A Mobile Diary App to Support Rehabilitation at Home for Elderly with COPD: A Preliminary Feasibility Study

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Abstract. The paper describes the design, development and preliminary evaluation of a *mobile* diary app for elderly with Chronic Obstructive Pulmonary Disease (COPD). The application, called My Daily Activity (MyDA), allows patients to follow personalized rehabilitation, based on physical training, cognitive stimulation and an educational program. MyDA is based on four different modules: configuration, exercise, assessment and education. The first version of the application has been developed for tablets based on Android OS. As a preliminary feasibility evaluation, 12 elderly with COPD have used the system at home for 3 months. Both objective and qualitative data have been analyzed. Preliminary results suggest that, despite some improvements should be applied, MyDA represents a feasible and valuable solution for motivating elderly with COPD to continue rehabilitation at home. Future works should focus on making the app more usable, more interactive and more attractive – especially for the technology rejecting users.

Keywords: mHealth · Home-based rehabilitation · Physical exercise · Cognitive training · COPD · Elderly

1 Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a chronic and progressive disease, affecting over 300 million people worldwide, characterized by respiratory function decline and an umbrella of extra-pulmonary manifestations and comorbidities, which makes it a disabling condition. People with COPD often suffer from skeletal muscle disfunction, limited physical performance, cognitive decline, anxiety and depression. Pulmonary rehabilitation, with physical training as a cornerstone, is a comprehensive and effective intervention aimed at improving the patient's physical, psychological and social status. Pulmonary rehabilitation is usually carried out in hospital, where patients follow a personalized and integrated program for a limited period of time (2–3 weeks)

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[1]. One of the main challenges for chronic respiratory diseases is the continuity of care: once returned home, patients should perform physical exercises on a daily basis, they should follow a controlled nutritional plan and should maintain themselves socially and physically active. However, the positive effects of the intervention tend to decline in the long-term period due to lack of adherence and lack of direct supervision at home.

2 Related Works

Researchers are investigating how to keep COPD patients motivated proposing safe and customized solutions such as telemedicine systems based on web-based applications, mobile apps, wearable sensor devices, as well as exergames (i.e. exercise + games). Mobile applications show a great potential to improve healthcare delivery especially when dealing with chronic conditions – as COPD is – even if lack of compliance with the use of technology is still a challenge [2]. Long term compliance could be achieved only whether information is provided correctly and appropriately, whether users feel empowered while using technology and – on the contrary – do not experience the perception of "being too difficult to use". To meet these requirements a patient-centered design approach – allowing personalization of interventions and considering natural variations in patient's behavior – is crucial, even if not always easy to be applied. Healthcare professionals, who also guarantee reliability and security of contents proposed, should be involved in the process; however, they are often included neither in the design nor in the validation of existing mobile health applications. Most of the currently available apps for COPD focus on education; other functionalities are: symptoms tracking, support for medication or treatment and a diary or calendar for reporting activities [3]. Although some studies prove that mobile and computer-based interventions are feasible and well accepted by patients, no firm conclusions can be drawn due to some methodological limitations. As recommended by a recent review, studies should cover a longer period of time, should consider subgroups (e.g. age, education level), should include outcomes as self-efficacy, cost-effectiveness and anxiety or depression and should provide also subjective data to explain participants' perspective towards the adoption of technology [4].

Within this context, we present MyDA (My Daily Activity), a mobile application for supporting COPD patients in performing rehabilitation at home. Unlike most of the existing applications, our solution allows the personalization of exercises based on the patient's needs and report of physiological parameters and symptoms. Another strong point is that MyDA has been designed by a multidisciplinary team formed of developers, clinicians and psychologists. Moreover, it has been evaluated, even if in a preliminary way, on a 3 month-period including also subjective experiences of participants.

3 Design of the Application

MyDA has been designed by our multidisciplinary team – including developers, clinicians and psychologists – considering end-users' perspective analyzing their specific needs and capabilities. The application has been designed to foster continuity of care: the same protocol followed during hospitalization is continued at home. The training program has been defined following the current practice, based on the ATS/ERS[1] guidelines on pulmonary rehabilitation. MyDA contains a weekly training timetable showing daily activities as configured by the physical therapist that can set specific parameters for each activity, monitor the patient's activities and update the prescription adjusting goals, if needed. The foreseen activities are: endurance exercise, consisting in cycling on an ergometer at constant intensity; strength exercises for upper and lower limbs, specifically arm raises, sit-to-stand, calf raises and supine arm-cross; and a serious game allowing users to train their cognitive functions in a virtual scenario representing a daily life activity (doing grocery). Patient's performance – represented by exercise-specific parameters – and self-reported data – breathlessness, perceived fatigue, heart rate and oxygen saturation – should be recorded in a report available to caregivers. A separate section of the app provides educational content, such as useful information on the disease, tips on how to manage its symptoms and guidelines for a healthier lifestyle. Users interact with the application through a Graphical User Interface (GUI), providing simple instructions and reducing the complexity of tasks thus minimizing risks of unintended actions. The application is accessible via tablet; this device has been preferred because it has a wider screen than smartphones and a higher portability than PC desktops/laptops, that makes the exercise setting more flexible. Motivation is addressed giving proper suggestions and instructions to the patients and showing them – through a simple color-based representation – accomplished tasks and future goals. Moreover, patients are aware that they are monitored and that a doctor or a physiotherapist evaluates their actions. Having an active role in reporting activities, feelings and symptoms helps improving mastery on the disease and, as a consequence, self-efficacy and independence.

4 MyDA

The application has been developed using Unity3D[2], based on C# language. The choice of using a game engine is mainly related to the development of the 2D serious game for cognitive training. Moreover, Unity3D is a cross-platform engine allowing to easily deploy the application on different platforms, such as Windows OS, Android OS, iOS etc. This makes MyDA accessible to a wider user audience with different preferences. In our study we provided patients with a tablet based on Android OS. MyDA is organized in five modules working as follows.

[1] American Thoracic Society/European Respiratory Society.

[2] https://unity.com/.

The **configuration** module consists in a dedicated section – secured with password – with access limited to clinicians. They can create the patient profile, specifying personal data and training data, setting the recommended frequency of training for the three activities and specific parameters for each of them (e.g. duration of the cycling exercise, number of sets and repetitions for the arm raises, duration of rest etc.).

The **activity** module contains all the classes and functionalities for managing the three training modalities with specific functions for each of them. When starting the application, in the "Home" panel, the patient selects the activity he/she wants to perform among the scheduled ones for that given day. Tapping on the activity icon, he/she begins the session. While performing the physical activities, patients are encouraged to listen to music, choosing among three different tracks provided by MyDA, according to their preferences. If endurance is the scheduled exercise, the patient, after setting the preferred track, receives instructions on the duration and intensity of the cycling activity and prepares the cycle-ergometer accordingly. When he/she declares to be ready (by tapping on a "START" button), a timer is displayed on the screen and the music starts playing. In a similar way, the patient receives support for strength exercises with proper instructions – both text and a video tutorial – on the correct starting position and execution and the task to be accomplished. The duration of each sets of movements is recorded as the time passing between a "tap" on "START" and a subsequent "tap" on "STOP" button. The cognitive training consists of completing a shopping task in a virtual supermarket. The patient, given a list of products to collect, has to select, first, the correct lane – i.e. the one containing the required products, as in a real supermarket – and then the product on a shelf by tapping on the corresponding image. As the levels of difficulty change, the number of products on the list, the number of lanes, the number of items on the shelf and the position of the product to find increase. Patients can pause the activity for a short time (e.g. if they need to rest) or interrupt the exercise session (Fig. 1).

Fig. 1. Some screenshots of the application: a) training timetable; b) educational program; c) symptoms assessment; d) warm-up of the endurance session; e) strength exercises session; f) virtual supermarket for cognitive training.

The **assessment** module manages the insertion and recording of the patients' health condition before and after each physical activity session. The self-assessment consists in a brief questionnaire focusing on four relevant issues: heart rate (HR), oxygen saturation (SpO2), breathlessness and muscle fatigue. The patient manually inserts HR and SpO2 values, measured by a finger pulse oximeter, through the GUI. In addition, the patient self-reports the levels of breathlessness and muscle fatigue by choosing on a 10-point Borg modified scale the symbol that corresponds to the perceived dyspnea or muscle fatigue at that given time.

The **education** module is organized as a "School of COPD" with 10 chapters. Each chapter is focused on a specific topic regarding different aspects of the disease and the strategies to handle with activities of daily living (e.g. travelling, preparing meals, social life, etc.). The educational contents combining images, text and videos have been realized by a group of lung specialists and physical therapists working at IRCCS INRCA (National Institute of Health and Science on Ageing).

The diary report includes the representation of the personalized schedule through a weekly timetable where each activity is identified by a representative icon; past activities are reported with an additional symbol – a red cross, a yellow bar or a green tick – indicating if the activity has been missed, interrupted or completed respectively. Report files contain the log data describing the patient's behavior during the training period. These data include the number and type of sessions interrupted/completed, the time spent exercising, the self-reported health assessment and specific information associated with each of the three activities. All the information gathered is available to professional caregivers and provides a comprehensive overview to track the patient's condition over time. This enables clinicians to discuss with the patient on his/her improvement or worsening and to adjust the prescribed program accordingly.

5 Preliminary Evaluation

5.1 Procedure

A preliminary feasibility study has been performed involving a group of patients with mild/moderate COPD, who used the app at home for 3 months. Participants were enrolled at IRCCS INRCA; after a period of rehabilitation in the hospital, they were given an Android based tablet with the application installed. At discharge, the physical therapist configured the app for each patient and showed him/her the main functionalities. All patients also received a user manual containing all the instructions, potential errors and troubleshooting written by the app developers. During the study, patients had the chance to phone call the physical therapist and developers to communicate technical problems and, eventually, ask for help. All participants were encouraged to follow the same training protocol, which was as follows: 20 min of endurance exercise (on a cycle-ergometer) for 5 days/week; 3 sets of 10 repetitions for each of the strength exercises for 3 days/week; cognitive serious game at least 3 times/week as they like; educational content as they like. After 3 months, patients returned the devices. The study protocol has been approved by the Ethical Committee of IRCCS INRCA.

The primary feasibility outcome was the frequency of use of the MyDA-based training program defined as: (number of attended sessions/number of planned sessions) %. Frequency of use for each type of activity (endurance, strength or cognitive) was also measured. Objective measures were obtained analyzing the log data of the application. Use of the application is classified as follows: very frequently (frequency of use > 95%); frequently (75–95%); occasionally (50–75%); rarely (25–50%); very rarely (5–25%); never (<5%). Qualitative responses were collected with semi-structured interviews carried out at the end of the three months and analyzed in combination with objective measurements to explain patients' behavior.

5.2 Results

Twelve elderly (6 male; age: 71 ± 7.3) with mild COPD participated in the study. Two participants encountered technical problems with the tablet; their data are incomplete so that they are not presented hereinafter. Results from the remaining 10 subjects (6 male; 4 female) are summarized in this section.

Considering the overall use of the application with no distinction on the activity performed, 2 patients never used the application for following the rehabilitation program and 1 patient very rarely used it. With respect to the first two users, the interviews revealed a total rejection of a technological tool. In particular, one subject declared: "I'm not inclined for technology, I don't even use a smartphone". The other subject instead reported that, in his opinion, the application was useless: the user carried out the motor exercises without the support of MyDA and he considered the cognitive task to be of little use. On the other hand, the patient who used the app very rarely, reported a problem with the usability ("difficulty using the device") and in particular that he was unable to navigate the interface, and this is why he only used MyDA when his grandchildren could help him. The remaining 7 participants used it for at least 65% of the planned activities. Among these, 3 patients trained with the support of the app exactly as planned (frequency of use > 100%).

The analysis of endurance sessions shows that 3 patients very rarely performed exercise with a minimum of 0 sessions to a maximum of 6 sessions performed; 1 patient occasionally followed the prescribed training. The remaining (n = 6) patients frequently (n = 3) or very frequently (n = 3) used the app. The first type of users reported they had the opportunity to perform physical exercise outdoor and therefore they did not always use the tablet for training. The subject who used MyDA occasionally, declared that he preferred cycling while watching television because time seemed to him to run faster. Among those who frequently used the app, users reported feeling more monitored and involved than in a standard situation, and found the device useful, especially at a general level and not specifically in the endurance session; the problem most frequently encountered by them was that the app was slow in loading a new session.

Regarding strength exercise sessions, 6 patients adhere to less than 50% of planned activities: 5 patients never used the application and 1 patient used it very rarely. During the interview, these subjects did not report any particular problem related to the tablet but they stated that they performed the exercises following the paper instructions given by the physiotherapist before discharge. The two subjects who were less inclined to the

use of a technological device were part of this group. 1 patient occasionally and 1 frequently used MyDA to perform strength exercises. These users explained that they did not always perform the exercises with the app for different reasons: one due to muscle pain, while the other one carried out the exercises following the personalized indications of the physiotherapist. Only two patients adhere to the program as expected, with frequency of use higher than 95%. These users considered the app as very usable and they found easy to understand both the explanation of the exercises and how to interact with the tablet during the strengthening session.

Finally, the analysis of the cognitive sessions shows that 2 patients never used the application, 3 patients used it only rarely and 1 subject occasionally used it. The first two subjects, the same ones not using the tablet also for the previous activities, considered the cognitive exercise useless, despite the doctor's advice. Patients who accessed the serious game very rarely or occasionally said they found it boring ("I felt like I was falling asleep") and they found some usability problems; specifically, not being able to properly select the right objects on the shelves. This problem, in their opinion, led them to frustration and to a subsequent less use of the game. The remaining 4 patients very frequently accessed the serious game for cognitive training. These patients stated that the tablet was a support for training their memory and that it could improve their speed in shopping in reality.

5.3 Discussion

Overall, MyDA was well accepted by the majority of our sample. In general, patients showing aversion toward technology at the beginning of the study did not change their attitude. In some cases, especially considering the muscle strength sessions, the non-use of the device is likely to be related to an unclear communication between caregivers and patients. Not all patients completely understood the expected use and the functionalities (exercise video tutorials and timing recording) of that area of the application. It is likely that a smaller number of strength sessions than performed were recorded because some patients did not use the section correctly. In fact, the system recorded numerous interrupted sessions lasting more than 10 min and not registered as "completed sessions". It is possible that patients performed all the exercises without interrupting the training at the end of each session. Efficient communication on the importance of training and of being monitored, together with an effective training on the use of technology are essential to persuade both the technology rejecting users and the less physically active patients. Problems of usability emerged among those who infrequently used MyDA even if they were not averse to use it; in particular, a delay in loading the sessions, which did not allow an agile use, was reported. Finally, those using the app very frequently have played the serious game for cognitive training more than three times a week, finding it both useful from the point of view of enhancing their mnemonic skills and an enjoyable way to spend their time.

6 Conclusions and Planned Activities

The present work describes the design and development of a mobile health application enabling COPD patients to follow personalized pulmonary rehabilitation programs at home. Our solution includes a training diary with a personalized schedule and self-report of symptoms and vital signs, a support for physical exercises and an education session. We have considered the users' needs and capabilities applying a user-centered approach based on the cooperation among developers, psychologists and clinical experts. End users are elderly people with mild/moderate COPD, with no serious cognitive or motor impairment preventing to independently follow a rehabilitation program. Preliminary results on a group of 12 elderly reveal that – although some improvements could be applied – MyDA represents a valuable and feasible solution for home-based pulmonary rehabilitation. Main improvements should make the app more usable more interactive and more attractive – especially by the technology rejecting users. Moreover, thanks its modular approach, additional functionalities may be added to the application both in terms of proposed exercises and in terms of provided feedback. For example, audio feedback and voice instructions may be added to allow those patients with mild visual impairment to interact more easily with the application. One of the main limitations of our study is the sample size: although the recruited participants are a discrete number to evaluate the usability of the application, a larger population should be studied to demonstrate the acceptability of our solution. Furthermore, it is necessary to carry out further assessments to evaluate if our solution motivates users and involves them in the long-term rehabilitation process at home. For this reason, a long-term randomized trial will be performed and psychological variables as intrinsic motivation will be measured; we will compare the results reported by MyDA users with a control group, with the aim of better understanding the effectiveness of mobile-based training intervention in improving COPD continuity of care. Finally, despite mostly positive feedback from users, our study highlighted some usability issues that did not allow some patients to use MyDA; these problems will be resolved to allow for a more satisfying experience.

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