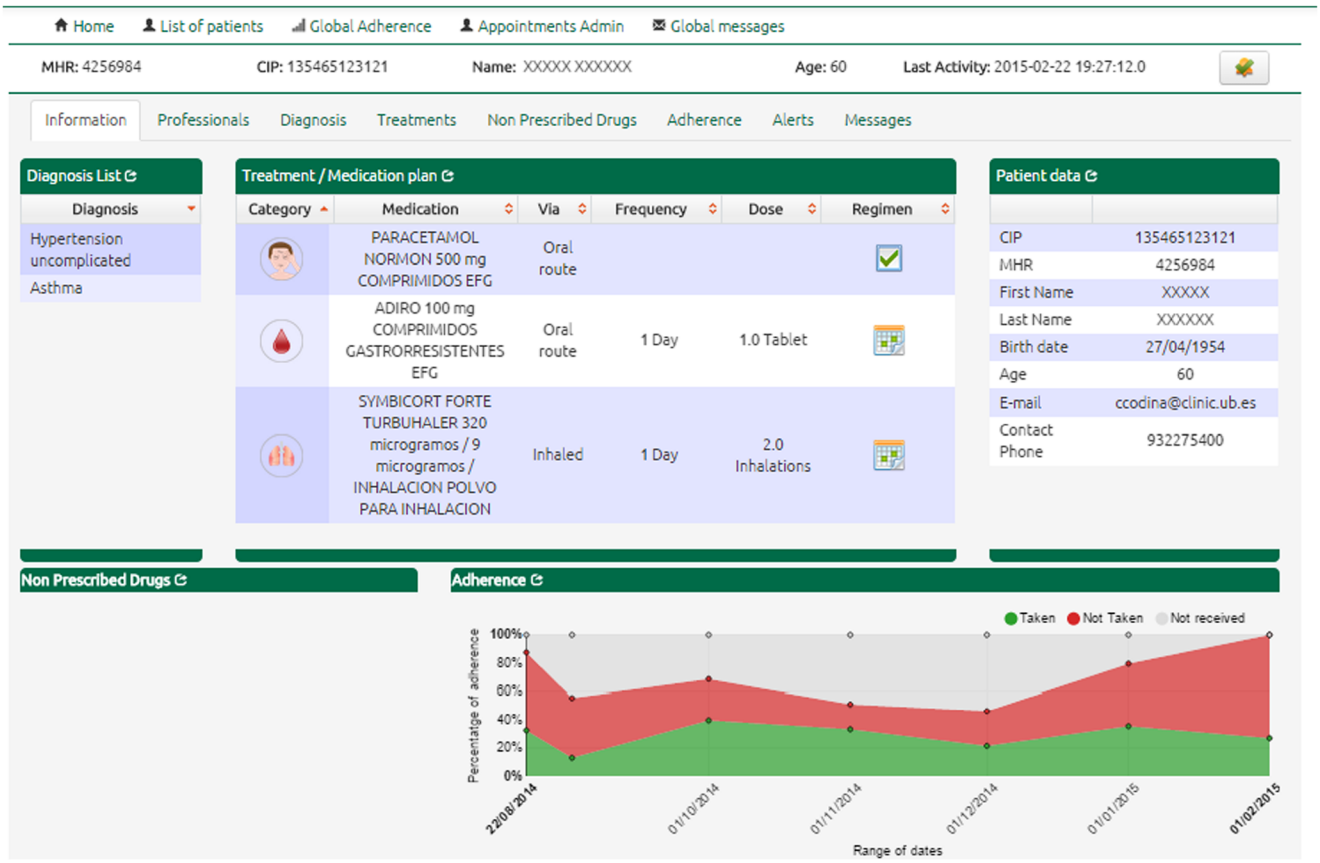

Fig. 4 Website: patient's profile

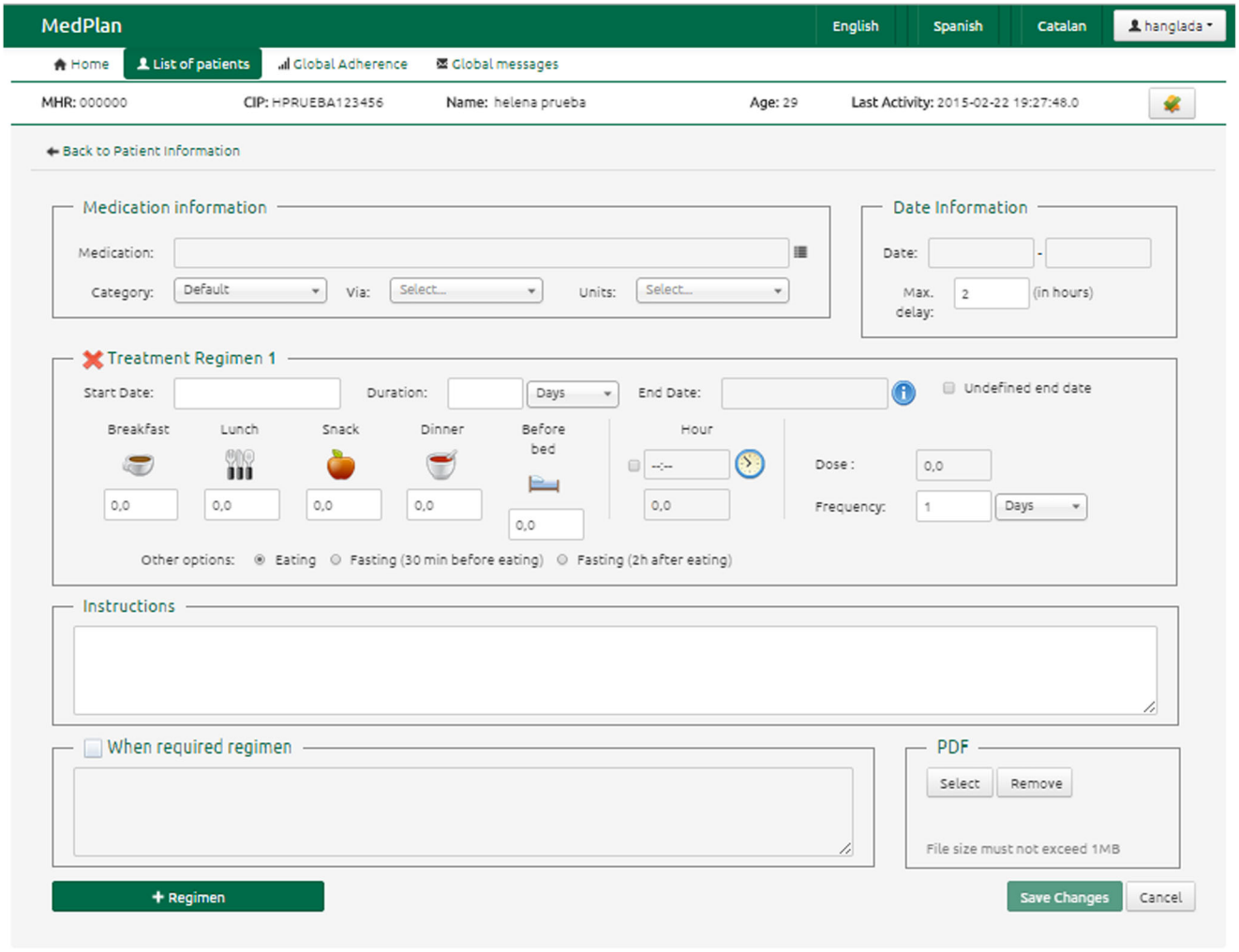

Fig. 5 Drug data entry

snack) or time of day (e.g., 07:05). Further medication instructions and information on healthy lifestyle can be incorporated.

Adherence is displayed graphically, and the information can be filtered by date, drug, time of administration, or ATC group. HCPs can revise the global adherence of the patients they care for in order to decide whether a special intervention has to be made and extract the list of patients with a specific adherence range.

Furthermore, HCPs can communicate with patients individually or send the same message to more than 1 patient simultaneously.

Discussion

We present a new information technology tool aimed at improving follow-up of pharmacotherapy and communication between patients and HCP. To our knowledge, this is the first interactive platform available in Spanish and Catalan based on the views and preferences of the target users, namely, patients and HCPs. The user-centered design has proven effective elsewhere [13, 14]. This approach was used in type 1 diabetes patients to identify the specific requirements for a diabetes self-management app. Patients were interested in fast and discreet transactions, collecting data rather than decision making, overcoming decision inertia, and ad hoc information sharing. In our study, potential users were more interested in user friendliness and data storage and confidentiality.

The potential benefits of mobile applications are the possibility of remotely tracking a patient's health and strengthening communication between the patient and the HCP. However, the issue of adherence is complicated by inadequate treatment supervision, poor communication with providers, and other patient-related barriers such as poor knowledge and lack of self-efficacy and motivation [3]. Medication reminders focus primarily on unintentional non-adherence, which is why

Medplan also incorporates feedback on current adherence level, enables bidirectional communication between patients and HCPs, and incorporates drug and healthy lifestyle information.

Dayer et al. reviewed 160 mobile adherence tracking apps for iOS, Android, and Blackberry devices and identified those features that would enable such an app to achieve the greatest impact [15]. The features were optimal management of complex medication instructions, online data entry, cloud data storage, availability of a medication database, data management (synchronization, exporting, and printing), tracking missed and taken doses, data input (the app enables providers to input and maintain the patient's medication regimen and "push" the regimen to the patient's device), multiple-platform app, free apps, generation of reminders offline, HIPAA compliance statement, and multilingual and multiprofile options (e.g., family use). Medplan meets all the recommended features except for multiprofile options. In the study by Dayer et al., only 29.4% of apps could track missed doses, 6.3% included a medication database, and 24.4% had the option to export data. In addition, only 3.1% had the HIPAA compliance statement.

An added value of the app we present is that the HCP introduces the patient's medication plan, thus reducing the risk of medication errors that may be generated when it is introduced by patients. In addition, the app also includes a reviewed and validated plan incorporating all the medications the patient takes, regardless of the care setting prescribed. Consequently, continuity of care is ensured, as HCPs have a complete list of the patient's medications. Patients have the option to request information on the suitability of OTC drugs (e.g., contraindications and drug interactions). A study of 309 elderly patients (median age, 75 years) showed that 74% used OTC drugs, among which the authors identified 166 potential interactions (between OTC treatments themselves or between OTC and prescription drugs). Besides, 55% of patients taking OTC medicines were exposed to potential interactions [16]. Herbal and dietary supplements can also interact with other drugs or worsen the disease [17]. An additional problem is that of transcription errors by HCPs [18, 19]. Therefore, one of our objectives is that information can be transferred directly into the Medplan platform from the electronic prescribing programs used in hospital and primary care centers in order to avoid these risks.

Unlike other apps to track adherence, the possibility of including photographs of the pills or packages was ruled out. In Spain, most brands are generic, and the pharmacy can dispense a different brand every time. Therefore, as this information is highly variable and the medication features (shape, size, and color) can change frequently, visual images could generate confusion and induce errors. Hence, incorporating icons that reflect the aim of treatment has a double advantage: it is a fixed variable and empowers patients through increased knowledge. Photographs of the pill or package can be incorporated for medications whose appearance rarely varies (e.g., HIV drugs).

Confidentiality is a crucial element of healthcare apps. In the study by Dayer et al., only 3.1% (5/160 apps) of the apps reviewed followed HIPAA requirements [15]. Confidentiality must cover all features of the app, such as medication reminders, text messages, medical appointments, and healthy lifestyle information. Medplan shows reminders with a plain text ("medication reminder" or "new message"), so that the information is visible only when the user displays it. In addition, at their outpatient pharmacy appointments, patients are able to choose whether they want to synchronize the information into their phone agenda, where the plain text "pharmacy" would be shown. Klasnja et al. reported that cancer patients expressed concerns about the synchronization of appointments when they synchronized their work calendar to their mobile phone, as they did not want that their colleagues to have access to this information [14]. In other medicine adherence apps, reminders are displayed in the mobile calendar and can include the drug name and the patient's name, thus potentially violating the patient's confidentiality right. Moreover, since mobile calendars can synchronize with work agendas, it is understandable that users may not want this information to be interfaced. The flexible design of Medplan means that it can be used for all types of diseases. In particular, it ensures confidentiality, which is particularly important in diseases such as HIV infection, since patients may not wish to have or may even refuse to download a mobile phone app specifically aimed at this disease. The risk of exposing their health status is increased, since downloads could be recorded in their iTunes or Google account.

As with other health apps, security requirements must be fulfilled. Data must be encrypted in transit and hosted in secure servers. Credentials should be required before access to information is granted, and an automatic disconnect feature must be incorporated in case the app is not used for a certain period of time. In addition, credentials must expire after a specific period [20].

The intervals established in Medplan to differentiate between high, intermediate, and low adherence are less strict than those reported in other studies [21, 22]. This is because the aim of the app is to act as a motivational and empowerment tool for patients and not as a tool for classifying patients as good, intermediate, and poor adherers, as is generally the case in clinical trials.

Unfortunately, this study is not free of limitations. Firstly, due to the lack of budget and not being of general interest, we could not include other functionalities requested by some patients such as refill reminders or consult laboratory results. On the other hand, the user centered design is limited to the population surveyed, so if the same formulary was made in a

different population the results could have been different. This makes this type of platforms to require a continuous validation and modification of its functionalities to feet into the customer's needs. For this reason, a before and after study with a quasi-experimental intervention is currently under way to assess whether Medplan helps to improve medication adherence, quality of life, and communication between HCPs and patients with hypertension, dyslipidemia, heart failure, or HIV infection.

Conclusion

The Medplan platform can significantly improve medication management. The development of the platform (application and website) based on the user centered design may enhance the feasibility and acceptability of this tool by taking the opinions and considerations of the end users before the platform is developed. A pilot study is being conducted to test whether Medplan is useful and effective.

Compliance with Ethical Standards

Conflict of Interest Authors have no conflict of interest to declare.

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