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Long-term exercise maintenance in COPD via telerehabilitation: A 2-year pilot study

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Running head

Telerehabilitation in COPD supports long-term exercise maintenance.

Abstract

Introduction. Pulmonary rehabilitation (PR) is an integral part of the management of Chronic Obstructive Pulmonary Disease (COPD). However, many patients do not access or complete PR, and long-term exercise maintenance has been difficult to

achieve after PR. This study aimed to investigate feasibility, long-term exercise maintenance, clinical effects, quality of life and use of hospital resources of a telerehabilitation intervention.

Methods. Ten patients with COPD were offered a 2-year follow-up via telerehabilitation after attending PR. The intervention consisted in home exercise, telemonitoring and self-management via a webpage combined with weekly videoconferencing sessions. Equipment included a treadmill, a pulse oximeter and a tablet. Data collected at baseline, 1 year and 2 years were 6-minute walking distance (6MWD), COPD Assessment Test (CAT), EQ-5D, hospitalisations and outpatient visits.

Results. No dropout occurred. Physical performance, lung capacity, health status, and quality of life were all maintained at 2 years. At 1 year, 6MWD improved by a mean of 40 meters from baseline, CAT decreased by 4 points, and EQ VAS improved by 15.7 points.

Discussion. Long-term exercise maintenance in COPD via telerehabilitation is feasible. Results are encouraging and suggest that telerehabilitation can prevent deterioration, improve physical performance, health status and quality of life.

Introduction

Pulmonary rehabilitation (PR) is an evidence-based component of the disease management of chronic obstructive pulmonary disease (COPD) [**1-3**]. The main goal of PR is to improve the patient's conditions, both physically and psychologically, and to promote long-term adherence of health-enhancing behaviours [**4**]. PR improves dyspnoea, physical performance and quality of life in COPD [**4**]. However, benefits diminish over the succeeding 12 months without any maintenance strategy [**5**], and long-term exercise maintenance has been difficult to achieve after short-term treatment [**6**]. Supervised post-rehabilitation exercise programs appear to be effective in preserving exercise capacity in the medium term [**7**]. Nevertheless, the optimal maintenance intervention to sustain benefits of PR over the long term remains still unknown [**5**,**6,8**]. Regular exercise for patients with COPD is difficult for many reasons, including variation in day to-day condition, exacerbations, hospital admissions, transportation problems, lack of support and follow-up programs [**9**]. Developing new ways to maintain regular exercise, thus extending the effects of PR, is an important goal in COPD management.

Telemedicine has the potential to support disease management of COPD. Telerehabilitation refers to the use of information and communication technologies to provide rehabilitation services to people remotely in their homes or other environments [**10**]. The primary aim is to provide equitable access to rehabilitation [**11**]. This is especially important to people living in rural areas. In contrast to traditional centre-based PR programs, undertaking PR within the home environment may promote more effective integration of exercise routines into daily life over the longer term [**12**].

Evidence of the use of telemedicine in PR is still scarce [**4**]. A recent review showed that telemedicine may lead to increased physical activity level in patients with COPD, but no effect was found on exercise capacity or dyspnoea [**13**]. Other studies showed promising results for telerehabilitation in COPD in regards to feasibility, safety, exercise capacity, physical activity and health-related quality of life [**14-19**]. However, all interventions had a short-term duration. So far, no telerehabilitation intervention was conducted to support exercise maintenance and long-term effects.

We conducted a pilot study where a long-term telerehabilitation intervention for patients with COPD was offered over a 2-year period. The aim was to investigate feasibility, long-term exercise maintenance, clinical effects, quality of life and use of hospital resources.

Methods

Study design

A 2-year pilot study was conducted to test long-term exercise maintenance in COPD via telerehabilitation. The study was conducted by the Norwegian Centre for Integrated Care and Telemedicine (NST), University Hospital of North Norway (UNN) and the rehabilitation centre LHL-klinikkene Skibotn. Participants were 10 patients with moderate to severe COPD recruited after attending a 4-week inpatient PR. Their clinical status was therefore stable and their physical conditions optimised. Inclusion and exclusion criteria are described in detail in Table 1. The study was approved by the Regional Committee for Medical and Health Research Ethics.

Objectives

The primary objective was to determine whether long-term telerehabilitation in COPD was feasible and could promote exercise maintenance and self-management. Feasibility was assessed in terms of completion rate, measured as the number of completers divided by the number of participants. Completers were defined as those participants actively undertaking the study procedures until the end of the intervention, while dropouts where those who abandoned before [**21**]. Frequency of training sessions was calculated to measure how active patients were in maintaining exercise. Frequency of registrations of daily symptoms were used to assess maintenance of self-management routines. Other study objectives included impact on patients' physical performance, lung capacity, body weight status, health status, quality of life, and subjective impression of change (Table 2). All data were collected at baseline, 1 year and 2 years. The study also tested whether long-term telerehabilitation was associated with a change in healthcare resources utilisation. Data on hospitalisations and outpatient visits were collected from the Norwegian Patient Registry for the 2 years of follow-up and for the 2 years prior to enrolment.

The telerehabilitation intervention

Telerehabilitation was designed as a comprehensive intervention consisting in home exercise, telemonitoring and self-management. The service was offered as 2-year follow-up to patients with COPD. The 2-year duration was proposed since there have been almost no previous reports of studies lasting longer than 12 months. After attending a PR program, participants were supplied with equipment for home exercise and videoconferencing so that they could be supervised by a physiotherapist. Equipment

for home exercise consisted of a treadmill installed in the patients' homes. Folding treadmills were chosen since they are ideal for in-home use, where space is a concern, and are less expensive. Treadmills supported speed up to 16 km/h and incline up to 10%. A pulse oximeter (Nonin GO2 LED) was provided to monitor oxygen saturation at rest and while exercising. A tablet computer (Apple iPad 2) was used to perform weekly videoconferencing sessions with a physiotherapist and to access a web-based self-management platform. A tablet holder mounted on the treadmill allowed using safely the tablet while exercising (Figure 1). A mobile application for videoconferencing (LifeSize, ClearSea) could connect the participant's tablet to H.323 and SIP standards-based systems, desktop computers or mobile clients. Communication was performed with AES encryption. Videoconferencing was initiated from a rehabilitation centre and performed through the application running on the participant's tablet (Figure 2). Participants used the web-based platform to access an individual training programme, to fill in a daily diary and a training diary, and to access historical data. The information was also accessible to the physiotherapist and used for discussion with the patients.

Statistical analyses

Data from baseline (post PR), 1-year, and 2-year visits for all subjects were evaluated with descriptive statistics and analysis of variance (ANOVA) with repeated measures. Continuous variables are reported as mean ± standard deviation [min-max]. Categorical variables are reported as counts and percentages. Normality of distribution was tested by means of the Shapiro-Wilk test. Effects of the long-term telerehabilitation were evaluated with an ANOVA with repeated measures. A value of $P<0.05$ was considered

significant. Bonferroni post hoc test was used to discover which specific means differed in case the overall ANOVA result was significant. All statistical analyses were performed with IBM SPSS Statistics Version 22.

Study procedures

Participants were enrolled by a lung specialist and a trained physiotherapist during a baseline visit at the rehabilitation centre. A clinical assessment included conduction of spirometry and 6-minute walking test, measurement of bodyweight and height, and collection of the study questionnaires. After enrolment, the equipment was installed at the participant's home. A training session on the use of the equipment was performed. A test videoconferencing session between the participant and the physiotherapist at the rehabilitation centre was also conducted.

During the study participants were asked to fill in a daily electronic form for self-management of symptoms including: oxygen saturation (at rest); and the Breathlessness, Cough and Sputum Scale (BCSS) [**22**]. Each participant received an individual exercise program consisting of interval training on the treadmill, recommended three times a week. This was accessible from the web-based platform. Participants were also encouraged to perform strength training exercises consisting mainly of squats and calf raise (3 sets of 10 reps) and to do any physical activity on their own. Interval training consisted of 10-min warm-up, followed by three or four 3-4-min exercise bouts with a perceived exertion of 5-6 on the Borg CR10 scale [**23**], interposed by 2-3-min active recovery periods with a perceived exertion of 3-4. The training session ended with a 5-min cool-down. This gave a total exercise time ≥ 30 min [**4**]. The number and length of intervals were adjusted to the participant's condition.

Speed and/or incline of the treadmill were adjusted individually during the study to reach the desired perceived exertion. After each training session, participants were asked to fill in an electronic form including: programme completion (duration); perceived exertion; oxygen saturation (lowest value during exercise); and heart rate (highest value during exercise).

Participants had weekly individual videoconferencing sessions with the physiotherapist, who was able to supervise them remotely while exercising. The physiotherapist supported and educated the patients in health-enhancing behaviour, focusing on increasing their motivation for exercise training and other physical activities. Self-efficacy strategies were emphasized so that the patients could gain insight in their own health and skills to optimally manage their illness and everyday life.

Participants had follow-up visits at the rehabilitation centre after 1 year and 2 years. During these visits spirometry, 6MWD, bodyweight and height were measured and the same baseline questionnaires were collected. At study exit, the Patient Global Impression of Change (PGIC) questionnaire was also collected [**24**]. During the study, participants received standard care, with their General Practitioner as main contact, and attended the hospital for specialised care when needed.

Results

Study timelines and population

Ten participants were enrolled from January 2012 to May 2012. The baseline characteristics of the participants are shown in Table 3. Follow-up visits were held in June 2013 and May 2014.

Feasibility and exercise maintenance

On average, patients participated in the study for 740±26 days. All patients attended the baseline, 1-year and 2-year visits and data were collected at all time points. No dropout occurred during the study. The completion rate was therefore 100%. Patients experienced voluntarily and non-voluntarily relapses due to holidays, traveling, sickness or hospital admissions. However, all patients rejoined the program after each break. On average, patients registered 1.7 training sessions/week via the webpage during the 2-year intervention period. Frequency decreased from the first to the second year, but all the patients maintained exercise until the end of the study. Patients registered on average 3.0 daily measurements/week, thus maintaining also their self-management routines.

Clinical status

After 1 year, 6MWD improved by a mean of 40 meters compared to baseline (post-PR) (Table 4). This exceeded the minimal important difference (MID) in COPD, corresponding to 30 meters [**25**]. After 2 years, 6MWD decreased to a value in line with baseline, but still higher then the pre-PR measurement (464±108). Mean FEV_1 (% of pred.) increased after 1 year, while it declined during the second year. BMI showed a slight reduction over the 2 years. Mostly, patients who were overweight reduced their weight reaching a BMI closer to 25. A repeated measures ANOVA did not show any statistically significant difference between time points. Long-term telerehabilitation succeeded in maintaining clinical effects over a 2-year period.

Health status and quality of life

After 1 year, the total score for the CAT decreased by a mean of 4 points (Table 5). This exceeded the MID, estimated as 2 points [**26**]. After 2 years, the mean score was in line with baseline value. Patients experienced statistically significant changes between time points in breathlessness (F= 4.729, P=0.022) and energy (F= 4.534, P=0.025). The impact level of the CAT showed an increase of patients with a low-medium score (0-20) after 1 year, thus experiencing a lower burden of symptoms.

After 1 year, the utility score calculated from the EQ-5D and the EQ Visual Analogue Scale (EQ VAS) increased by 0.036 and 15.7 points, respectively. Both measures declined during the second year. A repeated measures ANOVA did not show any statistically significant difference between time points for the EQ-5D states, the EQ VAS or any of the five dimensions. Overall, patients perceived an improvement of symptoms and quality of life during the first year, while during the second year they experienced a decline with results in line with those at baseline.

The average score from the PGIC questionnaire was 5.5±1.2. Nine out of 10 patients expressed a change-score ≥5 which is considered a significant and favourable change of their conditions, including activity, limitations, symptoms, emotions and overall quality of life [**24**]. Only 1 patient reported a little improvement (score 3), but without a noticeable change. To note that this patient had an exacerbation while attending the 2-year visit.

Healthcare utilisation

Overall, healthcare utilisation during the 2 years of follow-up was reduced by 32% compared to the 2 years prior to enrolment. In specific, 11 COPD-related hospitalisations and 38 COPD-related outpatients visits occurred during the follow-up,

while 5 and 67 respectively occurred during the previous period. Only two patients had a history of hospitalisation during the previous 2 years. Patients were thus not characterized by a high risk for hospitalisation and readmission. Average hospital length-of-stay was 4.6 days before the intervention and 5.3 days during the follow-up.

Discussion

We conducted a pilot study where telerehabilitation was offered to patients with COPD for 2 years. This intervention is innovative and brings PR in the patient's home, thus allowing remote supervision at distance. To our knowledge, this is the first telerehabilitation intervention with such a long-term follow-up. Ten patients were recruited after attending a PR program and participated actively to the intervention, maintaining their exercise and self-management routines along the whole study duration. No dropout occurred. In other long-term studies in PR dropout rates ranged from 21% [**27**] to 41% [**28**]. Long-term telerehabilitation is a feasible intervention and represents an effective strategy for long-term exercise maintenance and self-management.

For people living in rural areas it can be difficult to participate in traditional centre-based PR programs. In Norway, PR is offered either as 6 to 8-week outpatient program or as 4-week inpatient program. Practical barriers include harsh weather conditions, long traveling distances, and lack of follow-up programs locally. Home-based programmes have the potential to overcome these barriers and improve access to PR in underserved areas [**16**]. Telerehabilitation can also increase access to PR in urban areas, where PR programs are limited. Telerehabilitation might represent an innovative

and efficient strategy to provide both short-term PR programs and long-term maintenance strategies. Any individual could potentially perform PR at home remotely supervised by health personnel.

In the absence of any maintenance strategy, benefits of PR appear to diminish after 6-12 months [**5,29**]. The reasons for this decline include decrease in adherence to therapy, especially long-term regular exercise, progression of underlying disease and comorbidities, and exacerbations [**30**]. The telerehabilitation intervention trialled in this study aimed to support patients with COPD in maintaining benefits of PR in a long term. Results showed that physical performance, lung capacity, health status, and quality of life were all maintained at 2 years after completion of PR. Moreover, 6MWD, FEV_1 and CAT score improved considerably at 1 year compared to baseline. Statistically significant improvements were detected at 1 year for breathlessness and energy levels, which may explain the increase in lung capacity and functional exercise capacity, respectively. Similarly, patients reported a higher quality of life after 1 year. Since this study did not have a control group, comparison of outcomes is possible only with similar populations from other studies with follow-up longer than 12 months. Figure 3 shows the results of the 6MWD for the patients undergoing long-term telerehabilitation compared to a control group of patients with moderate to severe COPD and similar baseline characteristics followed up for 2 years after PR [**6**]. While in Ries et al. there is an overall decline of 10% over the period, patients participating to telerehabilitation experienced only a 4% reduction from baseline.

To date, there is limited evidence of the use of telerehabilitation in COPD. In a recent review, telemedicine interventions were promoted through phone calls, websites or mobile phones, often combined with education and/or exercise training [**13**].

However, no study specifically delivered telerehabilitation. A few studies have shown promising results for short-term telerehabilitation in COPD [**14-19**], but none addressed long-term effects.

Other studies evaluated longer-term benefits of maintenance exercise programs for patients with COPD with limited results. A 12-month maintenance program of weekly telephone contacts plus monthly supervised reinforcement sessions for patients with moderate to severe COPD was only modestly successful in maintaining health outcomes after PR [**6**]. In another study, 6 months of daily rehabilitation followed by 6 months of weekly supervised maintenance showed improvements in exercise tolerance, dyspnoea, and quality of life compared with a control group of subjects with moderate to severe COPD, but benefits diminished over the second year of follow-up [**27**]. Weekly maintenance training for 12 months after PR in moderate to severe COPD improved walking time but had no influence on quality of life or hospital admissions, compared with unsupervised daily training at home [**31**]. In a 12-month follow-up study, both weekly, supervised, outpatient-based exercise plus unsupervised home exercise and standard care of unsupervised home exercise successfully maintained 6MWD and quality of life in subjects with moderate COPD [**32**]. Participation in regular walking after completing PR was associated with slower declines in quality of life and walking self-efficacy as well as less progression of dyspnoea for patients with moderate to severe COPD [**33**]. Despite some positive results, no study had succeeded in maintaining the benefits of PR for a period longer than 1 year. In our pilot study, all outcomes at 2 years were still in line with baseline values.

The optimal combination of maintenance interventions after completion of a PR program remains unknown [**3**]. Telemedicine may represent a cost-effective alternative

for the follow-up of patients with COPD. In stable, optimized COPD patients who completed PR, telemonitoring reduced primary care chest contacts [**34**]. We believe that long-term telerehabilitation is an innovative intervention which might also limit the use of hospital resources.

Limitations

This study primarily aimed to investigate the feasibility of telerehabilitation on long-term exercise maintenance in COPD. Due to the innovative nature of the intervention, the study did not have any control group. However, its findings are unique. A multicentre randomized controlled trial (RCT) is currently ongoing to test clinical and cost-effectiveness of this long-term telerehabilitation.

Most of the existing studies have focused on attendance to short-term PR programs [**35**], where participants are required to undertake at least 70% of planned sessions [**36**]. The challenges of long-term adherence to exercise in COPD are not addressed [**37**]. In absence of reliable published data, and due to the 2-year follow-up during which interruptions were expected, we did not have any a priori definition of completion rate. The average adherence rate for registrations of daily measurements and training sessions was 43% and 56%, respectively. These results appear to be in line with adherence to long-term therapy in chronic diseases, which averages to 50% [**38**].

Due to the small sample, one physiotherapist was responsible to supervise the ten participants during the 2-year period. Another physiotherapist was substitute during holiday, absence or sick leave. The high completion rate and exercise maintenance might have been influenced by the presence of one motivated physiotherapist. Use of telerehabilitation in real settings should take into account variations due to supervision

by different physiotherapists. Moreover, the study was conducted with voluntary participants willing to attend telerehabilitation. This might also have represented a selection bias and influenced positively the results.

Patients with COPD experience often repeated exacerbations which can lead to a worsening of the health condition and to hospital admissions [**39]**. Most expenditures for COPD are for hospitalisations and emergency department visits, which account for over 70% of healthcare costs [**40**]. Long-term telerehabilitation, thanks to the benefits maintained over time, has the potential to prevent exacerbations in COPD and limit healthcare utilisation, which is expected to increase along with disease progression. A systematic cost analysis taking into accounts differential costs and savings was out of the scope of this study. Moreover, the participants had a low risk for readmission. Equipment costs included NOK 12,000 per patient for the 2-year period for treadmill, pulse oximeter, tablet, and holder, plus NOK 2,000 per patient per year for videoconferencing. These were covered by project funding. The participants kept the equipment after the study end. Assuming a 4-year equipment life expectancy, and 2-hour monthly follow-up per patient, yearly costs per patient would be approximately NOK 5,500 and NOK 6,500 for equipment and physiotherapist's time, respectively. As a mean of comparison, the average cost of a COPD-related hospitalisation and a COPD-related outpatient visit was NOK 60,000 and NOK 2,000, respectively. We believe that telerehabilitation might represent a cost-effective strategy and a valuable supplement to PR programs and maintenance programs. This hypothesis has to be tested with a proper RCT comparing long-term telerehabilitation to usual care.

Conclusion

Long-term exercise maintenance in COPD via telerehabilitation is feasible and patients succeeded in maintaining exercise over 2 years. Deterioration in the disease is expected over time [**29,30**]. Results from this pilot study are encouraging and suggest that telerehabilitation can prevent deterioration, improve physical performance, health status, quality of life, and limit hospital accesses.

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

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Tables

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Moderate/severe diagnosis of COPD in accordance with the GOLD guidelines [**20**]	Unwillingness or inability to give informed consent
Completion of a rehabilitation programme during the previous 6 months	Presence of comorbidities or physical conditions which might interfere with home rehabilitation
Aged 40-75 years	Home environment not suitable for installation and use of training and monitoring equipment (e.g. space, Internet connection, family needs)
Resident in Northern Norway	
Norwegian-speaking	

Table 2. Study objectives.

Objectives	Measure
Feasibility	Completion rate
Exercise maintenance	Frequency of training sessions
Self-management maintenance	Frequency of daily registrations
Physical performance	6MWD
Lung capacity	FEV_1 (% of pred.)
Body weight status	BMI
Health status	CAT
Quality of life	EQ-5D
Subjective impression of overall change	PGIC
Healthcare utilisation	COPD-related hospitalisations and outpatient visits

Definition of abbreviations: 6MWD = 6-Minute Walking Distance; FEV1 (% of pred.) = Forced expiratory volume in 1 second percentage; BMI = Body Mass Index; CAT = COPD Assessment Test; EQ-5D = EuroQol 5 Dimensions; PGIC = Patient global impression of change scale.

Table 3. Patients' characteristics at baseline.

Demographics	Measure
Age, years	55.2 ± 6.1 [48-67]
Sex	
Males	5 (50%)
Females	5 (50%)
Patients on LTOT	3 (30%)
Distance from closest hospital, km	99 ± 76 [3-218]
Travel time to closest hospital, minutes	101 ± 69 [5-198]
Patients living alone	5 (50%)
Patients working	2 (20%)
Higher educational level	
Secondary school	1 (10%)
High school	7 (70%)
University / University College	2 (20%)
Internet use	
Never	1 (10%)
Every month	1 (10%)
Every week	5 (50%)
Every day	3 (30%)

Definition of abbreviations: LTOT = Long-Term Oxygen Therapy.

Table 4. Results from the clinical status.

Outcomes	**Baseline**	**1 year**	**2 years**
6MWD, m	493 ± 106	533 ± 124	473 ± 108
FEV_1, L (% of pred.)	49.1 ± 20.9	54.9 ± 28.8	45.2 ± 20.6
BMI, kg/m^2	27.9 ± 7.3	26.7 ± 5.5	26.4 ± 5.3

Definition of abbreviations: 6MWD = 6-Minute Walking Distance; FEV_1 (% of pred.) = Forced expiratory volume in 1 second percentage; BMI = Body Mass Index.

Table 5. Results from the health status and quality of life.

CAT	**Baseline**	**1 year**	**2 years**
Total Score	21.5 ± 6.3	17.7 ± 5.5	20.3 ± 6.7
Cough	2.2 ± 1.0	2.0 ± 0.8	2.2 ± 1.1
Mucus	2.8 ± 1.0	2.2 ± 1.1	2.1 ± 1.4
Chest tightening	2.4 ± 1.1	2.2 ± 1.2	2.1 ± 1.0
Breathlessness	3.6 ± 1.3	3.0 ± 1.1	3.5 ± 1.0 *
Daily activities	3.4 ± 1.3	3.0 ± 0.8	3.0 ± 1.2
Confidence	1.5 ± 1.2	1.5 ± 1.3	1.8 ± 1.4
Sleep	2.6 ± 1.5	1.7 ± 1.6	2.8 ± 2.0
Energy	3.0 ± 1.2	2.1 ± 1.1	2.8 ± 0.9 *
Impact level			
Low (CAT <10)	1 (10%)	1 (10%)	0 (0%)
Medium (CAT 10-20)	3 (30%)	5 (50%)	4 (40%)
High (CAT 21-30)	6 (60%)	4 (40%)	6 (60%)
Very high (CAT 31-40)	0 (0%)	0 (0%)	0 (0%)
EQ-5D	**Baseline**	**1 year**	**2 years**
Utility score	0.624 ± 0.218	0.660 ± 0.210	0.557 ± 0.211
Mobility	1.6 ± 0.5	1.5 ± 0.5	1.6 ± 0.5
Personal care	1.3 ± 0.5	1.1 ± 0.3	1.1 ± 0.3
Usual activities	1.8 ± 0.6	1.9 ± 0.6	2.0 ± 0.7
Pain/discomfort	1.7 ± 0.7	1.7 ± 0.7	1.9 ± 0.6
Anxiety/depression	1.6 ± 0.5	1.5 ± 0.5	1.7 ± 0.7
VAS	48.6 ± 21.9	64.2 ± 20.4	52.3 ± 23.9

Definition of abbreviations: CAT = COPD Assessment Test; EQ-5D = EuroQol 5 Dimensions; VAS = Visual Analogue Scale.
* $P<0.05$.

Figures

Figure 1. Home telemedicine unit, including treadmill, pulse oximeter, iPad and holder.

Figure 2. Videoconferencing between physiotherapist and patient.

Figure 3. 6MWD for patients undertaking telerehabilitation compared with a control population from Ries et al. [**6**].