Telemedicine provides new treatment possibilities in COPD care

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) is a chronic, progressive lung disease. COPD has a high impact on quality of life, large social consequences, a progressive course and it cannot be cured. Physiotherapy, increasing physical participation in daily activities, and early detection and treatment of exacerbations are important elements in current COPD disease management. Home-exercise programmes and self- management of exacerbations are effective new treatment methods. When these programmes are offered as a telemedicine application, they could contribute to a reduction in labour and costs.

This paper describes a number of telemedicine applications designed for implementation in COPD care:

1) remote monitoring of physical activity and symptoms;
2) coaching and feedback in daily life to gain an active lifestyle;
3) a web portal for online exercising, self-management of exacerbations and communication between professionals and patient and;
4) serious gaming. For each application we share the motivation, design, and (future) evaluations with the target group: COPD patients.

The designed applications are in general positively received by patients and professionals and seem to be able to improve the patient's well-being. Further development and further scaling of these technologies in everyday care would be an important next step.

Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a respiratory disease characterised by the progressive development of airflow limitation in the lungs, mostly caused by cigarette smoking.[1] COPD has a progressive course especially in patients who continue to smoke and it influences quality of life drastically, causing primarily shortness of breath (dyspnoea) and lacking physical exertion capabilities. [1,2] Patients enter a downward spiral of dyspnoea, leading to inactivity, and subsequently to physical deconditioning. This vicious circle results in a loss of independence for the patient, and may be accelerated by acute exacerbations,[3] which is a worsening in the patient's baseline symptoms - dyspnoea, cough and/or sputum - beyond day-to-day variability, for which hospitalisation is often needed. Acute exacerbations occur one to three times per year in severe COPD patients and impair respiratory, physical, social and emotional functioning both acutely and longitudinally.[4]

Treatment can slow the progress of the disease and aims to reduce risk factors, prevent disease progression and manage exacerbations. The therapeutic approach involves both pharmacological and non-pharmacological treatment, but especially the maintenance of an active life style and physical condition are major targets.[1] Within the whole disease management programme the COPD patient is involved with several different health care workers, ranging from nurse practitioners to dieticians. The treatment of COPD is complicated due to the fact that it is a systemic disease: the strongly diminished physical condition is often complicated with several comorbidities.[1]

The provided care is felt to be suboptimal. Patients differ in e.g. symptoms and co-morbidities, which asks for personalised treatment. Providing face-to-face care to stimulate patients in regaining activity levels is difficult as care professionals lack insight in the patient's condition and well-being. Moreover, it will become more difficult and costly as the number of COPD patients is still rising.[5] Consequently, the burden of COPD on healthcare

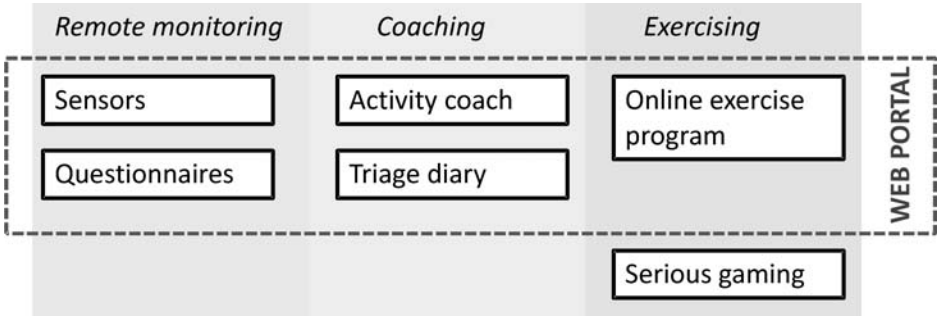


Figure 1: overview of telemedicine applications that are discussed, subdivided in 3 main categories: remote monitoring, coaching and exercising.

resources and costs increases, which argues for the need to find inventive ways to care for these patients. Information and communication technology (ICT) can play a crucial role, and as such telemedicine and telemedicine applications have been growing dramatically.[6,7]

With this in mind, we developed a number of telemedicine solutions that aim to address these problems by improving insight in the patients' health status, improving self-management of the patient, provide them with the support they need to develop and maintain an active lifestyle, reduce risk factors or worsening of disease, and directed towards behaviour change. The aim of this paper is to describe these solutions: remote monitoring, coaching and feedback, online exercising, self-management of exacerbations, and gaming, in the context of current COPD care (Figure 1). For each solution we share the motivation, design, results of evaluations with the target population and (future) implementation possibilities.

Remote monitoring

Insight in the daily behaviour of COPD patients is critically important for successfully improving quality of life in this population. Remote monitoring provides the possibility to gain insight in the activity and symptom behaviour of COPD patients; both in an objective (i.e. sensors) and subjective manner (i.e. questionnaires).

Triaxial accelerometer measurements are thought to be the most accurate and sensitive for detecting physical activity. At Roessingh Research and Development (RRD), we currently use the ProMove-3D wireless sensor (Inertia Technology, Figure 2), a highly-miniaturised inertial sensor node that can capture, process and communicate wireless full 3D motion and orientation information. The sensor operates as a long-term activity monitoring device, with the integral of the modulus of bodily acceleration - the IMA value - as output measure for physical activity. The IMA value correlates with the signal energy over the three axes, which is a good measure for the intensity of the measured motion.[8,9] The node communicates wirelessly with a smartphone (HTC Desire (S)) by Bluetooth, and is worn on the patient's hip by means of a clip holder.

Figure 2: ProMove-3D wireless sensor (Inertia Technology).

Not alone activity can be monitored in daily life, but this can be extended with oxygen saturation and pulse rate, measured by pulseoximeters. In healthy individuals, SpO_2 (saturation of peripheral oxygen) should be >95%. However, in COPD patients this value is often much lower, especially during exercise. Therefore, saturation is monitored for safety reasons: to notice if a patient is desaturating, and to determine the need for supplemental oxygen therapy in more severe cases. In addition, pulse oximeters estimate heart rate, which can be monitored for safety or for determining and maintaining optimal training intensities. At RRD, we currently use the Nonin WristOx$_2$ 3150, which is worn around the wrist and connected through a secure wireless Bluetooth 2.0 connection. SpO_2 (in %) and heart rate (in bpm) are automatically displayed on the smartphone when the patient starts wearing the sensor.

Figure 3: Example of a VAS question about patient's fatigue.

Remote monitoring can also be employed to retrieve specific information from the patient, which cannot be obtained by sensors. The smartphone is used to monitor symptom behaviour of the patient, by asking questions at fixed time intervals during the day about dyspnoea and fatigue levels using Visual Analogue Scales (VAS), see Figure 3. This is not limited by, and almost all types of questionnaires can be applied in a digital setting on a smartphone.

We performed monitoring studies to investigate this daily behaviour of COPD patients, which shows that COPD patients have a sedentary lifestyle and a specific daily activity pattern, which is less distributed compared to healthy individuals.[10] Furthermore, it shows that physical activity was mainly related to symptom levels at waking. In current COPD care, this detailed information about the activity and symptom behaviour in daily life is not known, and professionals have to take patient's word for it. Therefore, using remote monitoring in COPD care can provide useful additional information about the patient's physical condition and well-being in daily life, making timely intervention possible.

Coaching and feedback

For patients with COPD remaining physically active is important to prevent physical deconditioning, but also to reduce the risk of hospital (re)admission,[11,12] to increase life expectancy, [13] as well as slowing the rate of decline in lung function.[14] In conventional treatment the professional provides direct feedback to the patient to stimulate them in regaining activity levels. In telemedicine treatment the challenge is to replace some or all of this face-to-face feedback by technology-provided feedback to enable behaviour change. This is a staged and dynamic process and it is important that patients should first gain awareness about their behaviour. With this in mind, we developed a telemedicine solution - the activity coach - to improve activity behaviour and stop the vicious circle in COPD.

The development of the activity coach comes a long way, the first version being developed and tested in 2006, in patients with chronic low back pain.[15] Following an iterative user-centred design approach, the 2011 version is now finished, and can be specifically adapted to several target groups. The activity coach visualises the activity behaviour of the individual patient, and provides continuous and time-related feedback to promote an active lifestyle in daily life. The aim is that patients become aware of their amount of daily physical activity and their daily activity pattern, and can improve their physical activity behaviour. The system consists of a smartphone (HTC Desire (S)) and an activity sensor (ProMove-3D). The smartphone shows the measured activity cumulatively in a graph, together with the cumulative activity the patients should aim for: the reference activity line (see Figure 4). The reference activity is based on the baseline measurement of the patient. Patients are asked to try to follow the reference line displayed. In addition, the patients automatically receive feedback text messages, for awareness and extra motivation. These messages are based on the difference between the measured activity and the reference line and always consist of 1) a short summary of activity behaviour and 2) an advice to how to improve the activity behaviour (see Figure 4).
Our research showed that this intervention can indeed improve the activity behaviour of patients with COPD: they tend to be more active and balance activities more equally over the day.[16] The creation of a smart, autonomous coach that can determine the ideal contents and timing of the feedback messages for each individual patient is the current focus of our research in this area.[17]

Providing feedback to the patient about this physical activity behaviour is important to stimulate self-management. Therefore, the activity coach can

Figure 4: The activity coach running on a HTC Desire (Android 2.2), with on the left: continuous feedback in the form of the activity graph displaying the measured activity (blue) and reference activity (green). The status panel shows the deviation from the reference line. On the right an example of a feedback text message is shown.

be applied without or with supervision of a care professional. Examples include: as a follow-up treatment after a rehabilitation programme, or as an addition to regular physiotherapy sessions. Another possibility is to connect the activity coach with an online web portal, showing the measured activity levels, where both professionals and patients can log on to for monitoring the progress made.

Web portal

In order to monitor the patient's health status and progress by both patient and professionals, we designed a web portal where all applications are displayed in an organised way. The web portal's goal is to show monitored parameters and/or exercise programmes and its progress to the patient and/or professional, but it can also be used for gathering new data (e.g. diaries).

Triage diary: self-management of exacerbations

Patients are able to identify warning signs and symptoms of exacerbations, but often they do not report an exacerbation to their medical doctor, which can delay treatment and recovery. The majority of all costs are related to the treatment of acute exacerbations.[5] Self-treatment of exacerbations might make timely treatment of exacerbations possible, which could accelerate recovery and reduce the risk of hospitalisation, thereby potentially reducing their severity and associated costs.

Within the COPDdotCOM project (www.copddotcom.nl) an online decision-support system was developed for self-management of exacerbations: a triage diary. Every day, patients are asked to fill in the diary on a web portal. This diary consists of one question: *Did you have more complaints than usual in the past 24 hours?* (Figure 5) When patients experienced no deterioration of any of the symptoms, they could answer NO. In case of YES, they had to answer 9 more questions whether the level of each symptom was normal, slightly increased or clearly increased.[18] A decision-support system automatically forms an advice to start medication in case of an exacerbation. Before using this diary, patients have to attend two self-management sessions given by a nurse practitioner, to learn completing the daily diary. Patients are also educated in early

Figure 5: triage diary "Did you have more complaints than usual in the past 24 hours?"

recognition of exacerbations and in starting standardised treatment in case of an exacerbation.
Previous research that used the paper version of this diary, showed that self-management of exacerbations incorporated in a self-management programme leads to less exacerbation days and lower costs.[18]

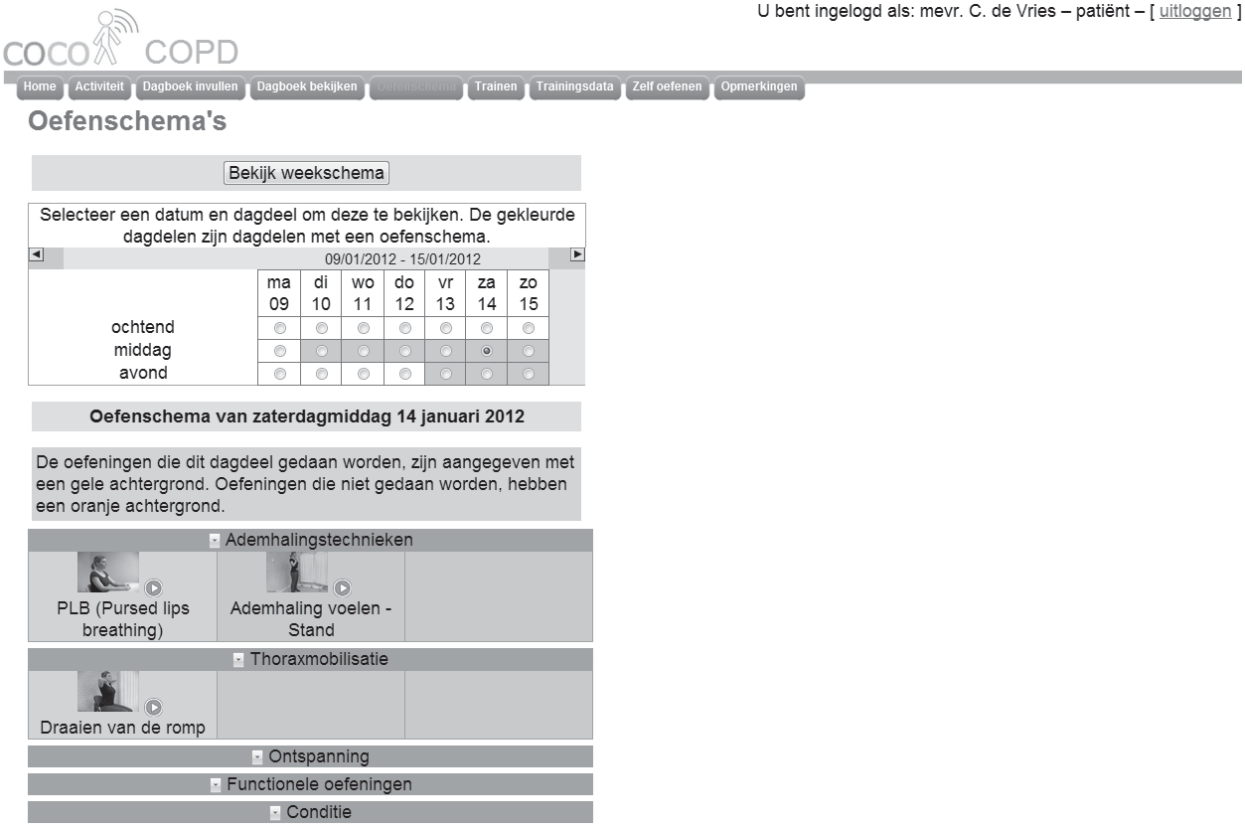
Online exercise programme

Increasing exercise tolerance is among the most important goals of COPD treatment and physical therapy is used to achieve that goal, sometimes as a part of lung rehabilitation. These rehabilitation programmes prove to be effective, but are labour-intensive and their beneficial effects often deteriorate quickly.[19] By transferring part of the physiotherapeutic exercises to the home environment, without constant supervision, the need for healthcare professionals can be lowered. Moreover, it would enable more disease self-management of COPD patients, which in turn can improve health status, reduce hospitalisations and improve health-related quality of life.[20]
Within the CoCo project, our web-based home exercise programme was developed to improve exercise capacity and muscle strength in patients with COPD. It is a clinical exercise protocol applied in a telemedicine setting by means of a web portal. The web portal contains an exercise book with a description and video of all training exercises. Based on the history of the patient and disease severity, the patient's physiotherapist composes a personal exercise programme from these exercises on the web portal. The patient will use the personal exercise programme as a guideline and compliance with the exercises is monitored. The physical therapist will bear the responsibility to determine training intensity for all exercises. In this manner we can guarantee an optimal training for each individual COPD patient.
This online exercise programme can be used as an addition to the rehabilitation or physiotherapeutic programme, or as partial replacement, thereby possibly reducing costs.

CoCo treatment programme

Previous studies already showed that exercise programmes at home can improve both short-term and long-term exercise tolerance.[21] Currently, we are investigating our web-based home exercise programme in the regular treatment of the local hospital (Medisch Spectrum Twente, Enschede) and associated physiotherapy practices. In this implementation research, the exercise programme

Figure 6: Online exercise programme on the web portal.



is extended to a complete programme called 'CoCo' (ConditionCoach). CoCo supports the treatment of COPD patients through active self-management and promotion of an active lifestyle. The healthcare professional can supervise from a distance.

The CoCo application is a technology-supported care service for self-management of COPD exacerbations and for promotion of an active lifestyle. The application consists of three modules: 1) activity monitoring and feedback, 2) online exercise programme (Figure 6) and 3) self-management of exacerbations by a triage diary. In addition, CoCo has a telemonitoring module for the patient and the involved professionals for monitoring the health status and progress of the patient, adjustment of the exercise programme, and where the patient can contact a healthcare professional.

To justify the implementation of the CoCo application in the regular treatment programme (on the long term) and to allow further scaling, evaluation of the deployment of the CoCo application is important. In a randomised controlled trial, we are currently investigating the use of the application, the application satisfaction, satisfaction of care and quality of care. The secondary aim of this study is to explore the clinical changes on the health status of the patient by the CoCo application in the regular treatment. Research showed that integrated care programmes with an interdisciplinary approach and emphasis on self-management maximise long-term patient outcome. [22,23] We therefore expect that the deployment of the application will have at least similar effects on the patient's health (compared to the regular treatment programme without using CoCo). The first results are expected late 2012.

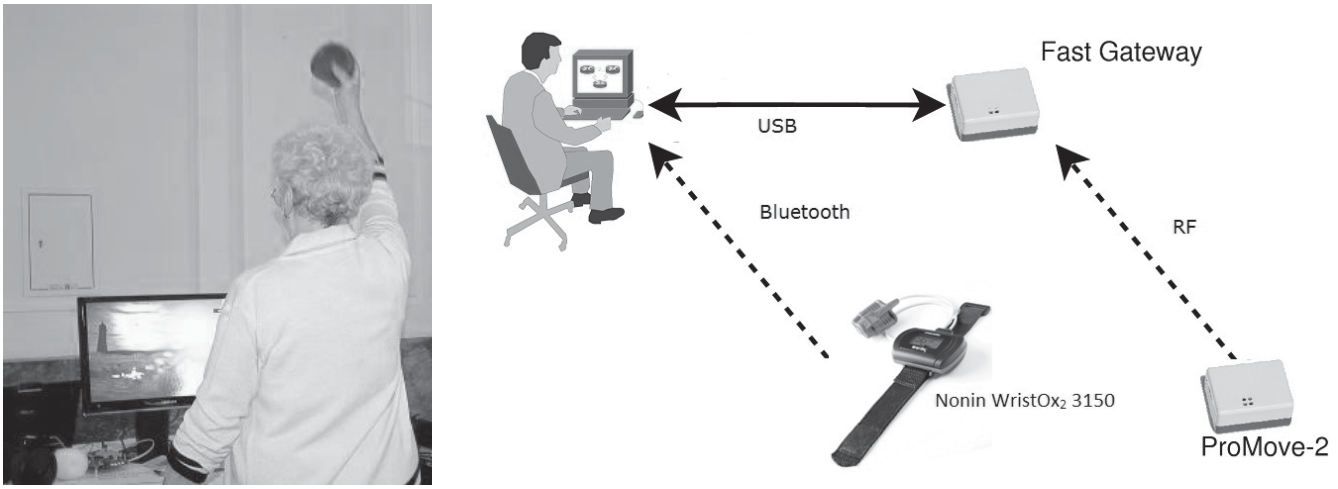
Serious gaming

Serious gaming, i.e. using games for other purposes than entertainment, is gradually finding its way to rehabilitation programmes. The advantage for games in rehabilitation is the fact that the game provides a variation or addition to the regular therapy, which can have a positive effect on motivation.

Within the IS-ACTIVE project (www.is-active.eu) the Orange Submarine game was developed. The game has one level, in which an orange submarine moves at a constant speed across an underwater landscape with hills at regular intervals. Air bubbles appear and continue to do so in a certain wave pattern. This pattern can be adapted to the exercise the patient has to perform. The goal of the game is to catch as many air bubbles by directing the submarine through them. The score is displayed in the upper right corner of the screen, together with pulse rate and oxygen saturation levels in real-time during game play. Thresholds for heart rate and saturation could be entered before game play and when the patient crosses these thresholds, the game stops and displays a warning message.

An accelerometer (ProMove-2 node, Inertia Technology) is used to control the orange submarine in the game. By moving the accelerometer up or down, the orange submarine moves in the corresponding direction. The node transmits data at 250 kbps through a 2.4 GHz wireless radio to the gateway, which in turn is connected through USB 2.0 to a computer. Oxygen saturation and heart rate are measured by the Nonin WristOx$_2$ 3150, which was worn around the wrist and connected to the computer through a secure wireless Bluetooth 2.0 connection. The accelerometer and pulseoximeter

Figure 7: Left: COPD patient performing exercise with the game, right: Schematic drawing of the pulse oximeter and the accelerometer connected to the computer.



are integrated in a dumbbell (see figure) for upper extremities exercises, or the node can be attached to the hip while the saturation is measured by a finger-clip sensor. The setup is shown schematically in Figure 7.
We tested the usability of the game with COPD patients, performing a squatting exercise, where the node was attached to the patient's hip. The game was positively received by the patients, and could provide a new fun way for performing physiotherapeutic exercises, either at home or as part of the regular treatment.

Conclusions

The telemedicine applications we designed aim to solve current issues in COPD care and support its disease management. This involves the increase of self-management of the patient by self-treatment of exacerbations, coaching in daily life to improve activity behaviour, and exercising by gaming or an online exercise programme. In order to gain more insight in the patients well being, activity behaviour and symptoms can be monitored, by sensors or a triage diary. To improve communication, this and other relevant medical data is shared between the involved care professionals and the patient.
The designed applications show positive results in patient outcome and are in general positively received by patients and professionals. We therefore believe that our systems are promising by making healthcare more qualitative, efficient, effective and less costly, which is important for patients, healthcare professionals and healthcare insurance companies. Further scaling of these technologies in everyday care would be an important next step.

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