Rehabilitation Support for Patients With Early Stage COPD in the Unsupervised Setting

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***Abstract* - This paper proposes a proof-of-concept prototype to increase the adherence rate to rehabilitation programs for early stage COPD patients in the unsupervised setting. The prototype is using various sensor technologies as adherence verifiers and adherence aids. The aim of this study was to evaluate the prototype in collaboration with two test users and there have been gathered results about: the physical device, the GUI, the functionality, and the effect the system has on the adherence rate. Results show that our solution increases the motivation and rehabilitation efforts of COPD patients**

***Keywords;* Proof-of-concept prototype, COPD, rehabilitation, adherence, unsupervised setting, sensors.**

I. Introduction

Chronic obstructive pulmonary disease (COPD) is a major chronic disease which affects about 400.000 people in Denmark [1]. Patients suffering from COPD need to follow a rehabilitation program, in order to self-manage their disease and improve health-related quality of life (HRQL) [2]. Studies show that the adherence rate is low when COPD patients exercise in the unsupervised setting. Additionally the adherence rate increases when the patients are supported by healthcare professionals [3].

The aim of this project is to support patients with early stage COPD in their rehabilitation in an unsupervised setting by creating a clinical proof-of-concept prototype and testing this in collaboration with COPD patients.

A number of telemedicine applications to support COPD patients have already been developed [4,5]. They mostly use personal home computers or provide portable devices to healthcare professionals. The system described in this article is slightly different because it uses mobile technology and emphasizes patient motivation and adherence, rather than focusing on monitoring.

II. Suggested Solution

We suggest creating a mobile pervasive healthcare solution to register and support early stage COPD patients during rehabilitation efforts. It should have the ability to verify if they are adhering to their rehabilitation program. If they are non-adherent the application will aid them by calmly reminding them about the importance of their rehabilitation. The rehabilitation program in this project consists of 15 minutes of training every day. The rehabilitation program varies for each COPD patient. It will also have an e-learning section to educate and cognitively aid them; additionally it shall offer a possibility for healthcare professionals to supervise the rehabilitation by receiving data about the patient during exercise, see figure 1. The raw data is: arterial oxygen saturation (Sp,O2), pulse and movement measured with an oximeter and an accelerometer. The raw data also contains a timestamp with each measurement. If Sp,O2 < 90% an alarm will be triggered, this will notify the patient if they are training too hard. The solution will be able to support training in the unsupervised setting which implies training without supervision by healthcare professionals.

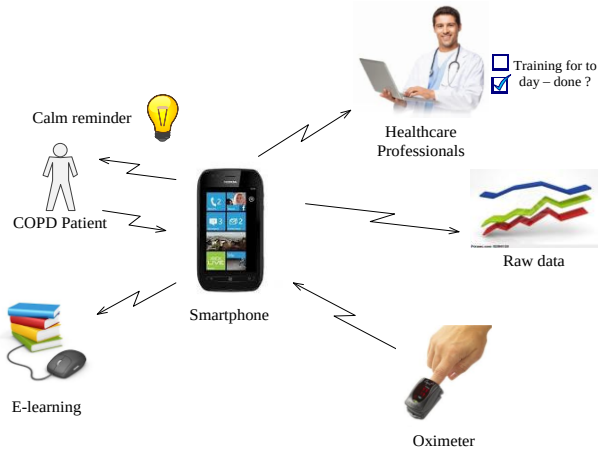

Figure 1: Overview of the suggested solution

III. Preliminaries

In the diagnosis of COPD, it is important to measure the FEV_1 and FVC after bronchodilation, because this value is used to determine the stage of COPD. FVC is

the forced vital capacity; it indicates the amount of air the patient can exhale. FEV_1 is the forced expiratory volume per second; it indicates the maximum amount of air the patient can exhale per second after maximum inhalation. FVC and FEV_1 are measured as a percentage of the normal value. When comparing these two values, the stage of COPD can be determined [6]. The target group of this study consists of early stage COPD patients, which is specified as mild to moderate COPD, see table 1. To manage COPD it is important to uphold a stable level of Sp,O_2 which is measured with an oximeter. The goal is to maintain $Sp,O_2 > 90\%$ during rest, sleep and exertion[7].

TABLE I
THE TABLE SHOWS THE DIFFERENT STAGES OF COPD [6]

Stage	**FEV_1-value**	**Symptoms**
Mild	> 80 %	Often no symptoms, sometimes cough or phlegm
Moderate	50 % < FEV_1 < 80 %	Phlegm, cough, dyspnoea during exertion
Severe	30 % < FEV_1 < 50 %	Dyspnoea, cough, phlegm and respiratory infections
Very severe	FEV_1 < 30% or FEV_1 < 50 % and respiration failure	Same symptoms as severe, but worse. Frequent hospitalization

IV. METHODS

The Adherence Strategy Engineering Framework (ASEF) is used in our project for developing technology-based solutions to evaluate and improve patient adherence levels and assess the quality of healthcare data. The ASEF consists of five elements; domain, stakeholders, context, technology and adherence [8]. Following ASEF, we have designed a proof-of-concept prototype that implements a reduced adherence model (RAM). Our prototype consists of sensor and alarm technology that can verify and aid the patient in their rehabilitation.

Apart from that we have made quantitative and qualitative studies. A questionary has been created to get information about COPD patients' needs and conditions relative to our prototype and to verify our current knowledge about COPD patients. In the usability test, interview and observation have been applied to evaluate the prototype from the user's point of view.

In the development process we have worked iteratively with structured and focused solutions towards the problems. If complications appeared they were solved in a logical and systematic way.

V. THE SYSTEM

The system consists of an application for a Windows Phone; the phone is a Windows Phone 8s by HTC. The accelerometer in the device is used to confirm that the patient is training at least 15 minutes every day by measuring the movement of the patient. If they are not adhering to their rehabilitation program the phone will make a shell tile and remind the user to train. To measure Sp,O_2 and pulse we are using an oximeter of the type Nonin 9560. It is connected to the phone via Bluetooth where it will send data packages containing; header information, the measured values and timestamps to the Bluetooth stack on the phone. Figure 1 and figure 2 show the interfaces of the application.

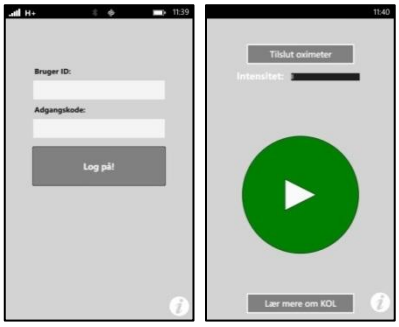

Figure 2 – The left picture is the start interface for the application. It requires a logon with user-ID and password. The right side is a picture of the main page of the application. The green start button indicates "start training" and the button "Learn more about COPD" leads to the right picture in figure 3**.** Both pictures contain an "*i*-mark" in the right lower corner if information is needed.

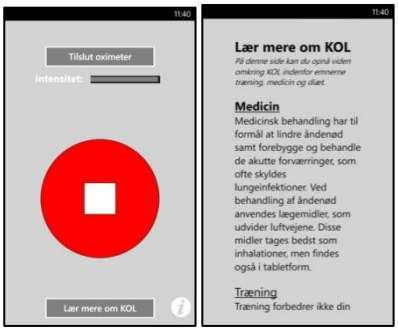

Figure 3 – The left picture will appear when the green start button is pushed on the main page (from figure 2). During training pulse, Sp,O_2 and the intensity will be measured and indicated above the red button. To stop training and return to the main page, push the red button. The right picture is an e-learning page where you can get information about the disease.

To develop the application visual studio 2012 has been used with the windows 8 SDK installed. The Windows Phone application is developed in Silverlight and Caliburn Micro is implemented to make the development easier. In the early stage of the development the application has been debugged with an emulator. The chosen design pattern is "Model, View, ViewModel" (MVVM). The MVVM pattern is an event-driven pattern. The model refers to a data

access layer that contains the content of the application. The view refers to the GUI of the application and the viewmodel is an abstraction of the view that connects the model and view.

VI. Test

The evaluation of our proof-of-concept prototype is divided into two sections; a functionality test to verify that the device is working as intended and a usability test to evaluate the prototype according to the ASEF.

A. Functionality test

To verify the functionality of the prototype we have set up a scenario which has been completed to test the system.

1. Check the lock-screen to see if training is complete
2. Turn on the Bluetooth connection on the phone
3. Open the application by pressing the app icon
4. Enter the user-ID and password to logon
5. Wear the oximeter on the finger
6. Press on the "Connect to oximeter" button to make a Bluetooth connection between the phone and the oximeter
7. Test if the alarm triggers if the Sp,O_2 value is under 90%
8. Start training by pushing the green "Start" button
9. Begin training
10. Check the intensity slider to verify the movement
11. After 15 minutes of training, stop training and make sure that the "Remember to train" tile on the lockscreen has disappeared
12. Check that the e-learning page is working
13. If no training has been performed, check that a toast appears, calmly reminding to train. When the toast comes up, the phone vibrates.

B. Usability test

To evaluate the prototype according to the ASEF focus elements; domain; stakeholders, context, technology and adherence, a usability test has been performed in collaboration with two test users. The test users are a part of our target group; they are diagnosed with moderate COPD and are between the ages of 60-79. Furthermore both test users regularly perform rehabilitation efforts in an unsupervised setting and they are both supervised by their general practitioner every six months.

A test setting has been established to evaluate our proof-of-concept prototype. The setting consists of the test users' ordinary rehabilitation efforts which normally include cardio training combined with different exercises. Before they start training, a short briefing about the functionality and the concept of our solution will be introduced. The duration of the training section is 15 minutes and while training, they have to wear our prototype which includes the phone strapped at the arm and the oximeter placed on the finger. During training the intensity, Sp,O_2 and pulse will be measured. At the training section we will observe how they behave with the technology; is it easy for them to use the application on the phone? How do they react to the alarm and the calm reminder? Are the devices possible to wear while training and is it feasible to use in different kinds of training sections?

After the training session we will interview them about the same aspects and besides that, we will ask about their subjective opinion about our solution. To cover the adherence we will ask if the calm reminder and the e-learning section will motivate them to train.

C. Expected results

As a result of the questionary and the usability test we expect to obtain some results;

The questionary will supposedly confirm our knowledge about the needs and conditions COPD patients are having about exercising, their knowledge about COPD and how adherent they are to their rehabilitation program.

The usability test is expected to provide results about; the physical device, the GUI, the functionality and the effect of the system related to the adherence rate. It is expected that problems can occur while training with the oximeter, depending on the type of training. By strapping the phone around the arm, it is expected to be possible to exercise without any complications. It is also expected that the users respond to the user friendliness of the system, is that it is simple and easy to use if they get an introduction to the system along with a manual to guide them. They will be asked in the interview if they think the calm reminder and alarm can increase their adherence rate, and to this it is expected that they think it will. The test is not expected to provide statistic data about the adherence rate, due to a limited testing period.

VII. Results

The following results were obtained from the usability test with the two test users.

There were no problems by starting the training themselves by strapping the phone to the arm and attaching the oximeter on the finger. The response to the application was that it was easy and manageable to start, by pushing the different buttons in the application. The buttons were easy to hit because of the size but it was mentioned that the interface could be a challenge for patients unknown to touch interfaces. The phone strapped to the arm was comfortable to wear while performing different exercises and they could barely feel it on the arm. The oximeter was attached on the finger which irritated them because it collided with their training and it felt like falling off. The alarm with $Sp,O_2 < 90$ % was not triggered at the usability test but was considered as a good feature because it provides safe environment during training. The calm reminder shown as a tile on the phone was a good idea because it

resulted in feeling obligated and motivated to complete the training. Furthermore they think they will feel motivated because health care professionals are able to observe their training and condition followed by an evaluation of the disease when they are meeting every six months. To make it memorable how to use the system and its features a manual should be created.

The e-learning section was not considered necessary since they gained enough knowledge about COPD in the pre-stage consultations of their rehabilitation where books and brochures where distributed.

VIII. Discussion

The results indicate that it is possible to develop a solution that can combine different sensors and devices in an intelligent environment. It has not yet statistically been verified that the suggested solution increases the adherence rate among early stage COPD patients during rehabilitation efforts in the unsupervised setting. In order to do this more extensive and thorough further usability testing is needed. We need to expand the usability test with more test users and in order to verify an increase in the adherence rate we need to follow them in a longer period with and without aid. On the other hand we can argue for an increased adherence rate based on our results. Apart from that we need to obtain more data from the windows phone 8s accelerometer.

It appears that the data from the accelerometer and the oximeter is useful for our prototype but to make proper use of the data from the accelerometer, the movement sensitivity has to be evaluated and further development has to be performed related to the meaning of the data displayed in the application.

The use of a windows phone 8s appears feasible but the oximeter is causing complications during training. To compromise the complications under training another solution for measuring pulse and Sp,O_2 has to be considered. Requirements for this solution are that it has to be placed so it does not collide with the training and additionally it has to be attached properly so the device is not falling off.

The results showed that the GUI was easy to use but because of the test users' high technical abilities we cannot generalize and be certain that it represents the majority of early stage COPD patients. So it is important to consider providing guides to the system to cover all users with different technical abilities. The e-learning section appeared unnecessary to the test users because they gained the needed knowledge in the pre-stage consultations of their rehabilitation, but it is difficult to generalize. Some might be more forgetful and will need to refresh their knowledge which the e-learning page can contribute to.

A. Conclusion and Future Work

In the future the system is meant to be a part of a package for early stage COPD patients. The package will include a consultation with a nurse, a rehabilitation program made in collaboration with a physiotherapist over a determined period and at last our system has to be brought home for continuing self-rehabilitation. The system will be used in the unsupervised setting and will replace the different regions' offers for COPD patients.

Further development of the oximeter is required and an example could be a watch looking device, which will make the current complications about wearing the device, disappear.

Further development of the app is required and an example is to test the app, and make it more user friendly. There has been used a local database and for further development it is required to make it externally, so a web application is able to get the necessary data from the application. This makes the information of the training available to the healthcare professionals.

A guideline to use the system could also be created to assist the COPD patients in using the system.

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