eHealth to stimulate physical activity in patients with chronic obstructive pulmonary disease

ISBN: 978-90-393-6565-6
Foto omslag: Wim van der Spiegel
Ontwerp omslag: Jelske Schaap (Jelske@skami.nl)
Uitgeverij BOXPress || Proefschriftmaken.nl

eHealth to stimulate physical activity in patients with chronic obstructive pulmonary disease

eHealth ter stimulatie van fysieke activiteit bij patiënten met chronisch obstructief longlijden
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. G.J. van der Zwaan, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op donderdag 9 juni 2016 des middags te 12.45 uur

door

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Dit proefschrift werd mede mogelijk gemaakt met financiële steun van de Stichting Innovatie Alliantie (projectnummer 2010-11-12P) en de Hogeschool Utrecht (promotievoucher en steunfonds).

Contents

General Introduction

❖ Background

Chronic obstructive pulmonary disease (COPD), a common disease that is both preventable and treatable, is characterized by a persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory airway and lung response to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients. Major risk factors for COPD are tobacco smoking and air pollution (1).

According to estimates of the World Health Organization, 65 million people worldwide have moderate to severe COPD. More than 3 million people died of COPD in 2012, which represents 6% of global deaths that year. COPD is expected to rise from the fifth leading cause of death worldwide in 2002 to the third leading cause of death in 2030 (2). In the Netherlands, the number of patients is expected to rise from 335 000 in 2007 to 600 000 in 2032 (3). Annual disease-related health care costs are high (4,5) (e.g., $30 billion in the US in 2010 (6); € 415 million in the Netherlands in 2007 (3)) and have been increasing over the past decades (7,8); costs are expected to continue to rise, with a predicted three-fold rise in the Netherlands by 2032 (3). Estimates of indirect costs due to reduced workforce participation range from 27–61% of total costs (indirect and direct costs combined) (9). The disease also greatly influences the personal lives of patients. COPD significantly reduces quality of life in all of the following domains: physical health, psychological health, independence, social relationships, personal environment, and spirituality (10). For Dutch patients, physical and social health, along with coping with COPD, are the most relevant domains (11).

❖ Treatment

While COPD is preventable, it is not curable (2). Pharmacologic and non-pharmacologic treatment can help slow disease progression by reducing symptoms and the frequency and intensity of exacerbations, as well as by improving health status and exercise tolerance (1). Pharmacologic treatment for COPD consists of short- and long-acting bronchodilators that open the airways to ease breathing and corticosteroids and phosphodiesterase-4 inhibitors to reduce inflammation (12). Non-pharmacologic treatment consists of smoking cessation, vaccination, pulmonary rehabilitation (PR), and strategies to enhance physical activity (PA) (1). COPD is a complex chronic disease that patients need to learn to self-manage. Specific self-management programs exist to support this process.

Physical activity

PA is defined as “any bodily movement produced by skeletal muscles that results in increased energy expenditure” (13). Persons with COPD demonstrate reduced PA levels compared to healthy age-matched controls (14-18). Both the amount and the intensity of PA are reduced. Patients show less time walking and standing, lower movement intensity during walking, and more time sitting and lying down (19). **Chapter 1** will discuss in more detail the extent to which patients reduce their PA. It has been suggested that patients reduce their PA early in the course of their disease (20), which could be a result of dyspnea. Dyspnea is unpleasant, becomes worse during exercise due to increased breathing frequency, and can cause anxiety. Inactivity leads to deconditioning, which increases ventilatory requirements and leads to increased symptoms (e.g., fatigue, excess mucus); this in turn results in a further reduction of PA. As this process continues, patients get stuck in a downward spiral of deconditioning and inactivity (**figure 1**) (21-23).

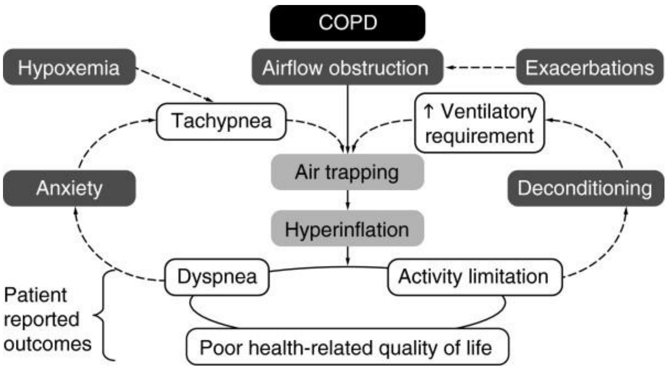

Figure 1. The downward spiral of symptoms and physical inactivity in COPD. Cooper. *American Journal of Medicine* 2006 **119**:10, 21-31 (23).

Physical inactivity worsens over time (24), has important clinical consequences and undoubtedly complicates the course of the disease (20,25). The cycle of dyspnea, deconditioning, and inactivity not only accelerates the progression of the disease but also puts patients at risk of developing or aggravating comorbidities (1,26,27). Prevalence of comorbidities and multimorbidities is high, with 79% of patients having at least one comorbidity (28). Comorbidities have been shown to further reduce the intensity and duration of PA (29,30).

In addition to dyspnea and comorbidities, personal factors also influence the PA level of patients with COPD. In the international classification of functioning, disability and health model (31) (**figure 2**), personal factors can influence one's health condition by influencing activity. The term activity in the ICF model is a broad term that refers to "the execution of a task or action by an individual". For the purpose of this thesis, we will narrow the definition of this term to PA. For patients with COPD, personal factors (for example self-efficacy and illness perception) can be barriers as well as enablers to PA. In **chapter 2** the thesis will look into patient-reported barriers and enablers to PA. In addition to personal factors that influence PA (motivation and patients' coping skills), environmental factors are also a major influence. For patients with COPD, indoor air quality is an example of an environmental factor (32). A further environmental factor is the knowledge and skills that physiotherapists can use to influence patients' PA.

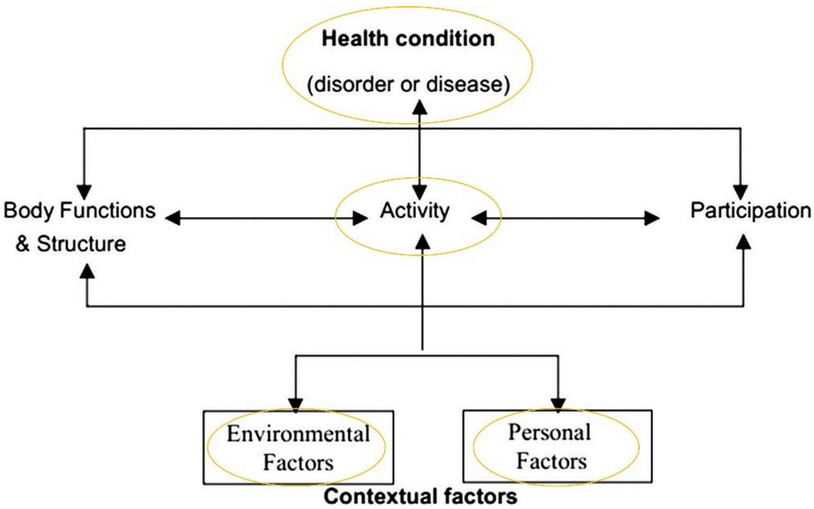

Figure 2. The international classification of functioning, disability and health (ICF) model. World Health Organization (31).

Regular PA reduces systemic inflammation and is positively correlated with muscle strength and mass (20,24), exercise tolerance (24), and health-related quality of life (25); it is also associated with lower mortality (26). This stresses the importance of increasing and/or maintaining PA in patients with COPD. According to the Dutch Lung Health Alliance, after diagnosis and assessment of the disease burden and demand for care, the standard of care for COPD includes monitoring as part of the treatment plan. However, this monitoring does not include a measure for PA (33).

Pulmonary rehabilitation

Pulmonary rehabilitation (PR) can be considered for patients with dyspnea or other respiratory symptoms, reduced exercise tolerance, those who are inactive as a result of their COPD, and those who have impaired health status. PR generally includes exercise training, education, psychosocial and behavioural interventions, nutritional therapy and outcome assessment (34). PR is known to improve exercise capacity (35-37,39). The longer the PR or exercise program, the greater the effect on exercise capacity. Improvements are shown in programs with durations of up to 18 months (37,38). However, most PR programs last for 8 to 12 weeks (39) and lack structured aftercare programs (25). However, these exercise tolerance benefits decline to pre-rehabilitation values (36,40-42) 1-2 years after patients discontinue exercise following the program (43). The acute effect of PR on PA is less consistent (20,36,44); the maintenance of any positive effect is poorly studied, but it seems to fade out rather quickly (36,45,46). The relationship between PA and exercise capacity is moderate to weak, which shows that PR and other exercise interventions should not only focus on exercise capacity but also on improving PA (47). More importantly, long-term maintenance of PA should be emphasized, as this will likely slow disease progression.

Behaviour change and self-management

It is important to note that exercise capacity is a functional status where PA is for a large part a behaviour (48). To increase PA in patients with COPD, one should focus on inducing behaviour change. Simply advising patients to increase their PA without specific assistance and follow-up seems to be ineffective in patientw with COPD (49). Self-management programs have the potential to support (PA) behaviour change in patients. Interventions should include self-monitoring and should attempt to increase patients’ self-efficacy and self-regulatory skills (49). Self-management interventions should help patients acquire and practice the skills needed to undertake disease-specific medical regimens, to guide changes in health behaviour and to provide emotional support.

Self-management interventions for people with COPD have shown large variances in effect size (50), and evidence of their value remains insufficient (51). The large heterogeneity of the trials makes it difficult to understand these effects. Furthermore, although overall patient groups seem to benefit from self-management interventions, some patients do not experience any positive effect. Some patients might benefit from self-management interventions with little assistance, while others require more intense support or even regular face-to-face contact. Individually tailored interventions seem more promising

(52,53). Self-management of COPD should not be seen as a replacement of regular care such as PR, but rather as an additional part of the therapy plan (54).

Changing PA behaviour and maintaining this behavioural change is a complex process (54), especially in patients with COPD where low motivation, rather than physical restrictions, seems to result in reduced PA (55). As the disease progresses, patients' health and activity level declines. This triggers a process of mourning, which starts with denial and is followed by resistance, sadness and eventual acceptance. This mourning process has a negative effect on the patient's motivation to change behaviour. In the phase of denial, the problem is not acknowledged; during resistance, patients want everything to return to normal; and during sadness, patients are mostly passive. A possible solution to increase motivation is to create a discrepancy between where the patient is and where the patient wants to be (56). For PA behaviour, this could mean providing insight into a patient's current PA level and comparing it to a PA level that would represent his or her healthy lifestyle.

While it is the patient who needs to change their behaviour, a health care professional (HCP) can help to reduce the discrepancy between present and desired behaviour (56). Here, innovative technology can also play a role (52,54-56). In 2009, Langer et al. (49) called for more research on interventions that initiate and maintain PA behaviour change in COPD patients with the use of objective measurements enabled by emerging technologies.

❖ eHealth

Definition

"eHealth is an emerging field of medical informatics, referring to the organization and delivery of health services and information using the internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a new way of working, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology" (57). While this is the most recent definition of eHealth, the discussion on what exactly constitutes eHealth remains ongoing (58). With respect to the ICF model (**figure 2**), eHealth has been described as an environmental factor, similar to indoor air quality (59).

mHealth

Mobile health (mHealth) has emerged as a special form of eHealth. This term refers to the delivery of healthcare services via mobile communication devices (such as mobile phones and tablet computers) (60). mHealth is an interdisciplinary field with various disciplines such as health care professionals (HCPs), biomedical engineers, and information technology specialists working together to support applications used by patients (61).

Hardware/sensors (such as a spirometer accessory) can be attached to a mobile communication device, and a health application subsequently displays and analyses the data. Internal sensors (such as accelerometers embedded in smartphones) can also be used to obtain data. The following five types of mHealth applications have been distinguished: those providing access to health records; consumer versions of existing medical devices; those for monitoring and management of a condition; fitness trackers and wellness coaches; and those related to diagnosis or treatment (62). The range of mHealth applications and their capabilities is rapidly evolving.

Information gathered by mHealth applications can be used by the consumer alone or together with an HCP. While health data have historically been in the hands of HCPs, recent mHealth applications provide this information directly to the consumer (i.e., the patient) (63). mHealth is often combined with eHealth; a mobile device that collects data and present them on the device, and a website that can use the data for monitoring or detection. It is noteworthy that this rapidly evolving field has many possible legal and practical stumbling blocks. Issues around qualification as a medical device, data protection, privacy, and 'medical' responsibility are important and need to be addressed with proper legislation and practical implementation. It is therefore important to realize that the present work focuses on the use of a 'lifestyle' intervention for patients with COPD rather than a 'medical' intervention.

Potential benefits and limitations

eHealth is a relatively new area in health care. The Dutch College of General Practitioners is positive about the potential of eHealth to optimize care but also pleads for a critical stance due to its lack of evidence (64).

Potential benefits

Older members of the community are the largest portion of healthcare consumers in the developed world. Worldwide, this group will increase dramatically between 2000 and 2050 (65). Among the EU population, 40% will be over age 65, and 11% will be over age 80 by 2050. Along the same trend, the number of people living with COPD, who are generally older adults, is increasing (66). However, there will be relatively fewer health and social care professionals available to provide the required amount and levels of services. eHealth could help to address this problem (67), as it has the potential to improve delivery and access to care, increase work efficiency, and help older adults remain in their community while they age (age-in-place) (68). eHealth can also facilitate disease diagnosis and improve treatment while reducing costs at the same time (63). This is possible because it reduces travel time to a centralized health care facility (by the patient) or to a patient's home (by the HCP), reduces time used to measure and analyse health data, and helps the HCP to attend to more patients in the same time period and specifically target those most in need. Patients may be more involved in their own health care and may be more prone to taking responsibility and improving their adherence to medical regimens. The ideal result would be a patient, who with the use of eHealth, is more compliant, self-regulating, and better informed (62). Furthermore, continuous monitoring can provide peace of mind to patients and their families because they know that an HCP will intervene in the case of health deterioration (61).

eHealth interventions for older adults have been shown to have a positive impact on the clinical process, patient health, productivity, efficiency and costs, clinician and patient satisfaction, and patient empowerment (69). When using eHealth interventions, self-efficacy for managing their disease(s) improves, and older adults benefit from receiving feedback and social support through communication with HCPs (70). Behavioural endpoints (e.g., adherence to medication, diet, or PA) appear to be most positively influenced (compared to medical and economic outcomes, and quality of life) (71).

For patients suffering from COPD, eHealth seems to improve the self-management of their health condition, which results in a feeling of satisfaction and empowerment (72). Generally, they find the technology useful and easy to learn and use (73). It is important to note that this is largely influenced by well-designed training (69,73).

Potential limitations

eHealth technologies are developing quickly, and researchers have difficulty keeping up due to the long duration of current study methodologies, which leads to scarce evidence of their usability and efficacy. Furthermore, there are concerns about data privacy, which stem from uncertainty about the technology's reliability and security (61,63). Concerns regarding the use of eHealth in daily practice consist of financing hurdles and competencies HCPs need to properly use the interventions. These include competencies and skills related to the profession as well as technology-specific competencies (74).

The enormous amount of data gathered by eHealth applications is an opportunity as well as an obstacle. These data are not useful until they are translated into actionable information.

The current challenge is to provide safe, high-quality and evidence-based health recommendations (63) while keeping costs at an acceptable level.

Questions have been raised about the role of the HCP in relation to eHealth, such as whether it is safe to reduce HCP contact and whether it will challenge HCP authority. In particular, inaccurate or misleading information could induce problems in the patient-HCP relationship (63). Data are less useful outside of the patient's context and without the expertise required for correct interpretation, which is why the HCP should participate in eHealth interventions (62).

An important issue concerning eHealth self-management interventions for older adults is how to engage them in these interventions (75). For successful implementation, education and training of all users (patients and HCPs) is crucial. Users should receive rapid support with technical issues and be given quick feedback about health-related incidents. Understanding disease-specific factors to elucidate how various populations may benefit from eHealth is important for increasing their efficacy (70).

Difficulties reported by COPD patients with the use of eHealth include physical restrictions that reduce usability of the technology. Small displays, buttons and font sizes are difficult for patients with sight and fine motor control problems. Technology that is easy to learn and use is important for the successful use of eHealth in this patient group (72,73). Because patients with COPD are more prone to have low socioeconomic status (76), this might raise concerns about their exclusion from eHealth interventions due to costly technology. However, mobile phones are widely used across levels of socioeconomic status, and their use is actually higher among groups most in need of health interventions (63). Furthermore, compared to previous generations, an increasing number of aging adults will be articulate and familiar with information and communication technologies (ICT) (77,78). In 2013, 85% of older adults in the Netherlands had access to the internet compared to 41% in 2005 (79), which could be beneficial for the adoption of eHealth. **Chapter 3** will look into the use of ICT devices and services by older adults and attempt to assess whether demographic variables and health status are predictors of ICT use.

eHealth for physical activity promotion

eHealth could help to support the self-management of PA for people suffering from COPD. Several eHealth interventions for PA engagement in patients with COPD have been described. They are available in various forms, such as wearable sensors (80), television applications (81), computer applications (82) manual input devices (83), and smartphones (84,85). Patients with COPD have problems recalling their PA (86,87), which underscores the importance of objective measurement in this population. Measuring PA objectively and returning it to the patient as biofeedback can work as a stimulus. Providing patients with adequate goal setting is also a powerful tool with which to alter behaviour. This method showed promising results in improving walking and quality of life (88,89). Limited ongoing support can be a barrier to exercise persistence (90). A physiotherapist who monitors and stimulates the patient's PA could help in this regard. Furthermore, monitoring variations in PA patterns might help in the early detection of exacerbations, as this generally reduces PA (86,91). **Chapter 4** describes the development of an eHealth intervention that aims to improve and/or maintain PA in patients with COPD through the benefit of real-time PA biofeedback, goal setting, and motivational support from their PT. This eHealth intervention was subsequently tested for efficacy in a randomized controlled trial (RCT). The results of this trial are described in **chapter 5.** After trial completion, subjects in the intervention group and PTs who participated in the trial were questioned about their experience with respect to the intervention and using the website (PTs) and how they valued the eHealth application on the smartphone (patients and PTs). These results are described in **chapter 6**.

❖ Aim and outline of the thesis

The overall aim of the thesis was to investigate how to improve and/or maintain physical activity in patients with COPD after pulmonary rehabilitation with the use of an eHealth intervention.

The first three chapters of the thesis aimed to gather more information with respect to PA and the use of ICT in patients with COPD (who are generally older adults). It is important to know to what extent the disease impacts PA, how patients themselves view their problems with maintaining a healthy PA level, and because we are examining an eHealth intervention, the extent of their experience with technology and whether this is affected by demographics and health status. The differences in objectively measured PA between patients and their healthy age-matched controls will be discussed in more detail in **chapter 1**. This chapter describes the extent of the impact that COPD has on the amount, duration, and intensity of PA and whether the severity of the disease is related to the level of PA. In **chapter 2**, the patient-reported barriers and enablers to PA are studied. This chapter aims to identify how patients with COPD view their daily PA engagement and how they feel it is influenced by their health status, healthcare providers, personal factors, medication and other factors. The thesis continues in **chapter 3** with a study that looks generally at older adults and their ICT use. Successful implementation of ICT among older adults is largely dependent on a thorough understanding of the factors that lead them to use or not use technologies. This chapter aims to determine the degree to which ICT devices and services are adopted and whether demographic factors and health status are predictors of ICT use in older Dutch adults.

Subsequently, the thesis continues in **chapter 4** with the description of the development of an eHealth intervention that can be used to maintain or improve PA. Assessment of an adequate ICT instrument is described followed by feasibility testing of successive prototypes of the intervention in three pilot studies.

The last two chapters concern the evaluation of the intervention. **Chapter 5** describes the results of a randomized controlled trial (RCT) that studies the efficacy of the developed eHealth intervention. The primary aim of the RCT was to study whether this intervention enhances and/or maintains PA after discharge from a PR program compared to usual care in patients with COPD. The secondary aim was to determine whether this improvement affects exercise capacity, health-related quality of life, and body mass index. Finally, in **chapter 6**, the thesis ends with a qualitative analysis of the experiences from the end-users of the eHealth intervention. These are the COPD patients who were randomized in the intervention group of the RCT and the physiotherapists who participated in the trial. This study aims to reveal personal factors from the patients' perspectives, as well as additional environmental factors from the experiences of the PTs (see ICF model, **figure 2**).

❖ References

(1) Global Initiative for Chronic Obstructive Lung Disease (GOLD). *Global Strategy for the Diagnosis, Management and Prevention of COPD.* Available from: http://www.goldcopd.org/. 2015.

(2) World Health Organization. Chronic obstructive pulmonary disease (COPD). 2015; Available at: http://www.who.int/topics/chronic_obstructive_pulmonary_disease/en/ (Archived by WebCite® at http://www.webcitation.org/6a2MSVKm1). Accessed 7/15, 2015.

(3) Suijkerbuijk AWM, De Wit GA, Wijga AH, Heijmans MJWM, Hoogendoorn M, Rutten-Van Mölken MPMH, et al. Societal costs of asthma, COPD and respiratory allergy. Ned Tijdschr Geneeskd 2013;157(50).

(4) Nielsen R, Johannessen A, Benediktsdottir B, Gislason T, Buist AS, Gulsvik A, et al. Present and future costs of COPD in Iceland and Norway: results from the BOLD study. The European respiratory journal 2009 04/08;34(4):850-857.

(5) Lökke A, Hilberg O, Tönnesen P, Ibsen R, Kjellberg J, Jennum P. Direct and indirect economic and health consequences of COPD in Denmark: a national register-based study: 1998ΓÇô2010. BMJ Open 2013 11/29;4(1):e004069.

(6) Guarascio AJ, Ray SM, Finch CK, Self TH. The clinical and economic burden of chronic obstructive pulmonary disease in the USA. ClinicoEconomics and Outcomes Research: CEOR 2013 06/17;5:235-245.

(7) Dalal AA, Liu F, Riedel AA. Cost trends among commercially insured and Medicare Advantage-insured patients with chronic obstructive pulmonary disease: 2006 through 2009. International Journal of Chronic Obstructive Pulmonary Disease 2011 10/14;6:533-542.

(8) Blanchette CM, Gross NJ, Altman P. Rising Costs of COPD and the Potential for Maintenance Therapy to Slow the Trend. Am Health Drug Benefits 2014 Apr;7(2):98-106.

(9) Patel JG, Nagar SP, Dalal AA. Indirect costs in chronic obstructive pulmonary disease: A review of the economic burden on employers and individuals in the United States. International Journal of COPD 2014;9:289-300.

(10) Tothova V, Bartlova S, Dolak F, Kaas J, Kimmer D, Manhalova J, et al. Quality of life in patients with chronic diseases. Neuro Endocrinol Lett 2014;35 Suppl 1:11-18.

(11) Paap MC, Bode C, Lenferink LI, Groen LC, Terwee CB, Ahmed S, et al. Identifying key domains of health-related quality of life for patients with chronic obstructive pulmonary disease: the patient perspective. Health Qual Life Outcomes 2014 Jul 9;12:106-014-0106-3.

(12) Kinman T, Spriggs B. COPD Drugs and Medications. 2014; Available at: http://www.healthline.com/health/copd/drugs#Overview1. Accessed: 2015-07-17. (Archived by WebCite® at http://www.webcitation.org/6a5Pn1Y7p). Accessed 07/17, 2015.

(13) Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985 Mar;100(2):126-131.

(14) Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. Respir Res 2011 Mar 22;12:33.

(15) Tudorache V, Oancea C, Avram C, Fira-Mladinescu O. Changes in physical activity in healthy people and COPD patients. Wien Klin Wochenschr 2014;126(1-2):30-35.

(16) Mador MJ, Patel AN, Nadler J. Effects of pulmonary rehabilitation on activity levels in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil Prev 2011 Jan-Feb;31(1):52-59.

(17) Arne M, Janson C, Janson S, Boman G, Lindqvist U, Berne C, et al. Physical activity and quality of life in subjects with chronic disease: chronic obstructive pulmonary disease compared with rheumatoid arthritis and diabetes mellitus. Scand J Prim Health Care 2009;27(3):141-147.

(18) Amorim PB, Stelmach R, Carvalho CRF, Fernandes FLA, Carvalho-Pinto RM, Cukier A. Barriers associated with reduced physical activity in COPD patients. Jornal Brasileiro de Pneumologia 2014;40(5):504-512.

(19) Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005 05/01;171(1073-449; 9):972-977.

(20) Watz H, Pitta F, Rochester CL, Garcia-Aymerich J, ZuWallack R, Troosters T, et al. An official European respiratory society statement on physical activity in COPD. European Respiratory Journal 2014;44(6):1521-1537.

(21) Polkey MI, Moxham J. Attacking the disease spiral in chronic obstructive pulmonary disease: an update. Clin Med 2011 Oct;11(5):461-464.

(22) Troosters T, van dM, Polkey M, Rabinovich RA, Vogiatzis I, Weisman I, et al. Improving physical activity in COPD: towards a new paradigm. Respiratory Research 2013 08/22;14(1):115-115.

(23) Cooper CB. The Connection Between Chronic Obstructive Pulmonary Disease Symptoms and Hyperinflation and Its Impact on Exercise and Function. Am J Med 2006;119(10 SUPPL.):21-31.

(24) Waschki B, Kirsten AM, Holz O, Mueller KC, Schaper M, Sack AL, et al. Disease Progression and Changes in Physical Activity in Patients with Chronic Obstructive Pulmonary Disease. Am J Respir Crit Care Med 2015 Aug 1;192(3):295-306.

(25) Hartman JE, Boezen HM, de Greef MH, Bossenbroek L, ten Hacken NH. Consequences of physical inactivity in chronic obstructive pulmonary disease. Expert Rev Respir Med 2010 Dec;4(6):735-745.

(26) Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H. Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. Am J Respir Crit Care Med 2008 04/01;177(7):743-751.

(27) Decramer M, Rennard S, Troosters T, Mapel DW, Giardino N, Mannino D, et al. COPD as a lung disease with systemic consequences--clinical impact, mechanisms, and potential for early intervention. COPD 2008 Aug;5(4):235-256.

(28) Dal Negro RW, Bonadiman L, Turco P. Prevalence of different comorbidities in COPD patients by gender and GOLD stage. Multidiscip Respir Med 2015 Aug 5;10(1):24-015-0023-2. eCollection 2015.

(29) Monteiro F, Camillo CA, Vitorasso R, Sant'Anna T, Hernandes NA, Probst VS, et al. Obesity and physical activity in the daily life of patients with COPD. Lung 2012;190(4):403-410.

(30) McNamara RJ, McKeough ZJ, McKenzie DK, Alison JA. Physical comorbidities affect physical activity in chronic obstructive pulmonary disease: a prospective cohort study. Respirology 2014 Aug;19(6):866-872.

(31) World Health Organization. Towards a Common Language for Functioning, Disability and Health, ICF, International Classification of Functioning Disability and Health. 2002; Available at: http://www.who.int/classifications/icf/. (Archived by WebCite® at http://www.webcitation.org/6dLxlpiVp). Accessed 11/27, 2015.

(32) M. C. L. Snijders. Indoor air quality and physical independence; an innovative view on healthy dwellings for individuals with chronic lung disease; 2001.

(33) Long Alliantie Nederland. Zorgstandaard COPD. 2013; Available at: http://www.longalliantie.nl/files/5113/7994/2952/LAN_Zorgstandaard_COPD-2013-juni.pdf. Accessed: 2015-11-10. (Archived by WebCite® at http://www.webcitation.org/6cwDx0s4d). Accessed 11/10, 2015.

(34) American Thoracic Society. Components of Pulmonary Rehabilitation. 2015; Available at: http://www.thoracic.org/copd-guidelines/for-health-professionals/management-of-stable-copd/pulmonary-rehabilitation/components-of-pulmonary-rehabilitation.php. Accessed: 2015-07-17. (Archived by WebCite® at http://www.webcitation.org/6a5ZWqBep). Accessed 07/17, 2015.

(35) Vestbo J, Hurd SS, Agusti AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med 2013 Feb 15;187(4):347-365.

(36) Egan C, Deering BM, Blake C, Fullen BM, McCormack NM, Spruit MA, et al. Short term and long term effects of pulmonary rehabilitation on physical activity in COPD. Respir Med 2012 Dec;106(12):1671-1679.

(37) Verrill D, Barton C, Beasley W, Lippard WM. The effects of short-term and long-term pulmonary rehabilitation on functional capacity, perceived dyspnea, and quality of life. Chest 2005 Aug;128(2):673-683.

(38) Berry MJ, Rejeski WJ, Adair NE, Ettinger WH,Jr, Zaccaro DJ, Sevick MA. A randomized, controlled trial comparing long-term and short-term exercise in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil 2003 Jan-Feb;23(1):60-68.

(39) Longfonds. longrevalidatie. Available at: https://www.longfonds.nl/copd/behandeling-van-copd/longrevalidatie. Accessed 3/31, 2015.

(40) Foglio K, Bianchi L, Bruletti G, Battista L, Pagani M, Ambrosino N. Long-term effectiveness of pulmonary rehabilitation in patients with chronic airway obstruction. Eur Respir J 1999 Jan;13(1):125-132.

(41) Heppner PS, Morgan C, Kaplan RM, Ries AL. Regular walking and long-term maintenance of outcomes after pulmonary rehabilitation. J Cardiopulm Rehabil 2006 01;26(1):44-53.

(42) Strijbos JH, Postma DS, van Altena R, Gimeno F, Koeter GH. A comparison between an outpatient hospital-based pulmonary rehabilitation program and a home-care pulmonary rehabilitation program in patients with COPD. A follow-up of 18 months. Chest 1996 Feb;109(2):366-372.

(43) Gross NJ. Extrapulmonary effects of chronic obstructive pulmonary disease. Curr Opin Pulm Med 2001 Mar;7(2):84-92.

(44) Spruit MA, Singh SJ, Garvey C, ZuWallack R, Nici L, Rochester C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. Am J Respir Crit Care Med 2013 Oct 15;188(8):e13-64.

(45) Dyer CA, Harris ND, Jenkin E, Langley-Johnson C, Lewis R, Taylor GJ, et al. Activity levels after pulmonary rehabilitation - what really happens? Physiotherapy 2013 Sep;99(3):228-232.

(46) Cruz J, Brooks D, Marques A. Impact of feedback on physical activity levels of individuals with chronic obstructive pulmonary disease during pulmonary rehabilitation: A feasibility study. Chron Respir Dis 2014 Nov;11(4):191-198.

(47) Zwerink M, Van Der Palen J, Van Der Valk P, Brusse-Keizer M, Effing T. Relationship between daily physical activity and exercise capacity in patients with COPD. Respir Med 2013;107(2):242-248.

(48) Garcia-Aymerich J, Pitta F. Promoting regular physical activity in pulmonary rehabilitation. Clin Chest Med 2014 Jun;35(2):363-368.

(49) Langer D, Hendriks E, Burtin C, Probst V, van der Schans C, Paterson W, et al. A clinical practice guideline for physiotherapists treating patients with chronic obstructive pulmonary disease based on a systematic review of available evidence. Clin Rehabil 2009 May;23(5):445-462.

(50) Zwerink M, Brusse-Keizer M, van der Valk PD, Zielhuis GA, Monninkhof EM, van der Palen J, et al. Self management for patients with chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2014 Mar 19;3:CD002990.

(51) Effing T, Monninkhof EM, van d,V, van der PJ, van Herwaarden CL, Partidge MR, et al. Self-management education for patients with chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2007(1469-493; 4):CD002990.

(52) Trappenburg J, Jonkman N, Jaarsma T, van Os-Medendorp H, Kort H, de Wit N, et al. Self-management: One size does not fit all. Patient Educ Couns 2013 7;92(1):134-137.

(53) Jonkman NH, Westland H, Trappenburg JC, Groenwold RH, Effing-Tijdhof TW, Troosters T, et al. Towards tailoring of self-management for patients with chronic heart failure or chronic obstructive pulmonary disease: a protocol for an individual patient data meta-analysis. BMJ Open 2014 May 23;4(5):e005220-2014-005220.

(54) Bourbeau J. The role of collaborative self-management in pulmonary rehabilitation. Semin Respir Crit Care Med 2009 Dec;30(6):700-707.

(55) Polkey MI, Rabe KF. Chicken or egg: physical activity in COPD revisited. Eur Respir J 2009 Feb;33(2):227-229.

(56) Vercoulen JH. A simple method to enable patient-tailored treatment and to motivate the patient to change behaviour. Chron Respir Dis 2012;9(4):259-268.

(57) Pagliari C, Sloan D, Gregor P, Sullivan F, Detmer D, Kahan JP, et al. What is eHealth (4): a scoping exercise to map the field. J Med Internet Res 2005 Mar 31;7(1):e9.

(58) Boogerd EA, Arts T, Engelen LJ, van de Belt TH. "What Is eHealth": Time for An Update? JMIR Res Protoc 2015 Mar 12;4(1):e29.

(59) Kort HSM. Intreerede: Bouwen voor zorg en gezondheid, Technische Universiteit Eindhoven. Eindhoven; 2012.

(60) Torgan C. The mHealth Summit: Local & Global Converge 2009; Available at: http://caroltorgan.com/mhealth-summit/ (Archived by WebCite® at http://www.webcitation.org/6cypxOtmi). Accessed 11/12, 2015.

(61) Olla P, Shimskey C. mHealth taxonomy: a literature survey of mobile health applications. Health and Technology 2015;4(4):299-308.

(62) Terry NP. Mobile health: Assessing the barriers. Chest 2015;147(5):1429-1434.

(63) Carrera PM, Dalton ARH. Do-it-yourself Healthcare: The current landscape, prospects and consequences. Maturitas 2014;77(1):37-40.

(64) The Dutch college of general practitioners. NHG-Standpunt: e-health voor huisarts en patiënt. 2015; Available at: https://www.nhg.org/nhg-e-health. (Archived by WebCite® at http://www.webcitation.org/6d4weQihR). Accessed 11/16, 2015.

(65) World Health Organisation. World Health Day 2012. Ageing and health. Toolkit for event organizers. 2012; Available at: www.who.int/world-health-day/2012 Accessed: 2015-05-08. (Archived by WebCite® at http://www.webcitation.org/6YMy8pkLl). Accessed 8/29, 2014.

(66) World Health Organisation. World health statistics. 2007.

(67) Layzell B, Manning B, Benton S. The elderly demographic time bomb - sharing the load with the active ageing: can eHealth technologies help defuse it? Stud Health Technol Inform 2009;146:166-170.

(68) Kobb R, Chumbler NR, Brennan DM, Rabinowitz T. Home telehealth: mainstreaming what we do well. Telemed J E Health 2008 Nov;14(9):977-981.

(69) Vedel I, Akhlaghpour S, Vaghefi I, Bergman H, Lapointe L. Health information technologies in geriatrics and gerontology: a mixed systematic review. J Am Med Inform Assoc 2013 Nov-Dec;20(6):1109-1119.

(70) Stellefson M, Chaney B, Barry AE, Chavarria E, Tennant B, Walsh-Childers K, et al. Web 2.0 chronic disease self-management for older adults: a systematic review. J Med Internet Res 2013 Feb 14;15(2):e35.

(71) van den Berg N, Schumann M, Kraft K, Hoffmann W. Telemedicine and telecare for older patients--a systematic review. Maturitas 2012 Oct;73(2):94-114.

(72) Goldstein RS, O'Hoski S. Telemedicine in COPD: time to pause. Chest 2014 May;145(5):945-949.

(73) Cruz J, Brooks D, Marques A. Home telemonitoring in COPD: a systematic review of methodologies and patients' adherence. Int J Med Inform 2014 Apr;83(4):249-263.

(74) Barakat A, Woolrych RD, Sixsmith A, Kearns WD, Kort HSM. eHealth Technology Competencies for Health Professionals Working in Home Care to Support Older Adults to Age in Place: Outcomes of a Two-Day Collaborative Workshop. Medicine 2.0 2013 07/18;2(2):e10.

(75) Arif MJ, El Emary IM, Koutsouris DD. A review on the technologies and services used in the self-management of health and independent living of elderly. Technol Health Care 2014;22(5):677-687.

(76) Gershon AS, Dolmage TE, Stephenson A, Jackson B. Chronic obstructive pulmonary disease and socioeconomic status: a systematic review. COPD 2012 Jun;9(3):216-226.

(77) Docampo Rama M, de Ridder H, Bouma H. Technology generation and age in using layered user interfaces. Gerontechnology 2001;1(1):25-40.

(78) Smith A. Older Adults and Technology Use. 2014; Available at: http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/.

(79) Centraal Bureau voor de Statistiek. ICT gebruik van personen naar persoonskenmerken. 2014; Available at: http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=71098ned&D1=33,55-59,93-95,97-100,102-104,106-109,112-113,119,124-133&D2=0&D3=0,l&HD=130422-1124&HDR=G2,G1&STB=T. (Archived by WebCite® at http://www.webcitation.org/6Yz02GrCQ). Accessed 6/2, 2015.

(80) Activity sensing in the wild: a field trial of ubifit garden. ; april 5-10; Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Pages 1797-1806; 2008.

(81) Whitten P, Mickus M. Home telecare for COPD/CHF patients: outcomes and perceptions. J Telemed Telecare 2007;13(1357-633; 2):69-73.

(82) Nguyen HQ, Carrieri-Kohlman V, Rankin SH, Slaughter R, Stulbarg MS. Is Internet-based support for dyspnea self-management in patients with chronic obstructive pulmonary disease possible? Results of a pilot study. Heart Lung 2005 Jan-Feb;34(1):51-62.

(83) Trappenburg JC, Niesink A, de Weert-van Oene GH, van der ZH, van SR, Peters A, et al. Effects of telemonitoring in patients with chronic obstructive pulmonary disease. Telemed J E Health 2008 03;14(2):138-146.

(84) Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. Int J Chron Obstruct Pulmon Dis 2009;4:301-313.

(85) Liu WT, Wang CH, Lin HC, Lin SM, Lee KY, Lo YL, et al. Efficacy of a cell phone-based exercise programme for COPD. Eur Respir J 2008 Sep;32(3):651-659.

(86) Casaburi R. Activity monitoring in assessing activities of daily living. COPD 2007 Sep;4(3):251-255.

(87) Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R. Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2005 10;86(10):1979-1985.

(88) Moy ML, Janney AW, Nguyen HQ, Matthess KR, Cohen M, Garshick E, et al. Use of pedometer and Internet-mediated walking program in patients with chronic obstructive pulmonary disease. J Rehabil Res Dev 2010;47(5):485-496.

(89) Giardino ND, Chan L, Borson S. Combined heart rate variability and pulse oximetry biofeedback for chronic obstructive pulmonary disease: preliminary findings. Appl Psychophysiol Biofeedback 2004 Jun;29(2):121-133.

(90) Donesky-Cuenco D, Janson S, Neuhaus J, Neilands TB, Carrieri-Kohlman V. Adherence to a home-walking prescription in patients with chronic obstructive pulmonary disease. Heart & Lung: The Journal of Acute and Critical Care 2007 0;36(5):348-363.

(91) Mercken EM, Hageman GJ, Schols AM, Akkermans MA, Bast A, Wouters EF. Rehabilitation decreases exercise-induced oxidative stress in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005 Oct 15;172(8):994-1001.

Chapter 1

Level of daily physical activity in individuals with COPD compared with healthy controls

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Respiratory Research 2011, 12:33

❖ Abstract

Background Persons with Chronic Obstructive Pulmonary Disease (COPD), performing some level of regular physical activity, have a lower risk of both COPD-related hospital admissions and mortality. COPD patients of all stages seem to benefit from exercise training programs, thereby improving with respect to both exercise tolerance and symptoms of dyspnea and fatigue. Physical inactivity, which becomes more severe with increasing age, is a point of concern in healthy older adults. COPD might worsen this scenario, but it is unclear to what degree. This literature review aims to present the extent of the impact of COPD on objectively-measured physical activity (PA). The focus is on the extent of the impact that COPD has on duration, intensity, and counts of PA, as well as whether the severity of the disease has an additional influence on PA.

Method A literature review was performed in the databases PubMed [MEDLINE], Picarta, PEDRO, ISI Web of Knowledge and Google scholar.

Results After screening, 11 studies were identified as being relevant for comparison between COPD patients and healthy controls with respect to duration, intensity, and counts of PA. Four more studies were found to be relevant to address the subject of the influence the severity of the disease may have on PA. The average percentage of PA of COPD patients vs. healthy control subjects for duration was 57%, for intensity 75%, and for activity counts 56%. Correlations of PA and severity of the disease were low and/or not significant.

Conclusions From the results of this review, it appears that patients with COPD have a significantly reduced duration, intensity, and counts of PA when compared to healthy control subjects. The intensity of PA seems to be less affected by COPD than duration and counts. Judging from the results, it seems that severity of COPD is not strongly correlated with level of PA. Future research should focus in more detail on the relation between COPD and duration, intensity, and counts of PA, as well as the effect of disease severity on PA, so that these relations become more understandable.

❖ Introduction

Persons with Chronic Obstructive Pulmonary Disease (COPD), who perform some level of regular physical activity, have a lower risk of both COPD-related hospital admissions and mortality [1-3]. COPD patients at all stages of the disease seem to benefit from exercise training programs, showing improvement with respect to both exercise tolerance and symptoms of dyspnea and fatigue [4]. Inactivity contributes to a further worsening of the physical condition of the subject and to even more dyspnea. This, in turn, contributes to a downward spiral of inactivity, deconditioning, and dyspnea [5,6]. COPD is a disease that mainly effects persons of older age. It develops over several decades of exposure to inhaled particulates, and, generally, becomes visible starting at the age of 40. In a global study, Buist et al. [7] found that the prevalence of COPD increases steadily with age for both men and women. The overall pooled Odds Ratio for COPD stage II or over was 1.94 (1.8-2.1) per 10-year age increment.

The American College of Sports Medicine and the American Heart Association provide physical activity recommendations for healthy older adults [8]. They recommend that each week older adults should do at least 30 minutes of moderate physical activity for 5 days or 20 minutes of vigorous physical activity for 3 days; 8-10 strength exercises for 2 days; and flexibility exercises for at least 10 minutes for 2 days. Many older adults do not meet these recommendations [9]. Caspersen et al. [10] studied the changes in physical activity patterns in the United States by sex and cross-sectional age. They found that both men and women reported more physical inactivity with greater age, with an increase between the 65-74-yr and >75-yr groups. After the age of 74, the prevalence of regular, sustained activity began to decline substantially for both sexes. Thus, physical inactivity, which becomes more serious with increasing age, is already a point of concern in healthy older adults. COPD might worsen this scenario, but it is unclear to what extent. There are various studies that examine the level of physical activities (PA) in COPD patients. However, as of now, there is no overview of the literature that combines these studies to see to what extent PA of COPD patients differs from healthy individuals.

This literature review aims to present the extent of the impact of COPD on PA. The focus is on the extent of the impact that COPD has on duration, intensity, and counts of PA, as well as whether the severity of the disease has an additional influence on PA.

❖ Methods

Potentially relevant literature was identified through computerized searches. PubMed [MEDLINE], Picarta, PEDRO, ISI web of knowledge, and Google scholar were searched for articles. PA was defined as: ‘‘the totality of voluntary movement produced by skeletal muscles during every day functioning’’ [5]. For this literature review we used the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines [1] to define disease severity. The severity of COPD is classified in four stages (mild to very severe) by postbronchodilator forced expiratory volume in 1 second (FEV1) value % predicted. The search was performed for the years 1966 to 2010 using the MeSH headings: "Pulmonary Disease, Chronic Obstructive", "Activities of Daily Living", "Motor Activity" and "Monitoring, Physiologic". Below the combinations of MeSH healdings entered in the databases are listed, with the resultant number of articles stated between brackets.

1. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND "Activities of Daily Living"[MeSH terms] AND "Motor Activity"[MeSH terms] AND "Monitoring, Physiologic"[MeSH terms] / (8)
2. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND "Activities of Daily Living"[MeSH terms] AND "Motor Activity"[MeSH terms] / (36)
3. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND "Activities of Daily Living"[MeSH terms] AND "Monitoring, Physiologic"[MeSH terms] / (16)
4. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND pedometer[All Fields] / (8)
5. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND accelerometer[All Fields] / (20)
6. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND activity[All Fields] AND monitors[All Fields]) / (8)
7. "Pulmonary Disease, Chronic Obstructive"[MeSH terms] AND monitors[All Fields] / (14)

Inclusion criteria were as follows: 1) patients were diagnosed with COPD. 2) The study included a control group consisting of age-matched healthy subjects. 3) PA was measured with an objective tool. 4) There was at least one whole day of measurements.

Exclusion criteria were as follows: 1) PA measured by questionnaires or diaries. 2) Measures on exercise capacity (for instance six minute walk test). These measures reflect one’s *capacity* to perform physical activity in daily living, but give no information on the degree of PA that is actually performed. 3) Measures on energy expenditure. Energy expenditure does not provide a direct measure of PA. This is especially true in COPD patients because they exhibit an increased total daily energy expenditure while their PA level is reduced in comparison with healthy subjects [11].

Inclusion criterion 2 was not used in the search for articles on the effect of the severity of COPD on PA. Articles were selected on the basis of title and abstract. References of obtained articles were verified whether they yielded any potentially relevant literature. After selection of the articles, full-text versions were obtained and read in their entirety after which, articles were either included or excluded based on the in- and exclusion criteria formulated above.

❖ Results

With the combinations of the keywords used, there were a number of 110 hits in total, 92 abstracts of which were screened. After screening, 11 studies were included based on the in- and exclusion criteria for comparison between COPD patients and healthy controls with respect to duration, intensity and counts of PA. Two [12,13] were excluded because they measured PA with questionnaires instead of objective measurements, resulting in 9 studies [14-22] used for data-extraction. Initially, the objective was to perform a meta-analysis with the data from all studies using the software package RevMan 5. Subgroup analyses with age, gender and disease severity were planned. Unfortunately, three studies were based on non-parametric data, and one study did not provide means and standard deviations [18]. This would leave 5 studies for analysis, which was decided to be too limited a basis to perform a meta-analysis. Instead, a descriptive review was written with 9 studies. In addition, four more studies [3,23-25] were included in this review as they address the subject of the influence the severity of the disease may have on PA. These additional studies did not compare the COPD patients with healthy control subjects.

The total number of subjects in all studies was 766; 597 COPD patients and 169 healthy controls. Although different outcome measures were used in the various studies, they all represented an objective measure of PA. The results were expressed in percentage of time of total recording time of PA spent in various intensities [14,23], vector magnitude units (VMU) (sum of the three axes of the accelerometer) [16,24,25], walking time in minutes [15,17], mean number of movements per day [19], steps per day [3,21], mean activity count [18], total activity count [20], and mean activity (x10^3 counts/h) [22]. Study characteristics are shown in **table 1**. This Table shows all 13 studies included for this review. The four studies analyzed with respect to disease severity display solely patient characteristics since these did not include healthy controls. Results of the individual studies are shown in **table 2**.

Table 1 - Study characteristics of included trials.

Reference	N (P/C)	Mean Age (yrs±SD, P;C)	Gender (Male/Female) (P/C)	Variation in GOLD stage	Measurement device	Duration of study (days)
Coronado (2003)	25 (15/10)	67±9; 57±5	13:2; 4:6	1-4	Uni-axial accelerometer	1
Hernandes (2009)	70 (40/30)	66±8;64±7	18:22; 14:16	2-4	Tri-axial accelerometer	2
Lores (2006)	35 (23/12)	62±7; 59±7	20:3; 9:3	2-4	Tri-axial accelerometer	3
Pitta (2005)	75 (50/25)	64±7; 66±5	36:14; 17:8	1-4	Tri-axial accelerometer	2
Pitta (2008)	40	68±7	21:19	1-4	Multisensor armband	2
Sandland (2005)	20 (10/10)	nd	nd	3	Uni-axial accelerometer	7
Schönhofer (1997)	50 (25/25)	56±12; 53±14	14:11; 14:11	2-3	Pedometer	7
Singh (2001)	20 (11/9)	66±9; 59±4	7:4; 5:4	3	Uni-axial accelerometer	2
Steele (2000)	47	66±8	44:3	1-4	Tri-axial accelerometer	3
Steele (2003)	63	nd	nd	nd	Accelerometer	3
Troosters (2010)	100 (70/30)	66±9; 65±7	58:12; 19:11	1-4	Multisensor armband	6-8
Walker (2008)	51 (33/18)	67±8; 70±6	17:16; 8:10	3	Uni-axial accelerometer	3
Watz (2008)	170	64±6.6	128:42	1-4	Multisensor armband	5-6

N = number of subjects, P = patients, C = controls, yrs = years, SD = standard deviation, nd= not described.

The effects of COPD on duration, intensity, and counts of physical activity

To make a comparison between the studies with respect to the effect of COPD on duration, intensity and counts of PA, the activity outcomes of COPD patients are given as a percentage of control values (**table 2**). For example, in the study of Pitta et al. [17], the COPD patients walked for 44 minutes per day compared to 81 minutes of the healthy controls; 44 was then divided by 81 to come to a PA percentage of 54 of COPD patients versus their healthy controls.

Duration of PA

Coronado et al. [14] showed in their study that the COPD patients were physically active for significantly less time of the day than healthy control subjects in low intensity activity (13% ± 4% vs. 22% ± 7%; p = 0.0001), and medium intensity activity (4% ± 4% vs. 11% ± 9%; p = 0.01). Hernandes et al. [15] evaluated the characteristics of physical activities in daily life in COPD patients in Brazil for 12 hours on two consecutive days. Mean walking time per day was shorter for COPD patients than for the controls (55 ± 33 vs. 80 ± 28

Table 2 - Results of included studies.

Reference	Duration of PA			Intensity of PA			Counts of PA		
	P	C	P/C ×100%	P	C	P/C ×100%	P	C	P/C ×100%
Coronado (2003)	17% of recording time active	33%	52%						
Hernandes (2009)	55 ± 33 min/day walking	80 ± 28	69%	1.9 ± 0.4 m/s^2	2.3 ± 0.6	83%			
Lores (2006)							184 ± 99 counts/3 days	314 ± 75	59%
Pitta (2005)	44 ± 26 min/day walking	81 ± 26	54%	1.8 ± 0.3 m/s^2	2.4 ±0.5	75%			
Schönhofer (1997)							3781 ± 2320 movements/day	8590 ± 4060	44%
Singh (2001)	136.1 min/2 days walking	386.2	35%				14.838 ± 7115 counts/2 days	24.028 ± 12399	62%
Troosters (2010)	106 min/ day active	232	46%				5584 ± 3360 steps/day	9372 ± 3574	60%
Walker (2008)	50.8% ± 15.4% of recording time mobile	61.4% ± 11.2%	83%	156 ± 63 ×10^3 counts/h	232 ± 90	67%	82 ± 49 ×10^3 counts/h	143 ± 61	57%
Average			57%			75%			56%

PA= physical activity, P=patients, C=controls, P/C×100%=percentage PA patients perform in comparison to healthy controls, value after ± is the standard deviation.

minutes per day; $p = 0.001$). In the study of Pitta et al. [17] patients also showed lower walking time than controls (44 ± 26 vs. 81 ± 26 minutes per day; $p < 0.0001$). Walker et al. [22] determined that patients spent significantly less time of the day being mobile than the controls (50.8% ± 15.4% vs. 61.4% ± 11.2% of recording time). Singh et al. [20] examined the discriminatory properties of an activity monitor by looking at the overall level of activity generated over two days by patients with COPD and healthy subjects. Patients completed a mean of 36.1 ± 17.1 minutes of brisk walking over the 48 hour period, whereas the healthy group completed 29.6 ± 41.4 minutes ($p<0.05$). Patients, furthermore, performed 100 ± 64.3 minutes of slow or intermittent walking, whereas healthy subjects achieved a mean of 356.6 ± 219 minutes ($p<0.05$). In the study of troosters et al. [21] subjects were instructed to wear a multisensor armband device able to assess PA continuously (day and night) for six to eight days. The time spent in activities with mild (80 ± 69 minutes vs. 160 ± 89 minutes, $p < 0.0001$), moderate (24 ± 29 minutes vs. 65 ± 70 minutes; $p < 0.0036$), and high intensity (2 ± 5 minutes per day vs. 7 ± 9 minutes per day; $p=0.01$) was significantly reduced in patients compared to controls. **Table 2** shows the values of duration of PA for the studies that include results on this parameter. Some studies reporting on the duration of PA distinguish between various intensities at which activities were carried out. These are summarized in **table 2** to provide a single value of duration of PA over a certain period of time. The ratio of duration of being active for healthy controls vs. patients with COPD is 1:0.57.

Intensity of PA

Hernandes et al. [26] showed that movement intensity was lower in patients vs. controls (1.9 ± 0.4 vs. 2.3 ± 0.6 m/s^2; $p = 0.004$). In the study of Pitta et al. [17] patients showed lower movement intensity during walking (1.8 ± 0.3 vs. 2.4 ± 0.5 m/s^2; $p < 0.0001$). Walker et al. [22] determined the relationship between lower limb activity and total PA and related PA to laboratory assessments before and after rehabilitation. The patients had a lower intensity of activity score (156 ± 63 vs. 232 ± 90 $\times 10^3$ counts/h) than the healthy volunteers. The study of Coronado et al. [14] assessed the usefulness of an accelerometer to characterize walking activity during a 3-week rehabilitation program. They recorded patients as well as healthy subjects with an uni-axial accelerometer on the first and last days of a rehabilitation program. The results of the first day showed that the COPD patients studied showed significantly less time spent in low and medium intensity activity. The values for high-intensity activity were negligible in all subjects and thus not reported. Specific values for intensity of PA were not mentioned, only the percentage of time spent in a certain intensity of PA (see previous paragraph). The same representation of results on intensity is seen in Troosters et al. [21] and Singh et al. [20]. The first study shows similar results to Coronado et al. [14]. In the study of Singh et al. [20] patients spent more time on brisk walking, but substantially less on slow or intermittent walking (see previous paragraph). The ratio of intensity of PA for healthy controls versus patients with COPD is 1:0.75 (**table 2**).

Activity counts

Lores et al. [16] assessed the agreement between different measurements of mean PA. All subjects wore a tri-axial accelerometer for 8 days. Activity counts in COPD patients were significantly lower than those of controls (184 ± 99 vs. 314 ± 75; p<0.01). The mean number of movements per day for patients and controls in the study of Schönhofer et al. [19] was 3781 ± 2320 and 8590 ± 4060, respectively (p<0.0001). They concluded that COPD patients had PA levels much lower than the average PA level recorded in age- and gender-matched healthy individuals. Also, the range of PA was much greater in healthy subjects than in COPD patients. Sandland et al. [18] explored the regular level PA in patients with COPD and healthy subjects during a 7-day study with accelerometers. Their results showed that there was a significant difference (p<0.001) in the level of PA between healthy controls and COPD patients. Exact numbers, however, were not mentioned in the article. They do mention that the activity counts in COPD patients compared to those in the healthy group were reduced by 49%. The total activity count for COPD patients in the study of Singh et al. [20] was significantly lower than the total activity count in healthy subjects (14.838 ± 7115 vs. 24.028 ± 12399; p<0.05). Troosters et al. [21] showed that patients took significantly less steps per day (5584 ± 3360) compared to controls (9372 ± 3574; p<0.0001). Walker et al. [22] also reported that patients had a lower activity count compared to healthy volunteers (82 ± 49 vs. 143 ± 61; p=0.001). The ratio of counts of PA for healthy controls versus patients with COPD is 1:0.56 (Table 2).

Disease severity and physical activity

The study of Pitta et al. [17] looked at the relation between disease severity and level of PA in their patients. They found that there was no significant difference between walking time in patients with GOLD stages I and II when compared to patients with GOLD stage III (p=0.10) and GOLD stage IV (p=0.19). Standing time was significantly lower in patients with GOLD stages III and IV. They concluded that it appears that the correlation between disease severity and physical activity in daily life is not strong. A different study by Pitta et al. [23] measured PA for two days using a multisensor armband device in 40 COPD patients. They correlated FEV1 with sedentary activities (r=-0.26), moderate activities (r=0.29) and vigorous activities (r=0.31; p=0.05). Only the correlation with vigorous activities proved to be significant.

Hernandes et al. [15] found that walking time per day was not significantly correlated with FEV1 % predicted (r=0.17). The time spent standing per day correlated positively with FEV1 % predicted (r=0.41; p<0.01).

Steele et al. [24] recorded PA in a sample of GOLD stage III COPD patients. They found that the accelerometers' output (vibrations in m/s^2) correlated positively with FEV1 % predicted (r = 0.62; p < 0.001). A different study by Steele et al. [25] measured 63 outpatients with COPD for three days and found a significant correlation between accelerometer measured daily activity and FEV1 % predicted (r=0.37; p<0.01)

In the study of Schönhofer et al. [19] patients with stable non-hypercapnic COPD, patients with respiratory failure, and healthy subjects were measured. For the COPD patients the number of movements per day was positively correlated with the FEV1 % predicted (r = 0.54, p = 0.006).

In the study of Singh et al. [20], total activity count was moderately correlated with FEV1 % predicted when measured with an activity monitor (r=0.41) but not statistically significant.

Walker et al. [22] found a correlation of r=0.57 (P<0.01) between mean activity of the legs and FEV1. Percentage of time spent mobile compared with FEV1 showed a correlation of r=0.51 (p<0.01).

In the study of Troosters et al. [21], the number of steps reached 87% ± 34%, 71% ± 32%, 49% ± 34% and 29% ± 20% of control values in GOLD-stages I to IV, respectively. The time spent in activities at moderate intensity was 53% ± 47%, 41% ± 45%, 31% ± 47% and 22% ± 34% of the values obtained in controls, respectively, with increasing GOLD-stage. These differences were statistical significant as of GOLD stage II (p < 0.05). The authors concluded that PA is reduced early in the disease progression (as of GOLD-stage II), and that reductions in physical activities at moderate intensity seem to precede the reduction in the amount of physical activities at lower intensity.

Watz et al. [3] measured PA for five to six consecutive days using a multisensor armband device in 170 stable COPD outpatients. Steps per day diminished with increasing GOLD level (I:7990±3370, II:7160±3284, III:5126±3692, IV:2377±1897; p<0.001). The same pattern was seen for mean PA level (I:1.63±0.25, II:1.62±0.27, III:1.45±0.25, IV:1.27±0.17; p<0.001).

❖ Discussion

First, the reason for excluding the two studies that measured PA with questionnaires will be elucidated. Studies that measured PA by questionnaires or diaries were excluded because these measures represent subjective PA. COPD patients significantly overestimate time spent walking and underestimate time spent standing [5,24,27], which makes results obtained via this method unreliable. The study of Gosker et al. [12] assessed PA administering the Physical Activity Scale for Elderly (PASE) questionnaire. They found that the 25 COPD patients scored significantly lower ($p<0.001$) than the 36 healthy gender- and age-matched controls; a lower score indicating a lower level of physical activity. Inal-Ince et al. [13] used the Activities of Daily Living Questionnaire (ADL-Q) in 30 COPD patients and 30 healthy controls. The ADL-Q scores were significantly higher in COPD patients ($p<0.0001$), indicating a more pronounced inability to perform activities of daily living. The two excluded studies are in line with the results of this review, thereby lowering the chances of selection bias.

The effect of COPD on physical activity

Table 2 shows similar results for all studies: COPD patients have lower levels of duration, intensity, and counts of PA compared to healthy subjects. The average of the percentage of PA of COPD patients vs. controls for duration was 57%, for intensity, 75%, and for activity counts, 56%. This shows that PA is significantly affected by COPD. When converting the results of the studies to these percentages, it has to be taken into account that the values used in this calculation are mean values with large standard deviations for the COPD patients as well as for the healthy controls. It seems that the large differences between persons in level of PA is not caused by the disease but merely by individual differences.

Next to a shorter duration of activity, the included studies also reported longer durations of inactivity. The COPD patients tended to spend more time seated than controls (294 ± 114 vs. 246 ± 122 min/day, $p = 0.08$) in Hernandes' study [15] as well as in Pitta's (374 ± 139 vs. 306 ± 108 minutes/day; $p = 0.04$) [17]. This latter study also reported a higher lying time (87 ± 97 vs. 29 ± 33 min/day; $p = 0.004$). Furthermore, they reported a lower standing time (191 ± 99 vs. 295 ± 109 min/day; $p<0.0001$). The study of Coronado et al. [14] showed that the COPD patients studied were significantly physically inactive for longer periods of time than the healthy control subjects (82% of recording time vs. 68% for controls).

It might be expected that having COPD would cause one to achieve the same duration of PA, albeit at a lower intensity. Interestingly, intensity of PA seems to be less affected by COPD than duration and counts. This trend is also evident in the study of Singh et al. [20].

The patients performed less PA overall, but interestingly enough, they completed more minutes of brisk walking than the healthy controls. It could be that the patients are trying to perform activities as fast as possible so as to alleviate the unease caused by PA. This puts a lot of strain on their bodies, which are already weaker as a result of the disease. The longer duration of inactivity seen in the studies of Hernandes et al. [15] and Pitta et al. [17] could be a result of this behavior. If trained to perform activities at a lower intensity, they might be able to improve their overall duration and count of PA.

Disease severity and physical activity

Overall there seems to be a relation between PA and severity of the disease, but this correlation is moderate at most and certainly not strong. Aliverti and Macklem [28] mention that shortness of breath is not necessarily the primary factor that limits exercise. They hypothesize that that both respiratory muscles and skeletal muscles do not receive sufficient oxygen to continue metabolizing aerobically. The fact that some individuals terminate exercising because of dyspnea, whereas others stop because of leg fatigue, suggests that sometimes the legs receive more oxygen and other times, the respiratory muscles. This would explain this moderate correlation between the severity of COPD based on the GOLD classification and PA.

There has been some discussion about whether FEV1 % predicted is a good variable to classify disease severity in COPD. It does not correlate well with important outcomes such as symptoms, quality of life, survival, exacerbation frequency, and exercise tolerance [29-31]. A different classification model might better correlate disease severity with PA. In the study of Sandland et al. [18], there was a significant reduction in the level of PA in the group of COPD patients with long term oxygen therapy (LTOT) compared with the group without LTOT. The two groups had the same level of disease severity according to the GOLD staging system. The difference between the two groups was the LTOT, which indicates that the group with LTOT had more severe hypoxemia and thus more symptoms. Here, the increase in severity of symptoms independent of disease severity according to the GOLD classification seems to further worsen the level of PA. It seems important that when prescribing exercise training to a COPD patient, one takes into account that a more severely inflicted patient does not necessarily need a less physically demanding program. The patient might be able to perform on a higher level than one might think judging by their disease severity measured by FEV1 (% predicted).

Limitations

The selection of patients and controls varied between the studies, which may constitute an important source of bias. Patients who were recruited were either participating in an inpatient rehabilitation program [14,15,18,22], an outpatient rehabilitation program [16,19,21], just graduated from a rehabilitation program [20], or recruitment of patients was not clearly stated [17]. Patients referred to rehabilitation programs may be more likely to be inactive than the general population of COPD patients. This latter group may prevent themselves from entering a period of rehabilitation because they are more physically active and thereby maintain a better health status. The selection of the healthy controls was not always clearly described. Coronado et al. [14] included subjects, who participated on a voluntary basis from a senior group practicing fitness. Pitta et al. [17] recruited relatives and friends from the researchers and patients. Hernandes et al. [15] and Troosters et al. [21] recruited relatives of students of the university. A random sample of healthy persons may be more inactive than volunteers, which would diminish the difference between COPD patients and their healthy controls.

It was decided that too few studies were available in order to perform a meta-analysis. This is due to limited research that is specifically directed at the relation between COPD and duration, intensity, and counts of PA, as well as the effect of disease severity on PA. Future research should focus in more detail on this subject so that these relations become more understandable.

Apart from the fact that there were too few studies for a meta-analysis, another difficulty in the comparison of the studies was that there was a great variety in the instruments used to obtain an objective measure of PA. When comparing studies with different kinds of pedometers and accelerometers, this can lead to some variation in the outcome that is not attributable to the subjects but rather to the different measurement devices. The methods of the studies also differed considerably in measurement time. However, since the difference in PA between COPD patients and healthy controls was so large in the included studies, the effect of various methodologies is probably negligible.

❖ Conclusion

Even though there was a great variation between the studies in terms of measurement devices and measurement time, the large differences between the healthy subject group and the COPD patient group allow us to draw conclusions. From the results of this review, it appears that patients with COPD have a significantly reduced duration, intensity, and counts of PA when compared with healthy control subjects. Intensity of PA seems less affected by COPD than duration and counts. Judging from the results, it seems that severity of COPD is not strongly correlated with level of PA. Future research should focus in more detail on the relation between COPD and duration, intensity, and counts of PA, as well as the effect of disease severity on PA, so that these relations become more understandable.

❖ References

1. Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, Fukuchi Y, Jenkins C, Rodriguez-Roisin R, van WC et al.: Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med* 2007, 176:532-555.

2. Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Anto JM: Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. *Thorax* 2006, 61:772-778.

3. Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H: Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. *Am J Respir Crit Care Med* 2008, 177:743-751.

4. Gold PM: The 2007 GOLD Guidelines: a comprehensive care framework. *Respir Care* 2009, 54:1040-1049.

5. Pitta F, Troosters T, Probst VS, Spruit MA, Decramer M, Gosselink R: Quantifying physical activity in daily life with questionnaires and motion sensors in COPD. *Eur Respir J* 2006, 27:1040-1055.

6. Spruit MA, Troosters T, Trappenburg JC, Decramer M, Gosselink R: Exercise training during rehabilitation of patients with COPD: a current perspective. *Patient Educ Couns* 2004, 52:243-248.

7. Buist AS, McBurnie MA, Vollmer WM, Gillespie S, Burney P, Mannino DM, Menezes AM, Sullivan SD, Lee TA, Weiss KB et al.: International variation in the prevalence of COPD (the BOLD Study): a population-based prevalence study. *Lancet* 2007, 370:741-750.

8. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, Macera CA, Castaneda-Sceppa C: Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007, 39:1435-1445.

9. Mathews AE, Laditka SB, Laditka JN, Wilcox S, Corwin SJ, Liu R, Friedman DB, Hunter R, Tseng W, Logsdon RG: Older adults' perceived physical activity enablers and barriers: a multicultural perspective. *J Aging Phys Act* 2010, 18:119-140.

10. Caspersen CJ, Pereira MA, Curran KM: Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Med Sci Sports Exerc* 2000, 32:1601-1609.

11. Baarends EM, Schols AM, Pannemans DL, Westerterp KR, Wouters EF: Total free living energy expenditure in patients with severe chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1997, 155:549-554.

12. Gosker HR, Lencer NH, Franssen FM, van d, V, Wouters EF, Schols AM: Striking similarities in systemic factors contributing to decreased exercise capacity in patients with severe chronic heart failure or COPD. *Chest* 2003, 123:1416-1424.

13. Inal-Inc, Savci S, Coplu L, Arikan H: Factors determining self-efficacy in chronic obstructive pulmonary disease. *Saudi Med J* 2005, 26:542-547.

14. Coronado M, Janssens JP, de MB, Terrier P, Schutz Y, Fitting JW: Walking activity measured by accelerometry during respiratory rehabilitation. *J Cardiopulm Rehabil* 2003, 23:357-364.

15. Hernandes NA, Teixeira DC, Probst VS, Brunetto AF, Ramos EM, Pitta F: Profile of the level of physical activity in the daily lives of patients with COPD in Brazil. *J Bras Pneumol* 2009, 35:949-956.

16. Lores V, Garcia-Rio F, Rojo B, Alcolea S, Mediano O: [Recording the daily physical activity of COPD patients with an accelerometer: An analysis of agreement and repeatability]. *Arch Bronconeumol* 2006, 42:627-632.

17. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R: Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2005, 171:972-977.

18. Sandland CJ, Singh SJ, Curcio A, Jones PM, Morgan MD: A profile of daily activity in chronic obstructive pulmonary disease. *J Cardiopulm Rehabil* 2005, 25:181-183.

19. Schonhofer B, Ardes P, Geibel M, Kohler D, Jones PW: Evaluation of a movement detector to measure daily activity in patients with chronic lung disease. *Eur Respir J* 1997, 10:2814-2819.

20. Singh S, Morgan MD: Activity monitors can detect brisk walking in patients with chronic obstructive pulmonary disease. *J Cardiopulm Rehabil* 2001, 21:143-148.

21. Troosters T, Sciurba F, Battaglia S, Langer D, Valluri SR, Martino L, Benzo R, Andre D, Weisman I, Decramer M: Physical inactivity in patients with COPD, a controlled multi-center pilot-study. *Respir Med* 2010, 104: 1005-1011.

22. Walker PP, Burnett A, Flavahan PW, Calverley PM: Lower limb activity and its determinants in COPD. *Thorax* 2008, 63:683-689.

23. Pitta F, Takaki MY, Oliveira NH, Sant'anna TJ, Fontana AD, Kovelis D, Camillo CA, Probst VS, Brunetto AF: Relationship between pulmonary function and physical activity in daily life in patients with COPD. *Respir Med* 2008, 102:1203-1207.

24. Steele BG, Holt L, Belza B, Ferris S, Lakshminaryan S, Buchner DM: Quantitating physical activity in COPD using a triaxial accelerometer. *Chest* 2000, 117:1359-1367.

25. Steele BG, Belza B, Cain K, Warms C, Coppersmith J, Howard J: Bodies in motion: monitoring daily activity and exercise with motion sensors in people with chronic pulmonary disease. *J Rehabil Res Dev* 2003, 40:45-58.

26. Hernandes NA, Teixeira DC, Probst VS, Brunetto AF, Ramos EM, Pitta F: Profile of the level of physical activity in the daily lives of patients with COPD in Brazil. *J Bras Pneumol* 2009, 35:949-956.

27. Belza B, Steele BG, Hunziker J, Lakshminaryan S, Holt L, Buchner DM: Correlates of physical activity in chronic obstructive pulmonary disease. *Nurs Res* 2001, 50:195-202.

28. Aliverti A, Macklem PT: How and why exercise is impaired in COPD. *Respiration* 2001, 68:229-239.

29. Celli BR, Cote CG, Marin JM, Casanova C, Montes de OM, Mendez RA, Pinto P, V, Cabral HJ: The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N Engl J Med* 2004, 350:1005-1012.

30. Gross NJ: Chronic obstructive pulmonary disease outcome measurements: what's important? What's useful? *Proc Am Thorac Soc* 2005, 2:267-271.

31. Kerstjens HA: The GOLD classification has not advanced understanding of COPD. Am J Respir Crit Care Med 2004, 170:212-213.

Chapter 2

COPD patients' views on physical activity engagement

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❖ Abstract

Background Patients with Chronic Obstructive Pulmonary Disease (COPD) demonstrate reduced levels of daily physical activity compared with healthy controls. This is accompanied by a higher risk of hospital admission and reduced survival. This study aims to identify how patients with COPD view their daily physical activity engagement and how they feel it is influenced by their health status, healthcare providers, themselves, medication and other factors.

Method A set of 14 questions was developed to address the study aim using the website www.surveymonkey.com which was online from 23 October 2009 to 12 January 2010. Analyses consisted of frequency distributions, the chi-square test for independence, and one-way analysis of variance.

Results 170 patients with COPD started and 116 completed the set of questions. Average age was 60±11 years. 65% had received exercise prescriptions/advice; however, of these only 29% were specific. 69% responded that they are in adherence. Health status, weather conditions and state of mind are important factors that patients with COPD feel influence their daily physical activity engagement.

Conclusions Patients with COPD have diverse views concerning their physical activity performance and whether this is influenced by their COPD, comorbidities or medication use. Barriers and enablers to PA according to patients should be considered when prescribing exercise prescriptions to this patient group.

❖ Introduction

Patients suffering from Chronic Obstructive Pulmonary Disease (COPD) demonstrate reduced levels of daily physical activity, (the totality of voluntary movement produced by skeletal muscles during every day functioning (1)), compared with healthy controls (2-5). Even in the healthy adult population, there are alarming attrition rates to exercise programs that approximate 50% in the first 6 months. Those who do adhere seldom comply with the prescribed exercise intensity, frequency and duration necessary to achieve and maintain health benefits (6).

The percentage of patients that do not meet the recommended daily physical activity level is significantly higher in patients with COPD (84%) compared with other chronic conditions such as rheumatoid arthritis (74%) and diabetes (72%) (7). The prevalence of COPD rises with age, for men as well as women (8).

Approximately 66% of healthy older adults do not meet the recommendations of the American College of Sports Medicine and the American Heart Association on physical activity (9,10); (11). Both men and women report more inactivity as they become older (12). Hence, physical inactivity is a matter of concern in the elderly in the general population, which is further worsened by coexisting COPD (5).

Significant correlations are found between physical inactivity and serious disease outcomes of COPD, such as a lower forced expiratory volume in 1 second (FEV1), dyspnea, muscle function, comorbidities, systematic inflammation and health-related quality of life (4,13-15). Even minimal daily physical activity can reduce risk of COPD-related hospital admissions and all-cause mortality (14). Patients who maintain physical activity after rehabilitation have less dyspnea during daily activity, better health-related quality of life and enhanced long-term functional, physiological and psychological outcomes (16).

In healthy older adults, the presence of a robust sense of self-efficacy (strength of one's belief in one's own ability to complete tasks and reach goals) and the development and nurturing of skills and strategies to enhance such cognitions have been consistently identified as determinants of physical activity in acute exercise bouts in laboratory settings, long-term exercise participation and in larger population studies (6,9). For patients with COPD, self-efficacy cognitions have been demonstrated to influence compliance to exercise in a rehabilitation setting (17,18). Perceived barriers have also been linked consistently to physical activity participation in healthy older adults. In order to help people to engage in a regular physical activity program, one should identify what the individual perceives to be potential barriers to physical activity and either eliminate or reduce the actual barrier or change the perception that this barrier can indeed influence regular physical activity (6).

This study aims to identify how patients with COPD view their physical activity engagement and how they feel it is influenced by their health status, healthcare providers, themselves, medication and other factors. Several surveys determined the amount and patterning of physical activity in older adults (19) and patients with COPD (20-22). To our knowledge, no survey has thus far addressed our study aim.

❖ Methods

A set of questions was devised to address patients' opinions about their physical activity engagement and how they feel it is influenced by their health status, healthcare providers, themselves, medication and other factors. The set of questions is found in the **appendix**. Literature on constructing questionnaires was used to properly state the questions to be asked (23,24). In order to make sure the set of questions contains all questions necessary to address the main research questions, several drafts of the questions were discussed in e-mail exchanges and meetings with several authors of this article (HK, TvK, SV and J-WL: two pulmonary physicians, a human movement scientist and a medical biologist). This allowed for easy communication and different people provided various views on necessary questions. In order to test for comprehensibility the questions were shown to three, randomly chosen, healthy older adults (2 females/ 1 male, average age: 57 years), which posed no problems. We used the website www.surveymonkey.com to design the questions and store and analyze the data. A meta-analysis by Gwaltney et al. (25) showed that comparability of paper-and-pencil measures versus electronic assessment of patient-reported outcomes is not an issue in various patient populations and is not affected by age, computer experience, or computer platform. Likewise, Beaumont et al. (26) assessed the equivalence of an internet-based COPD population screener and a paper-and-pencil administration and found no significant differences in mean scores. The predictive utility of the screener did not differ between the two methods of administration, even after accounting for age and smoking status.

In the current study there were 14 questions that took about 10 minutes to complete. In order to increase the response rate, the link to the set of questions was posted on the patients' forum of the Dutch Asthma Foundation and on relevant COPD group sites on Hyves, a Dutch social networking site. Therefore, patients were unknown to the research group. No detailed information about the extent of their COPD could be attained. Patients voluntary filled out the set of questions. The set of questions was online from 23 October 2009 to 12 January 2010. Data was anonymously recorded on the SurveyMonkey website.

Ethics: According to the Central Committee on Research involving Human Subjects, filling out a questionnaire generally does not require ethics approval (27). This was confirmed by the secretariat of the ethical board of the University Medical Centre Utrecht for this set of questions.

Statistics

In order to clearly outline the views from a large group of COPD patients, a quantitative methodology was chosen. the Statistical Package for the Social Sciences (SPSS), version 15, was used to analyze the data. Respondents who stated not to suffer from COPD (but, for example, from asthma) were excluded from analyses as were sets of questions in which only the questions on demographic information were answered (questions 1–4). Sets of questions which were partially filled in, with at least one question answered besides demographic information, were included for analyses.

For the descriptive statistics, frequency distributions were computed and subsequently converted to percentages. For the interactions between the questions, the chi-square test for independence was used. For the effect of age on other variables, one-way ANOVAs were used.

Several questions left an open space under the question to invite general remarks or to answer a supplementary open question (see **appendix**). These answers were manually open coded by the first author and a research assistant. Differences were compared and final decissions made.

❖ Results

Population characteristics [questions 1– 4, 7 and 11]

In total, 201 subjects started filling out the set of questions. Nine respondents were excluded from analysis because they mentioned suffering from asthma without COPD (7 women, 2 men; age: 56±13years), 11 respondents were excluded since they only answered the first 3 questions on demographics (8 women, 3 men; age: 51±12), and 11 respondents were excluded because they mentioned other lung conditions (asthma, sarcoidosis, cystic fibrosis, bronchiestasis) as comorbidities (3 women, 8 men; age: 50±12). Of the remaining 170 patients with self-reported COPD (as derived from question 3), 116 completed the set

of questions (64%). Characteristics of the respondents are shown in **Table 1**. Age did not make a significant difference in the experienced COPD severity (p=0.082).
On average, patients who completed the set of questions had been diagnosed 12 ± 13 years before. There was a positive (left) skewness in the distribution of years since diagnosis (2,58), which shows that most of the respondents had been diagnosed within the last 15 years. Fifty-one percent of the respondents suffered from comorbidities. Of this group 50% suffered from 1 comorbidity, 33% from two and 17% from three or more. Most-stated comorbities were cardiovascular disease (39%) and osteoporosis (15%). **Table 2** states pulmonary medication use by the respondents.

Table 1: Characteristics of respondents.

Gender (M/F)	60 (35%)/110 (65%)
Age	60 ± 11
Experienced COPD severity	
Mild Moderate Severe Very severe	30 (18%) 53 (31%) 51 (30%) 36 (21%)

Table 2: Pulmonary medication use mentioned by respondents (question 11, N=170).

Pulmonary medication	Frequency
long-acting beta agonist	99
inhaled steroid	93
long-acting anticholinergic	71
short-acting beta agonist	48
short-acting anticholinergic	15
oral steroids	8
theophylline	6
mucolytic	4

Performance of physical activity [questions 5 and 6]

Forty-five percent of the respondents reported that they have performed less physical activity since they were diagnosed with COPD; 26% said that they actually performed more physical activity and 29% mentioned no noticeable difference (N=170). Some respondents (N=53) clarified their response in the open space below the question. Sports (14 respondents), daily activities (11) and physiotherapy (9) were mentioned most often as extra activities engaged in since diagnosis. Some of the respondents who mentioned that their physical activity was reduced since diagnosis commented in the open space that this was due to dyspnea (6 respondents), difficulties with physical activity (5), ceasing specific activities, such as cycling (4), age (2) and worsening of the disease (2).

When asked if there were certain physical activities that had ceased due to their disease: 57% said yes and 43% answered no (N=170 . This most often concerned cycling (54 respondents), climbing stairs (49) and walking (37). Leisure sports activities (horse riding, badminton and jogging) and chores (shopping, gardening), walking up a hill and playing with the grandchildren were also mentioned in the open space. Older patients more frequently mentioned being unable to perform certain physical activities because of their COPD (p=0.006).

The experienced severity of COPD (question 3) had a significant effect on discontinuation of certain activities (question 6) and change in general physical activity since being diagnosed with COPD (question 5) (both p<0.001). Respondents who experienced their COPD as worse were more likely to say that they ceased certain activities and to have a reduced general physical activity pattern since being diagnosed with COPD (**Figure 1**).

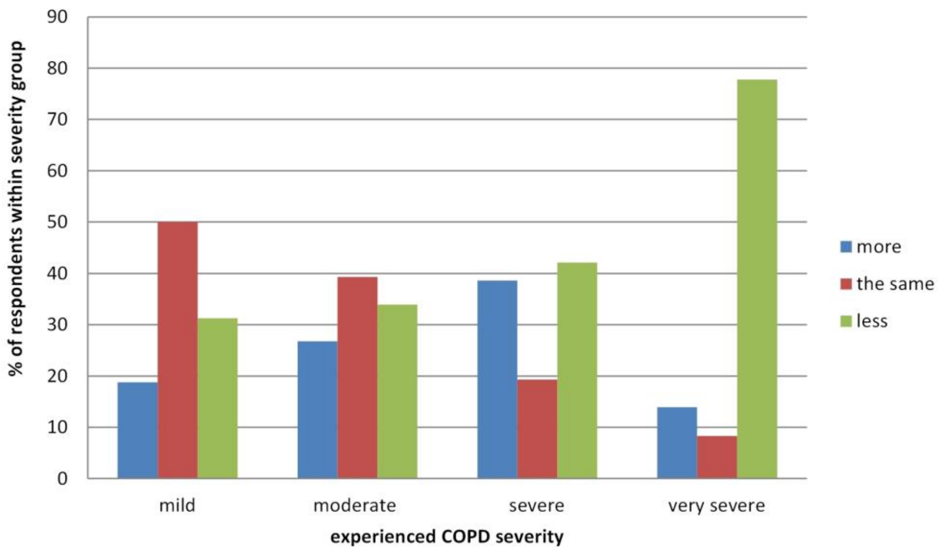

Figure 1: Effect of experienced COPD severity on change in physical activity since diagnosis (N=170).

Received exercise prescriptions [question 9]

Respondents were asked what kind of exercise prescriptions or advice they had received from their healthcare practitioners/therapists (N=162). Thirty-five percent of patients had never received any advice from their practitioner/therapist with regard to physical activity. Of the 65% that had received advice, the most frequently mentioned were physiotherapy or specific training prescriptions (29%), "be active" (non-specific advice) (17%) and education about the disease and the importance of physical activity (15%) (**Figure 2**).

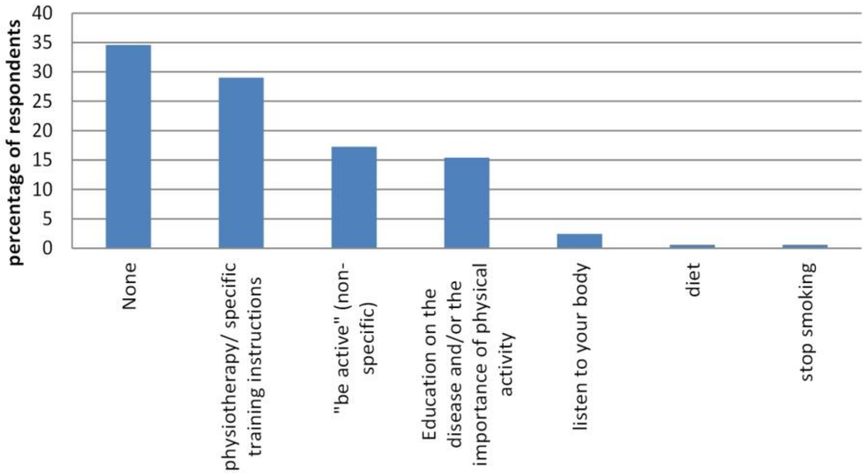

Figure 2: Exercise prescriptions received from healthcare practitioner (N=162).

Reasons for physical (in-)activity [questions 10, 12–14]

Of the patients that received exercise prescriptions (N=105), 69% reported to be adherent, 23% responded that they "did not always adhere to the provided exercise prescriptions" and 8% said that they never did exercise. In the open space under the question reasons mentioned for adherence (N=33) to exercise prescriptions were: knowledge of the benefits (55%), positive biofeedback (33%), enjoying the exercise (6%), receiving help from a physiotherapist (3%) and already being active (3%). Reasons for non-adherence (N=26) were: being tired from work/daily activities (33 %), physical restrictions/exacerbations (27%), disagreeing with the prescriptions (9%), time constraints (6%) and fear (3%). Women were 2.2 times more likely to respond that they "did not (always) comply with their exercise prescriptions" than men (p=0.02). Of the patients with comorbidities (N=93), 51% mentioned that these negatively influenced their daily physical activities. The activities that were influenced (mentioned in the open space, N=38) were daily activities in general (47%), walking (22%), climbing the stairs (14%), sports (10%) and cycling (8%).

Fifty three percent thought that their medication affected the amount of physical activity they perform while the other half thought that medication had no effect. Asked what they thought the effect is, the former (N=59) reported in the open space that their medication reduces their dyspnea (66%), which enables them to perform more physical activity. Increased energy was also mentioned (29%), as well as reduced coughing or coughing up sputum and increased self-efficacy (5%).

Respondents were asked to mention three factors stimulating them to increase their physical activity. They (N=116; 325 responses) mentioned improvement of physical health (26%), type of physical activity (i.e. gardening, housekeeping, cycling, walking the dog; 15%), weather conditions (low humidity, sunny, clean air, clear weather) (11%) and social support (10%) as the main influencing factors that stimulate them to engage in physical activity. (**Figure 3**).

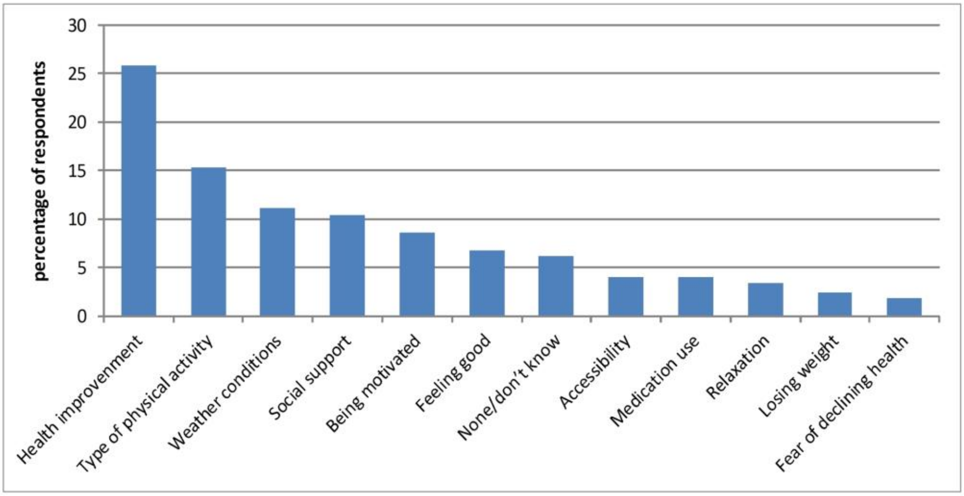

Figure 3: Factors that stimulate physical activity (N=116, 325 responses).

Respondents were also asked to mention three factors that cause them to decrease their physical activity. Respondents (N=116; 316 responses) mentioned fatigue/lack of motivation (28%), weather conditions (extreme temperatures (cold and hot), mist, high humidity, wind) (27%) and shortness of breath (20 %), as the main influencing factors that cause them not to engage in physical activity (**Figure 4**).

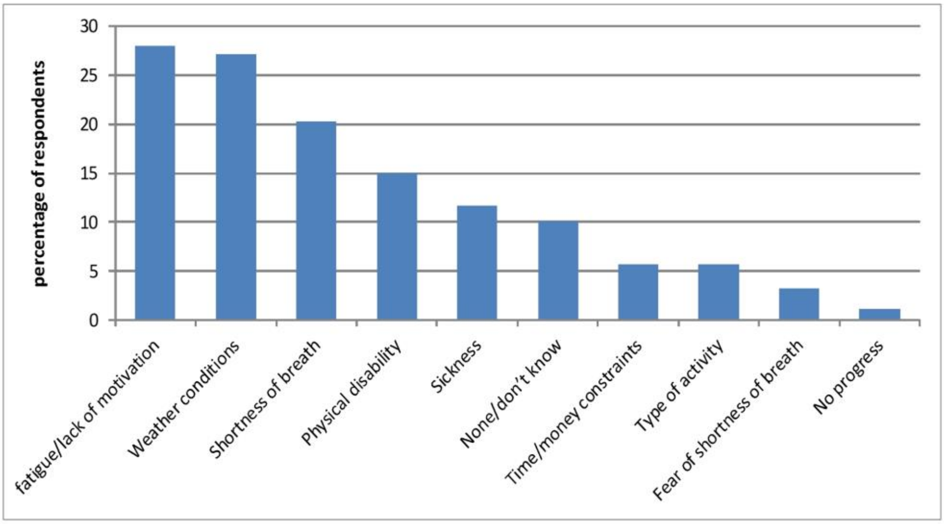

Figure 4: Factors that decrease physical activity (N=116, 316 responses).

❖ Discussion

The results of this study provide us with insights into COPD patients' views towards physical activity engagement and the various factors that influence this variable, in the patients' opinion.

Physical activity performed

Chronic Obstructive Pulmonary Disease is known to have an effect on physical activity, and in COPD patients physical activity has been found to be reduced in comparison with healthy age-matched controls. However, a large portion of our respondents mentioned being equally or even more active since they were diagnosed with COPD. Patients increasingly mentioned a reduction in physical activity when they experienced their COPD as more severe. But it was not until the most severe stages of COPD that the majority reported that their physical activity was reduced. As the disease progresses, patients are increasingly confronted with the impact it has on their physical condition. The contrast with their previous life, before being diagnosed with COPD, becomes more obvious to them. People who reported increasing their physical activity might be more actively combative towards their disease and have taken up exercise to slow down disease progression.
Older respondents more often state that their physical activity pattern was reduced since diagnosis and that they are unable to perform certain physical activities. These results were expected, since physical activity is reduced with increasing age (28).

Adherence to received exercise prescriptions

Twenty-nine percent of respondents mentioned receiving specific exercise prescriptions from their healthcare provider and/or engaging in physical therapy. These numbers are consistent with the 25% (National Institute for Public Health and the Environment, RIVM) to one-third (Dutch Asthma Foundation) of patients with COPD that attend physiotherapy in the Netherlands. The fact that the remaining 71% have not received specific exercise prescriptions is a point of concern and leaves room for improvement on the side of the healthcare provider. A large group only received general instructions such as "just be active" and "let your body tell you how active you can be". This might not be strong enough advice for patients with COPD struggling to maintain their physical activity level. The American College of Sports Medicine and the American Heart Association provide physical activity recommendations for healthy older adults (29). These guidelines might not be suitable for patients with COPD.

The effectiveness of exercise training as a component of pulmonary rehabilitation has been shown when continued for a minimum of 6 weeks (30). Exercise training varies among programs ranging from daily to weekly, in duration from 10 minutes to 45 minutes per session, and in intensity from 50% peak oxygen consumption to maximum tolerated. Aside from great variation in exercise training in rehabilitation programs, there is also a lack of specific exercise guidelines for patients with COPD who are not following a program. Many physicians advise their patients who are unable to participate in a structured program to exercise on their own but these recommendations are quite general (30). More specific exercise prescriptions may have a greater effect. In order for healthcare providers to provide these prescriptions, exercise guidelines specific to patients with COPD should be developed, taking into account the various stages, degree of symptoms, weather conditions and type of physical activity. Furthermore, guidelines developed for rehabilitation purposes might not be suitable as an ongoing exercise prescription following rehabilitation or for patients not following a program since goal-setting may differ (improvement vs. maintenance).

Another point of concern is the one-third of the subjects who did receive exercise prescriptions but admits to poor adherence or actually none at all. In our study women more often responded to not (always) comply with their exercise prescriptions than men. Studies on adherence to rehabilitation programs found that a short distance to the rehabilitation center, an FEV1 ≥ 20%, higher educational levels, an enthusiastic physician and social support were factors that significantly improved the likelyhood to complete the rehabilitation program (16,31,32). In a review by Thorpe et al. (33) four studies mentioned transportation and parking difficulties as one of the most common barriers faced by patients attending pulmonary rehabilitation (PR). In our study, only a few people mentioned lack of transportation and distance to sport center/ therapist as negative factors to engaging in

physical activity. In the Netherlands, distance to the physical therapist is generally short which probably makes this less of a barrier compared to other countries.
Motivation to continue long-term exercise was found to be related to the patient’s acceptance of the situation, their relational skills and the competence of the physiotherapist, the patient's perceived mastery of the intensity of the exercise program and the physiotherapist's ability to individualize the exercise prescription, peer/professional support, goal setting and the availability and continuity of the program (33,34). In our study, the type of physical activity was the second-most mentioned factor influencing physical activity, stressing the importance to individualize the exercise prescription.

Healthcare providers do not always have to focus exclusively on health benefits for the promotion of physical activity but can also highlight many of the other related benefits such as sociability, enjoyment and improved appearance (6).

Reasons for physical (in-)activity

We found fatigue/lack of motivation to be the main barrier to exercise. This barrier was also frequently mentioned by COPD patients in a study of Soicher et al. (16) who followed 215 patients over a period of 12 months, the first 3 of which they participated in a pulmonary rehabilitation program. Barriers to adherence to long term exercise were a major life event, such as moving house or a family illness/death and medical reasons (often unrelated to COPD). Extra attention from healthcare practitioners for patients going through major changes in life might halt their decline in daily physical activity.

Our respondents mentioned that cold air, fog, high humidity and rain were demotivating while dry, sunny weather was a strong motivator to engage in physical activity. The review by Thorpe et al. (33) also mentioned weather as a major environmental barrier perceived to affect health and exercise adherence in three studies. Social support was mentioned as a barrier when it was lacking and as an enabler in the form of encouragement by peers and professionals, as well as exercising with others.

Arnold et al. (32) and Hellem et al. (34) found this as well. We also found social support to have an important influence on physical activity engagement. Weather conditions were not cited in the previously mentioned studies while we found it to be a major factor stimulating as well as decreasing physical activity. A study by O’Shea et al. (35), however, found that health and weather factors were the major barriers to adherence to a progressive resistance exercise program for patients with COPD.

Knowing what reasons patients state as discouraging or stimulating them to be physically active could help in designing interventions directed toward improving their physical activity pattern. As mentioned in the introduction, the first step to minimizing barriers is to identify them. This study contributes to this knowledge about patients with COPD.

Limitations

Our study has a number of limitations:

1) The aim of this study was to get a general overview of patients' views towards their physical activity engagement and how this is influenced. A set of questions was devised since there was no validated questionnaire available to address this aim.
2) Posting the questions on a website made for easy distribution but also provided unknown respondents. We cannot say for certain if all respondents are truly patients with COPD.
3) More women (65%) than men answered the set of questions. Reasons for this disparity remain unclear.
4) Selection bias might have played a role in the responses to our survey. Our patients were website visitors actively searching for disease-specific information. This might be related to a more active lifestyle.

❖ Conclusion

Patients with Chronic Obstructive Pulmonary Disease have diverse views concerning their physical activity performance and whether this is influenced by their COPD, comorbidities or medication use. A group of 35% has never received any form of exercise prescriptions and in most cases prescriptions should be more specific. Most patients feel they are in adherence with their prescriptions. Health status, weather conditions and general state of mind are important factors that patients with COPD feel influence their physical activity engagement.

Implications for practice

Exercise prescriptions should be specific and individualized. A physiotherapist can then provide the patient with an individualized exercise program.

When creating an individualized exercise program for patients, the following should be taken into account: weather conditions, preferred type(s) of activity, health status, symptoms, age, and social support. This might improve motivation and adherence.

Implications for research

General exercise guidelines specific for patients with COPD should be developed taking into account the severity of the disease and symptoms, age and comorbidities.

In future studies exercise programs can be developed by use of eHealth. eHealth applications which measure physical activities levels, weather conditions and medication use need to be examined whether they contribute in improving patients motivations and adherence.

❖ References

(1) Pitta F, Troosters T, Probst VS, Spruit MA, Decramer M, Gosselink R. Quantifying physical activity in daily life with questionnaires and motion sensors in COPD. Eur Respir J 2006 05;27(5):1040-1055.

(2) Sandland CJ, Singh SJ, Curcio A, Jones PM, Morgan MD. A profile of daily activity in chronic obstructive pulmonary disease. J Cardiopulm Rehabil 2005 05;25(3):181-183.

(3) Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005 05/01;171(1073-449; 9):972-977.

(4) Hill K, Goldstein RS. Limited functional performance in chronic obstructive pulmonary disease: nature, causes and measurement. COPD 2007 09;4(3):257-261.

(5) Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. Respir Res 2011 Mar 22;12:33.

(6) Mcauley E, Courneya K. Adherence to exercise and physical activity as health-promoting behaviors: Attitudinal and self-efficacy influences. Applied and Preventive Psychology 1993;2(2):65-77.

(7) Arne M, Janson C, Janson S, Boman G, Lindqvist U, Berne C, et al. Physical activity and quality of life in subjects with chronic disease: chronic obstructive pulmonary disease compared with rheumatoid arthritis and diabetes mellitus. Scand J Prim Health Care 2009;27(3):141-147.

(8) Buist AS, McBurnie MA, Vollmer WM, Gillespie S, Burney P, Mannino DM, et al. International variation in the prevalence of COPD (the BOLD Study): a population-based prevalence study. Lancet 2007 09/01;370(1474-547; 9589):741-750.

(9) McAuley E, Jerome GJ, Elavsky S, Marquez DX, Ramsey SN. Predicting long-term maintenance of physical activity in older adults. Prev Med 2003 Aug;37(2):110-118.

(10) Wendel-Vos G. Neemt het aantal mensen met voldoende lichamelijke activiteit toe of af?. 2012; Available at: http://www.nationaalkompas.nl/gezondheidsdeterminanten/leefstijl/lichamelijke-activiteit/trend/. Accessed 2/15, 2013.

(11) Mathews AE, Laditka SB, Laditka JN, Wilcox S, Corwin SJ, Liu R, et al. Older adults' perceived physical activity enablers and barriers: a multicultural perspective. J Aging Phys Act 2010 04;18(2):119-140.

(12) Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. Med Sci Sports Exerc 2000 09;32(9):1601-1609.

(13) Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H. Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. Am J Respir Crit Care Med 2008 04/01;177(7):743-751.

(14) Hartman JE, Boezen HM, de Greef MH, Bossenbroek L, ten Hacken NH. Consequences of physical inactivity in chronic obstructive pulmonary disease. Expert Rev Respir Med 2010 Dec;4(6):735-745.

(15) Esteban C, Quintana JM, Aburto M, Moraza J, Egurrola M, Perez-Izquierdo J, et al. Impact of changes in physical activity on health-related quality of life among patients with COPD. Eur Respir J 2010 Aug;36(2):292-300.

(16) Soicher JE, Mayo NE, Gauvin L, Hanley JA, Bernard S, Maltais F, et al. Trajectories of endurance activity following pulmonary rehabilitation in COPD patients. Eur Respir J 2012 Feb;39(2):272-278.

(17) Kaplan RM, Atkins CJ, Reinsch S. Specific efficacy expectations mediate exercise compliance in patients with COPD. Health Psychol 1984;3(3):223-242.

(18) Toshima MT, Kaplan RM, Ries AL. Experimental evaluation of rehabilitation in chronic obstructive pulmonary disease: short-term effects on exercise endurance and health status. Health Psychol 1990;9(3):237-252.

(19) Dipietro L, Caspersen CJ, Ostfeld AM, Nadel ER. A survey for assessing physical activity among older adults. Med Sci Sports Exerc 1993 May;25(5):628-642.

(20) Williams K, Frei A, Vetsch A, Dobbels F, Puhan MA, Rudell K. Patient-reported physical activity questionnaires: a systematic review of content and format. Health Qual Life Outcomes 2012 Mar 13;10:28-7525-10-28.

(21) Garrod R, Bestall JC, Paul EA, Wedzicha JA, Jones PW. Development and validation of a standardized measure of activity of daily living in patients with severe COPD: the London Chest Activity of Daily Living scale (LCADL). Respir Med 2000 Jun;94(6):589-596.

(22) Garfield BE, Canavan JL, Smith CJ, Ingram KA, Fowler RP, Clark AL, et al. Stanford Seven-Day Physical Activity Recall questionnaire in COPD. Eur Respir J 2012 Aug;40(2):356-362.

(23) Baarda DB, Goede d, M.P.M. Methoden en technieken. 1st ed. Leiden, the Netherlands: Stenfert Kroese; 1992.

(24) Polit DF, Hungler BP. chapter 14: interviews and questionnaires. Nursing research. 4th ed. Philadelphia, USA: J.B. Lippincott company; 1991. p. 277.

(25) Gwaltney CJ, Shields AL, Shiffman S. Equivalence of electronic and paper-and-pencil administration of patient-reported outcome measures: a meta-analytic review. Value Health 2008 Mar-Apr;11(2):322-333.

(26) Beaumont JL, Victorson D, Su J, Baker CL, Wortman K, Shah H, et al. Examining web equivalence and risk factor sensitivity of the COPD population screener. Value Health 2011 Jun;14(4):506-512.

(27) The Central Committee on Research Involving Human Subjects (CCMO). Does your study have to be reviewed?. Available at: http://www.ccmo-online.nl/main.asp?pid=10&sid=30&ssid=51. Accessed 10/1, 2009.

(28) American College of Sports Medicine, Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 2009 Jul;41(7):1510-1530.

(29) Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007 Aug;39(8):1435-1445.

(30) Vestbo J, Hurd SS, Agusti AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global Strategy for the Diagnosis, Management and Prevention of Chronic Obstructive Pulmonary Disease, GOLD Executive Summary. Am J Respir Crit Care Med 2012 Aug 9.

(31) Fan VS, Giardino ND, Blough DK, Kaplan RM, Ramsey SD, Nett Research Group. Costs of pulmonary rehabilitation and predictors of adherence in the National Emphysema Treatment Trial. COPD 2008 Apr;5(2):105-116.

(32) Arnold E, Bruton A, Ellis-Hill C. Adherence to pulmonary rehabilitation: A qualitative study. Respir Med 2006 Oct;100(10):1716-1723.

(33) Thorpe O, Johnston K, Kumar S. Barriers and Enablers to Physical Activity Participation in Patients With COPD: a systematic review. J Cardiopulm Rehabil Prev 2012 Aug 30.

(34) Hellem E, Bruusgaard KA, Bergland A. Exercise maintenance: COPD patients' perception and perspectives on elements of success in sustaining long-term exercise. Physiother Theory Pract 2011 Aug 8.

(35) O'Shea SD, Taylor NF, Paratz JD. . . . But watch out for the weather: factors affecting adherence to progressive resistance exercise for persons with COPD. Journal of cardiopulmonary rehabilitation and prevention 2007;27(3):166-174.

❖ Appendix

Online set of questions

1. What is your gender?
    a. Female
    b. Male
2. What is your birth date?
   dd-mm-yyyy
3. What is the degree of your COPD?
    a. Mild
    b. Moderate
    c. Severe
    d. Very severe
4. When were you diagnosed with COPD (approximately)? [open space]
5. Are you more or less physically active since being diagnosed with COPD?
    a. More
    b. The same
    c. Less
6. Have you ceased certain physical activities since being diagnosed with COPD (for example: cycling, walking, walking the stairs)?
    a. Yes
    b. No

    If yes, which activities? [open space]
7. Do you have other conditions in addition to COPD (for example: osteoporosis, heart disease)?
    a. Yes
    b. No

    If yes, which other conditions? [open space]
8. Do these conditions influence your physical activity?
    a. Yes
    b. No

    If yes, which activities are influenced by these conditions? [open space]
9. What kind of exercise prescriptions have you received from your healthcare practitioners? [open space]
    a. I have not received any exercise prescriptions [> continue with question 11]

10. Are you compliant with these prescriptions?
    a. Yes
    b. Not always
    c. No

    Why? [open space]
11. Which medications are you using?
    a. I'm not on medication [> continue with question 13]
    b. I use the following medication(s): [open space]
12. Do you think your medication influences your physical activity performance?
    a. Yes
    b. No

    If yes, what do you think is the effect? [open space]
13. Name 3 factors that INCREASE your physical activity.

    1. [open space]

    2. [open space]

    3. [open space]

    More: [open space]
14. Name 3 factors that DECREASE your physical activity.

    1. [open space]

    2. [open space]

    3. [open space]

    More: [open space]

Chapter 3

Exploring predictors for technology use by older adults in the Netherlands

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Under revision

❖ Abstract

Background Information and communications technology (ICT) has the potential to increase the quality of life of older adults. The effect of demographics and various health outcomes on ICT use can be of significance in light of an emerging trend in health care: the use of technology based assistance (eHealth). This study aims to analyse the use of a broad array of ICT devices and services among older Dutch adults and to determine whether demographics and health outcomes are associated with this use.

Method A questionnaire constructed to predict older adults' willingness to use remote telecare was dispensed online, and a paper version was distributed among a group of Dutch older adults (65 ≥ years). Part of the results of this questionnaire was used to address the current study aim. The reported use of 33 technological devices and services was combined to form the dependent variable ICT use. Questions that address similar concepts regarding demographics or health status were combined to form the independent variables. Subsequently, a univariate analysis of covariance was used to find associations between ICT use and demographics or health status.

Results A total of 218 subjects started and 166 completed the online version of the questionnaire for this study. A total of 73 of the paper versions of the questionnaire were returned. The reported use of 'newer' technologies, such as smartphones (18%) and tablets (28%) was lower compared with 'older' technologies, such as computers (95%), e-mail (92%), and mobile phones (95%). The use of e-mail ($p=0.017$) and mobile phones ($p=0.007$) was higher for individuals aged <70 years within this sample of older adults. Increased age ($p=0.048$), lower degree of education ($p=0.008$), birthplace outside of Europe ($p=0.024$), lower income ($p=0.005$), less arthrosis of the hands ($p=0.042$), and a lower physical functioning ($p=0.008$) resulted in a lower ICT use score with an adjusted R^2 of 0.311.

Conclusions Older adults are slower to adapt to newer technologies, even within an age sample of 65 years and older. Judging by the results of this study, it appears that it is not the degree of physical restrictions but rather the degree of adaptability to these restrictions that influence the use of ICT. The factors that were significantly associated with ICT use should be taken into account during the development and implementation of technologies for this user group. Efforts should be made to make these factors less of a barrier to ICT use. This approach might help in the successful adaptation of technologies by older adults.

❖ Introduction

Information and communications technology (ICT) has the potential to ease the performance of tasks for older adults. It can enable them to accomplish activities that they might otherwise not be able to do on their own and in turn increase their quality of life (1,2). However, ICT use is generally higher in younger adults than in older adults (1,3-6), and technology literacy is lower in older adults compared with younger persons (7).

Older adults encounter more difficulties in adopting new technologies. They experience physical challenges due to an age-related decline in ability, they can have sceptical attitudes towards the benefits of new technologies, and they encounter difficulties in learning how to use new technologies (8). This may be due to a generation-related lack of earlier experience with ICT based interfaces. Experience with an interaction style during early adulthood, before the age of 25, influences interactions with software interface styles. Older adults are more likely to use technologies that have been available to them for longer periods of time (9). However, there is only limited evidence that older adults cannot or are averse to using technology (1).

While several U.S. and European studies have looked into the use of a broad array of ICT devices and services by older adults (1,3-5), for Dutch older adults, this remains restricted to the use of the internet (10). Internet use in the Netherlands among older adults is high compared to other European countries (10), which might also translate to increased use in other ICT areas.

Demographics such as age and level of education have been shown to influence the use of ICT (3,5); however, these associations are not always found (11). There are indications that reduced health status can be a barrier to ICT use among older adults (3). The effect of various health outcomes on the use of a broad array of ICT devices and services has not been studied, but health can be of significance in light of technology based assistance in health care (eHealth). This relatively new area in health care deploys various forms of ICT. It holds the promise to address the challenges of an ageing population (12) by enabling more informed decision making and creating more efficient (and potentially more cost-effective) delivery of care (13). A considerable amount of users of eHealth interventions are people with health issues. The effect of various health outcomes on the use ICT is important to consider if the goal is to develop and successfully implement these (technology based) eHealth interventions.

This study aims to analyse the use of a broad array of ICT devices and services among Dutch older adults and to determine whether demographics and health outcomes are associated with this use.

❖ Methods

Questionnaire

The questionnaire that was used in this study consists of 68 questions and was originally constructed to predict older adults' willingness to use a specific eHealth technology, namely remote telecare (14). The questionnaire is based on validated questionnaires on health and technology use and has been translated into Dutch from the original English version. The Dutch questionnaire was tested for face- and content validity (15). This questionnaire can be found in **appendix 3**. In this study, part of the results of this questionnaire is used to find factors that are associated with ICT use among older adults in the Netherlands. Two authors [AA and SV] used the gerontechnology based literature to independently select those items from the questionnaire that had the potential to be associated with ICT use in older adults. According to the study aim, all of the chosen items refer to demographics or health status. After a comparison, the differences were discussed among the two authors and final decisions made. The final items of the questionnaire that are used in this study are shown in the second column of the table in **appendix 2**. These items were subsequently used to form the (in-)dependent variables.

Ethics

According to the Central Committee on Research involving Human Subjects, filling out a questionnaire generally does not require ethics approval (16).

Sample and recruitment

Recruitment took place in September 2012 and varied for the paper and online versions of the questionnaire. The inclusion criteria were: Dutch citizenship, an age of 65 years or older, and the ability to live independently in one's own home. For the paper version, the subjects were recruited from two senior and/or client organizations, two social senior clubs, five healthcare organizations, and at a senior information day. Older adults were recruited with an information brochure, and they were asked to fill out a participant slip stating whether they wanted to take part in the study. After recruitment, the paper version of the questionnaire was sent and included a self-addressed, stamped envelope. For the online version, an existing client panel was recruited via email. This client panel consisted of a group of approximately 2000 older adults who have monthly experience representing a senior population by filling out surveys online.

Analysis

Descriptive statistics include frequencies, means and standard deviations of the variables where appropriate.

Dependent variable: ICT use. Question 41 (“Please fill out how often you have used the following electronical devices or services in the past year”) was based on the technology experience questionnaire (17) and lists 33 technological devices and services. The respondents enumerated their experience with these items. The scores are as follows: 0: no use/don’t know what it is; 1: used it once; 2: use it now and then 3: use it often. The scores of the 33 items were summed per respondent. This resulted in a range from 0-99 points on the dependent variable ICT use. The composition of the dependent variable can be found in **appendix 1**. The respondents with more than 10% of missing values in the 33 items (4 items or more) were excluded from the analysis. The remaining missing values were replaced with the respondent’s average score.

Independent variables. To reduce the data and simplify the analyses, the questions that addressed similar concepts were combined into one variable. The composition of each of these independent variables (the formulation of the questions that were used, as well as the calculation of the composite score) can be found in **appendix 2**.

The resultant independent *demographic* variables are: gender (male/female, q.2), age (years, q.3), degree of education (1: no education – 4: higher education, q.4), ethnicity (born outside/within Europe, in the Netherlands, q.5a), income (1: < half of Dutch average – 7: > 3x average, q.8), and employed/volunteer work (yes/no, q.14).

The resultant independent *health status* variables are: perceived general health (1: poor – 5: excellent, q.17-19), physical functioning (1: poor – 3: good, q.20-21), sight (1: impaired - 2: not impaired, q.22-25), hearing (1: impaired – 3: not impaired, q.26-29), arthrosis of the hands (1: severe problems - 4: no problems, q.30) and support with activities of daily living (ADL support) (1: no support – 4: maximal support, q.31,36,38).

A Cronbach’s alpha was used to determine the internal consistency of the pooled items. The variables with a Cronbach's alpha <0.6 were excluded from analyses due to a lack of internal consistency (18).

A univariate analysis of covariance (ANCOVA) was used to find associations between ICT use and the explanatory, independent variables. The primary model incorporated the independent variables and all of the two-way interactions (e.g., between hearing and age). Subsequently, the non-significant interactions were removed first, and the main factors were removed later, one by one, starting with the highest p-value. Finally, only significant main factors and interactions constitute the final model.

Furthermore, independent t-tests were conducted to analyse the differences between groups (e.g., <70yr vs. ≥70yr). Analyses were carried out using SPSS (IBM®, PASW Statistics, version 20.0, Chicago, IL, USA) for Windows.

❖ Results

Of the respondents who started the web-based questionnaire (n=218), 166 completed this version. A total of 73 paper versions of questionnaires were returned. The ICT use score for the respondents that filled out the web-based questionnaire was higher than it was for the paper questionnaire respondents (47.9 ± 13.2 vs. 39.6 ± 17.8, respectively, p=0.001). A total of 14 questionnaires were excluded from the analysis due to more than 10% of missing values in the 33 items of the dependent variable. This resulted in a total number of 225 questionnaires used for analysis. Gender was equally distributed over the respondents, and over half of them still worked or performed volunteer work. A total of 47% of the respondents had completed higher education, 31% received some form of ADL support, 30% perceived their health as worse than average, and 17% scored their physical functioning as being poor. The characteristics of the respondents are summarized in **table 1**. Additional insight into the distribution of these characteristics is provided in **figure 1**.

Table 1: Subject characteristics. Data are presented as frequencies or means ± SD. For composition and clarification of the variables, see appendix 2.

	Score/frequency	N
Gender (Male/Female)	113 / 112	225
Age (yr.)	71.7 ± 5.8	222
Education level (1: no education – 4: higher education)	3.2 ± 0.87	223
Ethnicity (1: born outside of Europe; 2: born in Europe; 3: born in the Netherlands)	1: 12; 2: 20; 3: 189	225
Income (1: < half of Dutch average – 7: > 3x average)	3.37 ± 1.21	185
Employed/volunteer work (yes/no)	114 / 110	224
Perceived general health (1: poor – 5: excellent)	2.98 ± 0.83	225
Physical functioning (1: poor – 3: good)	2.29 ± 0.62	225
Sight (1: impaired - 2: not impaired)	1.68 ± 0.19	225
Hearing (1: impaired – 3: not impaired)	2.31 ± 0.81	225
Arthrosis of the hands (1: severe problems - 4: no problems)	3.17 ± 0.89	224
ADL support (1: no support – 4: maximal support)	1.41 ± 0.62	205

The internal consistency was acceptable to excellent for the combined variables ‘ICT use’, ‘perceived general health’, ‘physical functioning’, ‘hearing’, and ‘ADL-support’ (Cronbach’s alpha’s: 0.852; 0.891; 0.959; 0.725; and 0.787, respectively) but poor for the variable ‘sight’ (Cronbach’s alpha: 0.346) (18). Removing items from this latter variable increased the Cronbach’s alpha to only 0.449. Hence, instead of the variable ‘sight’, the individual items ‘glasses/contacts’, ‘glaucoma/cataract’, and ‘poor vision’ were entered in the ANCOVA.

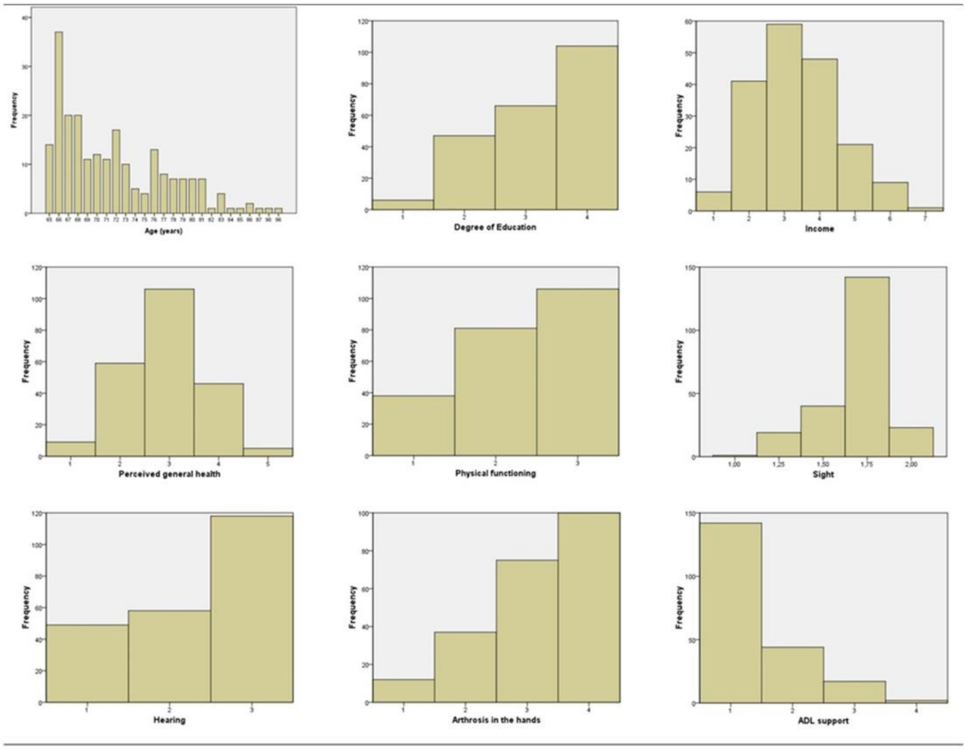

Figure 1: Distribution of subject characteristics. Score ranges are: Degree of education (1: no education – 4: higher education); Income (1: < half of Dutch average – 7: > 3x average); Perceived general health (1: poor – 5: excellent); Physical functioning (1: poor – 3: good); Sight (1: impaired - 2: not impaired); Hearing (1: impaired – 3: not impaired); Arthrosis of the hands (1: severe problems - 4: no problems); ADL support (1: no support – 4: maximal support). See table 1 for means ± SD.

For the dependent variable ‘ICT use’, 180 subjects filled out all 33 items (80%). Of all of the data points (7425), 94 were missing data (1.27%). ICT use is shown in **figure 2**. We see that 18% of the respondents use smartphones, whereas 95% use mobile phones. Computer use is high with 95% of the respondents as well as the use of e-mail, with 92%, whereas a tablet is used by 28%. Within this group of older adults, those who are below the age median (<70yr) reported a higher use of smartphones (23% versus 14% for the upper age median (≥70yr)), mobile phones (96% versus 93%), computers (98% versus 94%), tablets (35% versus 23%), and e-mail (96% versus 90%). These differences were significant for the use of e-mail (p=0.017) and mobile phones (p=0.007).

The first ANCOVA did not reveal any significant two-way interactions. The interaction education and income was borderline significant with p=0.056. As this is a logical interaction and explained the variance to some degree, this interaction was retained in the model. The respondents with a lower level of education and with an income that was average or lower had a lower ICT use score compared with those who received higher forms of education and had higher incomes.

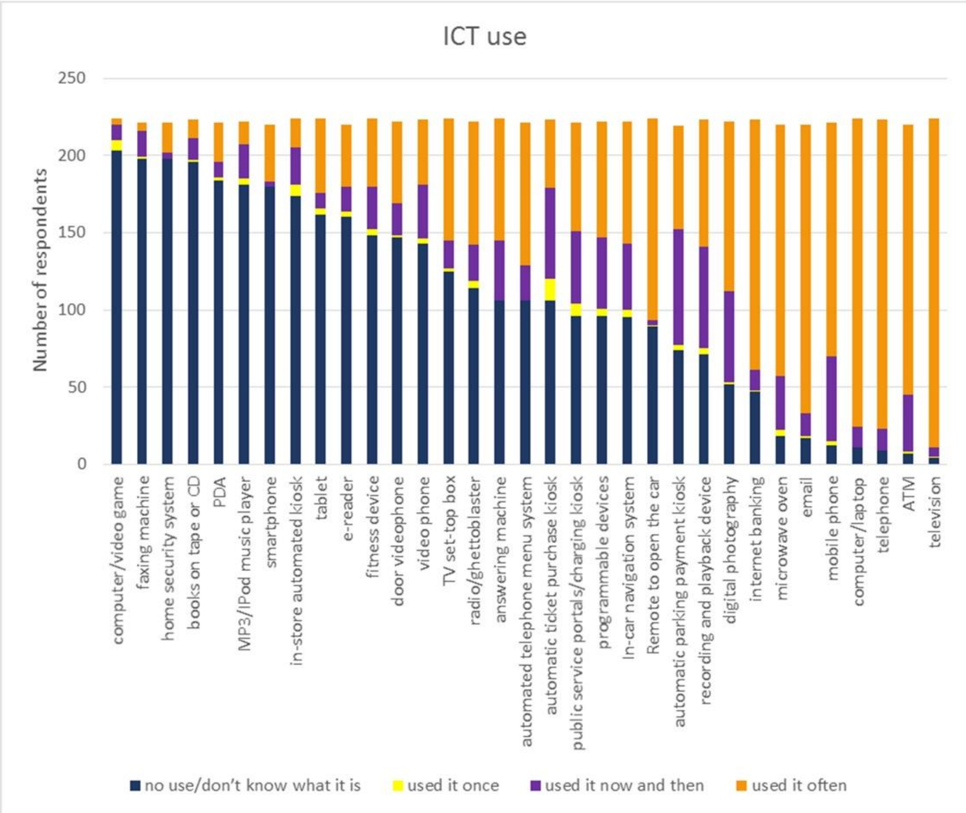

Figure 2: ICT use. Frequency distribution of the use of 33 ICT devices and services among the respondents.

The final model revealed that age, degree of education, income, arthrosis of the hands, physical functioning, and ethnicity significantly predicted ICT use with an adjusted R^2 of 0.311. The results are shown in **table 2**. For age, we see that with each additional year, the ICT use score diminishes by 0.366 points (out of a total possible score of 99 points). Generally, the respondents with a higher education also had higher ICT use scores. However, the respondents in the subgroup 'lower education' actually had higher scores. The overall trend with respect to income is that the higher one's income, the higher their ICT use score turns out to be. For example, the respondents that make < half of average scored 10.53 points lower on ICT use than respondents that make >3x average. The respondents that have more severe arthrosis of the hands have a higher ICT use score than respondents with less or no arthrosis of the hands. Furthermore, a higher physical functioning is associated with a higher ICT use score. Lastly, the respondents who were born outside of Europe on average scored 11.38 points lower on ICT use than natives, whereas those who were born within Europe actually have higher scores than natives.

Table 2. Factors associated with ICT use in older adults. B = regression coefficients, CI = 95% confidence interval. *Reference value and therefore set at 0.

	B	CI	p-value
Associated factors			
Age	-0.366	-0.73 : -0.004	**0.048**
Degree of education			**0.008**
None/primary school	-32.62	-59.64 : -5.59	0.018
Lower	31.12	5.08 : 57.16	0.02
Average	-18.86	-47.03 : 9.3	0.19
Higher	0*	-	-
Income			**0.005**
< half of average	-10.53	-46.44 : 25.38	0.563
half of average	-11.83	-37.33 : 13.66	0.36
average	-5.88	-30.88 : 19.12	0.642
1,5x average	-1.57	-26.56 : 23.43	0.902
2x average	-4.24	-29.50 : 21.03	0.741
3x average;	-3.5	-29.46 : 22.47	0.790
>3x average	0*	-	-
Arthrosis of the hands			**0.042**
Severe	9.87	-1,38 : 21.11	0.085
Moderate	8.51	1,97 : 15.06	0.011
Mild	1.22	-3,56 : 5.98	0.615
none	0*	-	-
Physical functioning	5.42	1.43 : 9.41	**0.008**
Ethnicity			**0.024**
Born outside of Europe	-11.38	-21.99 : -0.73	0.036
Born in Europe	6.17	-1.68 : 14.01	0.122
Born in the Netherlands	0*	-	-

❖ Discussion

Demographics

The variables degree of education, income, ethnicity, and age were significantly associated with ICT use, whereas gender and employed and/or volunteer work did not. Previous studies that looked at gender found that men are more willing to use telemonitoring (19), while women more often look for health information on the internet (20).

Degree of education

Generally, subjects with a higher degree of education reported more ICT use than the less educated subjects. Higher education was previously found to increase the use of computers and the internet (8,21,22). Here we see that a higher degree of education also increases ICT use in the broader sense (the use of various technological devices and services, not restricted to computers and the internet), whereas this was not found in a recent study (11). On the other hand, 'lower education' proved to be an exception. Education may be more strongly associated with the use of computers and internet than ICT use in the broader sense. Cognitive ability and memory may be underlying factors that influence the amount of ICT use. They have both been shown to be related to years of formal education (23-25). Cognitive ability has been shown to be an important predictor of technology use (26), and memory appears to be a good predictor of age related differences in digital skills with video and mobile phone interfaces (8,9).

Income

More affluent older adults had a higher ICT use score than less affluent ones. Internet access at home has already been shown to be more prominent in older adults with higher levels of income (8). Additionally, financial reasons have been mentioned as a limitation to smartphone use in older adults (27,28). ICT can be quite costly, and the fast developing rate in this area also results in a quick turnover rate of devices and software, causing less affluent persons to be at a disadvantage in this area.

Ethnicity

Regarding ethnicity, we see that those who were not born in Europe stand out for their low ICT use scores, which are significantly lower compared with those who were born in Europe and the Netherlands. In a study that was conducted in the Netherlands (29), interviews were held with 159 Iranian and Turkish immigrants on the use of e-government services. A total of 22% of the interviewees never used the internet. In the general Dutch population (including immigrants), this is only 3% (30). Stronger language skills and male gender were related to higher internet use in Far's study (29). There seems to be quite a bit of variation among ethnic minorities with respect to digital skills. For example, Turkish and Moroccan immigrants are found to have a relatively large disadvantage, whereas Surinamese and Antilleans have skill levels near those of the indigenous Dutch (21). The knowledge of the Dutch language and culture may play a role here because in Suriname and part of the Antilles, Dutch is the spoken language. However, these studies did not focus solely on older adults, whereas our study did. It may be easier for younger immigrants in the Netherlands to acquire ICT skills as they may have more interactions with Dutch peers and receive information technology lessons at school.

Age

The older respondents within this sample of older adults reported less use of ICT. Previous studies showed a reduction in the use of e-mail, sending text messages and internet use with increasing age, and similarly within senior groups (5,8,22). Additionally, the willingness to use telemonitoring has been found to decrease with age (19). The results of this study show that, especially with the use of more modern technologies, such as smartphones and tablets, older adults report low use. Within this senior group, those over 70 years old report less frequent use of e-mail and mobile phones than younger respondents. These technologies are again relatively new compared to technologies such as the landline telephone or television, for which no differences within the senior group are apparent. In general, Dutch older adults possess fewer adequate digital skills than their younger counterparts, and they mention a lack of interest and the belief that they are too old as reasons for their non-use (21). Age-related physical limitations can also contribute to a lower level of ICT use. For example, some major barriers for learning and using the computer and the internet include the age-related deterioration of visual, perceptual, motor, and cognitive abilities (31).

Health status

Physical functioning and arthrosis of the hands were significantly associated with ICT use in older adults, whereas perceived general health, hearing, sight items ('glasses/contacts', 'glaucoma/cataract', and 'poor vision'), and ADL support did not.

Physical functioning

The respondents with a lower physical functioning score, who are thus hindered in their activities of daily living (ADL) due to health issues, report less ICT use than those who are not hindered. Interestingly, the amount of support that is received for ADL was not associated with ICT use. Additionally, it is not the perception of one's health status (perceived general health) or physical restrictions but only functional restrictions that influence the use of ICT. Previous studies show a decreased use of the internet and smartphones with greater physical impairment (22,27). In both studies, vision impairment as a cause of difficulty in reading is mentioned as one of the barriers. This restriction could greatly restrict the use of ICT, which is mostly screen-based. However, we did not find sight items to be associated with ICT use. There were no respondents who suffered from blindness, so that item could not be used as an independent variable. The other sight problems might have been well enough compensated for in our respondents not to influence their ICT use. This may also be the reason why hearing was not found to be associated with ICT use.

Arthrosis of the hands

We found that older adults without or with less severe arthrosis of the hands had a lower ICT use score. Most ICT devices are hand-operated, which may lead one to assume this would prove problematic for these patients. However, ICT can also compensate for physical restrictions. Algar and Valdes (32) argue that the use of smartphone applications that facilitate neuromuscular control may even serve as a valuable component of a hand therapy programme for persons with arthrosis of the hands. Furthermore, the difficulties in using ICT devices due to arthrosis of the hands can be circumvented by devices that can also be operated without using the hands (for example with speech (33)). A word of caution is needed here. First, peripheral arthrosis is only seen in a small fraction of the Dutch population (2%) (34), and secondly, those who are too disabled to fill out the questionnaire are clearly not represented in our sample.

User centred design

There has been debate as to whether ICT represents an opportunity or whether it is a cause of exclusion for persons with disabilities (35). However, there is agreement that ICT can bring such persons innumerable benefits if accessibility is provided (36). A ‘design for all’ approach, or a ‘universal design’, can address this issue. The approach focuses on finding solutions in the design phase so that, without the need for special adaptations, as many people as possible, regardless of their age and physical functioning, can access products and services (35). This should not be seen as developing products that offer a single solution for everybody, but rather it is a user-centred approach where products can be adjusted depending on an individual’s abilities, skills, and preferences (37). From the results of this study, it appears that it is not the degree of physical restrictions but rather the degree of adaptability to these restrictions (from older adults) that influence the use of ICT. A more advanced user-centred approach might help older adults with less adaptability to increasingly benefit from the potential of ICT to ease the performance of tasks, enable them to accomplish activities they might otherwise not be able to do on their own, and in turn increase their quality of life.

Limitations

Most of the questionnaires were filled out by subjects that were part of the panel (68%). These persons might have better digital skills compared with the persons that filled out the paper questionnaire, because they have access to the internet and a computer and complete online questionnaires more often. Their ICT use score was indeed higher, which might have increased the overall ICT use in our respondents compared with the general population. However, there were only 5% of respondents who did not use a computer and 8% that did not use e-mail, which should make this less of a confounder. Being that internet-access in the Netherlands is high among older adults (10), overall our pool of respondents may still fairly reflect the Dutch older adult population.

There were only 32 non-native respondents (14%), so general conclusions from this study with respect to ethnicity and ICT use should be drawn with caution.

The predicted variance was not high (R^2 was 0.311). Finding factors that are associated with ICT use in older adults is a complex issue, where other variables in addition to demographics and health status also figure in. For example, according to the Telecare Acceptance and Use Model for older adults (38), perceived benefits are considered to be the key predictor for the use of telecare technologies with accessibility, facilitating conditions, and personal variables as influencing variables. Still, the demographic and health related outcomes that were (not) associated with ICT use provide new insights into which variables should be taken into account to develop successful (eHealth) technologies for older adults.

❖ Conclusion

Older adults are slower to adapt to newer technologies, even within a sample of 65 years and older. Increased age, a lower degree of education, being born outside of Europe, lower income, less arthrosis of the hands, and a lower physical functioning were significantly associated with lower ICT use in older adults. For the development and implementation of technologies for this user group, these variables should be should be taken into account as influencing factors. Efforts should be made to make these factors less of a barrier to ICT use. This could help in the successful adaptation of new technologies by older adults.

❖ References

(1) Olson KE, O'Brien MA, Rogers WA, Charness N. Diffusion of Technology: Frequency of Use for Younger and Older Adults. Ageing Int 2011 Mar;36(1):123-145.

(2) Czaja SJ, Charness N, Fisk AD, Hertzog C, Nair SN, Rogers WA, et al. Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). Psychol Aging 2006;21(2):333-352.

(3) Heart T, Kalderon E. Older adults: Are they ready to adopt health-related ICT? Int J Med Inf 2013 11;82(11):e209-e231.

(4) Hernández-Encuentra E., Pousada M., Gómez-Zúniga B. ICT and older people: Beyond usability. Educ Gerontol 2009;35(3):226-245.

(5) Vroman KG, Arthanat S, Lysack C. "Who over 65 is online?" Older adults' dispositions toward information communication technology. Comput Hum Behav 2015 2;43:156-166.

(6) Czaja SJ, Charness N, Dijkstra K, Fisk AD, Rogers WA, Sharit J. Computer and technology experience questionnaire. CREATE technical report REATE-2006-03 2006.

(7) Shelley MC, Thrane L, Shulman SW. Generational differences in informational technology use & political involvement. 2004:1-2.

(8) Smith A. Older Adults and Technology Use. 2014; Available at: http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/.

(9) Docampo Rama M, de Ridder H, Bouma H. Technology generation and age in using layered user interfaces. Gerontechnology 2001;1(1):25-40.

(10) Akkermans M. Internetgebruik ouderen fors toegenomen. Centraal Bureau voor de Statistiek. 2013; Available at: http://www.cbs.nl/nl-NL/menu/themas/vrije-tijd-cultuur/publicaties/artikelen/archief/2013/2013-4005-wm.htm. (Archived by WebCite® at http://www.webcitation.org/6YIPpX3ZG). Accessed 5/5, 2015.

(11) Scanlon L., O'Shea E., O'Caoimh R., Timmons S. Technology use and frequency and self-rated skills: A survey of community-dwelling older adults. J Am Geriatr Soc 2015;63(7):1483-1484.

(12) Layzell B, Manning B, Benton S. The elderly demographic time bomb - sharing the load with the active ageing: can eHealth technologies help defuse it? Stud Health Technol Inform 2009;146:166-170.

(13) Internet Innovation Alliance. 10 Benefits of Health IT. 2011; Available at: http://internetinnovation.org/files/telemed_infographic_palmcard.pdf. Accessed: 2015-05-18. Internet Innovation Alliance. 10 benefits of health IT. http://internetinnovation.org/library/special-reports/telemed-infographic/ (Archived by WebCite® at http://www.webcitation.org/6YcJQaCsv). Accessed 18/5, 2015.

(14) Chan M, Campo E, Esteve D. Assessment of activity of elderly people using a home monitoring system. Int J Rehabil Res 2005 03;28(1):69-76.

(15) Antonietti A, Barakat A, Van Houwelingen T, Kort H. Remote telecare in an aging dutch sample: Critical factors predicting their intention to use. Assistive Technology Research Series 2013;33:1229-1234.

(16) The Central Committee on Research Involving Human Subjects (CCMO). Does your study have to be reviewed? Available at: http://www.ccmo-online.nl/main.asp?pid=10&sid=30&ssid=51. Accessed 10/1, 2009.

(17) Czaja SJ, Charness N, Dijkstra K, Fisk AD, Rogers WA, Sharit J. *CREATE common core battery of measures:* Technical report No. CREATE-2006-01, GA: Center for Research and Education on Aging and Technology Enhancement (CREATE), Atlanta 2006.

(18) Bland JM, Altman DG. Cronbach's alpha. BMJ 1997 Feb 22;314(7080):572.

(19) Burmann Genannt Siggemann C, Mensing M, Classen T, Hornberg C, Terschuren C. Specific health status has an impact on the willingness to use telemonitoring: data from a 2009 health survey in north rhine-westphalia, Germany. Telemed J E Health 2013 Sep;19(9):692-698.

(20) Nölke L, Mensing M, Krämer A, Hornberg C. Sociodemographic and health-(care-)related characteristics of online health information seekers: a cross-sectional German study. BMC Public Health 2015 01/15;15:31.

(21) Ingen E, De Haan J, Duimel M. Achterstand en afstand. Digitale vaardigheden van lager opgeleiden, ouderen, allochtonen en inactieven. 2007:1-99.

(22) Gell NM, Rosenberg DE, Demiris G, Lacroix AZ, Patel KV. Patterns of Technology Use Among Older Adults With and Without Disabilities. Gerontologist 2013 Dec 30.

(23) Bennett DA, Wilson RS, Schneider JA, Evans DA, Mendes de Leon CF, Arnold SE, et al. Education modifies the relation of AD pathology to level of cognitive function in older persons. Neurology 2003 Jun 24;60(12):1909-1915.

(24) Berry MJ, Rejeski WJ, Adair NE, Ettinger WH,Jr, Zaccaro DJ, Sevick MA. A randomized, controlled trial comparing long-term and short-term exercise in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil 2003 Jan-Feb;23(1):60-68.

(25) Albert MS, Jones K, Savage CR, Berkman L, Seeman T, Blazer D, et al. Predictors of cognitive change in older persons: MacArthur studies of successful aging. Psychology and Aging 1995;10(4):578-589.

(26) Umemuro H. Computer attitude, cognitive abilities, and technology use among older Japanese adults. Gerontechnology 2004;3:64-76.

(27) 3rd International Conference on User Science and Engineering (i-USEr). A study of smartphone usage and barriers among the elderly; 2-5 Sept. 2014; IEEE 2014.

(28) Nguyen T, Irizarry C, Garrett R, Downing A. Access to mobile communications by older people. Australas J Ageing 2014 Apr 17.

(29) Razvi Far A. Access and use of e-government services: The case of Iranian and Turkish immigrants in the Netherlands. 2014.

(30) Centraal Bureau voor de Statistiek. ICT gebruik van personen naar persoonskenmerken. 2014; Available at: http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=71098ned&D1=33,55-59,93-95,97-100,102-104,106-109,112-113,119,124-133&D2=0&D3=0,l&HD=130422-1124&HDR=G2,G1&STB=T. (Archived by WebCite® at http://www.webcitation.org/6Yz02GrCQ). Accessed 6/2, 2015.

(31) Xie B. Older adults, computers, and the internet: Future directions. Gerontechnology 2003;2(4).

(32) Algar L, Valdes K. Using smartphone applications as hand therapy interventions. Journal of Hand Therapy 2014;27(3):254-257.

(33) Kashioka H. Spoken language communication technology: Overview of spoken language communication technologies. Journal of the National Institute of Information and Communications Technology 2012;59(3-4):11-14.

(34) Poos M, Gommer A. Hoe vaak komt artrose voor en hoeveel mensen sterven eraan? 2015-10-06. Available at: http://www.nationaalkompas.nl/gezondheid-en-ziekte/ziekten-en-aandoeningen/bewegingsstelsel-en-bindweefsel/artrose/omvang/ (Archived by WebCite® at http://www.webcitation.org/6c4gXmLpN). Accessed 10/6, 2015.

(35) Toboso M. Rethinking disability in Amartya Sen's approach: ICT and equality of opportunity. Ethics and Information Technology 2011;13(2):107-118.

(36) Landers SH. The case for "connected health" at home. Cleve Clin J Med 2013;80 (electronicsuppl.1): S27-S29.

(37) Emiliani PL. Technology for the independent living of people with activity limitations. BIODEVICES 2009 - Proceedings of the 2nd International Conference on Biomedical Electronics and Devices; 2009, IS9-IS12.

(38) AAG Sponselee. Acceptance and effectiveness of telecare services from the end-user perspective. Eindhoven: Eindhoven University of Technology; 2013.

Appendix 1. Composition of the dependent variable.

Variable	Question	Scores
ICT use	41. Please fill out how often you have used the following electronical devices or services in the past year: Remote to open the car, answering machine, automated telephone menu system, video phone (skype/facetime), automatic parking payment kiosk, computer/laptop, door videophone, digital photography (e.g., camera, camcorder), TV set-top box (e.g., programme TV, pay-per-view movies, music stations), email, e-reader, faxing machine, fitness device (e.g., pedometer, pulse metre, treadmill), home security system, internet banking, automatic ticket purchase kiosk (e.g., for a train ticket), books on tape or CD, microwave oven, mobile phone, MP3/IPod music player, In-car navigation system (e.g., GPS, TomTom), recording and playback device (e.g., CD, DVD, VCR), public service check in/out portals or charging kiosk, personal digital assistant (PDA), automatic teller machine (ATM), programmable devices (e.g., lights, thermostat, sprinkler, programmable coffee maker or food processor), radio/ghettoblaster, smartphone, in-store automated kiosk (e.g., self-checkout, price scanner, item locator), computer/video game (e.g., Gameboy, PlayStation, Nintendo, Wii, XBox), tablet (e.g., ipad), television, telephone.	0: no use/don't know what it is; 1: used it once; 2: use it now and then; 3: use it often. Scores of the 33 items were summed per respondent. This results in a range from 0-99 points.

Appendix 2. Composition of the independent variables.

Variable	**Question**	**Scores**
Demographics		
• Gender	2. Gender.	1: male; 2. female
• Age	3. Date of birth.	
• Degree of education	4. What is your highest completed education level?	1: no education/primary school; 2: lower education; 3: average education; 4: higher education.
• Ethnicity	5a. In which country were you born?	1: outside of Europe; 2: in Europe but not in the Netherlands; 3: in the Netherlands
• Income	8. Which category best describes the total gross income of your household, including holiday bonuses?	Average income is set as €33.300 per year. 1: < half of average; 2: half of average; 3: average; 4: 1,5x average; 5: 2x average; 6: 3x average; 7: >3x average
Employed/volunteer work	14. Are you currently employed or involved in volunteer work?	1: yes; 2.: no
Health status		
Perceived General Health	17. In general I score my health as: 18. Compared with my peers my health status is: 19. How content are you with your current health status?	q17 and 18: 1: poor; 2: fair; 3: good; 4: very good; 5: excellent. q19: 1: not content at all; 2: not very content; 3: neutral; 4: fairly content; 5: extremely content. Average of 3 questions.
Physical Functioning	20. How often do your health issues hinder you? 21. Does your health status currently hinder any of the following activities? Washing, kneeling, walking the stairs, carrying groceries, light activities (such as cooking or doing the dishes), moderate activities (such as mowing the grass or gardening), walking over a kilometre, walking 100 metres, cycling.	q20: 1: always/often; 2: sometimes; 3: rarely/never. q21(each activity is individually scored): 1: severely constricted; 2: moderately constricted; 3: not constricted. Average of 11 items. Range from 1: poor to 3: very good.
Physical restrictions		
• Sight	22. Do you wear glasses or contacts? 23. Do you have glaucoma or cataract? 24. Are you suffering from blindness? 25. Are you suffering from poor vision in one or two eyes, even with glasses?	1: yes; 2: no. Average of 4 questions. Range: 1: yes, vision impaired or 2: no, not impaired.
• Hearing	26. Do you use a hearing-aid? 27. Are you suffering from deafness? 28. Are you suffering from poor hearing in one or two ears, even with a hearing-aid? 29. Do you have trouble hearing a conversation when multiple people speak at once?	q26,28,29: 1: yes; 2: no. q27: 1 yes in both ears; 2: yes in one ear; 3: no. Average of 4 questions. Range: 1: hearing impaired; 2,25: no impairment

• Arthrosis of the hands	30. Do you have arthrosis of the hands?	1: yes, severe; 2: yes, moderate; 3: yes, mild; 4: no.
ADL support	31. Do you need assistance of others with the following activities? Taking a shower/bath, getting dressed, cooking, eating, walking the stairs, carrying groceries, moving a table or chair, doing groceries, swiping the floor, doing the dishes, vacuuming, walking more than 1 kilometre, walking from the beginning till the end of the street. 36. How many hours a week do you receive professional health support? 38. How many hours a week do you receive nonprofessional health support (e.g., from a friend or relative)?	q31(each activity is individually scored): 1: no assistance necessary or 2: assistance necessary. q 36, 38: 1: less than 2 hours; 2: 3-5 hours; 3: 6-12 hours; 4: more than 12 hours. Calculation for this variable is: mean (13 items q.31) + ((q.36 + q.38)/4) so that the amount of time for ADL support weighs equally to the number of ADL's support is needed for. Range: 1: no ADL support; 4: maximum ADL support.

Appendix 3 can be found online at:
http://www.onderzoek.hu.nl/onderzoekers/sigrid-vorrink
and in the online version of the thesis (www.narcis.nl).

Appendix 3 chapter 3 (PhD thesis S.N.W. Vorrink)

Questionaire remote telecare for older adults

Dear sir/madam,

In the USA the population of older adults (65 years and older) rises dramatically. Also, more and more technical products appear that make it possible to provide remote telecare. These e-health products support the traditional care and make it possible for older adults to live longer independantly in their own homes.

Among older adults as well as among health care professionals, uncertainty exists about the use of such e-health products. To take away this uncertainty, an international research has been started to the predictors for the use of e-health products or services.

The measure instrument for this research, this questionnaire, is developped by Florida State University (FSU) and research group for Demand-driven Care of Utrecht University of Applies Sciences (HU). The questionnaire consists of 68 multiple choise en short answer open questions. It takes about 20-30 minutes of your time to complete this questionnaire. Thank you for filling out this questionnaire!

The following members include the consortium in this research project:

- University of Applied Sciences Utrecht, Centre for Innovations in Health Care, Research Group Demand Driven Care
- Center for Research and Education on Aging and Technology Enhancement (CREATE), a cooperation of University of Miami, Georgia Institute of Technology and Florida State University
- Fontys University of Applied Sciences, Research Group Ambient Intelligence & Design
- Rotterdam University of Applied Sciences , Research Group Innovation and Product realization, Program Technology for Care
- Care organization Zuwe Aveant Careyn
- IVVU Vereniging van Instellingen voor Verpleging en Verzorging, Utrecht (Association of Nursing and Care Organizations)
- CliëntenBelang Utrecht (Client organization)

The project Predictors for the use of e-Health by older adults and care professionals (PETZ), (registration number 2010-2-004 INT) is facilitated by SIA Raak.

Demographic data

1. **What are the first ur digits of your zip code? ______**

2. **Gender:** ☐2 **Male** ☐2 **Female**

3. **Date of Birth: __ __ / __ __ / __ __**

4. **What is your highest completed level of education?**
   - ☐1 No formal education
   - ☐2 Less than high school graduate
   - ☐3 High school graduate/GED
   - ☐4 Vocational training
   - ☐5 Some college/Associate's degree
   - ☐6 Bachelor's degree (BA, BS)
   - ☐7 Master's degree (or other post-graduate training)
   - ☐8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)
   - ☐9 Different (please specify):____

5. **How would you describe your primary racial group?**
   - ☐1 No Primary Group
   - ☐2 White Caucasian
   - ☐3 Black/African American
   - ☐4 Asian
   - ☐5 American Indian/Alaska Native
   - ☐6 Native Hawaiian/Pacific Islander
   - ☐7 Multi-racial
   - ☐8 Other (please specify) _____________________________________

6. **How many years have you been retired? ___________** ☐ Not applicable

7. **What is your current living situation?**
   - ☐1 Alone
   - ☐2 with 1 other person
   - ☐3 with two other persons
   - ☐4 with 3 or more other persons

8. **Which category best describes the total monthly gross income of your household (including holiday allowances)**
   - ☐1 more than 3 x average
   - ☐2 3 x average
   - ☐3 2 x average
   - ☐4 1,5 x average
   - ☐3 average: €33.000 gross p/a (p/m: gross €2.541, nett: €1.829)
   - ☐4 0,75 x average
   - ☐5 0,5 x average
   - ☐6 I do not know / do not wish to answer

9. In what type of housing do you live?

☐1 Residence hall/College dormitory
☐2 House/Apartment/Condominium
☐3 Senior housing (independent)
☐4 Assisted living
☐5 Nursing home
☐6 Relative's home
☐7 Other (please specify) ________________

10.What type of housing fits the number of floors in your house?

☐1 One floored house
☐2 Only stairs inside the house
☐3 Only stairs outise the house
☐4 Stairs both inside and outside the house

11.Which of the following tools do you use in your house?

☐1 Stairs ☐2 Chair elevator ☐3 Elevator ☐4 Not applicable

12.Do you care for one or more needy people in your surrounding?

☐1 Yes, I received a voluntary caregivers alowance for it.
☐2 Yes, I did not receive a voluntary caregivers alowance for it.
☐3 No (go to question 14)

13.How many hours of care (as a voluntary caregiver) do you provide during a typical week?

☐1 0 – 5 hours
☐2 6 – 10 hours
☐3 11 – 20 hours
☐4 21 – 30 hours
☐5 31 – 40 hours
☐6 More than 40 hours

14.Are you doing paid or unpaid (volunteer) work?

☐ Yes ☐No (go to question 17)

15.What sector does your primary work belong to?

☐ All economic activities
☐ Argriculture and fishery
☐ Industrial work
☐ Transport and storage
☐ Food service industry
☐ Information and communication
☐ Finincial service providing
☐ Public staff and government services
☐ Education
☐ Healthcare and Welfare
☐ Culture, sport and recreation

☐ Other service providing
☐ Other, please specify:____

16.During a typical week, how many hours do you work/volunteer?

- ☐1 **0 – 5 hours**
- ☐2 **6 – 10 hours**
- ☐3 **11 – 20 hours**
- ☐4 **21 – 30 hours**
- ☐5 **31 – 40 hours**
- ☐6 **More than 40 hours**

Health Information

17.In general, I would say my health is:

☐1	☐2	☐3	☐4	☐5
Poor	Fair	Good	Very good	Excellent

18.Compared to other people of my age, I would say my health is:

☐1	☐2	☐3	☐4	☐5
Poor	Fair	Good	Very good	Excellent

19. How satisfied are you with your present health?

☐1	☐2	☐3	☐4	☐5
Not at all	Not very satisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied

20. How often do health problems stand in the way of doing the things you want to do?

☐1	☐2	☐3	☐4	☐5
Never	Seldom	Sometimes	Often	Always

21. The following items are about activities you might do during a typical day. Does your health <u>now</u> limit you in these activities?

	Limited a lot1	Limited a little2	Not limited at all3
a. Bathing or dressing yourself			
b. Bending, kneeling, or stooping			
c. Climbing one flight of stairs			
d. Climbing several flights of stairs			
e. Lifting or carrying groceries			
f. Light intensity exercise, such as: cooking, washing the dishes, changing bedsheets			
g. Moderate intensity exercise such as: mowing the lawn, gardening			
h. Walking more than a kilometer			
i. Walking 100 meter			
j. cycling			

The next set of questions are about your vision and hearing. Please indicate if any of the following conditions apply to you:

22.Do you wear eyeglasses?

☐1 Yes ☐2 No

23.Do you now have glaucoma or cataracts?

☐1 Yes ☐2 No ☐3 Do not know

24.Do you now suffer from blindness?
☐$_1$ Yes, in one eye ☐$_2$ No

25.Do you now have trouble seeing with one or both eyes, even when wearing glasses?
☐$_1$ Yes ☐$_2$ No

26.Do you use hearing aids?
☐$_1$ Yes ☐$_2$ No

27.Do you now have deafness?
☐$_1$ Yes, in both ears ☐$_2$ Yes, in one ear ☐$_3$ No

28.Do you now have any trouble hearing with one or both ears, even when using hearing aids?
☐$_1$ Yes ☐$_2$ No

29. Can you hear a conversation properly when multiple people talk at the same time?
☐$_1$ Yes ☐$_2$ No

30.Do you suffer from joint problems (Osteoarthritis, Rheumatism) in your hands?
☐$_1$ Yes, severe ☐$_2$ Yes, moderate ☐$_2$ Yes, mild ☐$_2$ No

31.Do you need assistance from others during the following activities?

	Does not Apply to me (n/a)	Yes	No
a. Taking a shower/bathing			
b. Dressing			
c. Preparing dinner			
d. Eating			
e. Climbing the stairs			
f. Lifting or carrying groceries			
g. Moving a table or a chair			
h. Doing groceries			
i. Wiping the floor			
j. Washing the dishes			
k. vacuum cleaning			
l. Walking more than a kilometer			
m. Walking to the end of the street			

32. If you receive assistence during one or more activities mentioned in the last question (31), who are you receiving this from? <u>Please tick all that apply.</u>

- ☐ Family
- ☐ Friends
- ☐ Neighbours
- ☐ Home carer
- ☐ Nurse
- ☐ Voluntary carer (other than abobe mentioned people)
- ☐ Not applicable (Go to question 40)

33. Do you have an indication of AWBZ or WMO law? (Dutch laws for financial support for people with special deseases en disabled elderly)

- ☐ Yes, AWBZ indication
- ☐ Yes, WMO indication
- ☐ No
- ☐ I do not know

34. Are you a member of a care organization/institution?

☐ Yes, please specify:____ ☐ No

35. Do you receive professional care in your own house?

- ☐ Yes, direct from a care institution
- ☐ Yes, via a personal budget
- ☐ Yes, via:____
- ☐ No, I do not receive professional care (go to question 38)

36. Approxemately how many hours <u>per week</u> are you receiving professional care support, e.g. from a nurse or home carer?

- ☐1 Less than 2hours
- ☐2 3-5h
- ☐3 6-12h
- ☐4 >12 h
- ☐5 Not appicable (go to question 38)

37. Are you satisfied with the professional care support you are receiving?

☐1	☐2	☐3	☐4	☐5
Not at all	Not very satisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied

38. Approxemately how many hours <u>per week</u> are you receiving voluntary care support, e.g. from a friend or relative?

- ☐1 Less than 2hours
- ☐2 3-5h
- ☐3 6-12h
- ☐4 >12 h
- ☐5 Not appicable (go to question 40)

39. Are you satisfied with the voluntary care support you are receiving?

☐1	☐2	☐3	☐4	☐5
Not at all	Not very satisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied

Healthcare related use of technology.

40. Which of the following devices have you used in your home in the last year?

	Not sure what it is$_1$	**Never used $_2$**	**Used once$_3$**	**Used occasionally$_4$**	**Used frequently$_5$**
a. Blood pressure device					
b. Digital thermometer					
c. Electronic dental hygiene (e.g., electric toothbrush, electronical floss device)					
d. Emergency call system (e.g., Lifeline, alarm button)					
e. Heating pads					
f. Infusion pump					
g. Monitoring device (e.g. for glucose, apnea, cardiac)					
h. Nebulizers					
i. Digital scale					
j. Oxygen equipment					

Technology and computer experience

41. Please indicate how often you have used the following technical devices in the last year:

	Not sure what it is$_1$	**Never used$_2$**	**Used once$_3$**	**Used occasionally$_4$**	**Used frequently$_5$**
a. Remote control to open/start the car b. Answering machine					
c. Automatic telephone menusystem d. Vedeo phone/Skype/Facetime e. Automatic parking payment kiosk					
f. Computer / Laptop g. Door Telecom h. Digital photo- or videocamera i. Digital TV set-top box (e.g., program TV, pay-per-view movies, music stations, TiVo)					

	Not sure what it is1	Never used2	Used once3	Used occasionally4	Used frequently5
j. E-mail k. e-reader/ Kindle l. Fax machine m. Fitness device (e.g., pedometer, pulse meter, treadmill, crosstrainer) n. Home security system o. Internet banking p. ticket purchase kiosk (e.g. for traintickets) q. Audiobooks on tape or CD r. Microwave s. Cell Phone t. MP3/iPod music player u. In-car navigation system (e.g., GPS, OnStar) v. Recording and playback device (e.g., CD, DVD, VCR) w. Automatic transport card					
x. PDA/Oranizer/Electronic agenda y. Automatic teller machine (ATM)					
z. Programmable devices (e.g., lights, thermostat, sprinkler, programmable coffee maker)					
aa. Radio/Ghettoblaster					
bb. Smartphone					
cc. In-store automated kiosk (e.g., self-checkout, price scanner, item locator)					
dd. Computer/Video game (e.g., Gameboy, PlayStation, Nintendo, XBox)					
ee. Tablet/Ipad					
ff. Television					
gg. Landline phone					

42.Do you have experience with using a computer?

☐1 Yes ☐2 No (go to question 45)

43. How long have you been using a computer?

☐1 Less than 6 months

☐2 6 months - 1 year

☐3 1 - 5 years

☐4 more than 5 years

44. On average, how many hours <u>per week</u> do you use the computer?

☐1 Less than 1 hour
☐2 1-5 hours
☐3 5-10 hours
☐4 More than 10 hours

45.Do you have experience with the use of Internet?

☐1 Yes ☐2 No (go to question number 50)

46.How long have you been using the Internet?

☐1 Less than 6 months
☐2 6 months - 1 year
☐3 1 - 5 years
☐4 more than 5 years

47.On average, How many hours per week do you use the Internet?

☐1 Less than 1 hour
☐2 1-5 hours
☐3 5-10 hours
☐4 More than 10 hours

48.Where do you use the Internet (tick all that apply)

☐ Community center
☐ Friend's or relative's house
☐ Home
☐ Public library
☐ Work
☐ internet café
☐ Somewhere else, (please specify):____

Development of training/course

49.What was your primary method to learn to use the Internet?

☐1 I taught it myself by exploring it on my own
☐2 I read books on how to use the Internet
☐3 I attended classes
☐4 I learned from friends or family
☐5 I used an online tutorial
☐6 I used a CD or videotape
☐8 Other way (please specify):____

Experience with technology: Remote telecare

With remote telecare one can communicate from a distance through a audio and video connection. In the healthcare sector, video conferencing is called screencare and is used as an addition to the traditional healthcare. For older adults, chronical ill people, people with a disability and care professionals, screencare makes it possible to communicate quick and easy. Via a television or computer, tablet or smartphone, video contact can be made with a nurse or phisican, but also with friends or family. In this way, remote care can be provided. Other options like games, agenda management or self measurement is also possible with remote telecare.

The following questions are about remote telecare:

50. Do you have experience with the use of remote telecare?

☐$_1$ Yes ☐$_2$ No (go to question 58)

51. How long have you been using remote telecate?

☐$_1$ Less than 6 months
☐$_2$ 6 months - 1 year
☐$_3$ 1 - 5 years
☐$_4$ more than 5 years

52. How many hours <u>per week</u> do you use video conferencing?

☐$_1$ Less than 1 hour
☐$_2$ 1-5 hours
☐$_3$ 5-10 hours
☐$_4$ more than 10 hours

53. Who did you made contact with via video conferencing? Please tick all that apply.

☐ Other older aduts/care clients
☐ Family/friends
☐ Healthcare professionals (e.g. nurse, residential supervisor, physician etc)
☐ Technical support
☐ Sombody else (please specify) : ______________________________

54. Who/what did you get instructions from for the use of video conferencing? <u>Please tick all that apply.</u>

☐ Form my healthcare institution
☐ From the installer
☐ From an information leaflet
☐ From the internet
☐ From the technical support
☐ From a course
☐ Other (please specify) : ____
☐ I did not receive instructions about the use of remote telecare.

55. What way of learning to use remote telecare do you <u>prefer</u>?

☐1 Attending classes

☐1 Exploring it on my own

☐2 Reading books on how to use remote telecare

☐4 Learn from friends or family

☐5 Reading the tutorial about remote telecare

☐6 Using a CD or videotape

☐5 Reading the online tutorial

☐8 Other way (please specify):______________________________

56. Do you know who you should contact if you have any problems with the remote telecare system?

☐1 Yes ☐2 No

57. When using video conferencing, I feel…

	Very Slightly or Not at All	A Little	Moderately	Quite a Bit	Extremely
1. Interested	1	2	3	4	5
2. Distressed	1	2	3	4	5
3. Excited	1	2	3	4	5
4. Upset	1	2	3	4	5
5. Strong	1	2	3	4	5
6. Guilty	1	2	3	4	5
7. Scared	1	2	3	4	5
8. Hostile	1	2	3	4	5
9. Enthusiastic	1	2	3	4	5
10. Proud	1	2	3	4	5
11. Irritable	1	2	3	4	5
12. Alert	1	2	3	4	5
13. Ashamed	1	2	3	4	5
14. Inspired	1	2	3	4	5
15. Nervous	1	2	3	4	5
16. Determined	1	2	3	4	5
17. Attentive	1	2	3	4	5
18. Jittery	1	2	3	4	5
19. Active	1	2	3	4	5
20. Afraid	1	2	3	4	5

Please continue with answering the questions from here. Also if you are <u>not</u> experienced with te use of remote telecare. In that case, please fill in the following questions based on your expectation of remote telecare.

Implementation

58. What possible services of remote telecare are essential/decisive to be willing to use remote telecare?

	essential	Useful additional service	Not important
a. Reguliere consults between healthcare provider and client			
b. 24 hours a day the possibility to video contact			
c. Have video contact with family and friends			
d. Specialized care through remote telecare			
e. Health records / anamnesia			
f. Direct communication with (other) clients			
g. Sport/exercise tips			
h. Health tips (e.g. to prevent to catch a flu)			
i. Medicine list/ medication use			
j. Nutritional guidelines			
k. Welfare: ‘good morning and good night’ service			
l. Games / recreation			
m. E-mail/ chat function			
n. Information about public services in the neighbourhood			
o. Social media (e.g. Twitter/ Facebook)			
p. Remote telecare device in contact with ararm button.			
q. other, please specify:_______________			

Perceived privacy/security

59. Please indicate the strength of your agreement of the following statements about security and privacy:

	Disagree Strongly$_1$	Disagree$_2$	Neither agree nor disagree$_3$	Agree$_4$	Strongly agree$_5$
a. Remote telecare will violate my privacy	1	2	3	4	5
b. My feeling of security will be enhanced with the use of remote telecare.	1	2	3	4	5
c. Because of the use of remote telecare my feeling of security will become stronger					
d. The possibility of immediate contact with a health care professional gives me a save feeling	1	2	3	4	5
e. The use of remote telecare is confedential	1	2	3	4	5
f. With the use of a remote system in my house I feel unsafe.	1	2	3	4	5
g. I have no problem with the idea that remote telecare cunsults are safed.	1	2	3	4	5
h. The use of remote telecare will not influence my feeling of privacy.	1	2	3	4	5

Motivation for selfcare

60.Please indicate the strength of your agreement for the following statements:

	Disagree Strongly$_1$	Disagree$_2$	Neither agree nor disagree$_3$	Agree$_4$	Strongly agree$_5$
a. I do <u>not</u> like others to help me when I can care for myself	1	2	3	4	5
b. As long as I am able to, I would like to do household activities myself.	1	2	3	4	5
c. By using remote telecare I can live longer in my own home independantly.	1	2	3	4	5
d. The use of remote telecare will give me more freedom	1	2	3	4	5
e. I will feel more lonely with the use of remote telecare	1	2	3	4	5
f. The use of remote telecare will enhance my self-reliance.	1	2	3	4	5

Facilitators

61. Please indicate the strength of your agreement of the following statements about the degree of support with the use of video conferencing.

	Disagree Strongly$_1$	Disagree$_2$	Neither agree nor disagree$_3$	Agree$_4$	Strongly agree$_5$
a. I have the necessary information to use remote telecare	1	2	3	4	5
b. My family and friends support my use of remote telecare	1	2	3	4	5
c. A training about how to use remote telecare is necessary for a good use of it	1	2	3	4	5
d. Healthcare professionals prefer traditional consults over remote telecare consults	1	2	3	4	5
e. Health care professionals would welcome the fact that I use remote telecare	1	2	3	4	5
f. Online technical support is necessary for a good use of the remote telecare system	1	2	3	4	5
g. Sharing experiences with othe healthcare clients will sopport a good use of remote telecare	1	2	3	4	5

Ease of use

62. Please indicate the strength of your agreement for the following statements about usefulness of remote telecare:

	Disagree Strongly$_1$	Disagree$_2$	Neither agree nor disagree$_3$	Agree$_4$	Strongly agree$_5$
a. I think remote telecare will be clear and easy to use	1	2	3	4	5
b. Remote telecare will be easy to operate and to use.	1	2	3	4	5
c. Remote telecare will be easy to learn	1	2	3	4	5
d. Remote telecare will have a clear instructions for the use of it.	1	2	3	4	5
e. It is more difficult to make eye contact with a health provider with remote telecare compared to direct physical contact	1	2	3	4	5
f. Non-verval communication is easier to identity with remote telecare than with direct physical contact.	1	2	3	4	5

Usability

63.How important are the following characteristics in impacting your willingness to use remote telecare?

	Not at all important		Neutral		Very important
a. Adjustable (font sizes, mouse sensitivity, brightness)	1	2	3	4	5
b. Speed (of the software)	1	2	3	4	5
c. I can use it anytime, night or day	1	2	3	4	5
d. Online support available	1	2	3	4	5
e. Durable	1	2	3	4	5
f. feedback (e.g., sounds, warnings)	1	2	3	4	5
g. size of the icons	1	2	3	4	5
h. Customized to physical barriers (e.g. Arthritis, vision probems)	1	2	3	4	5
i. Customized to physical injuries	1	2	3	4	5
j. size of the screen	1	2	3	4	5
k. Number of features	1	2	3	4	5
l. Reliability of the remote telecare system, e.g. does it always work.	1	2	3	4	5
m. Appearance	1	2	3	4	5

Self efficacy/performance expectation

64.Please indicate the strength of your agreement with the following statements about self efficacy.

	Disagree Strongly1	Disagree2	Neither agree nor disagree3	Agree4	Strongly agree5
a. I am confident enough to use remote telecare					
b. I do **not** have the necessary skills to use remote telecare					
c. After an appropriate training I will have the ability to use remote telecare					
d. I possess the necessary skills to learn to use remote telecare					
e. I am afraid I wil not learn how to use remote telecare					
f. I will find it hard to obtain the necessary skills to use remote telecare					

Financial Issues

65.How much would you maximally be willing to pay for the total costs of installation of a remote telecare system?

☐1 $0, I would not purchase a remote telecare system
☐2 Less than $50
☐3 $50 till $100
☐4 $100 till $200
☐5 over $ 200
☐6 I do not want to purchase/rent a remote telecare system (to to qestion 67)

66.How much would you maximally be willing to pay for the service costs of a remote telecare system? Price per month:

☐1 $0, free
☐2 Less than $10
☐3 $10 till $20
☐4 $20 till $40
☐5 over $40

67.How much time would you spend to go travel to your usual doctor appointments?

☐1 less than 15 min.
☐2 15 till 30 min.
☐3 30 till 45 min.
☐4 more than 45 min.

Willingness to use Remote Telecare

68.For each of the willingness to use remote Telecare related statements listed in the table, please indicate the strength of your agreement

	Disagree Strongly1	Disagree2	Neither agree nor disagree3	Agree4	Strongly agree5
a. I am willing to use remote telecare to complement my traditional care	1	2	3	4	5
b. I have the intention to use remote telecare routinely, to use to receive care	1	2	3	4	5
c. I am not willing to use remote telecare.	1	2	3	4	5
d. I am willing to try to use remote telecare if it is necessary to receive care	1	2	3	4	5
e. After an appropriate training I will be willing to use remote telecare	1	2	3	4	5

If you have any questions or remarks, please write them down on the lines:

____
____
____
____

This is the end of the questionnaire. Thank you very much for your coöperation!

Chapter 4

A mobile phone application to stimulate physical activity in patients with chronic obstructive pulmonary disease: development, feasibility and pilot studies

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JMIR mHealth uHealth 2016; 4(1):e11

❖ Abstract

Background Patients with chronic obstructive pulmonary disease (COPD) demonstrate reduced levels of physical activity (PA) compared to healthy controls. This results in a higher risk of hospital admission and shorter survival. Performing regular PA reduces these risks. The aim of this study is to develop an e-Health intervention that will support patients with COPD to improve or maintain their PA after pulmonary rehabilitation.

Method The design process consisted of literature research and the iterative developing and piloting phases of the Medical Research Council model for complex clinical interventions also involving end users. Participants were healthy subjects and persons with COPD.

Results Using a smartphone as an interface met all the set requirements. Subjects found that the application was stimulating and that reaching their PA goals was rewarding. The average scores on a 7 point scale for usability, ease of use, ease of learning, and contentment were 3.8 ± 1.8, 5.1 ± 1.1, 6.0 ± 1.6, and 4.8 ± 1.3, respectively. The average correlation between the smartphone and a validated accelerometer was 0.88 ± 0.12 in the final test. The idea of providing their healthcare professional with their PA data caused no privacy issues in the subjects. Battery life lasted for an entire day with the final version, and readability and comprehensibility of text and colors was good.

Conclusions By employing a user-centered design approach, a smartphone was found to be an adequate and feasible interface for an eHealth intervention. The smartphone and application are easy to learn and use by patients with COPD. The accuracy of PA measurement was good in the final test.

❖ Introduction

Regular physical activity (PA) has significant health benefits and contributes to the prevention of noncommunicable diseases (1). Inactivity is estimated to cause 9% of premature mortality worldwide (2). In older adults, there is strong evidence that regular exercise and participation in PA lowers mortality and morbidity (3) and has a significant impact on several psychological and cognitive parameters (4). Moreover, PA has been observed as a behavioral determinant for healthy aging (5).

PA is also a relevant behavioral determinant for patients with chronic diseases, such as Chronic Obstructive Pulmonary Disease (COPD), to maintain physical condition (6) and to improve health-related quality of life (HRQoL) (7). COPD is a disabling airway disease with variable extrapulmonary effects that may contribute to disease severity in individual patients. It mostly affects older adults with a history of tobacco smoke exposure (8). Patients with COPD demonstrate reduced levels of PA compared to healthy controls (9). This contributes to a higher risk of hospital admission and shorter survival (10).

Pulmonary rehabilitation (PR) generally includes exercise training, education, psychosocial and behavioral interventions, nutritional therapy and outcome assessment (11,12). It can help to improve physical capacity. Unfortunately, this effect does not always translate into improved PA, and when it does, it tends to fade out over time (13-15). In consideration of the benefits of regular PA (16), it is important for patients with COPD to improve or at least to maintain their PA levels after a rehabilitation program has ended.

Technology-based assistance in healthcare (eHealth) can help support patients with COPD by improving self-management of disease. Self-management interventions in COPD patients have been shown to improve HRQoL, to lower the probability of a respiratory-related hospitalization and to reduce dyspnoea (17,18). It has been postulated that an eHealth intervention might also be beneficial in the self-management of PA in patients with COPD. An important element for successful implementation of an eHealth intervention is to engage users in the design process because design flaws can affect ease of use, usability, and reliability of the system, which may reduce a user's willingness to use the intervention (19).

The objective of this study was to develop an eHealth intervention to support patients with COPD in improving or maintaining PA after PR. We investigated what type of interface is adequate and feasible toward obtaining this objective and scored the resultant eHealth intervention in terms of usability and privacy.

❖ Methods

Recruitment

The design process was in alignment with the first two phases (developing and piloting) of the Medical Research Council (MRC) model for complex clinical interventions. The key elements of the development and evaluation process of the MRC model were taken into account throughout the design process (20) (**Figure 1**). This paper primarily focuses on phase A2 through C. Users were defined as persons suffering from COPD, who were aged forty years and older, living independently, and had completed a PR program.

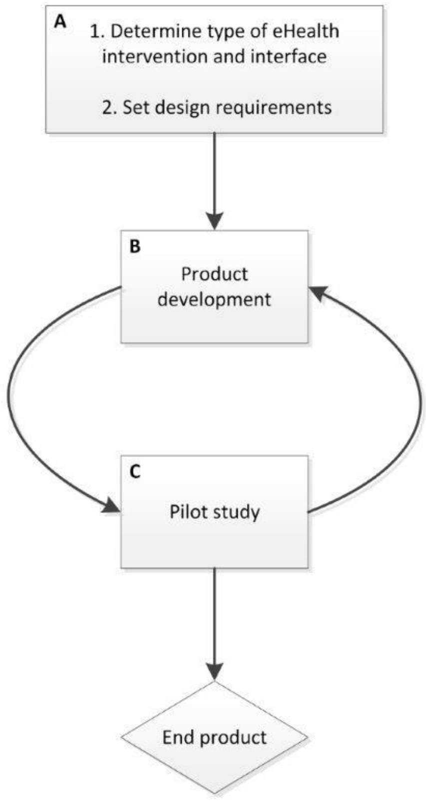

Figure 1. Design process.

A1. Determine type of eHealth intervention and interface

Based on the literature and our own practice-based experience in the treatment of patients with COPD, the eHealth intervention that we sought to develop had to meet the following requirements:

- Non-obtrusive/easily transportable
- Objective measurement of PA
- Direct feedback on personal PA
- Monitoring and feedback available from a healthcare professional (HCP)

At the time of this study in 2010, several eHealth interventions for PA engagement in patients with COPD had been described. They were available in various forms, such as wearable sensors (21), television applications (22), computers applications (23) a manual input device (24), and smartphones (25,26).

As an interface, a smartphone met all set requirements. Although the penetration rate among ageing adults was estimated to be low at the time, they were expected to become the majority of mobile phones over the next few years (27,28). Furthermore, mobile touchscreens are generally easy for the elderly to use (27). Moreover, smartphones are already equipped with an accelerometer that has been shown to be accurate and reliable in measuring and quantifying PA in a laboratory setting (29).

Although various applications for smartphones are available that stimulate engagement in PA, none of the applications met all of the requirements that were needed to fully address our research goal. Therefore, we decided to develop a new application and an associated website for HCPs (see results section “B. Product development” for more information). This paper mainly focuses on the development of the application.

We encountered two types of apps: those developed for smartphones running on iOS (interactive operating system) and those developed for smartphones running on Android. Following a comparison of these two operating systems, we used an HTC HD2. The HTC was chosen as the preferred device based on its higher battery capacity, an absence of restrictions in distributing the app and its affordable price.

C. Pilot studies

After phases A and B, the product was tested in three pilot studies and improved through an iterative process. The pilot studies were designed to test the usability of the interface and application, in addition to privacy concerns of the users. The associated website for HCPs (**Appendix**) was not yet employed in the pilot studies. We also sought to obtain an indication of the accuracy of PA measurements by the app. Specific sample size recommendations for this type of development and feasibility pilot studies are scarce, as most recommendations are for pilot studies that focus on the feasibility of corresponding RCT studies (30). The pilot studies were designed to minimize strain on patients with COPD. Therefore, we began the first pilot with healthy volunteers who had previous smartphone experience. A subsequent version was then tested in a subset of patients with COPD. Finally, a larger group of patients with COPD were invited to test the final version. We aimed to include 10, 3, and 10 subjects in pilot study groups C1, C2, and C3, respectively (31). The subjects in pilot group C1 were recruited from a school, in pilot group C2 they were recruited from a hospital, and in pilot group C3 they were recruited from a PR center. For inclusion criteria, see **table 1**. The subjects received instruction on the functionalities of the smartphone and application and information on the course of the study over a 1.5-hour-long training session. Thereafter, each subject received a HTC Desire A8181 smartphone with the app installed, and they were given the opportunity to practice, ask questions and provide feedback. They were instructed to wear the smartphone in a phone pouche (with various choices for personalization) on their belt. They were also instructed to wear accelerometers that had been previously validated in patients with COPD (BHC0100 Sensewear PRO armband, Body Media, Pittsburgh, USA) (32-35) on their right upper arms. The armband and smartphone were worn during waking hours. The subjects were instructed to perform their daily activities as usual. After each study, a group consultation session was held. The sessions started by asking the subjects their general impression of the application followed by writing down three positive and three negative aspects. The most occurring aspects were written on a flip-over and further discussed. The following topics were each discussed for 5 minutes: wearing the smartphone, using the application, comprehensibility, navigation, future use, and improvements to the application. Sessions were recorded and minutes were made. Afterwards, the main points were separately summarized by three researchers and taken into consideration for adjustment of the application. Furthermore, the subjects were asked to respond to three questionnaires: the Usefulness, Satisfaction, and Ease of use (USE) questionnaire on usability (36), the Florida State University (FSU) mobile device feedback preferences scale and the FSU physiological monitoring privacy scale (inspired by Beach et al. (37) and Kwazney et al. (38)). Results of the USE questionnaire were compared within and between pilot studies with (in-) dependent t-tests. All of the subjects were required to provide signed informed consent prior to the study. Pilot studies were waived from ethics committee approval by the UMC Utrecht Medical Ethical Research Board (number research protocol 10/259). Correlations between the accelerometers of the armbands and the smartphones were computed by calculating Pearson’s r in SPSS version 21. The distinctive characteristics of the three pilot studies can be found in **table 1**.

Table 1. Characteristics of the three pilot studies in study phase C.

Pilot study	Inclusion criteria	Duration of study	Version application
C1	Healthy persons, experience with mobile phones	One week	Figure 2
C2	Persons suffering from COPD, aged forty years and older, living independently, and having completed a rehabilitation program	Four days	Figure 3
C3	Same as pilot C2	Three weeks	Figure 4

An additional pilot study C4 was performed to provide an extra check on PA measurement accuracy. This was performed with 10 subjects who wore the armband and smartphone for one week. Subjects met the same inclusion criteria as pilots C2 and C3. These subjects did not participate in a consultation round and did not fill out questionnaires since the development of the application was deemed ready at this point.

In Pilot C1, subjects were asked to record their daily activities in diaries, including corresponding times of day and durations. In pilot C3, three randomly selected subjects wore accelerometers during the first week.

❖ Results

A2. Setting design requirements

A list of design requirements for the eHealth intervention was prepared with respect to the general requirements (see methods section A1). Some aspects of existing applications found during the desk research were also added as requirements. Furthermore, since COPD is inversely related to socioeconomic status and mostly affects older adults (39) special attention was paid to readability and comprehensibility. Focus was put on the smartphone application for the users (**table 2**).

The requirements for the monitoring website for the HCP can be found in **table 3**. Feedback from HCP on these latter requirements was obtained by consulting with 10 independent respiratory nurses (in a consultation round) and 2 physiotherapists (by phone) who work with COPD patients. Additions to the requirements with regard to privacy and communication were made due to their feedback.

Table 2. Smartphone application requirements (for the users).

Software	**Interface**
Reasonably accurate measurement of PA.	PA is presented in duration, frequency, and intensity.
PA data are recorded on the smartphone and available to the user in real time.	Data are available in graphs and numbers.
Filters out movement produced by riding a car/bus/train.	Visual display of progress and goal achievement on screensaver.
Data are available for at least 12 weeks after generation (preferably even longer, such as 6 months to a year).	Progress is visible in numbers (and % until goal is reached).
Data are sent automatically to a secured website for HCP (4-6 times a day).	Progress is visible based on day, week, and month.
Data are only available to users and HCP.	Letters and figures are easily readable (large font and high contrast).
Data are saved when phone runs out of battery.	Navigation is easy and comprehendible; only a few steps are required to reach a desired location.
Data acquisition continues when the smartphone is in standby mode or is being used for other purposes.	All text is formulated for persons with low literacy.
Goal achievement elicits a motivating/ complimentary message.	Application can be personalized.
Personal results can be published on social media if desired.	
The application uses little energy.	
An app-killer is added that can stop all applications except for the intervention.	
Application can be used on smartphones of different brands.	
Application can be adjusted in the future.	

B. Product development

The application and the website were created by a small business enterprise that is specialized in healthcare applications. Interactive team work sessions were held during this process. **Figures 2 through 4** illustrate the various designed versions of the application that were tested during the pilot studies. Communication and multimedia design students from Utrecht University of Applied Sciences were employed to assist in improving the design of the app and the widget after pilot C2.

Table 3. Website requirements (for the HCP).

Software	**Interface**
Data are available for at least 12 weeks after generation (preferably even longer, such as 6 months to a year).	PA is presented in duration, frequency, and intensity.
Data are only available to the HCP.	Data are available in graphs and numbers.
Text messages or phone calls can be made from the website.	Overview of the activity status of multiple patients.
PA goals can be adjusted from the website.	Progress of each patient is easily visible in an overview (e.g., traffic light colors).
Goals can be set based on steps, duration, frequency and intensity.	Individual page for each patient with detailed PA information.
Goals are individually adjustable.	

Figure 2. Version 1: The y-axis provides a measure for activity, while the x-axis does so for intensity. The PA goal is met when the blue ball (representation of current activity status) is kept in the green circle at all times. The widget shows a current status towards reaching a PA goal. (C1)

Figure 3. Version 2: The left axis shows amount of steps, while the right axis gives a measure of intensity. The PA goal is reached when the open circles (representation of current activity status) are kept in the rising green circles at all times (C2).

Figure 4. Version 3: The bar on the left side combines amount and intensity of steps. The PA goal is met when the vertical stripe (representation of current activity status) is kept in the rising rectangle at all times until the green area is reached (C3). Absolute number of steps and current advice on PA progress are also shown.

C. Pilot studies

Ten subjects participated in pilot C1, three in C2 and 7 in C3, of which 1, 3, and 4 were male, respectively. The average age of the subjects was 21.5 ± 2.84, 65 ± 10, and 60.4 ± 9.4 years in C1, C2, and C3, respectively. The subjects in C2 and C3 were limited in their PA due to having COPD and were enrolled in a PR program at the time of the study.

The results from the consultation rounds are shown in **table 4**. In pilot C2, one subject was not interested in the intervention; therefore, the results from the consultation round of this group are primarily focused on the remaining two subjects. This subject did fill out the questionnaires. Eleven subjects were recruited to participate in pilot C3. After the training session, four declined to participate due to the degree of expected effort. On day three and seven of pilot C3, corrected apps were installed due to discovered errors in the algorithm that caused the app to measure too few or no steps.

In **table 5**, the results from the USE questionnaire are shown. For C1 usability scores were significantly lower than ease of use, learning, and contentment scores ($P<0.05$ for all). For C3 usability scores were significantly lower than for ease of learning ($P<0.05$). Ease of learning was significantly lower in COPD patients compared with healthy subjects in C1 ($p<0.004$ for C2; $p=0.017$ for C3). The feedback preferences questionnaire did not give added insights to the consultation rounds.

Table 6 shows the correlations between the smartphones and the armband accelerometers for steps/day. The armband of subject 1 (C1) malfunctioned. Subject 2 (C3) only wore the armband for two days and was excluded from analysis. The additional pilot C4 was performed solely to provide an extra check on PA measurement accuracy. The numbers of valid days for analysis were 8, 4, 8, and 8 for all subjects in C1, C2, C3 and C4, respectively.

Table 4. Results from the consultation rounds.

	Pilot study	Feedback	Adjustments made
Use			
Smartphone			
	C1,3	Wearing the phone all day was not always practical, but because of the benefits it was not seen as problematic.	
	C1,2	Two subjects considered the smartphone to be quite large and preferred to carry it in their shirt pocket; seven preferred to carry it in their trouser pocket.	Not adjusted because better measurements are achieved by positioning the accelerometer as close to the center of gravity as possible (47,48).
	C1,2	Seven subjects found the phone pouch uncomfortable and did not like its appearance. Putting the smartphone in the pouch was difficult.	Different phone pouches were acquired.
	C2,3	Use of the touchscreen did not pose any problems in general, although it did for several subjects.	Additional instructions were added to the protocol.
	C1	Battery life was a problem. The smartphone had to be charged in the afternoon.	Continuous measurement was adjusted to include five minutes of measurement followed by five minutes of no measurement. Data were then multiplied by two to obtain an estimate of total daily steps. This accounted for diminished measurement accuracy but provided day-long battery life, which was deemed necessary for adherence to the intervention.
Application			
	C1,2	Learning how to use the app and navigation were found to be quite easy.	An explanatory pop-up screen that appeared when a small question mark icon was touched was added.
	C3	One subject lost interest after one week, but all of the remaining subjects found the app useful and stimulating.	
	C2	The messages helped to maintain interest.	
	C2,3	Reaching their PA goal was rewarding.	
	C3	Comparing PA goal progress was fun.	
	C1-3	The reported time points for looking at the app included during a moment of rest, when the phone was being used for other purposes, immediately following an activity and before going to bed.	
	C1-3	Sounds were not desired except for incoming text messages and a reminder to charge the phone.	
	C1-3	Subjects were willing to pay 10-25 euros a month for a subscription to the app that included monitoring from a physiotherapist.	
	C2,3	Reasons to not acquire the app included being confronted with incapacity, that sufficient PA advice was received, and the need to buy a smartphone. The main reason for using the app was for health maintenance.	

Table 4 (continued).

Design			
Version 1 (Figure 2)			
	C1	The activity and intensity axes in the dartboard were confusing.	The dartboard was changed to include two bars: steps and intensity.
	C1	The app only provided information on current PA status, and a cumulative approach would be preferable.	Added
	C1	PA over time would be a positive addition.	Added
	C1	The wording of the advice was clear.	
Version 2 (Figure 3)			
	C2	Subjects wanted to keep the open circles in the filled green circles at all times. It worked like a game and they found it fun.	
	C2	If an emoticon was to be added, they preferred it to be a dog because they had one at home.	The widget was given traffic light colors, and an emoticon with an expression corresponding to current PA status was added. A dog was the default but other options could be chosen.
	C2	The graph was quite clear; however, the blue line was difficult to see.	The colors yellow and blue were no longer incorporated in the app because elderly users have low perception ability for these colors. (28).
	C2	They suggested the addition of the absolute number of steps taken.	Added
Version 3 (Figure 4)			
	C3	Fun and stimulating advice and emoticons.	
	C3	There were a few mismatches between the advice given and the status of the activity bar, and some pieces of advice were not totally comprehended.	Unclear advice was adjusted, and mismatches were eliminated.
	C3	Readability of the advice could be better.	Contrast was improved, and font size increased.
Privacy			
	C1-3	The user should be able to determine who can see their PA data.	
	C1-3	HCP, family and friends posed no problem.	
	C1-3	With respect to local government and insurance companies, answers varied.	
Measurement of PA			
	C1	Unclear what aspects of PA were being measured.	PA goals were divided into 5 levels, which were computed based on the results from a previously conducted literature review (49), that incorporated number of steps as well as intensity of PA.
	C1-3	Subjects regretted that cycling, distance travelled, and intensity of strength training and stair walking were not fully captured by the app.	
	C2	A good way to get acquainted with your activity pattern.	The levels were discarded, and number of steps, minutes and number of steps for an intensive minute could be personalized on the website by the HCP.

Table 5. USE questionnaire scores ± standard deviation in the various pilot studies.

Pilot study	Usability	Ease of use	Ease of learning	Contentment
C1	3.8 ± 2	5.4 ± 1.7	6.6 ± 0.6	4.8 ± 1.7
C2	3.9 ± 2.9	5.1 ± 2.1	4.1 ± 2.9	5.7 ± 1.7
C3	3.7 ± 2	4.8 ± 2.2	5.9 ± 1.5	4.4 ± 1.8

Table 6. Correlation between smartphones and armband accelerometers. *=significant at $p<0.05$.

Subject	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Pilot study										
C1	-	0.94*	0.96*	0.76*	0.71*	0.76*	0.64	0.61	0.97*	0.13
C2	0.87*	0.54	0.72*							
C3	0.45	-	0.67							
C4	0.99*	0.98*	0.96*	0.90*	0.99*	0.74	0.69	0.69*	0.84*	0.99*

❖ Discussion

Principal Results

Engaging patients with COPD in active control over their PA can work as a preventive measure to prevent functional decline (40). Therefore, our objective was to develop an eHealth intervention that will help patients with COPD to improve or maintain their PA after a period of PR. The final product consists of two components: 1) a mobile phone application (the focus of this study) and 2) a website for HCPs. The application measures PA as steps per day, measured by the accelerometer of the smartphone, and shows this information to the patient via the display of a smartphone. A physiotherapist can monitor the patient via a (secure) website where PA measurements are accessible from all patients. PA goals can be adjusted and text messages sent to inform and to motivate patients. Furthermore, the website of the intervention can help an HCP work in a more efficient way by monitoring all of their patients at once and enabling them to intervene early on in patients who have trouble maintaining PA.

Use

The smartphone application was found to be easy to learn and to use by the students as well as the COPD patients. Usability scores were lower than ease of use, learning, and contentment scores. This was significant in C1 and C3 (for ease of learning). This might be explained by the fact that this was still the development phase of the app and therefore contained some errors, as demonstrated in pilot C3. Ease of use scores were lower for the

COPD patients, though not significantly. This could be because touch screen pointing performance reduces with age. It is influenced by size, spacing, and location of the target as well as by size of the device and practice (27,28). Older people like functions that support their declining functional capabilities, and enjoyability is an important determinant of adherence (27). During the development of the application, attention was paid to all of these aspects. Ease of learning was significantly lower in COPD patients compared with healthy subjects. Proper instruction will greatly influence success in smartphone usage (41). Older adults take longer in learning to use smartphones, and they commit more errors when entering information into smartphone-based software applications (42). Efforts to overcome these behavioral and attitudinal barriers must include well–designed training that is targeted to older adults to teach smartphone usage skills as well as creating software with an improved interface and operation (42).

Design

The graphic design of the app was adjusted several times to improve use and to provide a better understanding of the PA data, as well as to accommodate those with low technology literacy. A combination of qualitative and quantitative feedback proved the best fit.

Privacy

The key aspect with respect to privacy is to give the user control over their data distribution. An important element of the intervention is that an HCP has insight into a patient's PA data. This did not pose a problem for the subjects in the pilot studies.

Measurement of PA

Distance travelled, cycling, strength training, and the intensity of walking stairs were not properly captured by the app. The first two activities could be added by using GPS data, but this put too much strain on battery life. The accuracy of the measurement varied greatly between subjects. Reasons for bad correlations might have included the amount of time spent in a train/bus/car (subject 7, C1), unclear diary entries as to whether the smartphone was worn during exercise (subject 8, C1), a phone pouch that contained a magnet (subject 10, C1), using a walker (subject 2, C2) and using a mobility scooter (all subjects of C3). Using a walker, mobility scooter or other forms of assistive devices for PA were added to the exclusion criteria for participants in the randomized controlled trial (RCT). In pilot C3, the errors in the app in the first week probably also accounted for bad correlations. An additional pilot study (C4) showed an average correlation between the armbands and smartphone accelerometers of $r=0.88 \pm 0.12$.

Limitations

During pilot C3, errors in the algorithm were discovered twice in the distributed application. Although these were swiftly corrected, this could have had a negative impact on the subjects' views of the application.

In pilot C3 there were four drop-out subjects beforehand due to too much expected effort in learning how to use a smartphone and in pilot C2 there was one subject that was not interested and did not use the intervention. This subject had trouble understanding how to use the smartphone. As mentioned before, proper instruction is key in usage success. More extensive instruction might have improved understanding and prevented drop-out. The results of to the questionnaires in pilot C2 may have been negatively influenced by this participant.

Battery life posed a major problem while developing the app. Not all desired options, such as GPS-tracking and continuous measurement, were possible due to limited battery capacity. The '5 minutes on and off' configuration (see **table 4**) was chosen so the battery would last a whole day, which was deemed important for adherence. With the development of smartphone technology and accompanying batteries with higher capacity, the app could be adjusted back to continuous measurement, and GPS-tracking could be added.

Using a smartphone to measure PA is a good way to obtain objective data on this parameter; however, it is not a highly valid and reliable measurement instrument such as that used in research settings. Additional validated accelerometers would provide improved measurement accuracy of PA, but it was reasoned that (long-term) adherence to the intervention would benefit from the least amount of devices worn. This application can be useful in obtaining an indication of a patient's activity outside of a clinical setting. It will provide much more reliable data compared to a patient's recall (43,44).

Comparison with Prior Work

A review conducted by Bort-Roig et al. (45) evaluated 10 studies that described the accuracy of PA data as measured by a smartphone. The participants were mostly overweight or healthy adults. The studies reported measurement accuracy ranging from 52 to 100% in identifying certain activities and postures (e.g., walking, standing). As described, there is room for improvement in PA measurement accuracy when using a smartphone accelerometer.

This review also found that PA profiles, real-time feedback, social networking, expert consultation, and goal setting were identified as key features that facilitated PA engagement. Most of these features are also incorporated in our eHealth intervention.

We found one pilot study that similarly focused on PA stimulation in patients with COPD (46). Their intervention consists of a smartphone application, website and separate accelerometer. The subjects felt encouraged to be more active. The positive effects included an awareness of PA performance, the stimulating effect of a daily target goal and a positive effect on self-efficacy. Motivation dropped when technical problems occurred, which is something that we also encountered in pilot study C3.

Conclusion

By employing a user-centered design approach, a smartphone was found to be an adequate and feasible interface for an eHealth intervention because it is non-obtrusive, can measure PA objectively, and, by using an appropriate application, direct feedback on PA can be given. Moreover, by combining the application with an appropriate and secured website, monitoring and feedback by an HCP is possible. The smartphone and application are easy to learn and use by patients with COPD. Battery life lasted a whole day with the final version, and readability and comprehensibility of text and colors were good. The accuracy of PA measurement was good in the final test. The idea of providing an HCP with PA data caused no privacy issues in the subjects.

Acknowledgments

We would like to thank Lichelle Groot for her assistance with the pilot studies, Thom Huisman, Kevin Cheung, and Neo Cheung for their assistance in improving the design of the app and the widget; and finally we would like to thank all participants of the pilot studies.

4

❖ References

(1) World Health Organisation. Physical activity. 2015; Available at: http://www.who.int/mediacentre/factsheets/fs385/en/ (Archived by WebCite® at http://www.webcitation.org/6YMpveScM). Accessed 4/21, 2015.

(2) Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012 Jul 21;380(9838):219-229.

(3) Taylor D. Physical activity is medicine for older adults. Postgrad Med J 2013 07/01;90(1059):26-32.

(4) American College of Sports Medicine, Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 2009 Jul;41(7):1510-1530.

(5) Heikkinen R. The role of physical activity in healthy ageing. 1998;WHO/HPR/AHE/98.2.

(6) Bossenbroek L, De Greef MHG, Wempe JB, Krijnen WP, Ten Hacken NHT. Daily physical activity in patients with chronic obstructive pulmonary disease: A systematic review. COPD: Journal of Chronic Obstructive Pulmonary Disease 2011;8(4):306-319.

(7) Durr S, Zogg S, Miedinger D, Steveling EH, Maier S, Leuppi JD. Daily physical activity, functional capacity and quality of life in patients with COPD. COPD 2014 Dec;11(6):689-696.

(8) Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med 2007 09/15;176(1073-449; 6):532-555.

(9) Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005 05/01;171(1073-449; 9):972-977.

(10) Pitta F, Troosters T, Probst VS, Spruit MA, Decramer M, Gosselink R. Quantifying physical activity in daily life with questionnaires and motion sensors in COPD. Eur Respir J 2006 05;27(5):1040-1055.

(11) American Thoracic Society / European Respiratory Society Task Force. Standards for the Diagnosis and Management of Patients with COPD. 2005; Available at: http://www.thoracic.org/go/copd. Accessed 3/20, 2015.

(12) de Blasio F, Polverino M. Current best practice in pulmonary rehabilitation for chronic obstructive pulmonary disease. Ther Adv Respir Dis 2012 Aug;6(4):221-237.

(13) Egan C, Deering BM, Blake C, Fullen BM, McCormack NM, Spruit MA, et al. Short term and long term effects of pulmonary rehabilitation on physical activity in COPD. Respir Med 2012 Dec;106(12):1671-1679.

(14) Dyer CA, Harris ND, Jenkin E, Langley-Johnson C, Lewis R, Taylor GJ, et al. Activity levels after pulmonary rehabilitation - what really happens? Physiotherapy 2013 Sep;99(3):228-232.

(15) Cruz J, Brooks D, Marques A. Impact of feedback on physical activity levels of individuals with chronic obstructive pulmonary disease during pulmonary rehabilitation: A feasibility study. Chron Respir Dis 2014 Nov;11(4):191-198.

(16) Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H. Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. Am J Respir Crit Care Med 2008 04/01;177(7):743-751.

(17) Zwerink M, Brusse-Keizer M, van der Valk PD, Zielhuis GA, Monninkhof EM, van der Palen J, et al. Self management for patients with chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2014 Mar 19;3:CD002990.

(18) Effing T, Monninkhof EM, van d,V, van der PJ, van Herwaarden CL, Partidge MR, et al. Self-management education for patients with chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2007(1469-493; 4):CD002990.

(19) Pagliari C, Ammenwerth E, Aarts J. Design and Evaluation in eHealth: Challenges and Implications for an Interdisciplinary Field. J Med Internet Res 2007 May 27;9(2):. doi:10.2196/jmir.9.2.e15.

(20) Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ 2008 Sep 29;337:a1655.

(21) Activity sensing in the wild: a field trial of ubifit garden. ; april 5-10; Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Pages 1797-1806; 2008.

(22) Whitten P, Mickus M. Home telecare for COPD/CHF patients: outcomes and perceptions. J Telemed Telecare 2007;13(1357-633; 2):69-73.

(23) Nguyen HQ, Carrieri-Kohlman V, Rankin SH, Slaughter R, Stulbarg MS. Is Internet-based support for dyspnea self-management in patients with chronic obstructive pulmonary disease possible? Results of a pilot study. Heart Lung 2005 Jan-Feb;34(1):51-62.

(24) Trappenburg JC, Niesink A, de Weert-van Oene GH, van der ZH, van SR, Peters A, et al. Effects of telemonitoring in patients with chronic obstructive pulmonary disease. Telemed J E Health 2008 03;14(2):138-146.

(25) Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. Int J Chron Obstruct Pulmon Dis 2009;4:301-313.

(26) Liu WT, Wang CH, Lin HC, Lin SM, Lee KY, Lo YL, et al. Efficacy of a cell phone-based exercise programme for COPD. Eur Respir J 2008 Sep;32(3):651-659.

(27) Kobayashi M, Hiyama A, Miura T, Asakawa C, Hirose M, Ifukube T. Elderly user evaluation of mobile touchscreen interactions. Lect Notes Comput Sci 2011 5 September 2011 through 9 September 2011;6946 LNCS(PART 1):83-99.

(28) Hwangbo H, Yoon SH, Jin BS, Han YS, Ji YG. A Study of Pointing Performance of Elderly Users on Smartphones. Int J Hum -Comput Interact 2013;29(9):604-618.

(29) Manohar CU, McCrady SK, Fujiki Y, Pavlidis IT, Levine JA. Evaluation of the Accuracy of a Triaxial Accelerometer Embedded into a Cell Phone Platform for Measuring Physical Activity. J Obes Weight Loss Ther 2011 Dec 20;1(106):3309.

(30) Hertzog MA. Considerations in determining sample size for pilot studies. Res Nurs Health 2008 Apr;31(2):180-191.

(31) Nieswiadomy RM editor. Foundations of nursing research. 4th ed.: Upper Saddle River, NJ: Pearson Education; 2002.

(32) Patel SA, Benzo RP, Slivka WA, Sciurba FC. Activity monitoring and energy expenditure in COPD patients: a validation study. COPD 2007 06;4(2):107-112.

(33) Langer D, Gosselink R, Sena R, Burtin C, Decramer M, Troosters T. Validation of two activity monitors in patients with COPD. Thorax 2009;64(7):641-642.

(34) Rabinovich RA, Louvaris Z, Raste Y, Langer D, Van Remoortel H, Giavedoni S, et al. Validity of physical activity monitors during daily life in patients with COPD. Eur Respir J 2013;42(5):1205-1215.

(35) van Remoortel H, Raste Y, Louvaris Z, Giavedoni S, Burtin C, Langer D, et al. Validity of six activity monitors in chronic obstructive pulmonary disease: A comparison with indirect calorimetry. PLoS ONE 2012;7(6).

(36) Lund AM. Measuring Usability with the USE Questionnaire. http://hcibib.org/search:quest=U.lund.2001. Accessed: 2015-06-08. (Archived by WebCite® at [http://www.webcitation.org/6Z8HCH1Ad)](http://www.webcitation.org/6Z8HCH1Ad). Usability interface 2001;8(2).

(37) Beach S, Schulz R, Downs J, Matthews J, Barron B, Seelman K. Disability, age, and informational privacy attitudes in quality of life technology applications: Results from a national Web survey. ACM Transactions on Accessible Computing 2009;2(1).

(38) Kwasny, M. N., Caine, K. E., Fisk, A. D. & Rogers, W. A. Privacy and Technology: Folk Definitions and Perspectives. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems*; 2008.

(39) Global Initiative for Chronic Obstructive Lung Disease (GOLD). *Global Strategy for the Diagnosis, Management and Prevention of COPD.* Available from: [http://www.goldcopd.org/.](http://www.goldcopd.org/) 2015.

(40) Butts JF, Belfer MH, Gebke KB. Exercise for patients with COPD: An integral yet underutilized intervention. Phys Sportsmed 2013;41(1):49-57.

(41) van Houwelingen CT, Barakat A, Best R, Boot WR, Charness N, Kort HS. Dutch Nurses' Willingness to Use Home Telehealth: Implications for Practice and Education. J Gerontol Nurs 2014 Dec 10:1-10.

(42) Sterns AA, Mayhorn CB. Persuasive pillboxes: Improving medication adherence with personal digital assistants. Lect Notes Comput Sci 2006 18 May 2006 through 19 May 2006;3962 LNCS:195-198.

(43) Casaburi R. Activity monitoring in assessing activities of daily living. COPD 2007 Sep;4(3):251-255.

(44) Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R. Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2005 10;86(10):1979-1985.

(45) Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: A systematic review. Sports Medicine 2014;44(5):671-686.

(46) Verwey R, van der Weegen S, Spreeuwenberg M, Tange H, van der Weijden T, de Witte L. A pilot study of a tool to stimulate physical activity in patients with COPD or type 2 diabetes in primary care. J Telemed Telecare 2014;20(1):29-34.

(47) Making sense of accelerometer measurements in pervasive physical activity applications. 27th International Conference Extended Abstracts on Human Factors in Computing Systems, CHI 2009; 4 April 2009 through 9 April 2009; ; 2009.

(48) iPhone as a physical activity measurement platform. Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems New York, USA: ACM New York; 2010.

(49) Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. Respir Res 2011 Mar 22;12:33.

❖ Appendix

	Naam	Telefoon ID	Stappen doel	Week score	Maand score	Jaar score	Laatst gesynchroniseerd		
Kies		1000	5000				31-08-2012 15:12	Download gegevens	Verwijder patient
Kies		37	7831				08-02-2013 05:42	Download gegevens	Verwijder patient
Kies		41	6500				18-12-2012 01:28	Download gegevens	Verwijder patient
Kies		44	6775				12-02-2013 02:57	Download gegevens	Verwijder patient
Kies		39	8500				07-01-2013 00:43	Download gegevens	Verwijder patient
Kies		32	6214				28-11-2012 00:47	Download gegevens	Verwijder patient
Kies		31	9865				30-11-2012 01:55	Download gegevens	Verwijder patient

Website for HCPs. Anonymized overview of subjects and detailed PA information of a single subject.

Chapter 5

Efficacy of an eHealth intervention to stimulate physical activity in COPD patients after pulmonary rehabilitation

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Under revision

❖ Abstract

Background Physical inactivity in patients with Chronic Obstructive Pulmonary Disease (COPD) is associated with poor health status and increased disease burden. The present study aims to test the efficacy of a previously developed eHealth intervention to improve or maintain physical activity (PA) in patients with COPD after pulmonary rehabilitation (PR).

Method A randomized controlled trial was performed in 32 physiotherapy practices in the Netherlands. COPD patients were randomized into an intervention (I) or usual care group (U). The intervention consisted of a smartphone application for the patients and a monitoring website for the physiotherapists. Measurements were performed at 0, 3, 6 and 12 months. PA, exercise capacity, lung function, health-related quality of life (HRQoL), and body mass index (BMI) were assessed.

Results 157 patients started and 121 completed the study. There were no significant positive effects of the intervention on PA (0 months: I:5824 U:5717; 12 months: I:4819; U:4950 steps/weekday), exercise capacity, HRQoL and BMI. There was a significant decrease over time in PA ($p<0.001$), lung function ($p<0.001$), and mastery ($p=0.017$), but not in exercise capacity.

Conclusions Although exercise capacity did not deteriorate, our smartphone-based eHealth intervention did not improve or maintain PA in patients with COPD after a period of PR.

❖ Introduction

Persons with Chronic Obstructive Pulmonary Disease (COPD) demonstrate reduced daily physical activity (PA) compared to healthy age-matched controls (1). Both the amount and the intensity of PA is reduced (2), and data suggest that their PA is reduced early in the course of the disease (3). Physical inactivity worsens over time (4), has important clinical consequences, and undoubtedly complicates the course of the disease (3,5).

Pulmonary rehabilitation (PR) is known to improve exercise capacity (6), but this effect declines over time (7) when patients do not continue to exercise after finalizing the program (8). The effect of PR on PA yields inconsistent results (3,6). A 24-week duration of PR seems beneficial compared with 12 weeks and an exercise program of 18 months resulted in greater improvements than a 12-week program (9,10). However, most PR programs only last for 8 to 12 weeks (11), and structured aftercare programs are often lacking (5). Hence, there is a need for effective interventions aiming to improve, and subsequently maintain, PA in patients with COPD during and particularly after PR (12). There is some evidence that health technology can help to facilitate this behavior change (13). It is expected that the developments in information and communication technology and the proficiency of future patients will have a significant impact (5), making mobile-health support programs accessible to patients. The inclusion of accelerometers in mobile phones and the increasing availability of mobile technology further facilitates such developments.

This study aims to test the efficacy of a previously developed eHealth intervention (14) in a randomized controlled trial. The primary aim is to study whether this eHealth intervention, started immediately after discharge of a 12 week PR program, will enhance or maintain PA compared to usual care in patients with COPD. The secondary aim is to study whether these improvements would affect exercise capacity, health related quality of life (HRQoL), and body mass index (BMI).

❖ Methods

Design

This was a multicenter, investigator-blinded, randomized controlled trial with an intervention duration of 6 months. Participants were randomized into an intervention or a usual care group. All participants gave written informed consent and continued to receive usual care according to the guidelines of the Dutch College of General Practitioners (15). The study was approved by the Utrecht Medical Ethical Research Board (research protocol 11/279).

Participants

Physiotherapists (PTs) in primary care physiotherapy practices throughout the Netherlands were invited to participate. The physiotherapists (PTs) subsequently recruited patients from their practice that were diagnosed with COPD, GOLD stage 2 or 3 ($30\% \leq FEV1 < 80\%$, $FEV1/FVC < 70\%$ after bronchodilatation), aged >40 years, who had completed a PR program of ≥3 months and lived independently. Persons were not included in the trial if they were suffering from a comorbidity that greatly influences PA, using an assistive device for PA (e.g., walker, mobility scooter), intermittently ceased the PR program, and/or experienced an exacerbation resulting in a hospital admission in the 6 months previous to the study commencement.

Randomization and intervention

The patients included in the study were randomly assigned to the intervention or usual care group based on a random number sequence generated in Excel (Microsoft, Redmond, WA, USA) before enrollment. Patients with and without long-term physiotherapy after PR (1-2 sessions a week vs. no physiotherapy continuance) were separately randomized via stratification because this was seen as a confounder.

The intervention consisted of two components: 1. a smartphone application (**appendix figure 1**), and 2. a website for the PTs (**appendix figure 2**). The application showed PA in real time in quantitative and qualitative form, measured by the accelerometer embedded in the smartphone (HTC desire A8181 smartphone). Subjects were persuaded to obtain their personalized PA goal by automated persuasive messages and an emoticon (pictorial representation of an emotion). The PT could monitor their patients via the (secure) website, which showed both the PA data from all the participants from their practice and a more detailed view of individual patients. The PT was able to adjust each patient's PA goal and sent group or individual text messages. No automated adjustments of the PA goal were performed. PTs received an individual face to face (and written) instruction on the functionalities of the website.

The intervention group received a smartphone, a phone/internet contract, and an individual face to face (and written) instruction on the use of the smartphone and the application. The subjects in the intervention group were instructed to wear the smartphone in a pouch on their belt and use it as their usual phone. Those subjects in the possession of mobile phones were asked to transfer their SIM card into the study smartphone. For the first week of the study, PA goals were not set, and subjects were instructed to perform their day-to-day activities as usual. Afterwards, initial personal PA goals were calculated as follows: 1. Average steps/day + 20% as daily step goal; 2. Daily, the number of steps during the 30 most intensive minutes were averaged. These steps were averaged into a value for the week. This latter value + 20% was set as the minimum required number of steps in one minute to account for an intensive minute of PA; and 3. 30 minutes of intensive minutes performed per day, according to the Dutch healthy exercise norm (16). After this initial PA goal setting, PTs were given responsibility for PA goal adjustment.

Assessments

Measurement time points were at 0, 3, 6 and 12 months (T0, T3, T6, and T12, respectively). Assessments were performed by two researchers.

Lung function. Forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) were measured with a Spiromed 2000 (Medikro, Finland). Spirometry was performed according to ATS-ERS guidelines (17), and the results were compared to normal values of Quanjer et al. (18).

Exercise capacity. The modified six minute walk test (6 MWT) was performed on a 10 meter course using methodology suggested for primary care (19). 6 MWTs were performed twice each measurement time point (with a period of rest in between), and the best score was used for analysis. The results were expressed as percentage of the predicted normal values for the Dutch population (20).

HRQoL. Subjects filled out the self-administered standardized chronic respiratory questionnaire (crq-sas). The questionnaire has been found to be a reproducible, reliable, and stable measure of health status (21). Additionally, it has been found to be reliable and valid in the Dutch Language (22).

PA. Each subject was provided an accelerometer validated in patients with COPD (SenseWear PRO or MF-SW mini armband, Body Media, Pittsburgh, USA) (23). This device was worn following the manufacturer’s instructions. Subjects were asked to wear the armband during waking hours (except for water-related activities) for seven successive days after each measurement time point. When the armband was worn for more than 7 days, only the day with the longest wearing time was used for analyses. PA was analyzed using proprietary software (SenseWear v7.1).

BMI. Height was measured only at baseline. Weight was measured at all visits.

Weather. For each assessment humidity, atmospheric pressure and temperature of a meteorological point nearest to the location of the physiotherapy practice were written down from a Dutch meteorological website (24).

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Statistical analysis

Descriptive statistics include the mean (with standard deviation) or frequencies, where appropriate. Power calculations revealed the need for 70-80 subjects per group to be sufficient to achieve a satisfactory power (see **appendix A**).

Average steps/weekday was the main outcome measure and was computed as suggested by Demeyer et al. (25). Using repeated measures linear mixed modelling (LMM), we assessed the differences between groups, the effects of measurement time points, and whether group differences were dependent on measurement time points (=group by time interaction). If this latter group by time interaction is not significant, then the development of the outcome measure over time is similar in both groups, and there is no effect of the intervention. The chosen approach was a random intercept, random slope method with an unstructured covariance matrix. The primary explanatory parameters were the measurement time points (T0-12) and the group allocation (I/U). These two parameters constitute the basic model. Subsequently, other parameters were added to see if they improved the model. **Appendix B** describes the LMM analysis in more detail. This analysis process was repeated with the 6 MWD, CRQ-SAS outcomes, and BMI as outcome measures.

Adherence to the intervention was measured as percentage of days the intervention was used, and as percentage of days the PA goal was obtained. Analyses were carried out using SPSS (IBM®, PASW Statistics, version 23.0, Chicago, IL, USA) for Windows.

❖ Results

One hundred and fifty-seven subjects started the study, and 121 subjects completed all four measurements (**figure 1**). Subjects were recruited from from 32 physiotherapy practices throughout the Netherlands. Baseline characteristics of the subjects in the intervention (I) and the usual care (U) group can be found in **table 1**.

The intervention was used on 89 ± 18.5% of the study days. The personal PA goal was obtained on 34 ± 16% of these days (**figure 2**). On average, subjects achieved 10 ± 25% steps/day fewer than indicated in their PA goal. In the intervention group, FEV1 decreased at an average of 56 ml over the one year follow-up period (p=0.162) and in the usual care group with 98 ml (p=0.001). There was no group by time interaction (p=0.508).

The effect sizes of the measurement time points and added parameters that significantly improved the models can be found in **appendix C**. **Table 2** shows mean values and SD for the outcome measures.

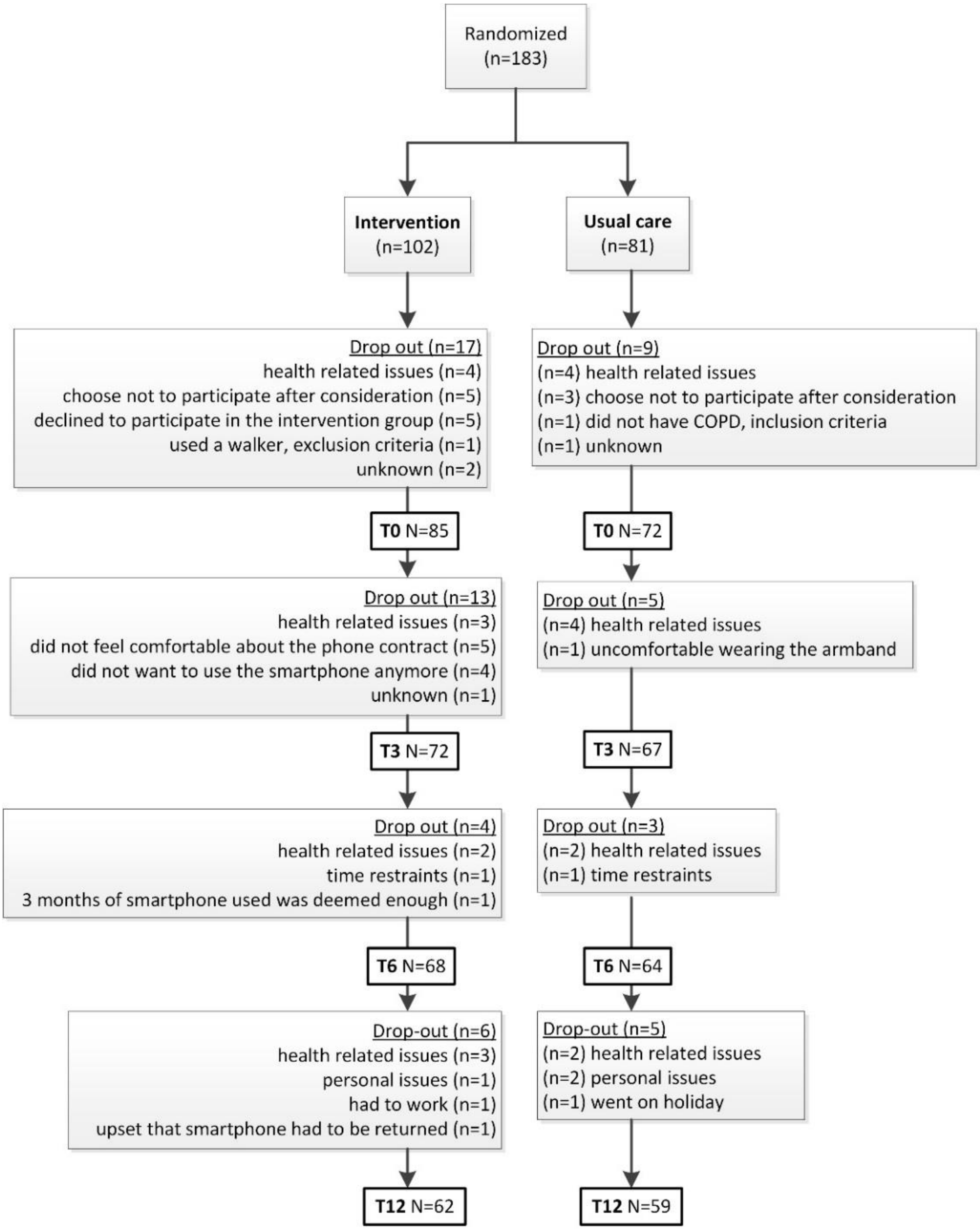

Figure 1. Consort diagram for patient retention in the study

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Table 1. Baseline characteristics and demographics.

	I (N=84)	U (N=73)
Age (years)	62 ± 9	63 ± 8
Females/Males	42/42	37/36
Body mass index		
Underweight (<18.5 kg/m^2)	1 (1%)	2 (3%)
Normal (18.5-24.9 kg/m^2)	24 (30%)	27 (37%)
Overweight (25-29.9 kg/m^2)	31 (38%)	22 (30%)
Obese (=30 kg/m^2)	25 (31%)	22 (30%)
Forced expiratory volume in 1 second (liters)	1.67 ± 0.59* (59 ± 20% predicted)	1.48 ± 0.43 (53 ± 15% predicted)
Forced vital capacity (liters)	3.6 ± 0.98 (101 ± 20 % predicted)	3.48 ± 0.98 (99 ± 19% predicted)
6-minute walking distance (meters)	465 ± 87 (80 ± 15% predicted)	459 ± 73 (79 ± 12% predicted)
CRQ-SAS (score 1-7)		
Dyspnea	4.8 ± 1.3	4.8 ± 1.3
Fatigue	4.3 ± 1.1	4.2 ± 1.2
Emotional function	5.0 ± 1.1	4.8 ± 1.2
Mastery	5.4 ± 1.1	5.3 ± 1.1
Average steps/day (weekday)	5824 ± 3418	5717 ± 2870
Average steps/day (weekend)	5219 ± 3696**	5328 ± 3424**
Long term physiotherapy	69 (82%)	58 (79%)

Data are presented as N or mean ± SD or number. I: intervention group; U: usual care group; BMI: 3 missing values for I; *significantly higher than U; **significantly lower than weekdays at p<0.001.

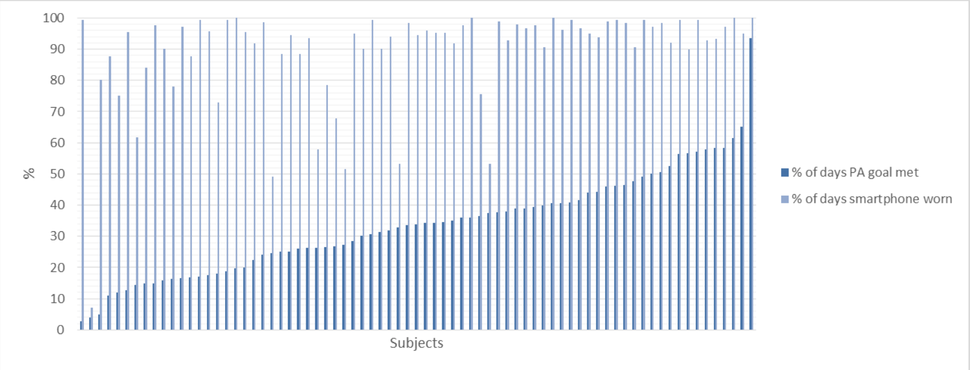


Figure 2. Percentage of days the PA goal was obtained per intervention group subject.

Primary outcome

On average, subjects wore the armband for 6.6 ± 0.76 days/week. Overall, PA as assessed by steps per weekday, decreased over time ($p<0.001$), but no group by time interaction ($p=0.811$) nor group effect was observed ($p=0.934$). These data show that both groups declined over time in a similar way (**figure 3**). There was no group by time interaction between subjects with long-term physiotherapy after PR and those subjects without long-term physiotherapy ($p=0.266$).

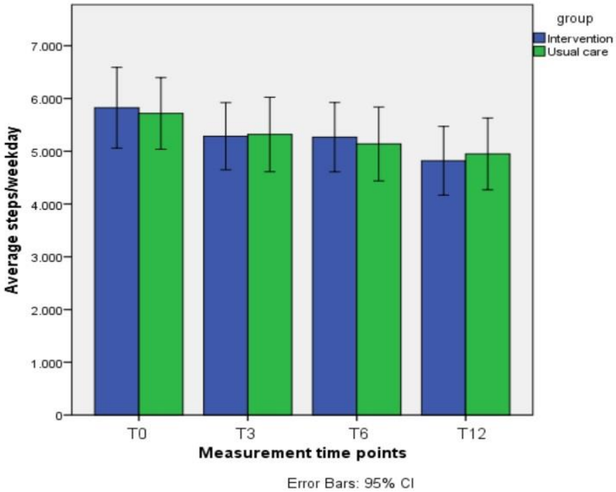


Figure 3. Average steps/weekday at the 4 measurement time points for the intervention and the usual care group.

Secondary outcomes

Exercise capacity. The 6 MWD did not show a significant group by time interaction ($p=0.585$), no significant decrease over time ($p=0.53$), and no group effect ($p=0.485$).

HRQoL. Only fatigue showed a significant group by time interaction, whereas the other variables did not. However, this was probably caused by great variability in the data rather than the intervention (see **figure 4**). No significant differences were found between the groups at each individual measurement time point (T0-12) for fatigue. There was significantly less dyspnea at T3 ($p=0.01$), and a lower emotional function at T0 ($p=0.04$) and T6 ($p=0.02$) compared with T12. Mastery significantly diminished over time ($p=0.017$) but fatigue did not. There were no significant group differences for all CRQ-SAS outcomes.

BMI. The group by time interaction of BMI was not significant. BMI was significantly higher at T6 ($p=0.02$), but this was not clinically relevant. There were no differences between the groups.

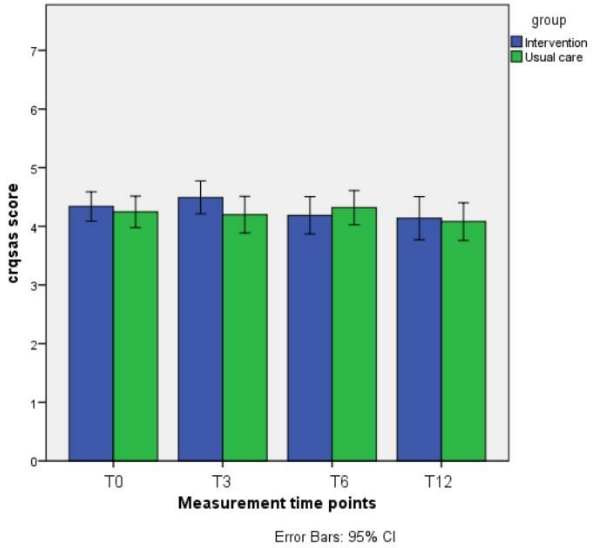


Figure 4. Group by time interaction for fatigue.

Table 2. Results of the dependent variables.

		T0	T3	T6	T12	Group*time interaction p-values
Average steps/weekday						0.811
	I	5824 ± 3418	5285 ± 2669	5267 ± 2669	4819 ± 2883	
	U	5717 ± 2870	5318 ± 2889	5139 ± 2804	4950 ± 2634	
6 MWD (in meters)						0.585
	I	465 ± 87	475 ± 86	480 ± 86	481 ± 89	
	U	459 ± 73	467 ± 70	470 ± 75	471 ± 70	
Dyspnea (1-7)						0.179
	I	4.83 ± 1.25	5.01 ± 1.31	4.88 ± 1.39	4.63 ± 1.49	
	U	4.81 ± 1.3	4.8 ± 1.25	4.64 ± 1.33	4.66 ± 1.21	
Fatigue (1-7)						0.018
	I	4.34 ± 1.13	4.49 ± 1.18	4.19 ± 1.31	4.14 ± 1.45	
	U	4.25 ± 1.15	4.2 ± 1.29	4.32 ± 1.18	4.08 ± 1.24	
Emotional function (1-7)						0.590
	I	4.95 ± 1.08	5.11 ± 1.06	4.89 ± 1.31	4.94 ± 1.28	
	U	4.78 ± 1.24	4.91 ± 1.19	4.87 ± 1.2	4.94 ± 1.17	
Mastery (1-7)						0.154
	I	5.4 ± 1.12	5.49 ± 1.09	5.22 ± 1.27	5.25 ± 1.22	
	U	5.32 ± 1.12	5.3 ± 1.1	5.37 ± 1.12	5.12 ± 1.23	
BMI (kg m^{-2})						0.458
	I	27.78 ± 4.86	27.93 ± 4.96	27.93 ± 4.97	27.95 ± 4.96	
	U	26.77 ± 5.06	26.69 ± 5.13	27.05 ± 5.07	26.62 ± 5.07	

Data are presented as the mean ± SD. I = intervention group, U = usual care group.

❖ Discussion

The present study shows that an eHealth intervention using a smartphone with support from a primary care PT did not improve or maintain PA in patients with COPD following PR. The intervention also did not affect exercise capacity, HRQoL outcomes (dyspnea, fatigue, mastery, and emotional function), or BMI. Our hypothesis that subjects with the intervention would improve or maintain their PA through the benefit of real-time PA biofeedback, goal setting, and motivational support from their PT could not be confirmed. We found nine other studies that examined the effect of personalized feedback based on real-time objective data on PA in patients with COPD (12,26-31). All studies used external pedometers as a source of feedback on PA, and most of these studies were pilot studies with a short duration of intervention, which makes it difficult to draw any evidence-based conclusions on their long-term effectiveness. Of two larger studies with a long term follow-up one did not find an effect of PA (32). The other showed a short term effect on PA but this was not maintained at the one year assessment (33).

Potential reasons for ineffectiveness of the intervention

<u>PTs involvement.</u> PTs were instructed to monitor patients, send stimulating text messages or adjust PA goals when necessary. However, patients might have received insufficient support from their PTs to adhere to the personalized PA goals. On the other hand, when indicators of website usage and PT characteristics were added to the LMM analyses, the model did not improve significantly (**appendix B**). Furthermore, there was no difference in steps per weekday between subjects with long-term physiotherapy after PR, thus receiving more attention from their PT, and those without long-term physiotherapy.

<u>Digital and self-management skills.</u> With a complex disease like COPD, eHealth interventions could be a valuable addition to the whole of multidisciplinary care offered to these patients. Strong self-management skills including the ability to act on incentives could improve the efficacy of these interventions. Digital skills and the aid of health care professionals will also help in this regard. It is plausible that a large number of subjects in this study might have lacked the skill-set that is needed to fully benefit from our eHealth intervention. It might be interesting to see if these skill-sets can be measured in individual patients and taught in a personally tailored form. Learning self-management skills only during PR does not seem to be sufficient (6), thus we should pay attention to how these skills can be maintained in the long-term. It is nevertheless plausible that during the PR program time can be set aside to learn how to use the eHealth application and take appropriate actions when prompted. This was not done in the present study.

Smartphone as an interface and as a pedometer. Adherence in wearing the smartphone was high, at 89%. However, on average, subjects only obtained their PA goal on 34% of the days they wore the smartphone and came 10% short of their PA goal throughout the intervention period. The interface of the smartphone to intermediately get feedback on the actual PA level may not have been optimal or its accuracy may have been insufficient. This could have reduced subjects' motivation to adhere to the PA goal.

PA significantly decreased over time as well as lung function and mastery. PA decreased by 889 average steps/weekday over the one-year study duration, which is more than double what was found in previous reports (4). It is possible that patients had increased their PA by the end of the three-month outpatient rehabilitation program preceding the study (25) and subsequently decreased their activity back to their pre-rehabilitation PA. In any case, our intervention could not prevent this from happening. Surprisingly, exercise capacity remained unchanged over the study duration of one year. This is in contrast to other studies where the 6 MWD deteriorated over time in post rehabilitation COPD patients (34-36). Our results indicate that subjects remained at the same capacity level but became less active during daily life; this holds true for patients with and without long-term physiotherapy after PR.

eHealth is a relatively new area in health care, and it has many potential benefits. Nonetheless, this study shows that in a population of patients with COPD, eHealth interventions are not always effective and expectations have to be adjusted. Future studies should try to identify those factors that influence the usability and efficacy of eHealth interventions. It is not only important to look at disease specific factors but also at individual factors as the population of COPD patients is comprised of a wide variety of persons with varying needs, abilities, and wishes.

Limitations

Subjects. Drop-out in the intervention group was higher (39% in the intervention group vs. 27% in the usual care group) and also higher among women. Initial worries about the telephone contract (linked to a personal bank account) and fear of losing the device were reasons for patients to drop out of the study. After the consent form was adjusted to state explicitly that there would not be any financial ramifications, the drop-out decreased.

There were patients who still had trouble using the smartphone, even after the individual face-to-face (and written) instructions and the availability of a help desk. Because smartphones are becoming more common, this probably will be less of a problem in the future.

PTs. After initial instruction the PTs were no longer prompted to use the eHealth intervention (they did have access to a help center). This was done by design to see how the intervention would work in practice. As an indication, PTs were told to monitor the website at least once a week. Multiple instructions/more prompting might have increased monitoring/stimulation from PTs and subsequently positively influenced patient outcomes.

❖ Conclusion

Compared to usual care, no differences were observed in PA, exercise capacity, HRQoL outcomes, or BMI in patients with COPD using a consumer smartphone-based eHealth intervention geared to enhance PA with support from a primary care PT following PR. There was a significant decrease over time in PA, mastery, and lung function, but not in exercise capacity. Unfortunately, this intervention did not succeed in enabling patients with COPD to transform their exercise capacity into PA.

Acknowledgements

We would like to thank Chantal Huisman, Angelo Antonietti, Ansam Barakat, Jamie van Dalum, Lisa Esteban Lopez, Vincent Keijzer, and Jeroen Frank from the University of Applied Sciences Utrecht for their assistance in executing the trial. We also like to thank Saïda de Vries and Sonja Barends for their assistance with the administration of the trial. The Utrecht network for COPD PTs and the FysioPraxis journal helped us to recruit PT practices to participate in the trial.

Support statement

A grateful acknowledgement goes to the Foundation Innovation Alliance (SIA RAAK) for co-funding the trial (project number: 2010-11-12P).

❖ References

(1) Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. Respir Res 2011 Mar 22;12:33.

(2) Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005 05/01;171(1073-449; 9):972-977.

(3) Watz H, Pitta F, Rochester CL, Garcia-Aymerich J, ZuWallack R, Troosters T, et al. An official European respiratory society statement on physical activity in COPD. European Respiratory Journal 2014;44(6):1521-1537.

(4) Waschki B, Kirsten AM, Holz O, Mueller KC, Schaper M, Sack AL, et al. Disease Progression and Changes in Physical Activity in Patients with Chronic Obstructive Pulmonary Disease. Am J Respir Crit Care Med 2015 Aug 1;192(3):295-306.

(5) Hartman JE, Boezen HM, de Greef MH, Bossenbroek L, ten Hacken NH. Consequences of physical inactivity in chronic obstructive pulmonary disease. Expert Rev Respir Med 2010 Dec;4(6):735-745.

(6) Egan C, Deering BM, Blake C, Fullen BM, McCormack NM, Spruit MA, et al. Short term and long term effects of pulmonary rehabilitation on physical activity in COPD. Respir Med 2012 Dec;106(12):1671-1679.

(7) Foglio K, Bianchi L, Bruletti G, Battista L, Pagani M, Ambrosino N. Long-term effectiveness of pulmonary rehabilitation in patients with chronic airway obstruction. Eur Respir J 1999 Jan;13(1):125-132.

(8) Gross NJ. Extrapulmonary effects of chronic obstructive pulmonary disease. Curr Opin Pulm Med 2001 Mar;7(2):84-92.

(9) Verrill D, Barton C, Beasley W, Lippard WM. The effects of short-term and long-term pulmonary rehabilitation on functional capacity, perceived dyspnea, and quality of life. Chest 2005 Aug;128(2):673-683.

(10) Berry MJ, Rejeski WJ, Adair NE, Ettinger WH,Jr, Zaccaro DJ, Sevick MA. A randomized, controlled trial comparing long-term and short-term exercise in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil 2003 Jan-Feb;23(1):60-68.

(11) Longfonds. longrevalidatie. Available at: https://www.longfonds.nl/copd/behandeling-van-copd/longrevalidatie. Accessed 3/31, 2015.

(12) Mendoza L, Horta P, Espinoza J, Aguilera M, Balmaceda N, Castro A, et al. Pedometers to enhance physical activity in COPD: a randomised controlled trial. Eur Respir J 2015 Feb;45(2):347-354.

(13) Smith SM, Elkin SL, Partridge MR. Technology and its role in respiratory care. Prim Care Respir J 2009 Sep;18(3):159-164.

(14) Vorrink SNW, Lammers JJ, Troosters T, Kort HSM. A Mobile Phone App to Stimulate Daily Physical Activity in Patients with Chronic Obstructive Pulmonary Disease: Development, Feasibility, and Pilot Studies. JMIR mHealth and uHealth .

(15) The Dutch College of General Practitioners. guidelines. 2015; Available at: https://www.nhg.org/dutch-college-general-practitioners. Accessed 4/7, 2015.

(16) Wendel-Vos G. Normen van lichamelijke (in)activiteit. In: Volksgezondheid Toekomst Verkenning, Nationaal Kompas Volksgezondheid. Bilthoven: RIVM.. 2014; Available at: http://www.nationaalkompas.nl/gezondheidsdeterminanten/leefstijl/lichamelijke-activiteit/normen-van-

lichamelijke-in-activiteit/#definition_1347. (Archived by WebCite® at http://www.webcitation.org/6b7TD8ubG). Accessed 08/28, 2015.

(17) Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J 2005 Aug;26(2):319-338.

(18) Quanjer PH, Tammeling GJ, Cotes JE, Pedersen OF, Peslin R, Yernault JC. Lung volumes and forced ventilatory flows. Report Working Party Standardization of Lung Function Tests, European Community for Steel and Coal. Official Statement of the European Respiratory Society. Eur Respir J Suppl 1993 Mar;16:5-40.

(19) Beekman E, Mesters I, Hendriks EJ, Klaassen MP, Gosselink R, van Schayck OC, et al. Course length of 30 metres versus 10 metres has a significant influence on six-minute walk distance in patients with COPD: an experimental crossover study. J Physiother 2013 Sep;59(3):169-176.

(20) Beekman E, Mesters I, Gosselink R, Klaassen MPM, Hendriks EJM, Van Schayck OCP, et al. The first reference equations for the 6-minute walk distance over a 10 m course. Thorax 2014;69(9):867-868.

(21) Williams JE, Singh SJ, Sewell L, Guyatt GH, Morgan MD. Development of a self-reported Chronic Respiratory Questionnaire (CRQ-SR). Thorax 2001 Dec;56(12):954-959.

(22) Rutten-van Molken M, Roos B, Van Noord JA. An empirical comparison of the St George's Respiratory Questionnaire (SGRQ) and the Chronic Respiratory Disease Questionnaire (CRQ) in a clinical trial setting. Thorax 1999 Nov;54(11):995-1003.

(23) van Remoortel H, Raste Y, Louvaris Z, Giavedoni S, Burtin C, Langer D, et al. Validity of six activity monitors in chronic obstructive pulmonary disease: A comparison with indirect calorimetry. PLoS ONE 2012;7(6).

(24) Meteo24. Available at: http://archive-nl.com/page/1421607/2013-02-17/http://www.meteo24.nl/nl/index.php?go=6,1. (Archived by WebCite® at http://www.webcitation.org/6YxRPPxXX).

(25) Demeyer H, Burtin C, Van Remoortel H, Hornikx M, Langer D, Decramer M, et al. Standardizing the analysis of physical activity in patients with COPD following a pulmonary rehabilitation program. Chest 2014 Aug;146(2):318-327.

(26) Tabak M, Vollenbroek-Hutten MM, van der Valk PD, van der Palen J, Hermens HJ. A telerehabilitation intervention for patients with Chronic Obstructive Pulmonary Disease: a randomized controlled pilot trial. Clin Rehabil 2013 Nov 29;28(6):582-591.

(27) Verwey R, van der Weegen S, Spreeuwenberg M, Tange H, van der Weijden T, de Witte L. A pilot study of a tool to stimulate physical activity in patients with COPD or type 2 diabetes in primary care. J Telemed Telecare 2014;20(1):29-34.

(28) Liu WT, Wang CH, Lin HC, Lin SM, Lee KY, Lo YL, et al. Efficacy of a cell phone-based exercise programme for COPD. Eur Respir J 2008 Sep;32(3):651-659.

(29) Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. Int J Chron Obstruct Pulmon Dis 2009;4:301-313.

(30) Hospes G, Bossenbroek L, Ten Hacken NH, van HP, de Greef MH. Enhancement of daily physical activity increases physical fitness of outclinic COPD patients: results of an exercise counseling program. Patient Educ Couns 2009 05;75(2):274-278.

(31) de Blok BM, de Greef MH, Ten Hacken NH, Sprenger SR, Postema K, Wempe JB. The effects of a lifestyle physical activity counseling program with feedback of a pedometer during pulmonary rehabilitation in patients with COPD: a pilot study. Patient Educ Couns 2006 04;61(1):48-55.

(32) Steele BG, Belza B, Cain KC, Coppersmith J, Lakshminarayan S, Howard J, et al. A randomized clinical trial of an activity and exercise adherence intervention in chronic pulmonary disease. Arch Phys Med Rehabil 2008 Mar;89(3):404-412.

(33) Moy ML, Collins RJ, Martinez CH, Kadri R, Roman P, Holleman RG, et al. An Internet-Mediated Pedometer-Based Program Improves Health-Related Quality-of-Life Domains and Daily Step Counts in COPD: A Randomized Controlled Trial. Chest 2015 Jul;148(1):128-137.

(34) Cortopassi F, Celli B, Divo M, Pinto-Plata V. Longitudinal changes in hand grip strength, hyperinflation and 6-minute walk distance in COPD patients and a control group. Chest 2015 May 21.

(35) Heppner PS, Morgan C, Kaplan RM, Ries AL. Regular walking and long-term maintenance of outcomes after pulmonary rehabilitation. J Cardiopulm Rehabil 2006 01;26(1):44-53.

(36) Brooks D, Krip B, Mangovski-Alzamora S, Goldstein RS. The effect of postrehabilitation programmes among individuals with chronic obstructive pulmonary disease. Eur Respir J 2002 Jul;20(1):20-29.

(37) Effing T, Zielhuis G, Kerstjens H, van der Valk P, van der Palen J. Community based physiotherapeutic exercise in COPD self-management: a randomised controlled trial. Respir Med 2011 Mar;105(3):418-426.

(38) Coxson HO, Dirksen A, Edwards LD, Yates JC, Agusti A, Bakke P, et al. The presence and progression of emphysema in COPD as determined by CT scanning and biomarker expression: a prospective analysis from the ECLIPSE study. Lancet Respir Med 2013 Apr;1(2):129-136.

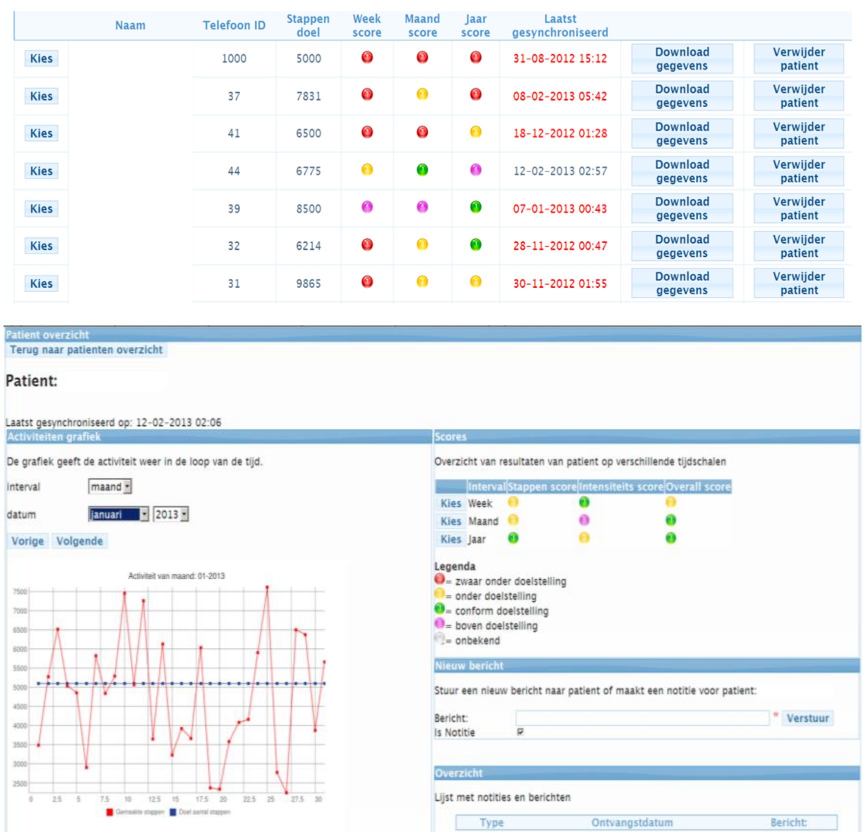
(39) Bandyopadhyay S, Ganguli B, Chatterjee A. A review of multivariate longitudinal data analysis. Stat Methods Med Res 2011;20(4):299-330.

The **appendix** can be found online at:
http://www.onderzoek.hu.nl/onderzoekers/sigrid-vorrink
and in the online version of the thesis (www.narcis.nl).

Appendix chapter 5

PhD thesis S.N.W. Vorrink

Figure 1. Smartphone application. Left image: the widget on the home screen shows current PA status. Middle image: the bar on the left side combines amount and intensity of steps. The PA goal is met when the vertical stripe (representation of current activity status) is kept in the rising rectangle at all times until the green area is reached. Absolute number of steps and current advice on PA progress are also shown. Right image: the graph shows PA over time.



	Naam	Telefoon ID	Stappen doel	Week score	Maand score	Jaar score	Laatst gesynchroniseerd		
Kies		1000	5000				31-08-2012 15:12	Download gegevens	Verwijder patient
Kies		37	7831				08-02-2013 05:42	Download gegevens	Verwijder patient
Kies		41	6500				18-12-2012 01:28	Download gegevens	Verwijder patient
Kies		44	6775				12-02-2013 02:57	Download gegevens	Verwijder patient
Kies		39	8500				07-01-2013 00:43	Download gegevens	Verwijder patient
Kies		32	6214				28-11-2012 00:47	Download gegevens	Verwijder patient
Kies		31	9865				30-11-2012 01:55	Download gegevens	Verwijder patient

Figure 2. Website. Anonymized overview of subjects and detailed PA information of a single subject.

A

Power calculations were based on the raw data of a previous study with similar subjects and protocol (1). With effect sizes based on this previous study by Effing et al., analysis with the random intercept, random slope linear mixed 'linear up' model calculations were made in software program PASS 11 for 60, 70, and 80 subjects per group. The power for the time-group interaction for these group sizes was ~72%, ~76%, and ~84% respectively (two-sided test, level of statistical significance: p=0.05). 70-80 subjects per group was deemed sufficient to achieve a satisfactory power.

B

When subjects are repearedly measured, within subject correlations between the measurement time points are high. In ANOVA these high correlations result in confidence intervals that are too small and to reduced p-values which might subsequently result in a type 1 error. Repeated measures linear mixed modelling (LMM) looks for the accurate correlation structure within the data and then corrects for the tendency of reduced p-values. Additionally, missing data points do not impose any problems in LMM. Therefore, LMM was used (similar to the study of Coxson et al. (2)) to assess the differences between group, the effects of measurement time points, and whether group differences were dependent on measurement time points (=group by time interactions). The chosen approach was a random intercept, random slope method with an unstructured covariance matrix (3).

Average steps/weekday was the primary outcome measure. The primary explanatory parameters were the measurement time points (T0-12) and the group allocation (intervention or usual care group). These two parameters constitute the basic model. Subsequently, other parameters were added to see if they improved the model. These parameters are: age, gender, height, weight, physiotherapy practice, season, temperature, humidity, atmospheric pressure, the number of messages sent, age of the physiotherapist, the number of physiotherapists, long-term care, and all the secondary outcome measures.

The -2log-likelihood (-2LL) is the fit measure of choice in linear mixed modelling: it is a unit-less value and serves the same role as R in linear regression. However, the difference between these two methods is that the value of the -2LL should decrease when the fit between the data and the model improves. The value for the 'extended' model was compared with the basic one and, when a significant decrease was shown based on a χ^2 test, the added parameter was retained. This better fitting model then formed the new 'basic' model to which new parameters were added, and the cycle started again. When the added parameter did not significantly decrease the -2LL value, the parameter was removed from the model and the previous model was maintained as the 'basic' model. This cycle was repeated until the best fitting model was found.

C

Average steps/weekday. The analysis of the primary parameters (time and allocation) showed a significant steps/day decrease over time (p<0.001), but no differences between the groups (p=0.934). The group by time interaction was also non-significant (p=0.811). These data show that both groups decline over time in a similar way. Age and relative humidity could be added to the above basic model as significant parameters. These parameters did not show significant interactions with time or group. These effects are thus constant over time and between groups.

The estimated values map the effect size of a parameter on the dependent variable (see table 1). E.g. an increase in age by one year means that subjects set 94 ± 26 steps/weekday less (p<0.001). Compared to the T12 measurement time point, at T0 subjects take 1178 ± 176 steps/weekday more. By adding all effects we can calculate the estimated steps/weekday for an individual at a chosen time point. When we consider measurement time point T0, a subject who is 60 years old, with 80% humidity, her/his average steps/weekday at that moment would be: 9574 + 1178 + (60 x -94) + (80 x 12) = 6072 steps/weekday. This way we can estimate the number of steps at each of the four measurement time points (see Figure 1).

Table 1. Dependent variable: average steps/weekday. *T12 is the reference value and therefore set at 0.

	estimate	Standard error of the difference	p-value
Intercept	9574		
Time dependent estimate			
T0	1178	176	<0.001
T3	614	176	0.001
T6	472	170	0.006
T12	0*	0*	
Time independent estimate			
Age (years)	-94	26	<0.001
Humidity (%)	12	5	0.027

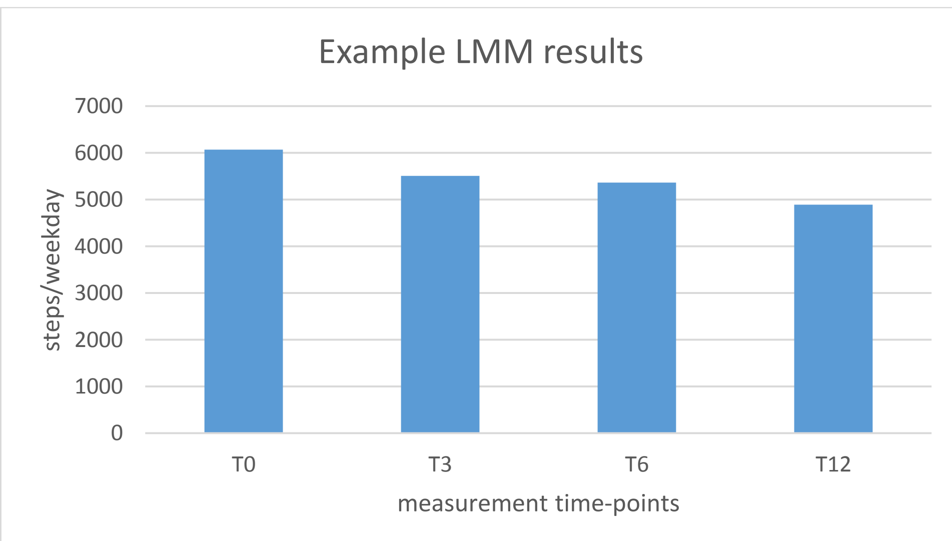


Figure 1. Example of the added effects of the parameters on the dependent variable (steps/weekday) for a subjects of 60 years old, with 80% humidity.

Six-minute walk distance (6MWD). There was no significant decrease in 6MWD over time (p=0.53), and no differences between the groups (p=0.485). The group by time interaction was also non-significant (p=0.585). Gender, BMI, and age could be added to the above basic model as significant parameters. These parameters did not show significant interactions with time or group. These effects are thus constant over time and between groups. The effect sizes of the parameters on the dependent variable are shown in table 2.

Table 2. Dependent variable: 6MWD in meters.

	estimate	Standard error	p-value
Intercept	703.3		
Time independent estimate			
Gender (male)	44.8	12.3	<0.001
BMI (points)	-3.9	1	<0.001
Age (years)	-2.6	0.7	0.001

<u>Lung function</u>

FEV1/FVC. There was a significant decrease of FEV1/FVC over time (p<0.001), but no differences between the groups (p=0.335). The group by time interaction was also non-significant (p=0.908). Secondary parameters did not affect FEV1/FVC significantly. The effect sizes of the various measurement time points on the dependent variable are shown in table 3.

Table 3. Dependent variable: FEV1/FVC in liters. *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	0.522		
Time dependent estimate			
T0	0.028	0.005	<0.001
T3	0.021	0.005	<0.001
T6	0.011	0.004	0.006
T12	0*	0*	

FEV1. There was a significant decrease of FEV1 over time (p<0.001), and a significantly higher FEV1 in the intervention group (p=0.05). However, the group by time interaction was non-significant (p=0.508), meaning that there was no effect of the intervention on FEV1. Secondary parameters did not affect the dependent variable significantly. The effect sizes of the parameters on the dependent variable are shown in table 4.

Table 4. Dependent variable: FEV1 in liters. *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	1.53		
Time independent estimate			
Group (intervention)	0.16	0.08	0.05
Time dependent estimate			
T0	0.07	0.02	<0.001
T3	0.04	0.02	0.05
T6	0.02	0.02	0.24
T12	0*	0*	

HRQoL

Dyspnea. The analysis of the primary parameters showed significantly less dyspnea at T3 compared with T12 (p=0.01), but no differences between the groups (p=0.859). The group by time interaction was non-significant (p=0.179). FEV1 could be added to the basic model as significant parameter, but did not show a significant interaction with time or group. The effect sizes of the parameters on the dependent variable are shown in table 5.

Table 5. Dependent variable: Dyspnea in points (1-7; a higher score represents less dyspnea). *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	3.9		
Time dependent estimate			
T0	0.13	0.09	0.14
T3	0.22	0.09	0.01
T6	0.11	0.08	0.17
T12	0*	0*	
Time independent estimate			
FEV1 (in liters)	0.49	0.18	0.007

Fatigue. Fatigue did not significantly change over time (p=0.393), and there were no differences between the groups (p=0.879). There was a significant group by time interaction (p=0.018), however, this was probably caused by great variability in the data rather than the intervention (see figure 2). There was no significant difference between the groups at each individual time piont (T0-T12). Dyspnea could be added to the basic model as significant parameter, but did not show a significant interaction with time or group. The effect size of dyspnea on the dependent variable is shown in table 6.

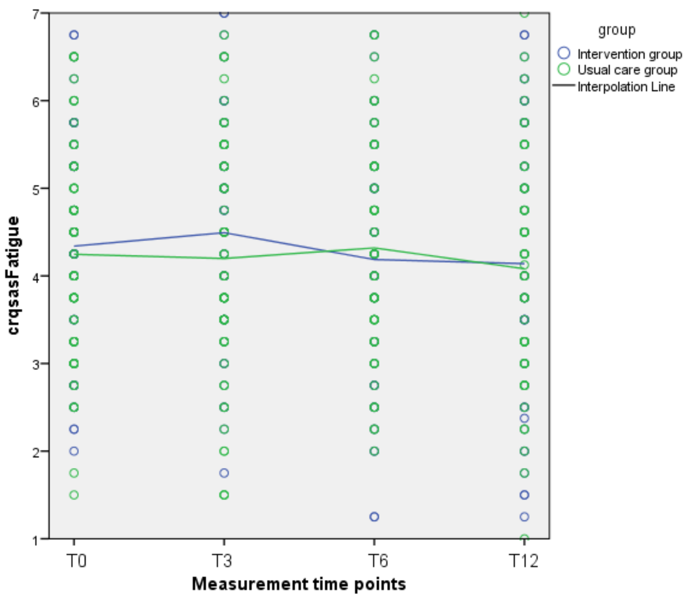


Figure 2. Group by time interaction of fatigue.

Table 6. Dependent variable: Fatigue in points (1-7; a higher score represents less fatigue).

	estimate	Standard error	p-value
Intercept	1.8		
Time independent estimate			
Dyspnea (in points)	0.53	0.04	<0.001

Emotional function. The analysis of the primary parameters showed that emotional function was significantly lower at T0 (p=0.04) and T6 (p=0.02) compared with T12, but there were no differences between the groups (p=0.6). The group by time interaction was not significant (p=0.590). Dyspnea and fatigue could be added to the basic model as significant parameter, but did not show a significant interaction with time or group. The effect sizes of the parameters on the dependent variable are shown in table 7.

Table 7. Dependent variable: Emotional function in points (1-7; a higher score represents a better emotional function). *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	2.5		
Time dependent estimate			
T0	-0.12	0.06	0.04
T3	-0.06	0.06	0.29
T6	-0.13	0.06	0.02
T12	0*	0*	
Time independent estimate			
Dyspnea (in points)	0.18	0.03	<0.001
Fatigue (in points)	0.43	0.03	<0.001

Mastery. Mathematical issues prevented us from performing a LMM analysis with this variable as described in the method. To account for this problem we used T0 als covariable instead of dependent variable. Dyspnea and emotional function could be added to the basic model as significant parameter, but did not show a significant interaction with time or group. The effect sizes of the parameters on the dependent variable are shown in table 8.

Table 8. Dependent variable: Mastery in points (1-7; a higher score represents a better mastery). *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	1.04		
Time dependent estimate			
T3	0.22	0.08	0.005
T6	0.14	0.08	0.09
T12	0		
Time independent estimate			
Dyspnea (in points)	0.14	0.04	<0.001
Emotional functioning (in points)	0.48	0.05	<0.001

<u>BMI</u>

The analysis of the primary parameters showed that BMI was significantly higher at T6 (p=0.02), but there were no differences between the groups (p=0.223). The group by time interaction was not significant (p=0.458). Height could be added to the basic model as significant parameter, but did not show a significant interaction with time or group. The effect sizes of the parameters on the dependent variable is shown in table 8.

Table 8. Dependent variable: BMI in points. *T12 is the reference value and therefore set at 0.

	estimate	Standard error	p-value
Intercept	52.6		
Time dependent estimate			
T0	-0.09	0.12	0.43
T3	0.03	0.1	0.76
T6	0.18	0.08	0.02
T12	0*	0*	
Time independent estimate			
Height (in meters)	-12.4	6.1	0.045

Reference list

(1) Effing T, Zielhuis G, Kerstjens H, van der Valk P, van der Palen J. Community based physiotherapeutic exercise in COPD self-management: a randomised controlled trial. Respir Med 2011 Mar;105(3):418-426.

(2) Coxson HO, Dirksen A, Edwards LD, Yates JC, Agusti A, Bakke P, et al. The presence and progression of emphysema in COPD as determined by CT scanning and biomarker expression: a prospective analysis from the ECLIPSE study. Lancet Respir Med 2013 Apr;1(2):129-136.

(3) Bandyopadhyay S, Ganguli B, Chatterjee A. A review of multivariate longitudinal data analysis. Stat Methods Med Res 2011;20(4):299-330.

Chapter 6

Perceptions of patients with COPD and their physiotherapists regarding the use of an eHealth intervention

SNW Vorrink, CAM Huisman, HSM Kort, T Troosters, J-W.J. Lammers

❖ Abstract

Background eHealth has the potential to improve the delivery of and access to care, to increase work efficiency, and to help older adults age in place. If eHealth interventions are not used (properly), their potential benefits cannot be fulfilled. User perceptions of eHealth are an important determinant of its successful implementation. This study examined how users value an eHealth intervention following a period of use.

Method In this study, we examined physiotherapists (PTs) and patients with chronic obstructive pulmonary disease (COPD) as users of an eHealth intervention (website and smartphone application) aimed at stimulating physical activity (PA). Participants in a randomized controlled trial (RCT) were asked how they valued the eHealth intervention beginning 6 months after a period of use of 6 months. Interview requests were made to 33 PTs from 26 participating practices, and a questionnaire was sent to 76 patients. The questionnaire was analysed in Excel (Microsoft, Redmond, WA, USA). The interviews with the PTs and text messages sent between patients and PTs were transcribed and independently coded in MAXQDA 10 for Windows (VERBI GmbH, Berlin, Germany).

Results Sixty patients with COPD filled out the questionnaire, and 24 PTs were interviewed. The smartphone application was used 89 ± 18.5% of the time by patients. Ten out of 19 practices reported spending little time on the intervention. Patients scored the ease of use of the smartphone and application as 5.7 ± 1.65 and 5.09 ± 1.14 (on a 7-point scale), respectively. They found the presentation of the PA information in the application to be clear, insightful, and stimulating. All PTs judged the website as explicit and user-friendly. Perceived usefulness of the intervention for the PTs was the objective measurement of PA, the ability to see PA patterns over time, and the ability to use the intervention as a tool to give their patients insight into their PA. Patients reported that the intervention supported them in increasing their PA and that it made them feel fitter. They found it important to have control over the distribution of their data. The PTs sent mostly motivating (56%) and positive (65%) messages concerning the PA goal (70%), whereas the patients sent mostly informative (66%) or neutral (62%) messages concerning the PA goal (58%). The messages were not perceived by the patients as supportive with respect to reaching the PA goal. Barriers to use of the intervention according to the PTs were time constraints and financial reasons. Devising a new PA goal for patients was considered difficult. Seventy-nine percent of the PTs and 58% of the patients mentioned they would be interested in using the intervention in the future.

Conclusions PTs and patients had positive feelings regarding the functionality and potential of the eHealth intervention. Use of the website and smartphone application was straightforward. This paper addresses a number of topics that may aid in the successful implementation of these types of eHealth interventions in the future.

❖ Introduction

eHealth is a relatively new field in health care. It is a broad term, and the discussion of what eHealth comprises remains ongoing (1). The most recent definition comes from Pagliari et al. (2):*"eHealth is an emerging field of medical informatics, referring to the organization and delivery of health services and information, using the internet and related technologies. In a broader sense, the term characterizes not only a technical development but also a new way of working, an attitude, and a commitment for networked, global thinking to improve health care locally, regionally, and worldwide by using information and communication technology"*. The emergence of this field is causing a shift in health care. Health data have historically been in the hands of health care professionals (HCPs); however, eHealth applications now provide this information directly to the patient (3).

eHealth has the potential to address the issue of increasing numbers of older adults (4) with relatively fewer HCPs available to provide the required level of service (5). Moreover, eHealth may also address the increasing number of persons living with chronic conditions, such as chronic obstructive pulmonary disease (COPD) (6), who are in need of long term health care. eHealth can improve the delivery of and access to care, increase work efficiency, and help older adults to remain in their community while they age (age in place) (7). This is possible because eHealth reduces travel time to centralized health care facilities (by the patient) or to a patients' home (by the HCP), reduces the time needed to measure and analyse health data, and helps HCPs to attend to more patients within the same time-frame and specifically target those most in need.

In addition to its potential benefits, there are also limitations of eHealth that must be mentioned. The limited evidence base is a challenge, as are concerns regarding the privacy of data and the use of eHealth in daily practice. Furthermore, the question of how to engage older adults in eHealth interventions remains an issue (8). If the interventions are not used (properly), their potential benefits cannot be fulfilled. Furthermore, understanding disease-specific factors to determine how various populations may benefit from eHealth seems important in increasing their use and, subsequently, their efficacy (9).

User perceptions are an important determinant of the successful use of eHealth. According to the Unified Theory of Acceptance and Use of Technology (UTAUT) model, there are four main constructs that influence the intention to use technology: performance expectancy, effort expectancy, social influence and facilitating conditions. Additionally, gender, age, voluntary nature of use, and experience with the technology moderate the relationship between the four main constructs and (intention to) use behaviour (10). According to the extended expectation-confirmation model in IT domain (extended ECM-IT), important predictors of the continued use of technology are perceived usefulness and ease of use, confirmation of expectations and satisfaction (11). Continued use of eHealth technologies is especially important when targeting patients with chronic conditions. Most eHealth projects begin without insight regarding user needs and perceptions, which can be an important barrier to implementation (12).

This study examined how users value an eHealth intervention following a 6 month period of use. The results may help in the development and successful implementation of future eHealth interventions.

❖ Methods

In this study, we examined physiotherapists (PTs) and patients with COPD as users of an eHealth intervention. Participants of a randomized controlled trial (RCT) (**chapter 5)** were asked to evaluate an eHealth intervention that was used for 6 months and consists of two components: 1. a smartphone application for patients with COPD and 2. a website for PTs. The application showed physical activity (PA) in real time in quantitative (steps taken) and qualitative (progress bar) forms as measured by an accelerometer embedded in the smartphone. Patients were encouraged to obtain their personalized PA goal by automated encouraging messages and an emoticon (pictorial representation of an emotion). PTs could monitor their patients via the (secure) website, which showed an overview of the PA data from all participants from their practice and a more detailed view of individual patients. The PT was able to adjust each patient’s PA goal and send group or individual text messages (**chapter 4)**. Beginning 6 months after the end of the intervention period, interviews were conducted with the PTs (relating to the total intervention, website and application), and the patients with COPD received a questionnaire (related to the application). Furthermore, the text messages that were sent during the trial via the website (PTs) and the smartphone application (patients) were analysed. **Figure 1** provides an overview of the methodologies used for this study.

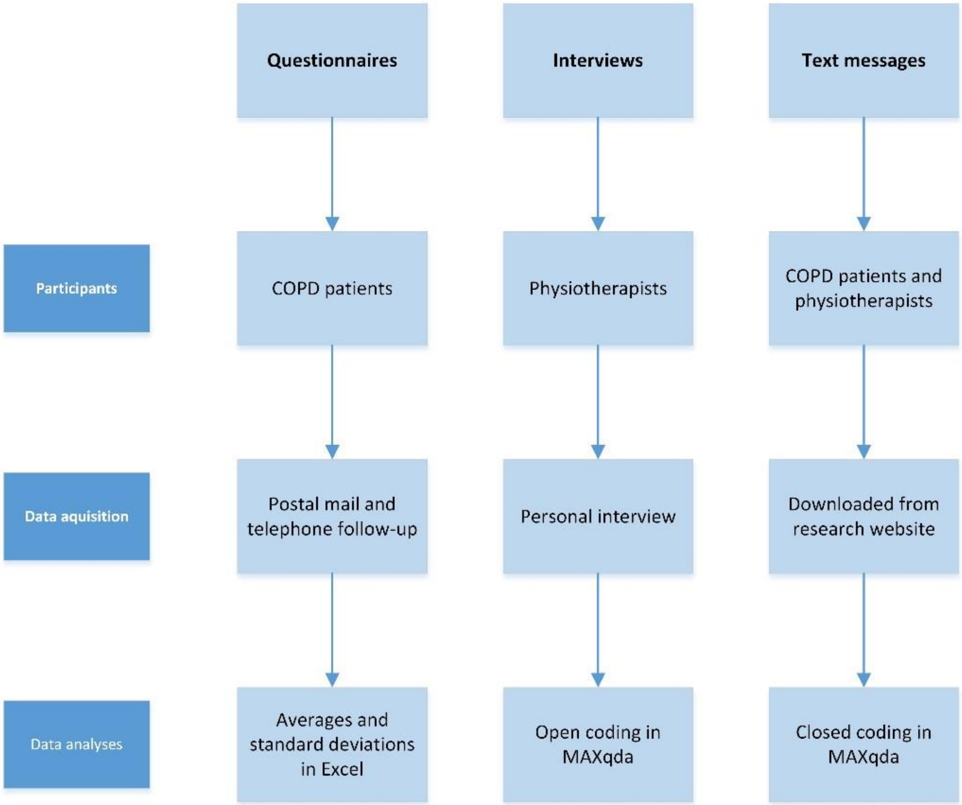


Figure 1. Overview of the methodologies used.

PT interviews

Semi-structured interviews were conducted with the PTs that had patients who were included in the intervention group of the RCT. The interview structure was based on the rational choice theory (13) and the theory of planned behaviour (14). The first theory states that individuals make choices with the objective of attaining the maximum achievable for themselves or of realizing a certain goal. The second theory accounts for the influence of circumstances and personal and social factors on choices. Interview questions can be found in **appendix D**. The interviews were transcribed and independently open coded (without a previously established code list) by the second author and two research assistants. Each interview was coded twice (by different coders) with the use of the MAXQDA 10 for Windows (VERBI GmbH, Berlin, Germany) software package. Differences were discussed between the coders and the first author, after which final decisions were made. The final code list can be found in **appendix B**.

Patient questionnaire

Questionnaires were sent by postal mail after completion of the RCT to patients with COPD who participated in the intervention group. A week later, one of the researchers discussed all of the questions with the patients during a phone appointment to ensure that they were properly understood because the questionnaire was long. The questionnaire was composed of three existing questionnaires: the Usefulness, Satisfaction, and Ease of Use (USE) questionnaire on usability (15), which results in total scores for the domains of usability, ease of use, ease of learning, and contentment; the Florida State University (FSU) mobile device feedback preferences scale; and the FSU physiological monitoring privacy scale (inspired by Beach et al. (16) and Kwazney et al. (17)). Eight out of 38 questions from the USE questionnaire, 15 from the FSU feedback scale and 14 from the FSU privacy scale were slightly adjusted to be specifically directed towards the intervention at hand. We added 6 questions regarding circumstances influencing the ability to reach the PA goal and whether patients would like to continue to use the intervention (questions 68 to 73). The questionnaire can be found in **appendix C**. The results of the USE questionnaire were summarized per its instructions (15). For the other results, averages and standard deviations were computed in Excel (Microsoft, Redmond, WA, USA). For the 8 point scales (0-7), a score of 4 or higher was seen as satisfactory, and for the 7 point scales (1-7), a score of 3.5 or higher was seen as satisfactory.

Text messages and use of the intervention

The frequency of text messages sent between the PTs and the COPD patients was recorded. Content was analysed by coding similar to the interviews. However, three code lists were established in advance by the second author after a read through of the messages; one for tone (positive, negative, neutral), type (motivating, informative, fun/social, question), and topic (PA goal, smartphone/app, health, study related, other). The second author and a colleague independently coded the messages, after which differences were discussed with the third author, and final decisions were made.

Adherence to the intervention was measured as the percentage of days that the intervention was used and as the percentage of days that the PA goal was attained.

❖ Results

There were 26 physiotherapy practices with patients in the intervention group during the RCT. Interviews were held with PTs from 19 of these. Fifteen practices sent text messages to their patients. Group messages were sent by 8 practices. Thirty-five patients sent text messages to their therapists. Information on the number of PTs, patients, messages studied and drop-out reasons can be found in **table 1**. The questionnaire for the patients did not contain missing values. The average age of the PTs was 44 ± 11 years, and 16 females and 8 males were interviewed. Demographics and baseline measurements of the RCT (**chapter 5**) of the COPD patients are shown in **table 2**.

Table 1. Number of PTs, patients, and messages studied.

	Invited	Response	Drop-out reasons	Text messages sent	Erroneous messages
PTs	33 (from 26 practices)	24 (from 19 practices)	Not available (4 practices) Unable to reach PT (3 practices)	Personal: 362 Group: 10	41 (10%)
COPD patients	76	60	Health status (4) Deceased (1) Could not form an opinion (2) Unwilling (2) No time (2) Unreachable (5)	162	16 (9%)

Table 2. Demographics of the COPD patients (N = 60).

Age (years)	62 ± 8
Females/Males	25/35
Body mass index (kg/m^2)	27 ± 5
Forced expiratory volume in 1 second (litres)	1.71 ± 0.60 (59 ± 20% predicted)
Forced vital capacity (litres)	3.61 ± 0.95 (99 ± 19% predicted)
6-minute walking distance (metres)	486 ± 84 (83 ± 15% predicted)
Average steps/day (weekday)	5980 ± 3035

The results are presented in three segments: the general results of the eHealth intervention, results of the intervention application, and results of the intervention website. **Appendix A** provides more detailed results of the questionnaire for the patients with COPD regarding use, privacy, feedback preferences, and personal circumstances. Below, the most important findings are described. In **table 3,** the key findings are summarized.

Table 3. Key findings.		
	Patients	**Physiotherapists**
Intervention general		
Use	The intervention was used on 89 ± 18.5% of the days that it was in their possession	10 out of 19 practices spent little time on the intervention
Perceived usefulness	Thought it helped to increase PA	Measure of objective PA data outside the clinical setting
	Made them feel fitter	Ability to see patterns in PA (to monitor exacerbations)
		Tool to start a conversation about PA with the patient
Text messages	Sent mostly informative, neutral messages concerning the PA goal	Sent mostly motivating, positive messages concerning the PA goal
	Messages were not perceived as supportive in reaching the PA goal	
Privacy	Important to have control over the distribution of their data	Important to keep in mind when working with eHealth
Applicability	58% would like to continue to use the intervention	15 out of 19 practices were interested in using the intervention
		May be useful in preventing relapse
		Financing concerns
		Face-to-face interaction is necessary in addition to monitoring
		Intervention should be individually tailored to the patient
Application		
	Easy to learn and use	Explicit and user-friendly to patients
	Training not necessary	Training necessary
	Clear, insightful, stimulating	
Smartphone	Easy to use	Use of and continuously wearing the smartphone troublesome for a few patients
	32% owned a smartphone, and 18% purchased one after the RCT	
Website		
		Explicit and user-friendly
		Used to look at PA data, adjust PA goals, and send messages
		Setting PA goals was considered difficult
		Reported low use, which was attributed to time-constraints
		Tedious additional log-in

Intervention

Use of the intervention

Patients with COPD used the intervention on 89 ± 18.5% of the days that it was in their possession (6 month period). They obtained their personal PA goals on 34 ± 16% of these days (**chapter 5**). The reported use of the intervention by PTs varied from 5 to 60 minutes per session. Nine practices used it every week, 3 practices used it every other week, 4 used it mostly at the start of the RCT, and 3 did not use it at all. Ten practices mentioned having spent little time on the intervention. Three PTs scheduled time in their agenda to use the intervention. PTs mentioned that patients' and their own motivation to use the intervention diminished over time.

Perceived usefulness

PTs mentioned that the intervention gave them insight into the objective PA data of their patients outside the clinical setting, whereas they previously had to rely on the account of the patient. This is seen as a major advantage. It also enabled them to see patterns in PA. Nine PTs mentioned that the ups and downs in the PA of patients with COPD are important to monitor in light of exacerbations. The data can be used to start a conversation with the patient about their PA level and to give them insights and tips. One PT mentioned that his patients learned how far they needed to walk to reach their PA goal with the intervention and continued to do so after the study ended. Nine PTs found it pleasant and necessary to follow patients after pulmonary rehabilitation (PR), whereas two PTs did not see this as a task for the PT. Patients thought that the eHealth intervention helped them to increase their PA and made them feel fitter. It was rewarding for patients to reach their PA goal (**table 1** and **3** of **appendix A**).

Text messages

The messages sent by the PTs mostly concerned the PA goal (73%). The remaining messages were related to the smartphone or application (11%), the study (7%), health (5%), or other topics (4%). For the patients, this was more evenly divided, with 30% of the messages concerning the PA goal; 20%, the smartphone or application; 9%, the study; 19%, health; and 22%, other topics. PTs sent mostly motivating messages, whereas patients mostly sent informative messages. **Table 4** presents the distribution of the types of messages sent. The tone of the messages sent by the PTs was mostly positive (64%), followed by neutral messages (36%), and 2 negative messages (0.5%). For patients, positive (55%) and neutral (43%) messages were more evenly divided. They sent 15 (3%) negative messages.

Table 4. Types of messages sent. Results are given as frequencies and percentages of total messages sent.

	By the PTs	Percentage of total messages	**By the COPD patients**	Percentage of total messages
Motivating	241	56%	0	0%
Informative	68	17%	117	66%
Question	43	10%	11	6%
Fun/social	20	8%	34	19%
Total	372	100%	162	100%

Patients mentioned that sending messages to and receiving them from the PT was rare and was not seen as supportive in reaching the PA goal. PTs from six practices explained that they used text messages to inform patients, to motivate them and to determine the reason why the PA goal was not met. One PT e-mailed patients instead of texting. During the RCT, the PTs contacted all subjects but mentioned that if the intervention was implemented, they would contact only those who did not reach their PA goals.

Privacy

Patients reported that they did not worry about privacy with regards to their PA data. Interested parties, such as family and PTs, are welcome to access the data; however, local authorities are not. It is important that patients have control over who can see their data (**table 2** of **appendix A**). Two PTs mentioned that privacy is an important consideration when using eHealth.

Applicability

PTs from 15 practices mentioned they would be interested in using the intervention, provided that it proved effective and that the helpdesk would remain available. Two practices stated that they would not be interested in using the intervention. Two practices were unclear on this matter. Fifty-eight percent of patients mentioned that they would like to start using the intervention again. The PTs believe that the eHealth intervention may be useful in preventing relapses and subsequent repeat PR. PTs form 8 practices thought that the intervention should already be used during PR, and 4 practices preferred to start after the program.

They believe that face-to-face contact every 2-3 months is necessary, in addition to monitoring from a distance. Additionally, the use of the intervention should be individually tailored to each patient.

There were questions regarding the financing of the intervention. PTs were concerned that they would not be paid by health care insurers because monitoring is not seen as a consultation; therefore, expenses cannot be claimed. Additionally, they considered it an issue that not all patients owned a smartphone.

Application

Patients considered the application to be fairly easy to learn and use (**table 5**). Training on the use of the application was not reported as highly necessary. The presentation of the PA information in the application was considered to be clear, insightful, and stimulating. Desired options included the possibility to measure cycling, swimming, and distance walked. Health status, energy level, personal circumstances and time-constraints did not negatively influence patient ability to reach the PA goal (**table 1**, **3**, and **4**, respectively of **appendix A**).

Table 5. Application: USE questionnaire scores (mean ± standard deviation). Scores range from 0-7 (0: totally disagree and 7: totally agree).

Ease of learning	5.55 ± 1.46
Ease of use	5.09 ± 1.14
Contentment	5.06 ± 1.54
Usability	4.97 ± 1.32

PTs mentioned that the application was explicit and user-friendly for their patients. Six PTs mentioned that some of their patients had trouble sending text messages as a result of the small keyboard or overlooked the possibility. Nine PTs mentioned that there were differences among the patients with regards to digital skill level. Personal instruction on the use of the intervention was deemed important, especially for older users. PA status was often viewed by patients and was stimulating. PTs suggested that patients should have the option to indicate if they were having a bad day and, subsequently, that their daily PA goal would be adjusted accordingly.

Smartphone

Patients scored the ease of use of the smartphone as 5.7 ± 1.65 (on a 7-point scale). Thirty-two percent of patients owned a smartphone prior to the start of the study, and 18% purchased one after the study. Technical failure of the smartphone or application or forgetting to bring the phone was not a major issue (**table 1** of **appendix A**).

Six PTs mentioned that the use of the smartphone, as well as continuously wearing the smartphone, was not a problem for most of their patient group but was considered troublesome for one of their patients. Personal instruction regarding the use of the smartphone was considered important, but the amount of information given at one time has to be taken into consideration.

Website

All interviewed PTs considered the website to be explicit and user-friendly. They used it to view PA data, adjust PA goals, and send text messages. However, reported use was low due to time constraints. The additional log-in was considered tedious, and the PTs mentioned that a website that could be incorporated into their usual patient software would be better.

Five practices adjusted PA goals via the website, and one adjusted PA goals via the researchers, whereas seven reported that they did not adjust PA goals. Devising a new goal was considered difficult, especially regarding PA intensity, which was seen as an important outcome and thought to predict exacerbations; however, the score was not always well understood. PTs noted that they would like to receive a notification when a patient was deteriorating over a longer time period. A smartphone application for the PT with the same PA information as the website was desirable.

❖ Discussion

This study evaluated the perceptions of patients with COPD and their physiotherapists and sent text messages regarding the use of an eHealth intervention aimed at stimulating PA in patients with COPD.

Use

Patients and PTs mentioned that use was satisfactory with regard to the application as well as the website. Measured use among patients was high, whereas PTs reported low use. Barriers to use of the intervention according to the PTs were time constraints and financial reasons. Implementation of the intervention in daily practice was challenging. Suggested features that may enable its use were a smartphone application for the PT, a notification when a patient deteriorates, and a website that is incorporated into the standard patient software.

Patients with COPD are mainly older adults, and in this user group, technology use decreases significantly with greater limitations in physical capacity and greater disability (18). A focus on the end user and their needs and wishes during the design process will drastically increase the number of people who can successfully use the technology (19). Patients with COPD participated in pilot studies during the development phase. During these pilot studies and in the current study, patients scored the smartphone and application satisfactory with respect to ease of learning and use (**chapter 4**). However, during the RCT (**chapter 5**), there were some patients who had trouble using the smartphone, according to the PTs. For technologies that have been around longer (e.g., computer or e-mail), use among older adults is generally high. On the other hand, use of newer technologies (e.g., smartphone and a tablet) is considerably lower because older adults are usually slower to adapt to new devices and technologies (**chapter 3**). However, with proper instruction, smartphone use in older adults has not shown to pose many problems (20). One-third of the patients owned a smartphone, and 18% purchased one after the study. This result, combined with the high use rate in patients, is promising in light of smartphone-based eHealth interventions for older adults and patients with COPD in particular.

By using eHealth, patients may be more involved in their own health and may therefore be more likely to take responsibility for and improve their adherence to medical regimens. The ideal outcome is a patient who, with the use of eHealth, is more compliant, better informed, and self-regulating (21). Furthermore, continuous monitoring can provide peace of mind to patients and family because they know that a HCP will intervene in the case of deterioration of their health (22). eHealth interventions for older adults have been shown to have a positive impact on the clinical process, patient health, productivity, efficiency and costs, clinician and patient satisfaction, and patient empowerment (23). When using eHealth interventions, self-efficacy (belief in one's own ability to complete tasks and reach goals) for managing their disease(s) improves, and older adults benefit from receiving feedback and social support through communication with HCPs (9).

Training

According to the patients, training on the use of the application was not highly necessary. This is in contrast to the opinion of the PTs, who deemed proper instruction important, especially for older adults. The literature also shows the importance of training for older adults when using technology (8,23-25). Face-to-face instructions are usually preferred by older adults (26). The PTs warned us of an information overload at the initial instruction for the patients. We may have provided too much information at once because we had to explain the study, the use of the smartphone, and the application. The written instructions and help desk were helpful in this regard. In a previous study, we found that increased age, less education, birthplace outside of Europe, lower income, and lower physical functioning significantly predicted lower use of information and communication technology (ICT) in older adults (**chapter 3**). Older adults with these characteristics will likely need more extensive training to acquire the digital skills needed to properly use eHealth technologies.

We thought it would be important to pay extra attention to the patients to ensure that they would use the intervention. The PTs were the ones who initially signed up their practice to participate in the RCT and were thus thought to need less attention. They were given one face-to-face instruction session, written instructions, and access to a helpdesk. In hindsight, they may have needed more prompting and training to use the intervention. For successful use of eHealth interventions, HCPs need new competencies, such as composite skills and technology-specific competencies (27). Inadequate training and education of HCPs can function as a barrier to implementation (12). Coaching skills, the ability to combine clinical experience with technology, communication skills, clinical knowledge, ethical awareness, and a supportive attitude are seen as core competencies needed by HCPs to effectively use eHealth technologies (28). Our study may have benefitted from training the PTs to improve these competencies.

During training, attention should also be paid to how the eHealth intervention can help in daily practice. This has recently been found to be the most important predictor of therapist acceptance and use of technology (29).

Physical activity goal

Interestingly, patients thought that the intervention helped them to increase their PA and made them feel fitter. However, the data from the RCT does not show a difference in PA over time compared with the usual care group, and PA actually diminished in both groups equally over the one year study duration (**chapter 5**).

Only 6 out of the 19 practices that were interviewed adjusted the PA goals of their patients. If there were patients in the other practices that had trouble achieving their PA goals or their goals were too easy for them, they may have been demotivated. Despite the personal instructions for the PTs regarding the intervention, some did not completely understand the intensity scores of the PA goal. Three PTs mentioned that they found it difficult to set a new goal. Because there are no COPD-specific PA guidelines available, PTs had to rely on their own practice-based expertise. This can be difficult, especially because minor changes in the frequency, intensity and time of general PA guidelines for older adults can have major consequences for patients with COPD regarding whether they can comply with these guidelines (30).

The PTs indicated that they would like to gain more insight into the current emotional and physical conditions of their patients. In the interviews, they mentioned that it would be beneficial if patients had the opportunity to indicate whether they are having a bad day. A few patients also mentioned during the measurements that there were days that they wanted to attain the PA goal but were too tired or were too affected by dyspnea to do so. Adjusting daily PA goals to account for fluctuating physical capacity may improve goal obtainment in this patient group. As a result, positive feedback may increase, and patients may be more motivated to use the intervention long-term.

Text messages

The text messaging function was not used to its full potential. Only 15 out of 26 practices sent messages. Additionally, only 10 group messages were sent. Similar to the PTs, there was a large portion of patients who did not use this function (53%). Patients did not perceive messaging as supportive in reaching their PA goal, which is not surprising considering its low use rate. Low use could stem from a suboptimal interface (e.g., the letters on the smartphone keyboard were small) because we found that both PTs and patients sent erroneous messages in approximately 10% of cases. One PT used e-mail instead of messaging.

In looking at the correct messages, we see that the messages sent by the PTs mainly focused on the PA goal and were positive and motivating. This was the intention of this aspect of the intervention. Perhaps if messaging had been applied in this way by all PTs, patient PA outcomes would have improved. Responses from patients would likely have been higher as well. On the other hand, 80% of patients were still seeing their PT once or twice a week. During these meetings, the PA measurements of the intervention were discussed and patients motivated (PTs mentioned using the intervention as a tool to start a conversation with their patients about their PA). This would have rendered messaging superfluous.

Applicability

Although the reported uses of the website and messaging function were low, PTs were positive about the functionalities of the intervention. Thus, one could argue it was not the intervention itself but rather its cumbersome implementation that caused the low use by PTs. Financing concerns were expressed regarding implementation. These may stem largely from a lack of awareness regarding the policies of the Dutch Health Authority concerning eHealth. Patient consultations and consultations with colleagues via eHealth can already be claimed. For new eHealth applications that are not in the current funding model, PTs and health care insurers can apply for funding (31). Educating PTs on these funding possibilities may make them more responsive to eHealth.

A different financing issue that was not addressed in the interviews is that the reimbursement of physiotherapy by health care insurers for chronic conditions was altered a few months before the RCT started. As of January 1st 2012, the first 20 sessions can no longer be reimbursed (0, 9, and 12 sessions in 2009, 2010 and 2011, respectively). This can prevent less affluent patients from visiting the PT and reduce the chances of them starting and continuing a form of eHealth monitoring. This is underscored by the fact that PTs mentioned that face-to-face contact every 2-3 months is necessary, in addition to long-term monitoring.

Patients were disappointed that the application could not measure cycling or swimming and that it did not capture the intensity of walking the stairs. There were quite a few patients who cycle a lot and were disappointed when this was not added to the overall PA goal attainment. For COPD patients living in countries with a strong cycling tradition, this activity is seen as an important part of PA, whereas it is not relevant for individuals living in other countries (32). This shows that nationality or culture can also influence the needs and wishes of the end user and should be considered.

As of the time of the study, battery capacity was too low to add GPS measurements or other features that could measure these activities. As the development rate of smartphone technologies and accompanying batteries is high, this seems likely to be possible in the near future. For example, identifying the activity of ‘walking the stairs’ has recently become possible (33).

Continued use

In the introduction, we mentioned that perceived usefulness and ease of use, confirmation of expectations and satisfaction with the technology are important predictors of continued use (11). Perceived usefulness for the PTs was that the PA data was objectively measured, the ability to see PA patterns over time, and that they could use this data to give their patients insight in their PA. For patients, it was that the eHealth intervention helped them to increase their PA and made them feel fitter. Reported ease of use by patients and PTs was satisfactory with regard to the application and the website. We cannot draw any conclusions regarding confirmation of expectations because this was not measured at the start of the RCT. For a measure of satisfaction in patients, we can examine the contentment score of the application, which was adequate. For PTs, this is more difficult because they reported low use. However, they were positive on the functionality and potential of the eHealth intervention.

Although this sounds promising for continued use, the RCT did not show an effect of the intervention on steps/day after 6 months of use compared with a usual care group (**chapter 5**). Looking at the current study, the reasons for this ineffectiveness could be due to the following:

- Low use of the intervention by PTs.
- Suboptimal use of the messaging function by patients and PTs.
- Difficultly setting PA goals.
- Not all activities were properly measured, such as cycling and walking the stairs.
- The intervention was not properly implemented in PTs’ daily practice (timewise and website).

From the results of this study we can identify a few possible solutions:

- Additional training sessions for PTs and patients may improve the competences needed to effectively use eHealth technologies, such as digital and coaching skills.
- More prompting for the PTs to increase use.
- Educating PTs on funding possibilities for eHealth.
- COPD specific PA guidelines to help PTs set PA goals.
- Adjusting the PA goals to account for patients' fluctuating physical capacity.
- Adding GPS data and adjusting algorithms to improve the measurement of (intensity of) certain activities.
- A smartphone application for PTs.
- A notification when a patient deteriorates.
- A website that is incorporated into standard patient software.

Implications for practice

It is recommended that HCPs perform an objective PA assessment at the beginning of treatment to establish PA status, adjust PA goals accordingly, and subsequently monitor PA progression. HCPs, as well as the patients, should attend training sessions to acquire the skills needed to fully benefit from eHealth interventions. To provide proficient support and monitoring, HCPs must be able to reserve designated time for this task. Financial structures concerning eHealth are available. However, most HCPs are not familiar with these regulations and should be made aware of them. Face-to-face contact every few months is seen as a valuable addition to monitoring patients from a distance. Furthermore, patients should be given control over their personal data distribution.

Limitations

Patients' attitudes were inconsistent with our results. They reported that the intervention supported them in improving PA; however, the RCT showed that it did not. They reported that training on how to use the intervention is not necessary, whereas the literature and the PTs report that it is, especially for older adults. The PTs may have provided more realistic feedback than the patients. On the other hand, use among patients was higher than among PTs, making their conclusions more experience-based.

PTs were interviewed by a member of the research group. This may have led to more favourable answers towards the intervention to please the researchers. The same holds true for the patients who were telephoned to ensure that they understood all of the questions in the questionnaire. Furthermore, the PTs (9) and patients (16) that did not take the time for the interviews or questionnaires may have had a lower use rate and more negative opinions.

❖ Conclusion

PTs and patients were positive regarding the functionality and potential of the eHealth intervention. Patients used the intervention on 89% of the days that it was in their possession. Fifty-three percent of PTs reported low or no use. Patients rated the smartphone and application as easy to use. They found the presentation of the PA information in the application to be clear, insightful, and stimulating. PTs considered the website to be explicit and user-friendly. Perceived usefulness of the intervention for the PTs was the objective measurement of PA, the ability to see PA patterns over time, and the ability to use the intervention as a tool to give their patients insights into their PA. The patients reported that it supported them in increasing their PA and made them feel fitter. They found it important to have control over the distribution of their data.

Fifty-eight percent of PTs and 47% of patients used the messaging function. PTs sent mostly motivating, positive messages concerning the PA goal, whereas patients sent mostly informative, neutral messages concerning the PA goal. The messages were not perceived as supportive in reaching the PA goal by patients.

Barriers to use of the intervention according to the PTs were time constraints and financial reasons. Devising a new goal was considered difficult. However, 79% of the PTs and 58% of the patients mentioned they would be interested in using the intervention in the future. Reported smartphone ownership and the high use rate of the intervention in patients is promising in light of smartphone-based eHealth interventions for older adults and patients with COPD in particular.

In this paper, a number of topics have been discussed that may aid in the development and successful implementation of these types of eHealth interventions in the future.

Acknowledgement

We would like to thank Marijke Luijten for her assistance in analysing the text messages. We would also like to thank the physiotherapists that made time for the interviews and the patients for filling out the questionnaire. We gratefully acknowledge the Foundation Innovation Alliance (SIA RAAK) for co-funding the trial (project number: 2010-11-12P).

❖ References

(1) Boogerd EA, Arts T, Engelen LJ, van de Belt TH. "What Is eHealth": Time for An Update? JMIR Res Protoc 2015 Mar 12;4(1):e29.

(2) Pagliari C, Sloan D, Gregor P, Sullivan F, Detmer D, Kahan JP, et al. What is eHealth (4): a scoping exercise to map the field. J Med Internet Res 2005 Mar 31;7(1):e9.

(3) Carrera PM, Dalton ARH. Do-it-yourself Healthcare: The current landscape, prospects and consequences. Maturitas 2014;77(1):37-40.

(4) World Health Organisation. World Health Day 2012. Ageing and health. Toolkit for event organizers. 2012; Available at: www.who.int/world-health-day/2012 Accessed: 2015-05-08. (Archived by WebCite® at http://www.webcitation.org/6YMy8pkLl). Accessed 8/29, 2014.

(5) Layzell B, Manning B, Benton S. The elderly demographic time bomb - sharing the load with the active ageing: can eHealth technologies help defuse it? Stud Health Technol Inform 2009;146:166-170.

(6) World Health Organisation. World health statistics. 2007.

(7) Kobb R, Chumbler NR, Brennan DM, Rabinowitz T. Home telehealth: mainstreaming what we do well. Telemed J E Health 2008 Nov;14(9):977-981.

(8) Arif MJ, El Emary IM, Koutsouris DD. A review on the technologies and services used in the self-management of health and independent living of elderly. Technol Health Care 2014;22(5):677-687.

(9) Stellefson M, Chaney B, Barry AE, Chavarria E, Tennant B, Walsh-Childers K, et al. Web 2.0 chronic disease self-management for older adults: a systematic review. J Med Internet Res 2013 Feb 14;15(2):e35.

(10) Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: Toward a unified view. MIS Quart Manage Inf Syst 2003;27(3):425-478.

(11) Hong S, Thong JYL, Tam KY. Understanding continued information technology usage behavior: A comparison of three models in the context of mobile internet. Decis Support Syst 2006 12;42(3):1819-1834.

(12) Kort H.S.M., Van Hoof J. Telehomecare in The Netherlands: Barriers to implementation. Int J Ambient Comput Intell 2012;4(2):64-73.

(13) Sen AK. Rational Fools: A Critique of the Behavioral Foundations of Economic Theory. Philosophy & Public Affairs 1977 Summer;6(4):317-344.

(14) Ajzen I. From Intentions to Actions: A Theory of Planned Behavior. In: Kuhl J, Beckmann J, editors. Springer Berlin Heidelberg; 1985. p. 11-39.

(15) Lund AM. Measuring Usability with the USE Questionnaire. http://hcibib.org/search:quest=U.lund.2001. Accessed: 2015-06-08. (Archived by WebCite® at http://www.webcitation.org/6Z8HCH1Ad). Usability interface 2001;8(2).

(16) Beach S, Schulz R, Downs J, Matthews J, Barron B, Seelman K. Disability, age, and informational privacy attitudes in quality of life technology applications: Results from a national Web survey. ACM Transactions on Accessible Computing 2009;2(1).

(17) Kwasny, M. N., Caine, K. E., Fisk, A. D. & Rogers, W. A. Privacy and Technology: Folk Definitions and Perspectives. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems*; 2008.

(18) Gell NM, Rosenberg DE, Demiris G, Lacroix AZ, Patel KV. Patterns of Technology Use Among Older Adults With and Without Disabilities. Gerontologist 2013 Dec 30.

(19) Toboso M. Rethinking disability in Amartya Sen's approach: ICT and equality of opportunity. Ethics and Information Technology 2011;13(2):107-118.

(20) Kobayashi M, Hiyama A, Miura T, Asakawa C, Hirose M, Ifukube T. Elderly user evaluation of mobile touchscreen interactions. Lect Notes Comput Sci 2011 5 September 2011 through 9 September 2011;6946 LNCS(PART 1):83-99.

(21) Terry NP. Mobile health: Assessing the barriers. Chest 2015;147(5):1429-1434.

(22) Olla P, Shimskey C. mHealth taxonomy: a literature survey of mobile health applications. Health and Technology 2015;4(4):299-308.

(23) Vedel I, Akhlaghpour S, Vaghefi I, Bergman H, Lapointe L. Health information technologies in geriatrics and gerontology: a mixed systematic review. J Am Med Inform Assoc 2013 Nov-Dec;20(6):1109-1119.

(24) Xie B. Older adults, computers, and the internet: Future directions. Gerontechnology 2003;2(4).

(25) Cruz J, Brooks D, Marques A. Home telemonitoring in COPD: a systematic review of methodologies and patients' adherence. Int J Med Inform 2014 Apr;83(4):249-263.

(26) Nguyen T, Irizarry C, Garrett R, Downing A. Access to mobile communications by older people. Australas J Ageing 2014 Apr 17.

(27) Barakat A, Woolrych RD, Sixsmith A, Kearns WD, Kort HSM. eHealth Technology Competencies for Health Professionals Working in Home Care to Support Older Adults to Age in Place: Outcomes of a Two-Day Collaborative Workshop. Medicine 2.0 2013 07/18;2(2):e10.

(28) van Houwelingen C, Moerman A, Ettema R, Kort H, ten Cate T. In press: Competencies Required for Nursing Telehealth Activities: a Delphi Study. Nurse Education Today 2016.

(29) Liu L, Miguel Cruz A, Rios Rincon A, Buttar V, Ranson Q, Goertzen D. What factors determine therapists' acceptance of new technologies for rehabilitation - a study using the Unified Theory of Acceptance and Use of Technology (UTAUT). Disabil Rehabil 2015;37(5):447-455.

(30) Hartman JE, Boezen HM, Zuidema MJ, de Greef MH, Ten Hacken NH. Physical activity recommendations in patients with chronic obstructive pulmonary disease. Respiration 2014;88(2):92-100.

(31) Zorg voor innoveren. Bekostiging en e-health: Fysiotherapie. Available at: http://www.zorgvoorinnoveren.nl/kennisbank/e-health-financiering/bekostiging-en-e-health/fysiotherapie/. (Archived by WebCite® at http://www.webcitation.org/6dhDaCiaX). Accessed 12/11, 2015.

(32) Dobbels F, de Jong C, Drost E, Elberse J, Feridou C, Jacobs L, et al. The PROactive innovative conceptual framework on physical activity. Eur Respir J 2014 Nov;44(5):1223-1233.

(33) Cleland I, Kikhia B, Nugent C, Boytsov A, Hallberg J, Synnes K, et al. Optimal placement of accelerometers for the detection of everyday activities. Sensors (Basel) 2013;13(7):9183-9200.

The **appendix** can be found online at:
http://www.onderzoek.hu.nl/onderzoekers/sigrid-vorrink
and in the online version of the thesis (www.narcis.nl).

Appendix chapter 6

PhD thesis S.N.W. Vorrink

A

Table 1. Results on use. Scores range from 0-7 with 0: totally disagree and 7: totally agree. Statements are arranged on degree of agreeability.

question	Statement	Mean ± standard deviation
20	The application is easy to use	5.95 ± 1.32
37	The application helped me to increase my PA	4.92 ± 2.2
38	The application made me feel more fit	4.32 ± 2.18
15	A training on the use of the application is necessary	3.25 ± 2.23
25	Battery life of the phone was short	3.15 ± 2.67
16	The smartphone suffered from technical failure	1.77 ± 2.37
17	The application suffered from technical failure	1.37 ± 1.93
24	I did not reach my PA goal because I forgot my phone	1 ± 1.43

Table 2. Results on privacy. Scores range from 1-7 with 1: totally disagree and 7: totally agree. Statements are arranged on degree of agreeability.

Question	Statement	Mean ± standard deviation
	I do **not** mind that the following persons have access to my PA information:	
40	• PT	6.48 ± 0.85
41	• Family	5.77 ± 1.72
44	• Family members I selected	5.72 ± 1.88
45	• Care insurers	4.33 ± 2.57
43	• A good friend	4.23 ± 2.34
46	• Local authority	3.25 ± 2.38
39	It is good to know the application continuously collects data on my PA	5.92 ± 1.34
51	I want to determine which PA information is sent to whom	5.52 ± 2.03
48	I do **not** mind that my PA information is saved in a medical file	5.47 ± 2
47	I do **not** mind that my PA information is saved forever	4.48 ± 2.53
50	I worry that I lose my phone and others can access my PA information	4.03 ± 2.22
49	Messages in the application should only be visible for me	4 ± 2.12
52	The application is an invasion on my privacy	2.65 ± 2.06
42	I worry that this information ends up in the wrong hands	2.73 ± 2.03

Table 3. Results on feedback preferences. Scores range from 1-7 with 1: totally disagree and 7: totally agree. For question 62 and 63 scores were 1: never to 7: very frequently. Statements are arranged on degree of agreeability.

Question	Statement	Mean ± standard deviation
61	It was rewarding to see that I reached my PA goal	6.3 ± 1.31
55	I liked the fact that PA was presented in steps	6.28 ± 1.39
53	I liked the fact that I could see my PA information on the smartphone	6.23 ± 1.14
56	The bar clearly showed my PA goal progress	6.22 ± 1.39
60	The graph provided extra insight into my PA	5.63 ± 1.74
65	The widget on the home screen of the smartphone clearly stated my PA status	5.6 ± 1.84
57	The emoticon was stimulating	5.25 ± 2.16
59	The written advice was stimulating	5.15 ± 1.81
58	It was pleasant to have various choices of emoticons	4.87 ± 1.89
64	The messages from the PT supported me in reaching my PA goal	3.34 ± 2.35
62	I received messages from the PT in the application	3.1 ± 2.15
63	I sent messages to the PT in the application	2.05 ± 1.71
54	My PA information should not be visible to me, only to my health care professional	1.68 ± 1.49

Table 4. Results on personal circumstances. Scores range from 1-7 with 1: never and 7: always. Statements are arranged on frequency of occurrence.

question	Statement	Mean ± standard deviation
68	I did not reach my PA goal because of my state of health	2.39 ± 1.33
69	I was too tired to be able to reach my PA goal	2.28 ± 1.49
70	I did not reach my PA goal because of personal circumstances	1.73 ± 1.21
71	I was too busy to reach my PA goal	1.68 ± 1.26

B

1. Application (app)
    a. General
    b. Tab status
        i. PA goal
    c. Tab graph
    d. Tab messages
    e. Tab settings
    f. Experience patient
    g. Areas of improvement
2. Website/portal
    a. General
    b. Overview page
        i. Messaging
        ii. Columns on the page
        iii. "Traffic light colors"
    c. Patients overview
        i. Graph
        ii. Scores
        iii. Messaging
        iv. Set and adjust PA goal
        v. Intensity score
    d. Areas of improvement
    e. Use by physiotherapist
3. Experiences smartphone
    a. Experiences patient
        i. Usability
        ii. Easy anxiety
    b. Experiences physiotherapist
4. Reasons of participation
    a. Approached or own initiative
    b. Motive of participation
        i. Expect benefits
        ii. Expect disadvantage
5. Provision of information from the researchers
    a. Before the start of the research
        i. Inclusion of patients
            1. Inclusion and exclusion criteria
        ii. Website/portal
        iii. Application
        iv. Research progress
    b. During the research
        i. Website
        ii. Application
        iii. Research progress
            1. Measurement moments
            2. Problems
            3. Support of researchers

6. Time allocation by physiotherapist
    a. How much time is spent
    b. Scheduled vs. not scheduled
    c. Individually or with colleagues
7. Applicability intervention in the future
    a. Expense to use de intervention
    b. Motive for using the intervention in the future
8. Practice information
    a. Personal information physiotherapist
    b. Team
    c. Usual care COPD patients
9. General information COPD
10. Research
    a. Information about patients
    b. Results measurement moments
    c. Number of patients
    d. Support of patients with intervention

C

Dear sir/madam,

You have participated in the study titled: “electronics in health care to improve COPD care”. During the study you used a smartphone (mobile phone) with an application (the program that counted your steps). We would like to know what your experiences were with the smartphone and the application. To do this we have created a questionnaire. We would like to ask you to fill this out. In total there are 73 questions and to answer them will take 20 minutes of your time. Some questions have additional space to write down a remark. Remarks can also be placed at the end of the questionnaire. With the outcomes of this questionnaire we can improve the application. When a question is unclear you can mark this question. We will call you to make an appointment to discuss and explain the unclear questions. Your comments will be treated confidentially according to the the Medical Research Involving Human Subjects Act (WMO), subject 12. If you have any questions, please contact Chantal Huisman (copdonderzoek@hu.nl or 06-14328209).

Name: …………………………………………………………………………………...

Date of filling out the questionnaire: ……………………………………………

Number of months you used the smartphone with application: ………….

……………………………………………………………………………………………...

Did you possess a smartphone before the start of the research? Yes / No

Did you purchase a smartphone after the research period? Yes / No

In the first part of the questionnaire you can answer the questions by using a scale from 0 to 7. See below the first statement:

“The smartphone was easy to use”
Totally disagree 0 1 2 3 4 5 6 7 Completely agree

If it was easy for you to use the smartphone you can circle the 7, and when it was very difficult for you to use the smartphone you circle the 0. If it is somewhere in between you can circle 1-6. The higher the number, the more you agree with the statement.
Please answer this question now.

Instructions: think back to the days when you used the smartphone with de application. Read the following statements carefully. Circle the number which matches your experience most.

Usefulness

1) The application supports me in an effective way.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

2) The application helps me to have a healthy physical activity pattern.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 2:………………………………………………………………… ………………………………………………………………………………………… ………………………………………………………………………………………… ………………………………………………………………………………………… …………………………………………………………………………………………

3) The application is useful.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

4) The application gives me control over the physical activities in my life.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

5) I can do the things that I want more easily.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

6) I save time by using the application.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

7) The application meets my needs.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

8) The application works as it should.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Ease of use

9) The application is easy to use.

   Totally disagree 0 1 2 3 4 5 6 7 Completely agree

10) I don’t have to tap the screen of the smartphone often to achieve what I want.

    Totally disagree 0 1 2 3 4 5 6 7 Completely agree

11) The application is flexible.

    Totally disagree 0 1 2 3 4 5 6 7 Completely agree

12) It takes effort to use the application.

    Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 12: ……………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

13) I can use the application **<u>without</u>** the written instructions.

    Totally disagree 0 1 2 3 4 5 6 7 Completely agree

14) The application is easy to use.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

15) It is necessary to receive a training on the use of the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

16) The **smartphone** experienced technical failures.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

17) The **application** experienced technical failures.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

18) There are things that contradicted each other when I used the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

19) The application is user friendly.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

20) The application is easy to use.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

21) Both people that use the application occasionally, and people that use the application regularly will find it pleasant.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 21: …………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

22) I can restore mistakes easily.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

23) I can use the application successful.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

24) I **didn't** reach my goal because I forgot the smartphone.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 24:……………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

25) The battery of the smartphone was drained fast.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remarks for question 25: ………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

Ease of learning

26) I have learned to work with the application quickly.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

27) I can easily remember how to use the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

28) It is easy to learn how to work with the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

29) I was quickly apt to work with the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Satisfaction

30) I am satisfied with the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

31) I will recommend the application to a friend.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

32) It is fun working with the application.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

33) The application works how I think it should work.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

34) The application is great.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

35) The application is in line with my needs.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

36) Use of the application is pleasant.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

37) The application helps me to increase my physical activity.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

Remark(s) on question 37: ……………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

38) By using the application I felt more powerful.

Totally disagree 0 1 2 3 4 5 6 7 Completely agree

In the second part of the questionnaire you will have to answer on a scale of 1-7 (instead of 0-7). The higher the number, the more you agree with the statement.

Privacy

39) It is comforting to know that the application continuously collects information about my physical activities.

Totally disagree 1 2 3 4 5 6 7 Completely agree

40) I **<u>don't</u>** think it is a problem that the physiotherapist can see information about my physical activities.

Totally disagree 1 2 3 4 5 6 7 Completely agree

41) I **<u>don’t</u>** think it is a problem that my family can see information about my physical activities.

Totally disagree 1 2 3 4 5 6 7 Completely agree

42) I’m worried that the information could end up in the wrong hands.

Totally disagree 1 2 3 4 5 6 7 Completely agree

43) I **<u>don’t</u>** think it is a problem that a good friend can see the information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

44) I **<u>don’t</u>** think it is a problem that selected family members can see the information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

45) I **<u>don’t</u>** think it is a problem that the health care insurance company can see the information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

46) I **<u>don’t</u>** think it is a problem that the government can see the information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

47) I **<u>don't</u>** think it is a problem that the information is stored forever.

Totally disagree 1 2 3 4 5 6 7 Completely agree

48) I **<u>don't</u>** think it is a problem that the information is stored in medical files.

Totally disagree 1 2 3 4 5 6 7 Completely agree

49) Messages on the application should be shown to me only.

Totally disagree 1 2 3 4 5 6 7 Completely agree

50) I worry that I will lose the smartphone and others will get access to my information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

51) I want to decide who gets to receive the information.

Totally disagree 1 2 3 4 5 6 7 Completely agree

52) I think the application is an infringement of my privacy.

Totally disagree 1 2 3 4 5 6 7 Completely agree

Feedback

53) I liked that I could see the information about my physical activities on the screen of the smartphone.

Totally disagree 1 2 3 4 5 6 7 Completely agree

54) Information about my physical activities does **not** need to be shown to me, this information is **only** for the caregiver.

Totally disagree 1 2 3 4 5 6 7 Completely agree

The figures below support the following questions.

Figure 1:
Tab status in the application. The bar left, the emoticon right, number of steps and the advice. **[question 55-59]**

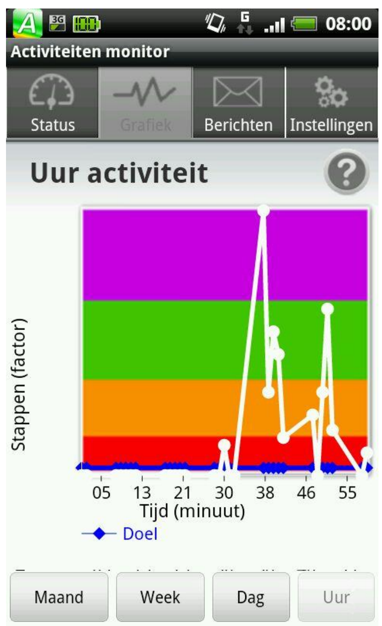


Figure 2:
Tab graph **[question 60]**

Figure 3:
Tab messages, text messages from en to the physiotherapist **[question 62]**

55) It was nice my physical activities were shown as number of steps [figure 1].

Totally disagree 1 2 3 4 5 6 7 Completely agree

56) The bar was a clear representation of how far I was towards reaching my step goal [see figure 1].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 56: ……………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

57) The emoticon, for example the dog, was stimulating [see figure 1].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 57: ……………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

58) It was pleasurable to have the option to choose different emoticons.

Totally disagree 1 2 3 4 5 6 7 Completely agree

59) The written advice was stimulating [see figure 1].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 59: …………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

60) The graph gave me additional insight into my physical activities [see figure 2].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 60: …………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

61) It was nice to see I reached my activity goal.

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) for question 61: …………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………

62) I received messages **from** the physiotherapist on the application [see figure 3].

Never 1 2 3 4 5 6 7 Very often

63) I have sent messages **to** the physiotherapist by using the application [see figure 3].

Never 1 2 3 4 5 6 7 Very often

64) The messages from the physiotherapist support to reach my activity goal [see figure 3].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) on question 64: …………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………

65) The pictures on the home screen of the smartphone (emoticon, like dog and the traffic light colors) clearly stated the current status of my physical activities [see figure below].

Totally disagree 1 2 3 4 5 6 7 Completely agree

Remark(s) on question 65: ………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

66) These aspects of the application were unnecessary, could be better, were unclear:

Remark(s) on question 66: …….……………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

67) These aspects in the application were nice, useful, clear:

Remark(s) on question 67: ………………………………………………………
……………………..………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

In the last part of the questionnaire you will have answer from 1 to 7 with ‘**never**’ (1) on the left side and ‘**always**’ (7) on the right side.

Circumstances

68) As a result of a bad health status I **couldn’t** reach my activity goal.

Never 1 2 3 4 5 6 7 Always

Remark(s) on question 68: …………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

69) I felt too tired to reach my activity goal.

Never 1 2 3 4 5 6 7 Always

Remark(s) on question 69: …………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

70) I **couldn’t** reach my activity goal because of personal circumstances.

Never 1 2 3 4 5 6 7 Always

71) I was too busy to reach my activity goal.

Never 1 2 3 4 5 6 7 Always

72) I quit smoking during the research period………. Yes / No……….

If the answer is yes, when did you quit? (date) …………………..………………...
………………………………………………………………………………………………
If the answer is no, how many cigarettes do you smoke per day?
…………………………………………………………………………………………
☐ No, I smoked no longer/ I have never smoked (tick if applicable)…………......
………………………………………………………………………………………………

73) I would like to use the application again so I can start using it again …Yes /

No …..

Thank you very much for completing the questionnaire!

Remarks:………………………………………………………………………………………

…………………………………………………………………………………………………

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……………………………………………….....

You will soon be called by Chantal Huisman.

D

Interview Structure – Open interview

Requirements: voice recorder (borrow from IT helpdesk) and smartphone with application.

Phase of consideration

Starting question:

"You have participated in the eHealth study to increase/retain physical activity of COPD patients after a rehabilitation period, could you tell us how you came to this decision?"

The answer must contain:

Rational factors

1) What did you do to try and increase/retain physical activity of COPD patients after a period of pulmonary rehabilitation in the past?
2) Beforehand, what were the perceived advantages and disadvantages of the eHealth intervention and which were the most important in deciding to participate in the study?
3) Which aspects did you miss in the application and/or website?

Personal factors

1) How were you informed about the study and was this information sufficient to use the intervention?
2) How much time were you given to use the website?
3) Were there aspects you missed in the given information?

Social factors

1) Who worked with the website within the physiotherapy practice?
2) What did these persons think about the website?
3) Do you feel communication between the researchers and these persons was sufficient?

Phase of use

Starting question:

"You have coached/monitored patients with the eHealth intervention after a rehabilitation period, could you indicate how you experienced this coaching/monitoring?"

The answer must contain:

Rational factors

1) Did you have the impression that you can positively affect physical activity of COPD patients by using the eHealth intervention?

2) Which aspects did you miss when coaching/monitoring your patients with the eHealth intervention and how did you solve this?

Personal factors

1) Did you have enough time, knowledge and skills to monitor the patients and intervene with the eHealth intervention?
2) What problems were you facing when you used the website?

Social factors

1) Who have been involved with the coaching/monitoring of the patients?
2) How did these persons rate the eHealth intervention?
3) What reactions did you hear about the intervention from your patients?

Final evaluation

Start question:

“Would you like to use the eHealth intervention again in the future and why? How can we improve the eHealth intervention?”

➔ Look at the pictures and ask for every aspect whether this is good or what can be done better. Also use the smartphone to show the application.

Rational factors:

1) Could you coach/monitor your patients enough by using the eHealt intervention?
2) What have you missed in coaching/monitoring your clients?

Applicatie

Website

	Naam	Telefoon ID	Stappen doel	Week score	Maand score	Jaar score	Laatst gesynchroniseerd		
Kies	Test simulator	1000	5000				31-08-2012 15:12	Download gegevens	Verwijder patient
Kies		37	7831				08-02-2013 05:42	Download gegevens	Verwijder patient
Kies		41	6500				18-12-2012 01:28	Download gegevens	Verwijder patient
Kies		44	6775				12-02-2013 02:57	Download gegevens	Verwijder patient
Kies		39	8500				07-01-2013 00:43	Download gegevens	Verwijder patient
Kies		32	6214				28-11-2012 00:47	Download gegevens	Verwijder patient
Kies		31	9865				30-11-2012 01:55	Download gegevens	Verwijder patient
Kies		2453230033	1282				12-02-2013 06:29	Download gegevens	Verwijder patient
Kies		36	2541				12-02-2013 05:49	Download gegevens	Verwijder patient
Kies			9999				30-01-2013 03:39	Download gegevens	Verwijder patient
Kies		42	9558				11-02-2013 17:08	Download gegevens	Verwijder patient
Kies		34	5000				18-06-2012 08:42	Download gegevens	Verwijder patient
Kies		40	10700				07-01-2013 05:27	Download gegevens	Verwijder patient
Kies		43	8500				07-01-2013 01:35	Download gegevens	Verwijder patient

General Discussion

❖ Introduction

Persons with COPD demonstrate reduced physical activity (PA) levels compared to healthy age-matched controls (1-5). Physical inactivity is associated with various negative health outcomes, whereas regular PA is associated with positive health outcomes. Inactivity leads to deconditioning, which leads to increased symptoms and a further reduction of PA. As this process continues, patients get stuck in a downward spiral of deconditioning and inactivity (6,7).

COPD care is multidisciplinary in nature and includes disciplines such as general practice, pulmonology, and physiotherapy, which are all involved in providing optimal care for patients. Part of the goal of non-pharmacological treatment is to attempt to enhance PA (8).

Pulmonary rehabilitation (PR) is known to improve exercise capacity (9); however, these benefits decline to pre-rehabilitation values after 1-2 years when patients do not continue to exercise after completing the programme (10-13). Furthermore, the effect of PR on PA is less consistent (12,14), and positive effects disappear rather quickly (12,15,16).

The work described in this thesis focussed on improving and/or maintaining PA in patients with COPD after PR.

Chapters 1-3 explored the target population, older adults with COPD, with respect to PA and the use of information and communications technology (ICT). **Chapter 4** described the development of an eHealth intervention to address the main aim of this thesis, and in **chapters 5 and 6,** we evaluated this intervention through efficacy testing in a randomized controlled trial (RCT) and by examining the experiences of those who received the intervention. In this chapter, the main findings, methodological considerations, and implications for practice are discussed, and the final conclusions are presented.

❖ Model

The blue lines in **figure 1** show the intended influence of the eHealth intervention on PA in COPD patients. As a frame of reference, the International Classification of Functioning, Disability and Health (ICF) model (17) was used. However, the concepts are slightly tailored to address the issue at hand. eHealth is categorized as an environmental factor (18), and it influences PA indirectly via the personal factors of the patient. This influence includes self-management assistance and the monitoring and coaching by the physiotherapists (PTs). The skills and motivation of the patient determine if she/he is able to induce a behavioural change and increase their PA. In addition to personal factors, PA is also influenced by the signs and symptoms and the physical condition of the patient. This triangle in the model represents the vicious cycle of inactivity, as described in the **general introduction**, in a simplified form. An increased PA level could halt and/or partly reverse this cycle. Subsequently, an improvement in physical condition and the level of PA can prevent further deterioration of the health condition COPD. To ensure the usability and the successful implementation in practice, a number of prerequisites have to be met regarding the eHealth intervention by the physiotherapists and the patients. These are presented in the model shown in **figure 1** and will be described in more detail throughout the **general discussion**.

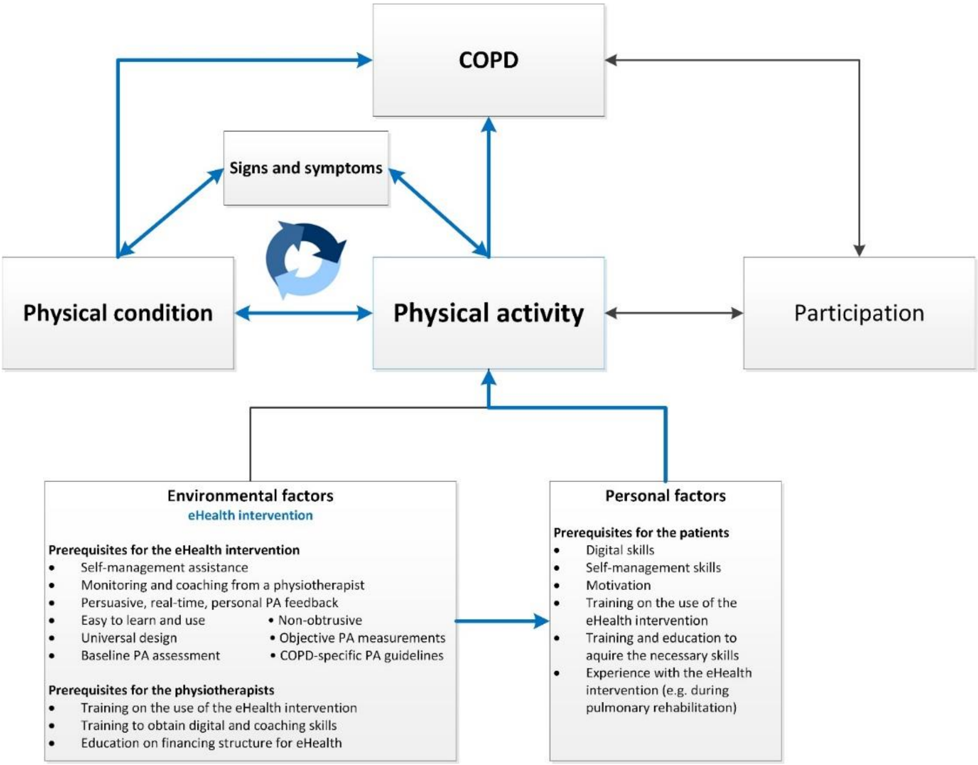

Figure 1. Intended influence of the eHealth intervention incorporated into the ICF model and the prerequisites for the usability and successful implementation of this intervention in practice.

❖ Physical activity

The literature review in **chapter 1** looked at the differences in objectively measured PA between patients and their healthy age-matched controls. This review shows that COPD has a substantial effect on the duration (57% in relation to healthy subjects) and amount (56%) of PA, but less of an effect on intensity of PA (75%). An explanation for these results could be that patients are trying to perform activities as quickly as possible because PA can cause dyspnea, anxiety, and fatigue. However, the added strain to the muscles and lungs will deplete energy reserves at a faster rate in those with COPD. If trained to perform activities at a lower intensity, they might be able to increase the overall duration and amount of PA and enjoy the benefits that come with an increased PA level. This idea is supported by Donaire-Gonzalez et al. (19), who found, during 8 days of measurements, that the risk of COPD hospitalisation was reduced by 20% for every additional 1000 daily steps taken at a low intensity, while an increase in high intensity steps did not reduce this risk.

Furthermore, **chapter 1** shows that there seems to be a relationship between PA and the severity of the disease, but this correlation is moderate at most. Reasons for this poor correlation could lie in the way the severity of COPD is classified. The most commonly used classification system for the severity of the disease is still the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification system (8), which uses FEV1% predicted values. However, the FEV1% predicted value does not correlate well with important outcomes such as symptoms, quality of life, survival, exacerbation frequency, and exercise tolerance (20-22). The GOLD initiative also recognizes this weak correlation between FEV1%, symptoms and the health related quality of life (HRQoL) and mentions that a formal symptomatic assessment is also required (8). An alternative, such as the Body-mass index (BMI), airflow Obstruction, Dyspnea, and Exercise capacity (BODE) index might better represent the severity of COPD, which is a complex and multi-facetted disease. The BODE index incorporates dyspnea, exercise capacity and BMI in addition to the FEV1% predicted value (23). This index shows a better correlation with important disease outcomes, such as HRQoL (24). However, the correlation between the disease severity as measured by the BODE index and PA was also found to only be moderate (25). The GOLD initiative has also proposed a classification system that tries to more fully capture the impact of COPD. In its assessment, it uses symptoms, dyspnea, spirometric classification, and the risk of exacerbation (8). It is more closely associated with the financial costs and HRQoL effects of COPD than the spirometric-based system (26). However, this system seems to be worse at predicting mortality (27).

As PA is now considered a main outcome of COPD (28), incorporating this outcome into a classification system might give an improved assessment of the severity of COPD. Until that time, it is important to appreciate that patients with a more severe GOLD classification do not necessarily need a less physically demanding exercise programme. The patient might be able to perform at a higher level than one might think based on their disease severity as measured by FEV1 (% predicted). An individual approach with an exercise regime tailored to objective measurements of physical capacity and activity may be more beneficial.

The results of the questionnaire completed by patients with COPD presented in **chapter 2** reveal that fatigue and a lack of motivation were the main barriers to exercise, followed by weather conditions, and dyspnea. Cold air, fog, high humidity and rain were considered demotivating factors, while dry, sunny weather was a strong motivator to engage in PA. In addition to beneficial weather conditions, the main enablers of PA were improvements in health, a pleasurable type of PA, and social support. In a recent study by Dobbels et al. (29), weather conditions were also among the factors mentioned by patients as influencing their PA. Humid air and extreme temperatures were found to be a barrier to PA. Activities that were mentioned to be the first to be affected were climbing stairs and walking.

The results from **chapter 2** show that PA in patients with COPD is influenced in many ways. With respect to the ICF model (17), we see that the reported influencing factors fall under the categories of environmental factors (e.g., weather conditions) and personal factors (e.g., lack of motivation). Additionally, signs and symptoms (e.g., dyspnea) were also reported to influence PA.

In the study presented in **chapter 2**, older patients (average age of the respondents was 60 ± 11 years) and those that experienced their COPD as more severe increasingly mentioned a reduction in PA. Of the respondents 29% mentioned having received specific exercise prescriptions from their healthcare professional (HCP) and/or to be engaged in physical therapy. The fact that the remaining 71% had not received specific exercise prescriptions is a point of concern and leaves room for improvement. Of the respondents, 17% received general instructions such as “just be active” or “listen to your body signals”. This does not appear to be strong enough advice for patients with COPD struggling to maintain their level of PA. Of the group that *did* receive exercise prescriptions, one-third admitted to poor adherence or to not actually following them at all. Treatment nonadherence is known to be an important problem in COPD with respect to medication, PR and oxygen supplementation (30). Unfortunately, this also translates to poor adherence to PA prescriptions. Looking at the results of this study, gains in PA can likely be achieved by prescribing specific exercise instructions and by individualizing these instructions to include activities preferred by the patient while taking the current weather conditions in mind.

COPD-specific PA recommendations

To provide COPD patients with proper exercise prescriptions, physiotherapists (PTs) and other health care professionals (HCPs) will need guidelines on what sort of advice to give to each individual patient. PA recommendations have been provided for healthy older adults (31), but COPD-specific guidelines regarding PA advice (after PR) are not available yet. When applying general PA recommendations for healthy adults with small differences in frequency, intensity and duration to COPD patients, the recommendations used will greatly influence the number of patients who are sufficiently physically active (32). This calls for PA recommendations specific for patients with COPD. When developing these recommendations, an important point to consider is the great variation between patients in the degree of PA reduction (33) and in the factors that influence PA. Factors that are most strongly associated with low PA differ between healthy people (e.g., obesity) and COPD patients (e.g., age, cardiovascular disease, fatigue) (34).

Comorbidities, such as cardiovascular disease, have been shown to further reduce the intensity and duration of PA (35,36) independent of the type of comorbidity or the degree of airflow limitation (37). It has been proposed that the combined, detrimental effect on PA of having multiple diseases may be greater than the effects of each disease alone (38).

The severity of the disease should be taken into account as patients in the more severe stages of COPD are mainly limited by physical factors (hyperinflation, dyspnea, leg muscle function, and oxygen use), while PA limitations for patients in less severe stages are associated with more general factors, such as self-efficacy (belief in the ability to complete tasks and reach goals) and seasonal influences (39). Patients with anxiety and depression may need a different approach because increased knowledge of self-management can lead to increased PA in patients with low levels of anxiety and depression, while this knowledge actually reduces PA among patients with high levels of anxiety and depression (40). Furthermore, it seems that PA is strongly associated with dynamic hyperinflation, regardless of the severity of the disease (41). Aspects that should also be considered are airway obstruction, as measured by the FEV1, degree of symptoms, diffusion problems (42), exercise capacity, BMI, and the patient’s current level of PA.

❖ ICT use

In **chapter 3**, the thesis continued with a study that looked into the use of information and communication technology (ICT) in older adults and whether demographics and health status outcomes are able to predict this use. For the technologies most commonly used by the general public, we see that a computer or laptop and e-mail are often used by older adults (95% and 92% of respondents, respectively). On the other hand, the use of a smartphone and a tablet is considerably lower (18% and 28% of respondents, respectively). These latter two technologies are newer modalities, and older adults are usually slower to adapt to new technologies. They are more likely to use those technologies that have been available for a longer period of time. However, there is only limited evidence that older adults are opposed to using technology in general (43,44). A study by Kontos et al. (45)

looked at the use of eHealth among 2358 adults via an online questionnaire. Adults in the 18-34-year-old age group had higher odds ratio's (OR) than adults aged 65 years and older for engaging in online health-provider searches (OR = 2.24), using the internet to search for health information (OR = 3.51), using websites to help with diet, weight, or PA (OR = 3.37), and in engaging in health-related social media use (OR = 2.81). This trend holds true to a lesser extent for the 35-49- and 50-64-year-old age groups. However, these age differences were not found for downloading health-related information to a mobile device, participating in an online support group for people with a similar medical issue, using e-mail or the internet to communicate with a doctor, or purchasing medicine or vitamins online. So, while there are still age-related differences in the use of technology, and more specifically, eHealth, adoption by older adults is steadily increasing (46).

In the study in **chapter 3**, we found that increased age, a lower degree of education, being a non-Western immigrant, a lower income, less arthrosis of the hands, and a lower physical functioning significantly predicted lower ICT use in older adults. On the other hand, gender, employment/volunteer work, perceived general health, hearing, vision-related conditions ('glasses/contacts', 'glaucoma/cataract', and 'poor vision'), and support for activities of daily living (ADL) did not affect ICT use in our study. Previous studies have shown a reduction in the use of computers and the internet with increasing age (similar to patterns observed within senior groups), a lower education, and a lower income (46-48). Here, we found that these results can also be generalized to ICT use in a broader sense because we studied the use of a range of common ICT devices and services.

Most ICT devices are hand-operated, which might lead one to assume that this would prove problematic for patients with arthrosis of the hands. However, ICT can also compensate for physical restrictions, which might have led to increased use in this group. It is interesting to see that physical functioning influenced the use of ICT in our study but perceived general health, hearing, sight, or ADL support did not. It appears that it is not the degree of physical restrictions but rather the degree of adaptability to these restrictions that influences the use of ICT.

Universal design

There has been debate whether ICT represents an opportunity or is a cause of exclusion for people with disabilities (49). However, it is agreed that ICT can bring these people multiple benefits if usability is ensured (50). A 'design for all' approach, or 'universal design', can address this issue. It focuses on finding solutions in the design phase itself so that, without the need of special adaptations, as many people as possible, regardless of their age and physical functioning can use ICT products and services (49). This should not be considered as developing products that are a single solution for everybody but rather as a user-centred approach where products can be adjusted depending on an individual's abilities, skills, and preferences (51). Patients with COPD are mainly older adults, and in this user group, technology use decreases significantly with greater limitations in physical capacity and with levels of greater disability (48). This is why a universal design was set as a prerequisite for the eHealth intervention in the model illustrated in **figure 1**.

The successful use and implementation is also greatly dependent on the acceptance of eHealth. In a review conducted by Peek et al. (52), factors influencing the acceptance of eHealth by older adults were investigated. In the pre-implementation stage, acceptance was influenced by the perceived concerns and benefits of the technology, the necessity of use (needs and alternatives), social influences, and the personal characteristics of the older adults. Conclusions concerning the post-implementation acceptance of eHealth cannot yet be drawn due to a lack of studies. Several of these factors, such as perceived concerns and benefits, can be positively influenced by using a universal design approach and by including end-users early on during the developmental process.

❖ Development of an eHealth intervention

The process of developing an eHealth intervention is described in **chapter 4** and entails the determination of a type of ICT interface, setting the design requirements, product development, and pilot testing. Three pilot studies were performed to test the intervention and improve it through an iterative process. We sought to develop an intervention that 1) was non-obtrusive and easily transportable to enhance adherence, 2) was able to provide objective measurements of PA because patients with COPD often have trouble correctly recalling their PA (53,54), 3) could give continuous real-time feedback on personal PA, and 4) enabled monitoring and feedback from the HCP because their motivation has been shown to stimulate engagement in PA (55). These are also set as prerequisites in the model for the eHealth intervention for increasing its usability and its successful implementation in practice (**figure 1**).

As an interface, a smartphone met all the requirements set. It is equipped with an accelerometer, the penetration rate among older adults was expected to increase over the next few years (56,57), the device can easily be carried during most waking hours, and mobile touchscreens are generally easy for older adults to use (56). Design requirements were set for the software (what the intervention should be able to do) and for the interface (how it should look). Because the user group (patients with COPD) generally consists of older adults, special attention was paid to the size and spacing of icons, contrast of colours, and visibility of text. The final product consists of two components: 1) a smartphone application and 2) a website for the HCP. The application shows PA in real time in quantitative and qualitative forms, measured by the accelerometer embedded in the smartphone. Patients are persuaded to obtain their personalized PA goal by automated persuasive messages and an emoticon (pictorial representation of an emotion). The HCP can monitor their patients via the secure website, which shows both the PA data from all the participants in their practice and also a more detailed view of individual patients. The HCP is able to adjust each patient's PA goals and send group or individual text messages.

Battery life posed a major problem while developing the application in 2010 and 2011. The '5 minutes on and off' configuration to measure PA was chosen so the battery would last a whole day, which was deemed important for adherence. Furthermore, distance travelled, cycling, swimming, strength training, and the intensity of walking up/down stairs were not properly captured by the application, which was disappointing to the patients. At the time the intervention was developed, the battery capacity of smartphones was too low to add features that could more properly measure these activities. With the development of new smartphone technology and batteries with higher capacities, the application could be reverted to continuous measurement, and GPS-tracking could be added, potentially, along with current weather-based activity advice.

When measuring cycling, one should take into consideration that a large group of patients use electric bicycles that assist with the propulsion thereby reducing the intensity of this activity. The inability to cycle as an outcome of reduced PA was specifically mentioned by Dutch, and to a lesser extent Belgian, patients, showing that nationality/culture can influence the perceived importance of measuring certain activities (29). Identifying the activity 'walking the stairs' has recently been made possible (58), and incorporating this feature into the application could give a better measure of the intensity of this activity, but for strength training activities, this would be more difficult. With the recent appearance of waterproof smartphones, the possibility to measure swimming has arisen (59).

Using a smartphone to measure PA is a good way to obtain objective data on this parameter. However, it is important to note is that a smartphone is not a highly valid and reliable measurement instrument such as those used in research settings. The use of additional, validated accelerometers would provide improved measurement accuracy of PA, but it was reasoned that long-term adherence to the intervention would benefit from the least amount of devices worn. Furthermore, as the smartphone is a device with increasingly daily usage, most patients will carry the device irrespective of whether they use the eHealth application.

An important element of the intervention is that a HCP has insight into a patient's PA data. This did not cause privacy issues for the subjects in the pilot studies. However, with respect to local government and insurance companies, answers varied. The key aspect with respect to privacy is to give the user (here the patient with COPD) control over their personal data distribution.

From the pilot studies, we learned that the use of a smartphone and the application were easy to learn and use by patients with COPD, and readability and comprehensibility of the text and colours were good. The accuracy of PA measurements was satisfactory in the final pilot study and battery life lasted a whole day with the final version.

Fast developing technologies vs. slow research

An important challenge in developing and evaluating eHealth interventions with the current gold standards for research, such as an RCT, is that, at the time the study is finished and results are analysed, chances are high that the technology used will be replaced by a new, improved type of technology. For example, in the current thesis, the improvements in the battery capacity of smartphones and the increased ability to measure various types of activity could currently improve the studied eHealth intervention. There is a need for research methods that will deliver results more quickly while still maintaining quality.

The discussion on how to do this is still ongoing. A model that can be applied when studying eHealth interventions is the Medical Research Council (MRC) model for developing and evaluating complex interventions (60). Working with the MRC model can increase study efficiency and the chances of successful implementation as it puts an increased emphasis on the development (pilot and feasibility testing) and implementation phases. However, evaluating the intervention could still take a considerable amount of time.

Baker et al. (61) have proposed various strategies to improve the efficiency and quality of eHealth research that have yet to be further elaborated. One example is to study more universal concepts (e.g., general approaches that increase motivation). In other words, analyse the mechanisms that underlie the usability and efficacy of eHealth interventions (62). Other examples include trying to anticipate strategies that will work in future environments and to find ways to increase communication and the sharing of results among researchers. One example of this is the ‘big data alliance’ in the Netherlands where parties in academia and in the industry work together to advance the field of data science (63). The latter could result in extensive eHealth databases in which universal concepts can be studied. However, such solutions will also raise concerns, for example, regarding authorship and financing, which will need to be addressed (61).

❖ Evaluation of the eHealth intervention

To test the efficacy of the developed eHealth intervention, an RCT was performed among 32 physiotherapy practices in the Netherlands. A total of 157 patients with COPD started the trial and 121 completed it. The results of this RCT are described in **chapter 5** of the thesis. Our hypothesis that subjects that used the intervention for 6 months would improve or maintain their PA through the benefits of real-time PA biofeedback, goal setting, and motivational support from their PT could not be confirmed. In addition, the intervention did not affect exercise capacity, HRQoL outcomes (dyspnea, fatigue, mastery, and emotional function), or BMI. PA, lung function, and mastery significantly decreased over time in both groups.

Other studies that tried to find ways to improve PA in patients with COPD have used external pedometers as a source of feedback about PA (64-70). However, most of these studies were pilot studies with a short duration of intervention, which makes it hard to draw any evidence-based conclusions on their long term effectiveness. Of two larger studies with a long term follow-up, one did not find an effect on PA (71). The other showed a short-term effect on PA, but this was not maintained at the one-year follow-up assessment (72). In a Belgian study that has not yet been published, a smartphone-based PA goal-setting and monitoring approach was also used (73). In that study, they did find an effect on steps per day in favour of the intervention group. Nonetheless, the RCT described in **chapter 5** shows that, in a population of patients with COPD, eHealth interventions are not always effective and expectations should be adjusted.

eHealth interventions that target PA are also available for chronic conditions other than COPD. Kuijpers et al. (74) evaluated 18 studies regarding eHealth interventions for patients with diabetes, cardiovascular disease, COPD, heart failure, and cancer. Significant, positive effects on PA were found in 2 studies. The remaining studies reported mixed results or no significant differences between the intervention and comparison groups. In line with our RCT, this shows that eHealth interventions are not always effective and expectations should be adjusted. Another review that looked at health-related smartphone apps developed for diabetes, mental health problems, overweight, cancer, and COPD shows that these apps can have promising results in monitoring patients' symptoms, supporting patients, or helping them to manage their chronic illness. Applications combined with the internet seem to be more effective because HCPs can intervene quickly and provide support. However, this study also mentions that the use of smartphone applications in the long-term health management of people with chronic diseases is still at the beginning stage and that more studies are warranted. Furthermore, applications that combine the management of several chronic diseases seem promising (75).

Exercise capacity and physical activity

Across all patients, there was a one-year decrease in average steps per weekday of 889 steps. This is a large deterioration compared to other studies (76) and lies within the range of estimates determined to be the minimal important difference for PA (between 576 and 1181 steps) (77). It is possible that patients had increased their PA by the end of the three-month outpatient rehabilitation programme preceding the study (78) and subsequently decreased their activity back to their pre-rehabilitation level of PA. In any case, our intervention could not prevent this from happening. This makes it all the more surprising that exercise capacity remained unchanged over the one-year study duration. This is in contrast to other studies where the six-minute walk test, which measures exercise capacity and was used in the RCT described in **chapter 5**, has been shown to deteriorate over time after PR in COPD patients (11,79,80). There are several studies that report no significant relationship between exercise capacity and PA (76,81), and when this relationship is found, it is often moderate or weak (82). These variables represent two different concepts because exercise capacity is a functional status and PA is primarily a behavioural trait (see physical condition and physical activity in the model in **figure 1**) and should therefore be targeted separately by exercise interventions.

In **chapter 6**, the perceptions of physiotherapists and patients regarding the eHealth intervention and the text messages sent between the two groups are evaluated.

<u>*Use*</u>. The measured use of the eHealth intervention by patients was high, while PTs reported low usage. The use of the application and the website received satisfactory scores from patients and PTs. Patients mentioned that the presentation of the PA information in the application was clear, insightful, and stimulating. It was rewarding to reach a PA goal. COPD patients participated in the pilot studies because including the end user early on will substantially increase the number of people who can use the technology successfully (49). This likely improved its perceived usefulness and ease of use.

Implementing the intervention in daily practice was challenging. Time constraints and financial limitations were mentioned by PTs as barriers to using the intervention during the study and, potentially, in the future. The financing concerns may stem largely from an unawareness of the policies of the Dutch Health Authority concerning eHealth. Expenses for patient consultations via the internet or e-mail and consulting with colleagues via eHealth can already be claimed. For new eHealth applications that are not yet in the funding model, HCPs can apply to obtain funding (83). Educating PTs on these funding possibilities could make them more responsive to eHealth (prerequisite in **figure 1**). Furthermore, added features to the intervention, such as a smartphone application for the

PT, a notification when a patient deteriorates, and a website that is incorporated in the standard patient software, would likely help to increase its use among PTs.

PA goal setting. Only six out of the 19 practices that were interviewed adjusted the PA goals of their patients. If there were patients in the other practices that had trouble achieving their PA goal or if their goal was too easy, this could have been demotivating. Despite the personal face-to-face instruction provided to the PTs about the intervention and the availability of a help desk, some did not completely understand the intensity scores of the PA goals. A few PTs also mentioned that they found it difficult to set a new goal. Because there are no COPD-specific PA guidelines available, PTs have to rely on their own practice-based expertise. Developing these guidelines will likely help to more successfully guide patients in the self-management of their PA. Furthermore, a patient's health status can differ throughout the week and their exercise capacity levels may fluctuate from day-to-day. Readjusting personal PA goals accordingly could increase the motivation to reach the following day's goal.

PTs should be trained properly to acquire the needed digital and coaching skills to support and monitor patients using eHealth interventions (**figure 1**). During these training sessions, attention should also be paid to how the eHealth intervention can help them in their daily practice. This has recently been found to be the most important predictor of therapists' acceptance and use of technologies (84).

Text messages. Sending messages to and receiving them from the PT was rare and not considered supportive in reaching the PA goal. Only 15 out of the 26 practices that had patients in the intervention group sent text messages. Similar to the PTs, there was a large portion of the patients who did not use this function (53%). When we looked at the messages that were sent, we found that the messages from the PTs mainly commented on the PA goal and were positive and motivating. This was exactly the intention of this part of the intervention. Maybe if text messages were applied in this way by all PTs, patients' PA outcomes would have improved. Text message responses from patients would likely have been higher as well. On the other hand, 80% of the subjects in the intervention group received long-term physiotherapy after PR and were thus still seeing their PT once or twice a week. During these meetings, PA measurements of the intervention were sometimes discussed and patients were motivated which could have made the messaging superfluous. An additional interesting outcome is that there was no significant difference over time in the average steps/weekday between subjects with long-term physiotherapy after PR and those without. Thus, receiving more attention from a PT did not seem to affect the maintenance of PA.

In the **general introduction** a potential limitation of eHealth is addressed suggesting that it might challenge HCP's authority. The text messages sent by the PTs did not always have a professional tone, which might not be beneficial in this respect. Teaching PTs professional communication skills during training sessions might be a valuable addition to this intervention.

Applicability. Patients felt that the intervention helped them to increase their PA and made them feel more fit. Of the respondents, 58.3% mentioned that they would like to receive the application so that they can start using it again. However, the PA goal was only obtained on 34% of the days the intervention was used, and on average, subjects acquired 10% less than their PA goal throughout the intervention period. Furthermore, when we look at the data of the RCT presented in **chapter 5**, we do not see a difference in PA over time compared with the usual care group. PA diminished in a similar manner over the one-year study duration in both groups.

The perceived usefulness of the intervention for the PTs was that 1) the PA data were objectively measured outside of a clinical setting, which provides more reliable data compared to a patient's recall (53,54); 2) they were able to see PA patterns over time, which might aid in the early detection of oncoming exacerbations (85); and 3) the eHealth intervention could be used as a tool to start a conversation with patients about their PA. This is why one could argue it was not the intervention itself but rather its cumbersome implementation in practice that caused the low usage by the PTs. Additionally, a better focus on encouraging PTs to use the intervention, such as through the use of more prompting or additional training sessions, might increase its use.

The results presented in **chapter 6** show that the inefficacy of the eHealth intervention might be attributed to several components of the model shown in **figure 1**. Not all prerequisites were met to ensure the intervention's usability and successful implementation in practice. In regard to the PTs, improvements could be made in the areas of use, training of digital and coaching skills, education on financial reimbursements concerning eHealth, and COPD-specific PA guidelines to help set PA goals. For patients, improvements in developing the skills and motivation to become physically active could be beneficial. The means to reach these goals are training, education, and providing experience with the eHealth intervention in a controlled clinical setting before beginning the self-management phase.

Long-term maintenance of PA behavioural change

A review that looked into techniques to change PA behaviour in COPD patients found that the most commonly used techniques were to give information on when, where, and how to perform PA, as well as self-monitoring. Significant between-group differences in favour of the group receiving PA intervention were only found in 7 of the 16 studies (86). This leaves room for improvement and stresses the difficulty of PA behavioural changes in patients with COPD.

Strategies during PR that let patients adopt and maintain PA behaviours after the programme ends may include the following: 1) training for an extended duration; 2) alternative environments to undertake the initial PR programme, such as home-based programs; 3) maintenance programs; 4) repetition, although whether improvements are clinically relevant and what a suitable time of repetition is remain unclear; and 5) incorporation of approaches to change behaviours (87). The potential benefits of a longer programme duration are discussed in the **general introduction**. It has been suggested that, although exercise capacity can improve in 3 months (a common duration of PR in the Netherlands), improving PA during PR might take at least 6 months (88). When patients have learned how to improve their PA during PR and, even better, have learned to use the eHealth interventions during the program, these changes might have a better chance of translating into a long-term maintenance of this behavioural change. This improvement may also be strengthened by effective monitoring from a HCP.

Self-management and digital skills

Self-management can be seen from different perspectives (89). It can be viewed as a paradigm-shift at the level of policymakers, where health care shifts from a providing to a demand driven form. Another perspective is self-management as therapeutic stimuli aimed to bring about behavioural changes. The e-Health intervention discussed in this thesis falls under this second category. It is important to note that eHealth interventions should not be considered a replacement for but rather as an addition to the whole of the multidisciplinary care offered to COPD patients. A third perspective is to see self-management as a competency or skill possessed by the patient; the capacity to address their chronic disease. Strong self-management skills, including the ability to act on incentives, could improve the efficacy of eHealth interventions. Patients with COPD have a positive view of acquiring these self-management skills. The results show that they feel it helps them to more evenly distribute their energy and to listen to their body signals, as well as, to increase their self-confidence, autonomy, and coping behaviour (90).

It is plausible that a large number of the subjects in the study described in **chapter 5** might have lacked the skill-set that is needed to fully benefit from our eHealth intervention. It might be interesting to see if these skill-sets can be measured in individual patients and subsequently be taught in a personally tailored form. Learning self-management skills only during PR does not seem to be sufficient (12), thus, we should pay attention to how these skills can be maintained over the long-term. Integrating PR with ongoing, collaborative self-management (a multicomponent model of health care delivery to guide self-management behaviours) may elicit behavioural changes and maintenance over the long-term (91). However, self-management may not suit all patients, and efforts should be made to identify those more open or responsive to this approach in advance. Furthermore, successful self-management also depends on the experience, training, and skills of the HCPs in guiding the patient in their behavioural modification process (91).

Digital skills will also help patients to benefit more from eHealth interventions. It has been suggested that greater engagement with the internet is associated with more positive behavioural (e.g., physical activity) and clinical (e.g., HRQoL) outcomes when using self-management interventions (92). This supports the potential benefits of teaching patients to increase their digital skills. Additionally, it is important to understand disease-specific factors that influence the effect of self-management interventions, in which contexts these treatments are most effective, and how to determine the proper ratio of human and computerized support. At the moment, these factors are not fully understood (92). Self-management interventions have been proven to elicit a range of positive outcomes in various patient groups (93). However, considerable heterogeneity is found in these outcomes and, for COPD patients even negative outcomes have been reported (94). A study has been announced that will look into which components are responsible for eliciting effects in self-management interventions and in which subgroups of patients these interventions work best (93).

❖ Methodological considerations

There are some general methodological considerations of the studies presented in **chapters 2-6**. These concern the selection of subjects, the quality of the questionnaires, technical issues, and the research protocols.

Selection of subjects. The use of online questionnaires in the studies described in **chapters 2 and 3** may have resulted in a bias in the respondents. For **chapter 2**, we cannot be certain if they were truly people with COPD, and for **chapter 3**, the online respondents might have had better digital skills compared with those that filled out the paper questionnaire. For the pilot studies and the RCT, we experienced a higher drop-out in the intervention group due to the expected effort, anxiety of using and losing the smartphone, fear of liability, and lack of interest in using the intervention. The resulting subjects could have been more open-minded to, and skilful in, the use of the intervention than the general population of COPD patients. Lastly, ‘comorbidities that result in a significant restriction in PA’ was used as part of the exclusion criteria in the RCT. The decision to include or exclude a patient was mostly based on the report from their PT. However, making this decision was not always clear-cut as it is difficult to access to which degree comorbidities influence PA, especially in the presence of multimorbidities.

Quality of the questionnaires. For the study described in **chapter 2** a set of questions was devised because there was no validated questionnaire available to address the study aim. The validated questionnaires that were used in the studies described in **chapters 4 and 6** were slightly adjusted to more accurately address the research topic at hand. This could have somewhat reduced the quality of the questionnaires and their results.

Technical issues. During the pilot studies the battery capacity of the smartphones was not high enough to use the application all day long. Subjects had to recharge the smartphone in the afternoon. In the third pilot study errors in the algorithm were discovered twice in the distributed version of the application. Although these technical problems were corrected as quickly as possible, this could have had a negative impact on the subjects' views of the application. During the RCT we dealt with broken smartphones, defective applications, broken batteries, data that did not synchronize well, and server issues that made the website inaccessible for a short period of time. We had a helpdesk that dealt with all technical failures, but they might have had some negative impact on subjects' and PTs' experiences with the intervention.

Research protocols. The potential benefits of the intervention might have been increased if PTs participating in the RCT would have been prompted more often to use the intervention. Therefore, a repetition of the instructions seems warranted. Another solution to the low use of the intervention by PTs might be to automate the setting of PA goals and the sending of motivational messages. However, that would reduce the personal interaction between the PTs and their patients and possibly decrease monitoring even further. Developing an application for the PT that incorporates the intervention into their standard patient software and establishing designated times to perform the monitoring would probably increase the use of the intervention by PT's.

The reimbursements by health care insurers for physiotherapy for COPD patients was significantly reduced a few months before the RCT started. This could have resulted in a bias towards more affluent patients in our study group.

In the study described in **chapter 6**, PTs and patients were interviewed and contacted by a member of the research group. This might have led to more favourable answers towards the intervention to please the researchers. Furthermore, those PTs (7) and patients (16) that did not take the time for the interviews or questionnaires might have had more negative views.

❖ Conclusions

Physical activity patterns and patients' views

- Suffering from COPD has a substantial negative effect on the duration and amount of PA but, apparently, less of an effect on the intensity of PA.
- There seems to be a relation between PA and the severity of the disease (as classified by the GOLD criteria), but this correlation is moderate at most.
- Fatigue, lack of motivation and weather conditions greatly influence engagement in PA in patients with COPD.
- Only approximately one-third of patients mentioned having received specific exercise prescriptions from their HCP, and of this group, one-third admitted to poor adherence to these prescriptions.

Older adults and ICT use

- For the technologies most commonly used by the general public, a computer or laptop and e-mail are often used by older adults, whereas the frequency of use of a smartphone or a tablet is conceivably lower.
- Increased age, a lower degree of education, being a non-Western immigrant, a lower income, less arthrosis of the hands, and a lower physical functioning significantly predicted lower ICT use in older adults.
- It appears that it was not the degree of physical restrictions but rather the degree of adaptability to these restrictions that influenced the use of ICT.

Evaluation of the eHealth intervention

- The developed eHealth intervention, which was aimed at improving and/or maintaining PA in patients with COPD after PR, did not affect physical capacity, HRQoL outcomes (dyspnea, fatigue, mastery, and emotional function), or BMI. PA, lung function, and mastery significantly decreased over time. Surprisingly, exercise capacity remained unchanged over the one-year duration of the study. The benefit of real-time PA biofeedback, goal setting, and motivational support from their PT was not sufficient to enable COPD patients to translate their exercise capacity into PA.

- The inefficacy of the eHealth intervention might be attributed to several factors. Not all prerequisites were met to ensure the usability and successful implementation of the intervention in practice. In regard to the PTs, improvements could be made in the areas of use, training of digital and coaching skills, education on financial reimbursements concerning eHealth, and COPD-specific PA guidelines to help set PA goals. For patients, improvements in developing the skills and motivation to become more physically active could be beneficial. The means to reach these goals include training, education, and providing experience with the eHealth intervention in a controlled clinical setting before the start of the self-management phase.
- These results show that, in a population of patients with COPD, eHealth interventions are not always effective and expectations should be adjusted.

❖ Implications for practice

Physical activity recommendations

- If trained to perform activities at a lower intensity, patients might be able to improve the overall duration and amount of their PA and enjoy the benefits that come with an increased PA level.
- An individual approach using an exercise regime tailored to objectively measured levels of PA, fluctuating signs and symptoms, and exercise capacity that takes into account the weather conditions and those activities preferred by the patient may help to improve adherence to prescribed PA goals.
- There should be a larger focus on increasing PA in patients with COPD during the PR programme. This, in combination with practical experience with eHealth self-management interventions during the programme, could help patients be more prepared to maintain PA over the long-term.

Classification system

- An alternative to the GOLD classification system for the severity of the disease should be used to provide a better correlation with important disease outcomes, such as HRQoL and functionality. As PA is now seen as a main outcome in

COPD, incorporating PA into a classification system might give an improved measure of the severity of COPD.

Physical activity monitoring

- Measuring exercise capacity alone as an outcome of treatment is not sufficient as this does not translate directly to PA.
- Objective PA measurements will give the HCP a more accurate insight into the patients' PA level outside the clinical setting and enable them to see PA patterns over time. This can be used to give patients insight in their PA data. It is recommended that HCPs perform an objective PA assessment at the beginning of treatment to establish PA status, adjust PA goals accordingly, and subsequently monitor the progression of PA.
- To provide proficient support and monitoring, HCPs need to be able to reserve designated times for this task. Financial support programs for eHealth are available. However, most HCPs are not familiar with these regulations, and they should be made aware of them.

❖ Future research

- More long-term studies are needed that look into the effect of eHealth interventions on PA in patients with COPD.
- There is a need for COPD-specific PA recommendations.
- Future studies should look in more detail into the role of the HCP in relation to eHealth interventions. These studies should examine how HCPs can be more actively engaged in their use and which skills are needed to properly use eHealth.
- Studies are needed on the measurement, proper teaching, and maintenance of self-management skills and digital skills in patients with COPD to improve outcomes of eHealth interventions.
- It is important to understand disease-specific factors that influence the effects of self-management interventions, in which contexts these interventions are most effective, and how to determine the proper ratio of human and computerized support.
- There is a need for new research methods that can provide results on eHealth interventions more quickly while still maintaining study quality.

❖ References

(1) Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. Respir Res 2011 Mar 22;12:33.

(2) Tudorache V, Oancea C, Avram C, Fira-Mladinescu O. Changes in physical activity in healthy people and COPD patients. Wien Klin Wochenschr 2014;126(1-2):30-35.

(3) Mador MJ, Patel AN, Nadler J. Effects of pulmonary rehabilitation on activity levels in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil Prev 2011 Jan-Feb;31(1):52-59.

(4) Arne M, Janson C, Janson S, Boman G, Lindqvist U, Berne C, et al. Physical activity and quality of life in subjects with chronic disease: chronic obstructive pulmonary disease compared with rheumatoid arthritis and diabetes mellitus. Scand J Prim Health Care 2009;27(3):141-147.

(5) Amorim PB, Stelmach R, Carvalho CRF, Fernandes FLA, Carvalho-Pinto RM, Cukier A. Barriers associated with reduced physical activity in COPD patients. Jornal Brasileiro de Pneumologia 2014;40(5):504-512.

(6) Polkey MI, Moxham J. Attacking the disease spiral in chronic obstructive pulmonary disease: an update. Clin Med 2011 Oct;11(5):461-464.

(7) Troosters T, van dM, Polkey M, Rabinovich RA, Vogiatzis I, Weisman I, et al. Improving physical activity in COPD: towards a new paradigm. Respiratory Research 2013 08/22;14(1):115-115.

(8) Global Initiative for Chronic Obstructive Lung Disease (GOLD). *Global Strategy for the Diagnosis, Management and Prevention of COPD.* Available from: [http://www.goldcopd.org/.](http://www.goldcopd.org/) 2015.

(9) Vestbo J, Hurd SS, Agusti AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med 2013 Feb 15;187(4):347-365.

(10) Foglio K, Bianchi L, Bruletti G, Battista L, Pagani M, Ambrosino N. Long-term effectiveness of pulmonary rehabilitation in patients with chronic airway obstruction. Eur Respir J 1999 Jan;13(1):125-132.

(11) Heppner PS, Morgan C, Kaplan RM, Ries AL. Regular walking and long-term maintenance of outcomes after pulmonary rehabilitation. J Cardiopulm Rehabil 2006 01;26(1):44-53.

(12) Egan C, Deering BM, Blake C, Fullen BM, McCormack NM, Spruit MA, et al. Short term and long term effects of pulmonary rehabilitation on physical activity in COPD. Respir Med 2012 Dec;106(12):1671-1679.

(13) Strijbos JH, Postma DS, van Altena R, Gimeno F, Koeter GH. A comparison between an outpatient hospital-based pulmonary rehabilitation program and a home-care pulmonary rehabilitation program in patients with COPD. A follow-up of 18 months. Chest 1996 Feb;109(2):366-372.

(14) Watz H, Pitta F, Rochester CL, Garcia-Aymerich J, ZuWallack R, Troosters T, et al. An official European respiratory society statement on physical activity in COPD. European Respiratory Journal 2014;44(6):1521-1537.

(15) Dyer CA, Harris ND, Jenkin E, Langley-Johnson C, Lewis R, Taylor GJ, et al. Activity levels after pulmonary rehabilitation - what really happens? Physiotherapy 2013 Sep;99(3):228-232.

(16) Cruz J, Brooks D, Marques A. Impact of feedback on physical activity levels of individuals with chronic obstructive pulmonary disease during pulmonary rehabilitation: A feasibility study. Chron Respir Dis 2014 Nov;11(4):191-198.

(17) World Health Organization. Towards a Common Language for Functioning, Disability and Health, ICF, International Classification of Functioning Disability and Health. 2002; Available at: http://www.who.int/classifications/icf/. (Archived by WebCite® at http://www.webcitation.org/6dLxlpiVp). Accessed 11/27, 2015.

(18) Kort HSM. Intreerede: Bouwen voor zorg en gezondheid, Technische Universiteit Eindhoven. Eindhoven; 2012.

(19) Donaire-Gonzalez D, Gimeno-Santos E, Balcells E, De Batlle J, Ramon MA, Rodriguez E, et al. Benefits of physical activity on COPD hospitalisation depend on intensity. Eur Respir J 2015;46(5):1281-1289.

(20) Celli BR, Cote CG, Marin JM, Casanova C, Montes de OM, Mendez RA, et al. The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. N Engl J Med 2004 03/04;350(10):1005-1012.

(21) Gross NJ. Chronic obstructive pulmonary disease outcome measurements: what's important? What's useful? Proc Am Thorac Soc 2005;2(4):267-271.

(22) Kerstjens HA. The GOLD classification has not advanced understanding of COPD. Am J Respir Crit Care Med 2004 08/01;170(1073-449; 3):212-213.

(23) Cote CG, Celli BR. BODE index: a new tool to stage and monitor progression of chronic obstructive pulmonary disease. Pneumonol Alergol Pol 2009;77(3):305-313.

(24) Sarkar SK, Basuthakur S, Das SK, Das A, Das S, Choudhury S, et al. Evaluation of correlation of BODE index with health-related quality of life among patients with stable COPD attending a tertiary care hospital. Lung India 2015 Jan-Feb;32(1):24-28.

(25) Mantoani LC, Hernandes NA, Guimaraes MM, Vitorasso RL, Probst VS, Pitta F. Does the BODE index reflect the level of physical activity in daily life in patients with COPD? Rev Bras Fisioter 2011 Mar-Apr;15(2):131-137.

(26) Boland M.R.S., Tsiachristas A., Kruis A.L., Chavannes N.H., Rutten-van Mölken M.P.M.H. Are GOLD ABCD groups better associated with health status and costs than GOLD 1234 grades? A cross-sectional study. Prim Care Respir J 2014;23(1):30-37.

(27) Leivseth L, Brumpton BM, Nilsen TIL, Mai X, Johnsen R, Langhammer A. GOLD classifications and mortality in chronic obstructive pulmonary disease: the HUNT Study, Norway. Thorax 2013 April 23.

(28) Gimeno-Santos E, Frei A, Steurer-Stey C, de Batlle J, Rabinovich RA, Raste Y, et al. Determinants and outcomes of physical activity in patients with COPD: a systematic review. Thorax 2014 Aug;69(8):731-739.

(29) Dobbels F, de Jong C, Drost E, Elberse J, Feridou C, Jacobs L, et al. The PROactive innovative conceptual framework on physical activity. Eur Respir J 2014 Nov;44(5):1223-1233.

(30) Bender BG. Nonadherence in chronic obstructive pulmonary disease patients: what do we know and what should we do next? Curr Opin Pulm Med 2014 Mar;20(2):132-137.

(31) Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007 Aug;39(8):1435-1445.

(32) Hartman JE, Boezen HM, Zuidema MJ, de Greef MH, Ten Hacken NH. Physical activity recommendations in patients with chronic obstructive pulmonary disease. Respiration 2014;88(2):92-100.

(33) Bossenbroek L, De Greef MHG, Wempe JB, Krijnen WP, Ten Hacken NHT. Daily physical activity in patients with chronic obstructive pulmonary disease: A systematic review. COPD: Journal of Chronic Obstructive Pulmonary Disease 2011;8(4):306-319.

(34) Andersson M, Stridsman C, Ronmark E, Lindberg A, Emtner M. Physical activity and fatigue in chronic obstructive pulmonary disease - A population based study. Respir Med 2015 Aug;109(8):1048-1057.

(35) Monteiro F, Camillo CA, Vitorasso R, Sant'Anna T, Hernandes NA, Probst VS, et al. Obesity and physical activity in the daily life of patients with COPD. Lung 2012;190(4):403-410.

(36) McNamara RJ, McKeough ZJ, McKenzie DK, Alison JA. Physical comorbidities affect physical activity in chronic obstructive pulmonary disease: a prospective cohort study. Respirology 2014 Aug;19(6):866-872.

(37) Sievi NA, Senn O, Brack T, Brutsche MH, Frey M, Irani S, et al. Impact of comorbidities on physical activity in COPD. Respirology 2015 Apr;20(3):413-418.

(38) Maltais F. Exercise and COPD: therapeutic responses, disease-related outcomes, and activity-promotion strategies. Phys Sportsmed 2013 Feb;41(1):66-80.

(39) Hartman JE, Marike Boezen H, De Greef MH, Hacken NHT. Physical and psychosocial factors associated with physical activity in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2013;94(12):2396-2402.e7.

(40) Schüz N, Walters JAE, Cameron-Tucker H, Scott J, Wood-Baker R, Walters EH. Patient Anxiety and Depression Moderate the Effects of Increased Self-management Knowledge on Physical Activity: A Secondary Analysis of a Randomised Controlled Trial on Health-Mentoring in COPD. COPD J Chronic Obstructive Pulm Dis 2015;12(5):502-509.

(41) Garcia-Rio F, Lores V, Mediano O, Rojo B, Hernanz A, López-Collazo E, et al. Daily physical activity in patients with chronic obstructive pulmonary disease is mainly associated with dynamic hyperinflation. Am J Respir Crit Care Med 2009;180(6):506-512.

(42) Aliverti A, Macklem PT. How and why exercise is impaired in COPD. Respiration 2001;68(3):229-239.

(43) Docampo Rama M, de Ridder H, Bouma H. Technology generation and age in using layered user interfaces. Gerontechnology 2001;1(1):25-40.

(44) Olson KE, O'Brien MA, Rogers WA, Charness N. Diffusion of Technology: Frequency of Use for Younger and Older Adults. Ageing Int 2011 Mar;36(1):123-145.

(45) Kontos E., Blake K.D., Chou W.-Y.S., Prestin A. Predictors of ehealth usage: Insights on the digital divide from the health information national trends survey 2012. J Med Internet Res 2014;16(7).

(46) Smith A. Older Adults and Technology Use. 2014; Available at: http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/.

(47) Ingen E, De Haan J, Duimel M. Achterstand en afstand. Digitale vaardigheden van lager opgeleiden, ouderen, allochtonen en inactieven. 2007:1-99.

(48) Gell NM, Rosenberg DE, Demiris G, Lacroix AZ, Patel KV. Patterns of Technology Use Among Older Adults With and Without Disabilities. Gerontologist 2013 Dec 30.

(49) Toboso M. Rethinking disability in Amartya Sen's approach: ICT and equality of opportunity. Ethics and Information Technology 2011;13(2):107-118.

(50) Landers SH. The case for "connected health" at home. Cleve Clin J Med 2013;80 (electronicsuppl.1): S27-S29.

(51) Emiliani PL. Technology for the independent living of people with activity limitations. BIODEVICES - Proceedings of the 2nd International Conference on Biomedical Electronics and Devices; 2009.

(52) Peek STM, Wouters EJM, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJM. Factors influencing acceptance of technology for aging in place: A systematic review. Int J Med Inf 2014 4;83(4):235-248.

(53) Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R. Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2005 10;86(10):1979-1985.

(54) Steele BG, Holt L, Belza B, Ferris S, Lakshminaryan S, Buchner DM. Quantitating physical activity in COPD using a triaxial accelerometer. Chest 2000 05;117(5):1359-1367.

(55) Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: A systematic review. Sports Medicine 2014;44(5):671-686.

(56) Kobayashi M, Hiyama A, Miura T, Asakawa C, Hirose M, Ifukube T. Elderly user evaluation of mobile touchscreen interactions. Lect Notes Comput Sci 2011 5 September 2011 through 9 September 2011;6946 LNCS(PART 1):83-99.

(57) Hwangbo H, Yoon SH, Jin BS, Han YS, Ji YG. A Study of Pointing Performance of Elderly Users on Smartphones. Int J Hum -Comput Interact 2013;29(9):604-618.

(58) Cleland I, Kikhia B, Nugent C, Boytsov A, Hallberg J, Synnes K, et al. Optimal placement of accelerometers for the detection of everyday activities. Sensors (Basel) 2013;13(7):9183-9200.

(59) MobyDick: An interactive multi-swimmer exergame. SenSys 2014 - Proceedings of the 12th ACM Conference on Embedded Networked Sensor Systems; 2014.

(60) Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ 2008 Sep 29;337:a1655.

(61) Baker TB, Gustafson DH, Shah D. How can research keep up with eHealth? Ten strategies for increasing the timeliness and usefulness of Ehealth research. J Med Internet Res 2014;16(2).

(62) Jacobs J. Wetenschap worstelt met mHealth apps. 2015; Available at: http://www.smarthealth.nl/2015/11/26/healthy-lifestyle-solutions-mhealth-apps/. (Archived by WebCite® at http://www.webcitation.org/6dwJhZguU). Accessed 12/21, 2015.

(63) Big Data Alliance. Available at: http://www.bigdata-alliance.org/.

(64) Mendoza L, Horta P, Espinoza J, Aguilera M, Balmaceda N, Castro A, et al. Pedometers to enhance physical activity in COPD: a randomised controlled trial. Eur Respir J 2015 Feb;45(2):347-354.

(65) Tabak M, Vollenbroek-Hutten MM, van der Valk PD, van der Palen J, Hermens HJ. A telerehabilitation intervention for patients with Chronic Obstructive Pulmonary Disease: a randomized controlled pilot trial. Clin Rehabil 2013 Nov 29;28(6):582-591.

(66) Verwey R, van der Weegen S, Spreeuwenberg M, Tange H, van der Weijden T, de Witte L. A pilot study of a tool to stimulate physical activity in patients with COPD or type 2 diabetes in primary care. J Telemed Telecare 2014;20(1):29-34.

(67) Liu WT, Wang CH, Lin HC, Lin SM, Lee KY, Lo YL, et al. Efficacy of a cell phone-based exercise programme for COPD. Eur Respir J 2008 Sep;32(3):651-659.

(68) Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. Int J Chron Obstruct Pulmon Dis 2009;4:301-313.

(69) Hospes G, Bossenbroek L, Ten Hacken NH, van HP, de Greef MH. Enhancement of daily physical activity increases physical fitness of outclinic COPD patients: results of an exercise counseling program. Patient Educ Couns 2009 05;75(2):274-278.

(70) de Blok BM, de Greef MH, Ten Hacken NH, Sprenger SR, Postema K, Wempe JB. The effects of a lifestyle physical activity counseling program with feedback of a pedometer during pulmonary rehabilitation in patients with COPD: a pilot study. Patient Educ Couns 2006 04;61(1):48-55.

(71) Steele BG, Belza B, Cain KC, Coppersmith J, Lakshminarayan S, Howard J, et al. A randomized clinical trial of an activity and exercise adherence intervention in chronic pulmonary disease. Arch Phys Med Rehabil 2008 Mar;89(3):404-412.

(72) Moy ML, Collins RJ, Martinez CH, Kadri R, Roman P, Holleman RG, et al. An Internet-Mediated Pedometer-Based Program Improves Health-Related Quality-of-Life Domains and Daily Step Counts in COPD: A Randomized Controlled Trial. Chest 2015 Jul;148(1):128-137.

(73) Demeyer H, Louvaris Z, Tanner R, Rubio N, Frei A, de Jong C, et al. LATE-BREAKING ABSTRACT: Increasing physical activity in patients with COPD using a telecoaching program: A multicenter RCT. ERS international congress 2015.

(74) Kuijpers W, Groen WG, Aaronson NK, van Harten WH. A systematic review of web-based interventions for patient empowerment and physical activity in chronic diseases: relevance for cancer survivors. J Med Internet Res 2013 Feb 20;15(2):e37.

(75) Wang J, Wang Y, Wei C, Yao NA, Yuan A, Shan Y, et al. Smartphone interventions for long-term health management of chronic diseases: an integrative review. Telemed J E Health 2014 Jun;20(6):570-583.

(76) Waschki B, Kirsten AM, Holz O, Mueller KC, Schaper M, Sack AL, et al. Disease Progression and Changes in Physical Activity in Patients with Chronic Obstructive Pulmonary Disease. Am J Respir Crit Care Med 2015 Aug 1;192(3):295-306.

(77) Demeyer H, Hornikx M, Marcal Camillo CA, Van Remoortel H, Burtin C, Langer D, et al. An estimation of the minimal important difference in physical activity for patients with COPD. European Respiratory Journal 2014 European Respiratory Society;44(Suppl 58).

(78) Demeyer H, Burtin C, Van Remoortel H, Hornikx M, Langer D, Decramer M, et al. Standardizing the analysis of physical activity in patients with COPD following a pulmonary rehabilitation program. Chest 2014 Aug;146(2):318-327.

(79) Cortopassi F, Celli B, Divo M, Pinto-Plata V. Longitudinal changes in hand grip strength, hyperinflation and 6-minute walk distance in COPD patients and a control group. Chest 2015 May 21.

(80) Brooks D, Krip B, Mangovski-Alzamora S, Goldstein RS. The effect of postrehabilitation programmes among individuals with chronic obstructive pulmonary disease. Eur Respir J 2002 Jul;20(1):20-29.

(81) Fastenau A, van Schayck OC, Gosselink R, Aretz KC, Muris JW. Discrepancy between functional exercise capacity and daily physical activity: a cross-sectional study in patients with mild to moderate COPD. Prim Care Respir J 2013 Dec;22(4):425-430.

(82) Zwerink M, Van Der Palen J, Van Der Valk P, Brusse-Keizer M, Effing T. Relationship between daily physical activity and exercise capacity in patients with COPD. Respir Med 2013;107(2):242-248.

(83) Zorg voor innoveren. Bekostiging en e-health: Fysiotherapie. Available at: http://www.zorgvoorinnoveren.nl/kennisbank/e-health-financiering/bekostiging-en-e-health/fysiotherapie/. (Archived by WebCite® at http://www.webcitation.org/6dhDaCiaX). Accessed 12/11, 2015.

(84) Liu L, Miguel Cruz A, Rios Rincon A, Buttar V, Ranson Q, Goertzen D. What factors determine therapists' acceptance of new technologies for rehabilitation - a study using the Unified Theory of Acceptance and Use of Technology (UTAUT). Disabil Rehabil 2015;37(5):447-455.

(85) Pitta F, Troosters T, Probst VS, Spruit MA, Decramer M, Gosselink R. Physical activity and hospitalization for exacerbation of COPD. Chest 2006 Mar;129(3):536-544.

(86) Wilson JJ, O'Neill B, Collins EG, Bradley J. Interventions to Increase Physical Activity in Patients with COPD: A Comprehensive Review. COPD 2015 Jun;12(3):332-343.

(87) Lee AL, Holland AE. Time to adapt exercise training regimens in pulmonary rehabilitation--a review of the literature. Int J Chron Obstruct Pulmon Dis 2014 Nov 10;9:1275-1288.

(88) Polkey MI, Rabe KF. Chicken or egg: physical activity in COPD revisited. Eur Respir J 2009 Feb;33(2):227-229.

(89) Trappenburg JC, Schuurmans MJ. speerpunt zorg en technologie. taste: het succes van zelfmanagement ontrafelen. http://www.zonmw.nl/fileadmin/documenten/Tussen_Weten_en_Doen/TASTE_brochure.pdf archived by webcitation: http://www.webcitation.org/6eeN5FcHE .

(90) Monninkhof E, van der Aa M, van der Valk P, van der Palen J, Zielhuis G, Koning K, et al. A qualitative evaluation of a comprehensive self-management programme for COPD patients: effectiveness from the patients' perspective. Patient Educ Couns 2004 Nov;55(2):177-184.

(91) Rice K, Bourbeau J, MacDonald R, Wilt TJ. Collaborative self-management and behavioral change. Clin Chest Med 2014 Jun;35(2):337-351.

(92) Stellefson M, Chaney B, Barry AE, Chavarria E, Tennant B, Walsh-Childers K, et al. Web 2.0 chronic disease self-management for older adults: a systematic review. J Med Internet Res 2013 Feb 14;15(2):e35.

(93) Jonkman NH, Westland H, Trappenburg JC, Groenwold RH, Effing-Tijdhof TW, Troosters T, et al. Towards tailoring of self-management for patients with chronic heart failure or chronic obstructive pulmonary disease: a protocol for an individual patient data meta-analysis. BMJ Open 2014 May 23;4(5):e005220-2014-005220.

(94) Fan VS, Gaziano JM, Lew R, Bourbeau J, Adams SG, Leatherman S, et al. A comprehensive care management program to prevent chronic obstructive pulmonary disease hospitalizations: a randomized, controlled trial. Ann Intern Med 2012 May 15;156(10):673-683.

❖ Summary

Chronic Obstructive Pulmonary Disease (COPD), a common preventable and treatable disease, is characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients. Persons with COPD demonstrate reduced physical activity (PA) levels compared to healthy age-matched controls. Physical inactivity is associated with various negative health outcomes, whereas regular PA is associated with positive health outcomes. Inactivity leads to deconditioning, which leads to increased symptoms and a further reduction of PA. As this process continues, patients get stuck in a downward spiral of deconditioning and inactivity.

COPD care is multidisciplinary in nature and includes disciplines such as general practice, pulmonology, and physiotherapy, which are all involved in providing optimal care for patients. Part of the goal of non-pharmacological treatment is to attempt to enhance PA.

Pulmonary rehabilitation (PR) is known to improve exercise capacity; however, these benefits decline to pre-rehabilitation values after 1-2 years when patients do not continue to exercise after completing the programme. Furthermore, the effect of PR on PA is less consistent, and positive effects disappear rather quickly. The overall aim of this thesis is to improve and/or maintain PA in patients with COPD after PR.

The literature review in **chapter 1** looks at the differences in objectively measured PA between patients and their healthy age-matched controls. This review shows that COPD has a substantial negative effect on the duration (57% in relation to healthy subjects) and amount (56%) of PA, but less of an effect on intensity of PA (75%). Furthermore, there seems to be a relation between PA and the severity of the disease (as classified by the GOLD criteria), but this correlation is moderate at most.

The results of the questionnaire completed by patients with COPD presented in **chapter 2** reveals that fatigue and a lack of motivation were the main barriers to exercise, followed by weather conditions, and dyspnea. Cold air, fog, high humidity and rain were considered demotivating factors, while dry, sunny weather was a strong motivator to engage in PA. In addition to beneficial weather conditions, the main enablers of PA were improvements in health, a pleasurable type of PA, and social support. Only approximately one-third of patients mentioned having received specific exercise prescriptions from their healthcare professional, and of this group, one-third admitted to poor adherence to these prescriptions.

In **chapter 3**, the thesis continues with a study that looks into the use of information and communication technology (ICT) by older adults (≥65 years old) and whether demographics and health status outcomes are able to predict this use. For the technologies most commonly used by the general public, we see that a computer or laptop and e-mail are often used by older adults (95% and 92% of respondents, respectively). On the other hand, the use of smartphones and tablets is considerably lower (18% and 28% of respondents, respectively). Increased age, a lower degree of education, being a non-Western immigrant, a lower income, less arthrosis of the hands, and a lower physical functioning significantly predicted lower ICT use in older adults. It appears that it was not the degree of physical restrictions but rather the degree of adaptability to these restrictions that influenced the use of ICT.

Chapter 4 describes the development of an eHealth intervention to address the overall aim of this thesis. Several pilot studies were conducted to ensure usability and accuracy of the measurement. The final product consists of two components: 1) a smartphone application and 2) a website for the healthcare professional. The application provides feedback on PA, measured by the accelerometer embedded in the smartphone. Patients are encouraged to obtain their personalized PA goal. The healthcare professional can monitor their patients' PA via the website and is able to adjust each patient's PA goal and send motivating group or individual text messages. The pilot studies showed that a smartphone and the application were easy to learn and use by patients with COPD, and legibility and comprehensibility of the text and colours were good. The accuracy of PA measurements was satisfactory in the final pilot study and battery life, which initially posed a problem, lasted a whole day with the final version.

In **chapter 5** this intervention is evaluated through efficacy testing in a randomized controlled trial among 32 physiotherapy practices in the Netherlands. A total of 157 patients with COPD started the trial and 121 completed it. Our hypothesis that subjects that used the intervention for 6 months would improve or maintain their PA through the benefits of real-time PA biofeedback, goal setting, and motivational support from their physiotherapist could not be confirmed. In addition, the intervention did not affect exercise capacity, health related quality of life outcomes (dyspnea, fatigue, mastery, and emotional function), or body mass index. PA, lung function, and mastery significantly decreased over time in both groups. Surprisingly, exercise capacity remained unchanged over the one-year duration of the study.

In **chapter 6**, the perceptions of physiotherapists and patients regarding the eHealth intervention are evaluated with interviews and questionnaires. The inefficacy of the eHealth intervention might be attributed to several factors. Not all prerequisites were met to ensure the usability and successful implementation of the intervention in practice. In regard to the physiotherapists, improvements could be made in the areas of use, training of digital and coaching skills, education on financial reimbursements concerning eHealth, and COPD-specific PA guidelines to help set PA goals. For patients, improvements in developing the skills and motivation to become more physically active could be beneficial. The means to reach these goals include training, education, and providing experience with the eHealth intervention in a controlled clinical setting before the start of the self-management phase.

Main conclusions

- Suffering from COPD has a substantial negative effect on the duration and amount of PA but less of an effect on the intensity of PA.
- Fatigue, (lack of) motivation and weather conditions greatly influence engagement in PA in patients with COPD.
- It appears that not the degree of physical restrictions but rather the degree of adaptability to these restrictions influences the use of ICT in older adults.
- The developed eHealth intervention, which was aimed at improving and/or maintaining PA in patients with COPD after PR, did not affect PA.
- These results show that, in a population of patients with COPD, eHealth interventions are not always effective and expectations should be adjusted.

Main recommendations

- There is a need for COPD-specific PA recommendations.
- Measuring exercise capacity alone as an outcome of treatment is not sufficient as this does not translate directly to PA.
- Future studies should look in more detail into the role of the healthcare professional in relation to eHealth interventions. These studies should examine how healthcare professionals can be more actively engaged in their use and which skills are needed to properly use eHealth.
- Studies are needed on the measurement, proper teaching, and maintenance of self-management skills and digital skills in patients with COPD to improve outcomes of eHealth interventions.
- There is a need for new research methods that can provide results on eHealth interventions more quickly while maintaining study quality.

❖ Samenvatting

De afkorting COPD staat voor *Chronic Obstructive Pulmonary Disease* (Chronische Obstructieve Long Ziekte). Het is een verzamelnaam voor chronische bronchitis en longemfyseem. Bij chronische bronchitis zijn de bronchiën continu ontstoken. De bronchiën zijn de vertakkingen van de luchtpijp naar de longen. Daardoor maakt het lichaam meer slijm aan en is ademhalen lastiger. Bij longemfyseem gaan er langzaam longblaasjes verloren. De longblaasjes zorgen ervoor dat zuurstof na het inademen in het bloed komt en dat afvalstoffen uitgeademd kunnen worden. Hoe minder longblaasjes er zijn, hoe moeilijker dit wordt. Hierdoor ontstaat benauwdheid. COPD is niet te genezen.

Mensen met COPD bewegen minder in vergelijking met gezonde mensen. Fysieke inactiviteit verslechtert de gezondheid van deze mensen. Daarentegen zorgt regelmatig fysiek actief zijn voor verbetering of behoud van de gezondheid. Inactiviteit zorgt voor deconditionering, wat leidt tot verergerde symptomen en een verdere vermindering van fysieke activiteit (FA). Hierdoor kunnen mensen vast komen te zitten in een negatieve spiraal van deconditioneren en inactiviteit.

De zorg rond COPD is multidisciplinair van aard met disciplines zoals de huisarts, longarts en fysiotherapeut. Een belangrijk doel van de niet-medicamenteuze behandeling is om de FA te verhogen. Longrevalidatie (LR) kan de fysieke conditie verbeteren, maar dit effect verdwijnt meestal na 1-2 jaar. Het effect van LR op FA is minder duidelijk en positieve effecten verdwijnen meestal snel. Dit proefschrift richt zich op het verbeteren en/of behouden van FA in patiënten met COPD na LR.

Het literatuuronderzoek in **hoofdstuk 1** kijkt naar de verschillen in objectief gemeten FA tussen patiënten met COPD en gezonde mensen. Dit onderzoek laat zien dat COPD een belangrijk negatief effect heeft op de duur (57% in vergelijking met gezonde mensen) en hoeveelheid (56%) van FA, maar minder op de intensiteit van FA (75%). Daarnaast lijkt er een relatie te zijn tussen FA en de ernst van de ziekte (zoals geclassificeerd door de GOLD criteria), maar deze relatie is niet sterk.

De resultaten van de vragenlijst in **hoofdstuk 2**, ingevuld door patiënten met COPD, laten zien dat vermoeidheid en lage motivatie de belangrijkste redenen zijn om niet te bewegen. Daarnaast worden weersomstandigheden en kortademigheid veel genoemd. Koude lucht, mist, hoge luchtvochtigheid en regen worden demotiverend genoemd, en droog, zonnig weer is een sterke motivator om meer te bewegen. Naast weersomstandigheden zijn de sterkste motivators om te bewegen: verbetering van de gezondheid, een prettige vorm van bewegen en sociale support. Slechts een derde van de patiënten noemt dat ze specifieke bewegingsinstructies hebben ontvangen van hun zorgverlener. Van deze groep geeft een derde toe zich zelden of nooit aan deze instructies te houden.

In **hoofdstuk 3** gaat het proefschrift verder met een onderzoek dat kijkt naar het gebruik van informatie en communicatie technologie (ICT) onder ouderen en of demografische en gezondheidsvariabelen dit gebruik kunnen voorspellen. Van de technologieën die het meest gebruikt worden door het algemene publiek zien we dat een computer of laptop het meest gebruikt wordt door ouderen (95% van de respondenten). Het gebruik van een smartphone en tablet is aanzienlijk lager (respectievelijk 18% en 28%). Een hogere leeftijd, lager opleidingsniveau, niet-westerse afkomst, lager inkomen, minder artrose in de handen en een lager fysiek functioneren voorspellen significant een lager ICT gebruik onder ouderen. Het lijkt erop dat niet de mate van fysieke restricties, maar eerder het vermogen om zich aan te passen aan deze restricties, voorspellers zijn voor het gebruik van ICT.

Hoofdstuk 4 beschrijft de ontwikkeling van een eHealth interventie die zich richt op het algemene doel van dit proefschrift. eHealth is het gebruik van nieuwe ICT toepassingen om de gezondheid en de gezondheidszorg te ondersteunen of te verbeteren. Er zijn meerdere kleine studies uitgevoerd om de gebruiksvriendelijkheid van de interventie en de nauwkeurigheid van de meting te garanderen. Het eindproduct bestaat uit de volgende componenten: 1) een smartphone applicatie en 2) een website voor de zorgverlener. De applicatie geeft de patiënt feedback over zijn/haar FA gemeten door de bewegingsmeter in de smartphone. Patiënten worden dagelijks gestimuleerd om hun persoonlijke FA doel te behalen. De zorgverlener kan de patiënten monitoren via de website en heeft de mogelijkheid om de persoonlijke FA doelen aan te passen en motiverende individuele of groepsberichten te sturen. De studies laten zien dat een smartphone en de applicatie makkelijk te leren en te gebruiken zijn door patiënten met COPD. De leesbaarheid en het begrip van de teksten en kleuren zijn goed. De nauwkeurigheid van de FA metingen in de laatste studie is adequaat. Aanvankelijk was de batterijduur van de smartphone een probleem, maar in de laatste versie van de applicatie houdt deze het een hele dag vol.

In **hoofdstuk 5** wordt deze interventie getest op effectiviteit in een gerandomiseerde studie in 32 fysiotherapie praktijken in Nederland. 157 COPD patiënten zijn gestart en 121 voltooiden de studie. Onze hypothese dat proefpersonen die de interventie 6 maanden gebruiken hun FA zullen verbeteren of behouden met behulp van real time feedback over hun FA, het stellen van doelen en motiverende steun van hun fysiotherapeut kan niet worden bevestigd. Daarnaast blijkt de interventie geen effect te hebben op fysieke capaciteit, gezondheidsgerelateerde kwaliteit van leven (kortademigheid, vermoeidheid, gevoel van controle en emotionele functie) en BMI. FA, longfunctie en gevoel van controle verslechteren significant over de tijd in beide groepen. Verrassend genoeg blijft de fysieke capaciteit onveranderd tijdens de 12 maanden durende studie.

In **hoofdstuk 6** wordt de eHealth interventie geëvalueerd met interviews en vragenlijsten onder de fysiotherapeuten en patiënten die deelnamen aan de studie. Er komen meerdere factoren naar voren die er mogelijk toe hebben geleid dat de interventie niet effectief was. Er is niet voldaan aan alle voorwaarden die nodig zijn om het gebruik en succesvolle implementatie van de interventie in de praktijk te bewerkstelligen. Mogelijke verbeteringen voor de fysiotherapeuten zijn: verhogen van het gebruik, het trainen van ICT en coaching vaardigheden, educatie over vergoedingen rond eHealth en COPD specifieke richtlijnen rond FA om te assisteren bij het stellen van FA doelen. Voor de patiënten kan het ontwikkelen van vaardigheden en motivatie om meer te bewegen een positief effect hebben. Om dit te bereiken is het nodig om training, educatie en ervaring met de interventie in een gecontroleerde setting aan te bieden, voor de start van de zelf-management fase.

Belangrijkste conclusies

- COPD heeft een belangrijk negatief effect op de duur en hoeveelheid van FA, maar minder op de intensiteit van FA.
- Vermoeidheid, (afwezigheid van) motivatie en weersomstandigheden hebben een grote invloed op het beweegpatroon van patiënten met COPD.
- Het lijkt erop dat het niet de mate van fysieke restricties, maar eerder het vermogen om zich aan te passen aan deze restricties, voorspellers zijn voor het gebruik van ICT onder ouderen.
- De ontwikkelde eHealth interventie, die als doel heeft om de FA te verhogen of te behouden bij patiënten met COPD na LR, heeft geen effect op FA.
- Deze resultaten laten zien dat eHealth interventies niet altijd effectief zijn in een populatie van patiënten met COPD en dat verwachtingen bijgesteld moeten worden.

Belangrijkste aanbevelingen

- Er zijn richtlijnen nodig rond FA die specifiek gericht zijn op COPD patiënten.
- Het meten van de fysieke capaciteit als een uitkomstmaat van de behandeling is niet afdoende aangezien dit zich niet direct laat vertalen in FA.
- Toekomstig onderzoek is nodig om te kijken naar de rol van de zorgverlener in relatie to eHealth interventies. Deze studies zullen moeten bekijken hoe zorgverleners actiever betrokken kunnen worden en welke vaardigheden zij nodig hebben voor het gebruik van eHealth.
- Het meten, aanleren en behoud van zelf-management en digitale vaardigheden onder COPD patiënten moet nader onderzocht worden om de effecten van eHealth interventies te kunnen verbeteren.
- Er zijn nieuwe methodologieën nodig voor het doen van eHealth onderzoek die zorgen voor snellere resultaten zonder af te doen aan de kwaliteit van de studies.

❖ Dankwoord

“Promoveren, dat ga ik dus nooit doen” riep ik nog tijdens mijn studie. Jarenlang je met hetzelfde onderwerp bezighouden leek me vreselijk saai. Toch rolde ik in een promotietraject na aangenomen te zijn bij de Hogeschool Utrecht, en toen bleek het stiekem eigenlijk best wel leuk. Ja, een lange adem, die heb ik wel nodig gehad. Vooral bij het verkrijgen van goedkeuring van de ethische commissie en het werven van genoeg proefpersonen. Maar ik ontdekte dat hoe meer je van een onderwerp te weten komt, hoe interessanter het wordt. Het doen van onderzoek en het schrijven van artikelen vind ik inmiddels heerlijk. Ik ben trots dat al het harde werken en mijn doorzettingsvermogen zijn vruchten heeft afgeworpen, en mijn proefschrift nu klaar is.

Ik ben dankbaar dat de Hogeschool Utrecht mij de kans heeft geboden om een promotieonderzoek uit te voeren aan de Universiteit Utrecht. Het College van Bestuur van de Hogeschool Utrecht dank ik voor het stimulerende beleid rondom promotieonderzoek vanuit de hogeschool en de mij toegekende promotievoucher. Mijn dank gaat ook uit naar de directie van de Faculteit Gezondheidszorg, in het bijzonder mr. Harm Drost en directeur van het Instituut voor Paramedische Studies, drs. Hans Merkx, voor het in mij gestelde vertrouwen.

Prof. dr. J-W.J. Lammers, geachte promotor, beste Jan-Willem, hartelijk dank voor de jarenlange begeleiding. Ondanks een enorm drukke agenda wist je altijd tijd voor me vrij te maken. Als er iets geregeld moest worden was de vraag nooit waarom, maar hoe gaan we dat regelen. Besprekingen waren efficiënt, maar niet ten koste van de inhoud. Deze spijkers-met-koppen mentaliteit heb ik zeer gewaardeerd tijdens mijn promotie.

Prof. dr. H.S.M. Kort, geachte promotor, beste Hilly, hartelijk dank voor alle begeleiding vanaf het begin van mijn werkzaamheden bij de Hogeschool Utrecht. Bedankt voor alle kansen en de ruimte om mezelf te ontwikkelen. Van presentatieangst is geen sprake meer na jaren van congressen en symposia. Als ik een idee had of iets nodig had voor het onderzoek was er meestal wel iets te regelen. Dat heb ik als enorm prettig ervaren voor en tijdens mijn promotie.

Prof. dr. T. Troosters, geachte promotor, beste Thierry, bedankt voor de jarenlange begeleiding vanuit Leuven. Je sterke inhoudelijke feedback op het gebied van fysieke activiteit en COPD gaf me nieuwe inzichten en maakte de artikelen sterker. Serieus als het over de inhoud ging, maar er kon ook altijd wel een grapje vanaf. Erg fijn dat je deel uitmaakte van de 3-koppige begeleiding.

Dr. P. Zanen en dr. C. Kruitwagen wil ik bedanken voor alle hulp rondom de statistiek. Pieter, je hebt een gave om lastige statistiek begrijpelijk uit te leggen en toe te spitsen op de praktijksituatie. Heel veel dank voor je grote bereidbaarheid om toelichting te geven, voor je snelle reacties, en voor de gezelligheid.

Dr. A.R.J. van Keimpema, beste Ton, bedankt voor het meedenken, meeschrijven en het openstellen van behandelcentrum Heideheuvel voor de 3e pilotstudie.

Alle leden van het kenniscentrum Innovatie van Zorgverlening en van het LOEP team van de opleiding huidtherapie wil ik hartelijk danken voor de samenwerking. In het bijzonder bedank ik mijn collega's van het lectoraat Vraaggestuurde Zorg: Marianne Sinoo, Geesje Spenkelink-Schut†, Joost van Hoof, Emelieke Huisman, Jacqueline Dijkstra, Karlijn Karsten, Thijs van Houwelingen, Chantal Huisman, Angelo Antonietti, Ansam Barakat, Marijke Luijten, Jikke Reinten, Mirjam van Tilborg en Karin Grooten. Het grootste deel van mijn promotie heb ik doorgebracht op kamer 1.058 op de Bolognalaan. Ik wil jullie vooral bedanken voor die tijd: de steun, de discussies, het meedenken, het uitwisselen van computervaardigheden, de wandelingen tijdens de pauze en natuurlijk de gezelligheid. Jullie zijn hele fijne collega's, daar heb ik enorm mee geboft.

Saskia Weldam, bedankt voor het onderling uitwisselen van kennis en ervaringen.

Alle patiënten en studenten die geparticipeerd hebben in de verschillende studies wil ik van harte bedanken. Zonder uw bereidheid zich te onderwerpen aan vragenlijsten, looptesten, blaastesten en andere metingen was dit proefschrift niet mogelijk geweest. Mijn dank is groot.

Alle fysiotherapeuten die hun praktijk openstelden voor het uitvoeren van het onderzoek, hun patiënten opgaven als proefpersonen en zelf participeerden in het onderzoek wil ik ook hartelijk danken. Een speciaal dankwoord gaat uit naar Cor Zagers, als lid van het consortium wist je veel leden van het fysiotherapie netwerk COPD Utrecht enthousiast te maken voor het onderzoek. Verder wil ik ook Catharina Colli bedanken, je enthousiasme en betrokkenheid gaven mij keer op keer goede moed.

Het uitvoeren van de gerandomiseerde studie was een enorm karwei. Dit was nooit gelukt zonder het harde werk van het onderzoeksteam bestaande uit Chantal Huisman, Angelo Antonietti, Ansam Barakat en Jamie van Dalum. Wat hebben we een kilometers gemaakt, kris kras met de onderzoekskoffer door Nederland naar 32 fysiotherapiepraktijken. Acht bezoeken per praktijk, en veelal meer als er later nog extra aanmeldingen voor het onderzoek waren. De NS zal tevreden met ons zijn. Chantal, je was er de gehele studie bij, eerst als onderzoeksassistent en later als collega. Hartelijk dank voor jouw enorme inzet, ook na de studie bij het verwerken van de data. Marijke, bedankt voor je hulp bij het analyseren van de tekstberichten.

Studenten: Lichelle Groot, Lisa Esteban Lopez, Vincent Keijzer, Jeroen Frank. Bedankt voor de hulp bij de uitvoering van de studies. Thom Huisman, Kevin Cheung en Neo Cheung voor hun assistentie bij het ontwikkelen van het design van de applicatie.

Berry van Eijk, Mariken van Nimwegen, Saïda de Vries en Sonja Barends. Bedankt voor alle administratieve ondersteuning. Jullie zijn altijd enorm behulpzaam, heel erg fijn. De ICT helpdesk, met name Nico Holvast en Okko Kuik, wil ik bedanken voor hun hulp bij al mijn lastige vragen.

De leden van de promotiecommissie wil ik bedanken voor het beoordelen van mijn proefschrift: prof.dr. M.J. Schuurmans, prof.dr. J.A.M. van der Palen, prof.dr. C. Veenhof, prof.dr. T.J.M. Verheij en prof.dr.ir. J.E. Eggen.

Paranimfen: Jeannette Leegwater, Marieke Nieuwenhuis. Jeannette: studeren, fietsvakantie, wintersport, volleyballen, high-tea; ik geniet van alle leuke dingen die we samen doen. Marieke: je staat altijd voor je vrienden klaar, nooit te beroerd om iets te regelen en je hebt een gave om het gezellig te maken. Jullie zijn toppers.

Jelske Schaap, bedankt voor je hulp bij het maken van de omslag. Mariken van Nimwegen, Barbara de Beer, Jochem Kaas, Jeannette Leegwater en Joris Brakkee bedankt voor het meelezen. Arie Peterson en Wieteke de Boer, bedankt voor het delen van jullie ervaringen met het drukken van een proefschrift.

Al mijn vrienden wil ik heel erg bedanken voor alle steun door de jaren heen, de afleiding en de gezelligheid. De familie van Joris wil ik ook bedanken voor alle interesse en steun. Alle volleyballers waar ik mee heb gespeeld (Zeeslag en K.V.A.) wil ik van harte bedanken voor het sportplezier, de nodige ontspanning en de gezelligheid.

Lydia Vorrink, mama, je hebt me altijd gestimuleerd om het beste uit mezelf te halen, en kijk eens waar het toe geleid heeft.

Joris Brakkee, lief, bedankt voor al je steun tijdens dit jarenlange proces met ups en downs. Met jou is alles leuker.

❖ Curriculum Vitae

Sigrid Nadine Wimke Vorrink was born on July 14, 1984 in Amsterdam. She obtained her Atheneum diploma in 2002 at the Amsterdams Lyceum in Amsterdam. Afterwards she studied Human Movement Sciences at the Vrije Universiteit in Amsterdam where she obtained her Bachelor of Science in 2005 as well as her Master of Science in 2006 specializing in Rehabilitation. In 2007 she started working at the research group Demand Driven Care at the University of Applied Sciences Utrecht. In 2010 she started her PhD project in this research group, as well as, at the University Medical Centre Utrecht, Department of Respiratory Medicine, Division Heart and Lungs. The PhD project was supervised by professor dr. J.W.J. Lammers, professor dr. H.S.M. Kort, and professor dr. T. Troosters. After her PhD, Sigrid will continue to work as a researcher/lecturer at the research group Demand Driven Care at the University of Applied Sciences Utrecht.