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Title: A qualitative study of chronic obstructive pulmonary disease patient perceptions of the barriers and facilitators to adopting digital health technology

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Abstract:

Objective: Non-adherence to self-management plans in chronic obstructive pulmonary disease (COPD) results in poorer outcomes for patients. Digital health technology (DHT) promises to support self-management by enhancing the sense of control patients possess over their disease. COPD digital health studies have yet to show significant evidence of improved outcomes for patients, with many user-adoption issues still present in the literature. To help better address the adoption needs of COPD patients, this paper explores their perceived barriers and facilitators to the adoption of DHT.

Methods: A sample of convenience was chosen and patients (n=30) were recruited from two Dublin university hospitals. Each patient completed a qualitative semi-structured interview. Thematic analysis of the data was performed using NVivo 12 software.

Results: Barriers sub-themes included: lack of perceived usefulness; digital literacy; illness perception and social context; while facilitator sub-themes included: existing digital self-efficacy; personalized education; and community-based support.

Conclusion: The findings represent a set of key considerations for researchers and clinicians to inform the design of patient-centred study protocols, that aim to account for the needs and preferences of patients in the development of implementation and adoption strategies for DHT in COPD.

Keywords: COPD, digital health, qualitative, barriers, facilitators.

Introduction

Chronic obstructive pulmonary disease (COPD) is a manageable, largely preventable respiratory disease and is the fourth leading cause of death globally [1]. In the European Union, annual costs of COPD have been estimated at €23.3b with expenditure primarily attributed to exacerbation-related hospitalizations [2]. Exacerbations that require hospitalization are related to greater mortality and morbidity compared to those treated in out-patient settings [3]. Early recognition of an exacerbation and timely intervention can reduce the risk of hospitalization but achieving this requires effective management of the disease in the community [4]. It is well-established that patients are now expected to take an active role in the management of their disease [5]. Engaging in pro-active self-management in COPD is linked to enhanced health-related quality of life, reduced admissions and decreased duration of exacerbations [6–8]. However, self-management does not appear to work consistently in COPD, with non-adherence to therapeutic regimes and action plans frequently attributed to poorer outcomes [9–11].

Digital health technology (DHT), including self-monitoring devices (e.g. oximeters and pedometers) and healthcare 'apps', have been identified as an innovative model to help optimize the provision of COPD care by supporting patients to enhance the knowledge and sense of control they possess over self-management practices such as self-monitoring and problem solving [12–14]. Healthcare professionals (HCP) can benefit from longitudinal datasets captured outside the clinic to inform decision-making and support self-management through the personalization of treatment plans that are more aligned with patient needs and preferences [15–18].

The promises are appealing, however digital health research in COPD has yet to significantly impact routine care, with convincing evidence of improved outcomes for patient self-management in limited supply [19–21]. A common problem facing COPD digital health studies is cultivating user adoption, with low adherence and sustained engagement levels with deployed interventions frequently cited for both patients and HCP [22,23]. For patients, user-experience issues have been found to impact negatively on adoption such as digital and health literacy [24,25], the usability of the technology [26,27] and the burden of completing added self-management tasks using technology [28].

Such issues are generally identified through post-study user-evaluations with adoption needs rarely addressed or prioritized in the design or implementation phases of digital health studies in COPD[29]. Furthermore, previous research has highlighted the tendency for digital health

studies to define pre-determined research goals, which often lead to the development of "one-size-fits-all" solutions that prioritize clinical outcomes at the expense of accounting for individual needs [30,31].

This raises questions about the value of identifying the adoption needs of COPD patients to inform the design and implementation of a DHT. As Clemensen et al., suggest, understanding user needs prior to the design of a digital health intervention can help researchers establish patient issues before the specifications of a solution are considered [32]. Indeed, recent systematic reviews have concluded that further qualitative research investigating the user needs of COPD patients is required to highlight the 'key ingredients' that will better inform the development of implementation and adoption strategies for digital health interventions in a patient-centred manner [19,33]. Although current COPD research in mHealth has begun focusing on patient needs in the early-development phase [34], the literature in this space is sparse.

It will be useful therefore to explore the adoption needs of COPD patients, particularly to investigate the potential barriers and facilitators they perceive to the use of DHT. As such, this study employed a qualitative design to explore the following research question: what are COPD patients' perceived barriers and facilitators to using digital health technology? The findings of this study seek to contribute patient-centred design considerations to support researchers and clinicians in the development of implementation and adoption strategies to mitigate adoption issues in COPD digital health interventions.

Methods

Study Design

This research employed a qualitative study design using semi-structured interviewing.

Recruitment and Sample

Patient recruitment took place in the respiratory clinics of two university hospitals. A sample of convenience was chosen for pragmatic reasons. Patients were identified by respiratory consultants (MB and JC) and possible participants were then invited to partake. Exclusion criteria were: any existing cognitive or psychotic disorders, or severe life-limiting co-morbidities, such as lung cancer. Inclusion criteria included: a confirmed diagnosis of COPD guided by the GOLD guidelines [35]. An information leaflet and consent form were given to interested patients and a 48-hour reflection period was provided prior to the researcher (PS) contacting the patient to confirm participation. Upon confirmation, a date and time convenient

to the patient was scheduled for the interview. The number of patients that declined participation was not gathered. Interviews were conducted at the patients' homes and written consent was obtained before each interview.

Procedure

Semi-structured interviews were conducted by PS who is an experienced qualitative researcher. An interview topic guide (Table 1) was used and patient's perceptions of the barriers and facilitators to adopting DHT were explored. The combination of semi-structured interviewing and open-ended questions, allowed for new topics of conversation to emerge and these were explored with the patients [36].

Table 1 Interview Topic Guide

Topic	*Questions*
Demographics	Age; marital status; occupation status; highest education attained; technology (mobile or smartphone; PC; laptop) Smoking History.
Disease Experience	Can you discuss your experience of your COPD? What is the role of family and friends when managing your COPD? What types of self-management practices do you perform? How do you feel about self-managing? Can you discuss how you manage your symptoms? Can you tell me about an exacerbation you had? Can you discuss the last time you ended up in the general practitioner (GP) clinic and/or hospital?
Healthcare Experience	Can you tell me about the kinds of care you receive or have received for your COPD? How do you feel about the care you receive for your COPD? Is the care you are receiving meeting your needs?
Health Data and DHT	Do you record/log information about your health? If so, why/how? If not, why? Do you think you could provide HCP (e.g. GP or consultant) with more information about your health day-to-day? What types of information do you think your doctor should have about your health? How would you feel about using a digital health technology e.g. oximeter, COPD related smartphone app, spirometer, self-reported outcomes platform etc, to generate health information/data about yourself? What do you think about capturing information/data in the home? How might collecting health information/data at home impact how you manage your COPD? Can you discuss why you might share information/data you collect with your HCP? How do you think these types of information/data could be used by your HCP to manage and treat your COPD?

Can you tell me how these types of data could be collected that would be suitable for you and your needs?

Data Analysis

Interviews lasted between 60-90 minutes. They were audio-recorded with a Dictaphone, transcribed verbatim and anonymized. NVivo 12 software was used to perform thematic analysis of the data (QSR International Pty Ltd, Victoria, Australia). Thematic analysis of the transcripts was conducted in line with Braun and Clarke [37] and the topic guide provided an initial structure for developing the codebook [38]. A subset of transcriptions were initially analysed by PS and TK to iterate and finalize the codebook [39,40]. Analysis involved reading each transcript closely, identifying emergent patterns, labelling codes to data, and generating themes and sub-themes [37]. Analytical rigour was ensured by PS and TK coding the data independently and afterwards scrutinizing, comparing and discussing the coding to resolve any discrepancies identified [41]. Analysis was conducted after every ten interviews and data saturation was determined at thirty participants when no new patterns or themes were emerging from analysis [42].

Results

In total, thirty interviews were completed. Sample characteristics can be observed in Table 2. Of the thirty participants, only two had experience of using a DHT, both were using an oximeter. The following themes and sub-themes were identified in the data: Barriers to Adopting DHT, with three sub-themes: Lack of Perceived Usefulness; Digital Literacy; Illness Perception and Social Context; and Facilitators to Adopting DHT, including three sub-themes: Existing Digital Self-efficacy; Personalized Education; and Community-based Support.

Table 2 Sample Characteristics*

Characteristics	*Data*
Gender and Age	
No. Male/Female	17/13
Age Range	46-88 yrs
Smoking History	
Current Smoker	5
Ex-smoker	25

Occupational Status	
Homemaker	1
Carer's Allowance Recipient	1
Retired	20
Employed	5
Unemployed	3
Marital Status	
Married	19
Widowed	7
Single	3
Separated	1
Technology	
Smartphone	16/30
Laptop	18/30
Both Smartphone and Laptop	15/30
No smartphone, laptop or PC	11/30
Oximeter	2/30
Highest Education Level Attained	
Primary	12
Secondary	6
Third Level or Above	12
COPD Severity Classification**	
	2
Mild (Gold Stage 1: $FEV_1 \geq 80\%$ predicted)	16
Moderate (Gold Stage 2: $50\% \leq FEV_1 < 80\%$ predicted)	9
Severe (GOLD stage 3: $30\% \leq FEV_1 < 50\%$ predicted)	3
Very Severe ($FEV_1 < 30\%$ predicted)	

* Sample Characteristics data self-reported at interview
** Data collected from patient medical charts

Barriers to Adopting DHT

Lack of Perceived Usefulness

There was a lack of perceived usefulness highlighted on several fronts by patients. It was felt by patients that their current self-management practices are already overwhelming and time-consuming, and therefore were not receptive to the addition of a DHT.

> *I spend enough time taking medications and inhalers, so if I have to start using a new gadget, I'm not sure there's a place for it, as I said, it gets overwhelming.* (Aged 70, Stage 2, Secondary)

Patients also discussed their preference for clinical visits with concerns being raised about the consequences for clinical decision-making in situations where digitally shared health information replaces traditional face-to-face conversations.

> *A conversation is worth so much to me, it is hard enough to get time with the GP, let alone the doctor in the hospital. So, when you get them you want to tell them everything that is happening. But if you are telling them how you are with something they have to read, are they going to really get what they need?* (Aged 64, Stage 2, Undergraduate)

Others perceived little benefit accruing from HCP having continuous access to captured data, for example, patients felt that the continuous sharing of health data would not disrupt current healthcare practices such as visiting the clinic.

> *If the oximeter levels were down low I'm not sure what he [General Practitioner (GP) could do if he had that information in the meantime, I'd still end up going in which I would have done anyways.* (Aged 82, Stage 2, Apprenticeship)

Digital Literacy

Digital literacy was highlighted as an adoption barrier for the use of DHT. Patients responses related to their sense of technological self-efficacy and how this could negatively affect their ability to correctly perform the required tasks appropriately.

> *It's a confidence thing isn't it? I couldn't do it by myself. I'd just be worried I'd do it and it wasn't right then it might waste the doctor's time.* (Aged 65, Stage 3, Primary)

It was also highlighted that if patients do not possess particular digital literacy skills this would create a barrier to their ability to interpret and act upon device readings in a beneficial manner.

> *If I do not understand what the readings mean for me, then I can't really do anything about it, I am just seeing a number and that's useless.* (Aged 67, Stage 4, Undergraduate)

Illness Perception and Social Context

Illness perception emerged as a barrier to patient's readiness to adopt DHT, for instance, patients may perceive that their current physical functioning does not align with the goals of the prescribed digital intervention.

> *I am getting to a stage where I am not well enough to try anything new because say something like the exercise apps, they apply to someone who is able to go out and walk. I'm really not there at the moment.* (Aged 73, Stage 3, Apprenticeship)

Patients also discussed the impact of their social context as an adoption barrier. The burdens associated with living on one's own were emphasized such as the lack of familial support to help with managing their COPD, and this was extended to the adoption of digital interventions also.

> *Like I'm totally dependent on myself, I've no wife or children. It puts a lot of burden on me to deal with all the appointments and going to my GP… so I think I would be at a disadvantage when taking this type of technology on.* (Aged 69, Stage 2, Primary)

Facilitators to Adopting DHT

Existing Digital Self-efficacy

Although digital literacy and technological self-efficacy were perceived as a barrier by many, other patients felt that because they have already established digital skills and knowledge from using various digital technologies this would facilitate easier adoption.

> *Because I am already using a smartphone I would be more open to trying things like recording information at home. The technology to do that wouldn't be as big as problem for me either, so I wouldn't need much training.* (Aged 46, Stage 2, Undergraduate)

> *I don't go an hour of the day without checking my phone and I see tracking as part of life now. I have GPS on my phone and that tells me everywhere I've been and how to get places, so I am happy to take that into my healthcare.* (Aged 61, Stage 2, Undergraduate)

Personalized Education

The primary adoption facilitator patients discussed was education. However, it was perceived by patients that a 'one-size-fits-all' education approach will not be appropriate for DHT. For example, many felt that the education received should be personalized and should reflect the clinical and psychosocial factors of an individual's disease.

> *The education you are getting shouldn't be general, it should take your illness and quality of life into the equation… because if it's just general that might not give you the best results.* (Aged 65, Stage 2, Secondary)

Patients also highlighted the need to provide this education as early as possible to help demystify the use of digital interventions in the management of their disease.

> *Teaching people as early as they can with technology would take the mystery out of it and might mean that people wouldn't be as afraid of it.* (Aged 57, Stage 4, Secondary)

Community-based Support

Patients spoke about their desire for community-based support to ease the adoption process. Many patients mentioned their preference to receive on-going education and supervision as their digital competencies develop.

> *It would be great to have the nurse come out here [to their home] to show you and to do rounds until the person can cope on their own with it.* (Aged 74, Stage 4, Primary)

Patients also highlighted their preference for a social learning environment to support adoption.

> *I'd see it working best if you were able to do it in a group, like if a group of 6 people were given a device or an app on their phone and were adding information together…you could see how everyone else is doing along with you and learn from each other and maybe talk about your information with them too.* (Aged 69, Stage 2, Primary)

Discussion

This study identifies new perspectives regarding the barriers and facilitators perceived by COPD patients for the adoption of DHT. The results identify three primary barriers. It is well established that perceived usefulness is a core determinant to a person's intention to adopt a technology [43,44]. For self-management technology, perceived usefulness refers to the degree to which a person believes the technology could improve or enhance the effectiveness of their ability to manage their disease [45]. However, the perceived usefulness of DHT was questioned by participants in this study. Patients expressed a sentiment that due to the burden associated with their existing self-management task-load [46,47], the addition of a DHT was not perceived as appropriate. Previous research in COPD posits that self-management benefits associated with DHT may not be perceived by all patients because of the commitment to actively engage in long term management, however they suggest that this barrier can be addressed by assessing and accounting for the patients particular self-management approaches during implementation [48].

Some patients were not receptive to the prospect of digital health data replacing the opportunity to share information through face-to-face conversations with HCPs with concerns raised about the appropriateness of digital data to adequately inform treatment decision-making. These concerns align with recent findings regarding the use of digital health data by HCPs who often perceive these data to offer inadequate evidence or experience a lack of confidence when interpreting and actioning for treatment decisions [49,50]. Other patients were unconvinced about the effectiveness of their HCP having continuous access to health data generated in the home, for example, patients did not perceive this would reduce the need for clinical visits. Interestingly, reducing clinical visits has long been an aim of COPD digital health studies, yet

very few have achieved significant outcomes in this area [51–53]. This raises questions about the level of priority patient's needs are provided in the development of study aims for digital health research in COPD.

Digital literacy was widely discussed as an adoption barrier to DHT. Digital literacy refers to the "interplay of individual and social factors in the use of digital technologies to search, acquire, comprehend, appraise, communicate and apply health information in all contexts of health care with the goal of maintaining or improving the quality of life throughout the lifespan." [54]. Aspects of this definition are found in patients' perceptions of digital literacy in this study. With regard to individual and social factors, patients drew attention to the negative impact a reduced sense of technological self-efficacy can have on a person's perceived ability to use a DHT appropriately. This perception may be explained by the mean age of this study sample at 68.2±10.1, who traditionally, as an over-65 cohort, have lower computer literacy and technological self-efficacy levels [55,56]. However, this is consistent with the age-profiles observed in COPD populations [57], therefore, because age has been found to negatively correlate with technological self-efficacy [58], addressing the digital literacy needs of patients participating in COPD digital health studies should help to ease age-related adoption issues.

Patients also perceived potential barriers arising from their ability to comprehend the data generated by DHT. This was articulated in the findings as an uneasiness about how to action the data provided to make a health-related decision. The potential of DHT to create positive patient outcomes, relies heavily on the individual to possess a unique set of digital literacy skills to properly interpret and apply the data to their health. However, the impact of digital literacy on the adoption of DHT is an under researched topic, even though it is recognized as a road-block to reducing the digital divide [59]. Participatory design approaches are recommended in the development of digital health interventions to ensure that the spectrum of health and digital literacy needs in patient populations are catered for [60].

The findings also revealed that a patient's illness perception and social context are perceived as barriers to the adoption of DHT. Illness perception refers to the ideas, views and beliefs that a patient has about their symptoms and illness [61]. The impact of illness perception on DHT in COPD has not received adequate attention, but this research has shown that if a patient does not believe their current health status is conducive to the proposed digital intervention, this can create an adoption barrier. Additionally, patients perceived that their social context will be a factor impacting the adoption of DHT. This was particularly pertinent for those patients who

live on their own, or for those lacking a strong social ecology consisting of friends and family that could otherwise support them to manage the use and adoption of DHT. Previous research has shown that the presence or perception of a strong social support structure improves patient compliance to self-management plans in COPD and across chronic disease in general [62,63] yet, family support is understudied with respect to adopting DHT.

Three facilitators to aid adoption of DHT were identified in the findings. Although digital literacy was a perceived barrier for the majority, there were patients who felt that the adoption of DHT would be eased due to their existing knowledge and skills with digital technology such as smartphones. Prior knowledge and experience of technology has been shown to increase a person's intention to use as it facilitates understanding the technologies purpose while helping to foster ease of use through intuitive interaction [44,64]. Patients felt that adoption can be facilitated through the provision of personalized DHT education that takes into consideration the individual needs and preferences of the patient. It was also felt that DHT education should be provided as early as possible to COPD patients to help demystify technology and mitigate adoption barriers caused by unfamiliarity. To facilitate smoother user adoption, patient-centred approaches for delivering technology education have been proposed for eHealth implementation strategies [65–67] while a recent wearable and mHealth study in COPD found that their educational component should have been tailored to the individual sedentary behaviours of patients to better support adherence [68].

The findings also show a preference from patients for the DHT adoption process to involve a variety of community-based supports. Patients referenced the desire for on-going supervision from healthcare professionals as their digital competencies evolve. Although on-going support may be outside the resource capabilities of many HCP, patient-clinician partnerships have been emphasized to facilitate adoption as they afford HCP the opportunity to work collaboratively with patients to aid with the development of data synthesizing and decision-making skills [69]. Others perceived adoption could be facilitated by the creation of a peer-to-peer social learning environment. Peer coaching has shown success in mHealth research aiming to increase physical activity in individuals with Parkinson's who benefitted from cooperative goal setting and regular feedback [70].

Limitations

This study used qualitative methods to gain an in-depth understanding of the barriers and facilitators COPD patients perceived to adopting DHT. The findings are strengthened by the

rigour demonstrated in data collection and the use of NVivo 12 software to aid analysis. However, when considering the generalizability of findings, the relatively small sample size should be viewed as a limitation. For instance, the mean age of this cohort is 68.2±10.1 with 11/30 patients having no smartphone, laptop or PC which may offer a reason as to why this cohort placed an emphasis on digital literacy as a barrier and the need for technology-focused education as a central aspect of their perceived facilitators. Additionally, further research is needed in COPD to understand the barriers and facilitators HCP perceive towards the use of DHT to determine how these technologies can be most effectively integrated into their workflows and clinical decision-making practices.

Conclusion

Digital health interventions promise to improve self-management engagement in COPD patients, but many user-adoption issues are still commonly cited in the literature. The findings demonstrate that patients perceive several barriers and facilitators to adopting DHT. Lack of perceived usefulness, illness perception and social context, and digital literacy were all highlighted as barriers to adoption. These findings suggest that future COPD interventions using DHT should consider the use of person-centred design approaches, such as conducting ethnographic user-research in the requirements gathering phase, to help ease adoption barriers associated with factors of the digital divide. Existing digital self-efficacy, personalized education and community-based support were discussed as facilitators. The findings suggest that future DHT studies in COPD should consider budgeting for added human resources to effectively integrate training and education programmes into their implementation strategies. This paper offers fresh insights regarding the DHT adoption needs of COPD patients while also highlighting a number of facilitators to help tackle user-adoption issues. These findings contribute a set of key considerations for researchers and clinicians to inform the design of patient-centred study protocols, aiming to account for the needs and preferences of patients in the development of implementation and adoption strategies for DHT in COPD but should not be relied upon as a substitution for the independent exploration of the adoption needs of other COPD cohorts partaking in a digital health intervention study.

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Conflict of Interests

The authors have no conflicts of interest to declare.

Contributorship

PS and BC conceived the study. PS and BC were involved in protocol development while MB, SD and JC were involved in gaining ethical approval and patient recruitment. Data analysis was completed by PS and TK. PS wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the submission version of the manuscript.

Ethical Approval

Ethical approval was granted by St. Vincent's University Hospital and Tallaght University Hospital, Dublin, Ireland.

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Guarantor

Patrick Slevin

References

1. Lõpez-Campos JL, Tan W, Soriano JB. Global burden of COPD. *Respirology*. Epub ahead of print 2016. DOI: 10.1111/resp.12660.

2. Gibson GJ, Loddenkemper R, Lundbäck B, et al. Respiratory health and disease in Europe: The new European Lung White Book. *European Respiratory Journal*, 2013. Epub ahead of print 2013. DOI: 10.1183/09031936.00105513.

3. Müllerova H, Maselli DJ, Locantore N, et al. Hospitalized exacerbations of COPD: Risk factors and outcomes in the ECLIPSE cohort. *Chest*. Epub ahead of print 2015. DOI: 10.1378/chest.14-0655.

4. Wilkinson TMA, Donaldson GC, Hurst JR, et al. Early Therapy Improves Outcomes of Exacerbations of Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med*. Epub ahead of print 2004. DOI: 10.1164/rccm.200310-1443OC.

5. Holman H, Lorig K. Patients as partners in managing chronic disease. Partnership is a prerequisite for effective and efficient health care. *BMJ*. Epub ahead of print 2000. DOI: 10.1136/bmj.320.7234.526.

6. Lenferink A, Brusse-Keizer M, van der Valk PDLPM, et al. Self-management interventions including action plans for exacerbations versus usual care in patients with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*. Epub ahead of print 2017. DOI: 10.1002/14651858.CD011682.pub2.

7. Zwerink M, Brusse-Keizer M, van der VPD, et al. Self management for patients with chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews*. Epub ahead of print 2014. DOI: 10.1002/14651858.CD002990.pub3.

8. Effing TW, Vercoulen JH, Bourbeau J, et al. Definition of a COPD self-management intervention: International Expert Group consensus. *Eur Respir J* 2016; 48: 46–54.

9. Bourbeau J, Bartlett SJ. Patient adherence in COPD. *Thorax*. Epub ahead of print 2008. DOI: 10.1136/thx.2007.086041.

10. Bischoff EWMA, Hamd DH, Sedeno M, et al. Effects of written action plan adherence on COPD exacerbation recovery. *Thorax*. Epub ahead of print 2011. DOI: 10.1136/thx.2009.127621.

11. Jolly K, Sidhu MS, Bates E, et al. Systematic review of the effectiveness of community-based self-management interventions among primary care COPD patients. *npj Prim Care Respir Med* 2018; 28: 44.

12. Farmer A, Williams V, Velardo C, et al. Self-Management Support Using a Digital Health System Compared With Usual Care for Chronic Obstructive Pulmonary Disease: Randomized Controlled Trial. *J Med Internet Res*. Epub ahead of print 2017. DOI: 10.2196/jmir.7116.

13. Wouters EFM, Wouters BBREF, Augustin IML et al. Personalized medicine and chronic obstructive pulmonary disease. *Curr Opin Pulm Med* 2017; 23: 241–246.

14. Wu R, Liaqat D, De Lara E, et al. Feasibility of using a smartwatch to intensively monitor patients with chronic obstructive pulmonary disease: Prospective cohort study. *J Med Internet Res*; 20. Epub ahead of print 2018. DOI: 10.2196/10046.

15. Nundy S, Lu CY, Hogan P, Mishra A, Peek ME. et al. Using patient-generated health

data from mobile technologies for diabetes self-management support: Provider perspectives from an academic medical center. *Journal of Diabetes Science and Technology*. Epub ahead of print 2014. DOI: 10.1177/1932296813511727.

16. Chung AE, Sandler RS, Long MD, et al. Harnessing person-generated health data to accelerate patient-centered outcomes research: The Crohn's and Colitis Foundation of America PCORnet Patient Powered Research Network (CCFA Partners). *J Am Med Informatics Assoc* 2016; 23: 485–490.

17. Ahern DK, Woods SS, Lightowler MC, et al. Promise of and potential for patient-facing technologies to enable meaningful use. *Am J Prev Med*. Epub ahead of print 2011. DOI: 10.1016/j.amepre.2011.01.005.

18. Wood WA, Bennett A V., Basch E. Emerging uses of patient generated health data in clinical research. *Molecular Oncology*. Epub ahead of print 2015. DOI: 10.1016/j.molonc.2014.08.006.

19. Mccabe C, Mccann M, Brady AM. Computer and mobile technology interventions for self-management in chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews*. Epub ahead of print 2017. DOI: 10.1002/14651858.CD011425.pub2.

20. Bourbeau J, Farias R. Making sense of telemedicine in the management of COPD. *Eur Respir J*. Epub ahead of print 2018. DOI: 10.1183/13993003.00851-2018.

21. Buekers J, De Boever P, Vaes AW, et al. Oxygen saturation measurements in telemonitoring of patients with COPD: a systematic review. *Expert Rev Respir Med* 2018; 12: 113–123.

22. Chau JP-C, Lee DT-F, Yu DS-F, et al. A feasibility study to investigate the acceptability and potential effectiveness of a telecare service for older people with chronic obstructive pulmonary disease. *Int J Med Inform*. Epub ahead of print 2012. DOI: 10.1016/j.ijmedinf.2012.06.003.

23. Antoniades NC, Rochford PD, Pretto JJ, et al. Pilot Study of Remote Telemonitoring in COPD. *Telemed e-Health*. Epub ahead of print 2012. DOI: 10.1089/tmj.2011.0231.

24. Witry M, Comellas A, Simmering J, et al. The Association Between Technology Use and Health Status in a Chronic Obstructive Pulmonary Disease Cohort: Multi-Method

Study. *J Med Internet Res* 2018; 20: e125.

25. Stellefson ML, Shuster JJ, Chaney BH, et al. Web-based Health Information Seeking and eHealth Literacy among Patients Living with Chronic Obstructive Pulmonary Disease (COPD). *Health Communication*, 2017. Epub ahead of print 2017. DOI: 10.1080/10410236.2017.1353868.

26. Mair FS, Hiscock J, Beaton SC. Understanding factors that inhibit or promote the utilization of telecare in chronic lung disease. *Chronic Illn*. Epub ahead of print 2008. DOI: 10.1177/1742395308092482.

27. Ure J, Pinnock H, Hanley J, et al. Piloting tele-monitoring in COPD: A mixed methods exploration of issues in design and implementation. *Prim Care Respir J*. Epub ahead of print 2012. DOI: 10.4104/pcrj.2011.00065.

28. Velardo C, Shah SA, Gibson O, et al. Digital health system for personalised COPD long-term management. *BMC Med Inform Decis Mak*. Epub ahead of print 2017. DOI: 10.1186/s12911-017-0414-8.

29. Slevin P, Kessie T, Cullen J, et al. Exploring the potential benefits of digital health technology for the management of COPD: a qualitative study of patient perceptions. *ERJ Open Res* 2019; 5: 00239–02018.

30. Morton K, Dennison L, May C, et al. Using digital interventions for self-management of chronic physical health conditions: A meta-ethnography review of published studies. *Patient Education and Counseling*. Epub ahead of print 2017. DOI: 10.1016/j.pec.2016.10.019.

31. Brunton L, Bower P, Sanders C. The contradictions of telehealth user experience in chronic obstructive pulmonary disease (COPD): A qualitative meta-synthesis. *PLoS One*; 10. Epub ahead of print 2015. DOI: 10.1371/journal.pone.0139561.

32. Clemensen J, Rothmann MJ, Smith AC, et al. Participatory design methods in telemedicine research. *J Telemed Telecare*. Epub ahead of print 2017. DOI: 10.1177/1357633X16686747.

33. Cruz J, Brooks D, Marques A. Home telemonitoring in COPD: A systematic review of methodologies and patients' adherence. *International Journal of Medical Informatics*. Epub ahead of print 2014. DOI: 10.1016/j.ijmedinf.2014.01.008.

34. Korpershoek YJG, Vervoort SCJM, Trappenburg JCA, et al. Perceptions of patients with chronic obstructive pulmonary disease and their health care providers towards using mHealth for self-management of exacerbations: A qualitative study. *BMC Health Serv Res*; 18. Epub ahead of print 2018. DOI: 10.1186/s12913-018-3545-4.

35. GOLD. Global Initiative for Chronic Obstructive 2018 Report. *Glob Obstr Lung Dis*. Epub ahead of print 2018. DOI: 10.1097/00008483-200207000-00004.

36. Cohen D, Crabtree B. Qualitative Research Guidelines Project. *Robert Wood Johnson Foundation*.

37. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. Epub ahead of print 2006. DOI: 10.1191/1478088706qp063oa.

38. Saldana J. Coding manual for qualitative researchers. *Sage J*. Epub ahead of print 2015. DOI: 10.1093/oxfordhb/9780199811755.001.0001.

39. Fereday J, Muir-Cochrane E. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *Int J Qual Methods*. Epub ahead of print 2006. DOI: 10.1177/160940690600500107.

40. DeCuir-Gunby JT, Marshall PL, McCulloch AW. Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field methods*. Epub ahead of print 2011. DOI: 10.1177/1525822X10388468.

41. Thomas DR. A General Inductive Approach for Analyzing Qualitative Evaluation Data. *Am J Eval*. Epub ahead of print 2006. DOI: 10.1177/1098214005283748.

42. Fusch PI, Ness LR. Are we there yet? Data saturation in qualitative research. *Qual Rep*. Epub ahead of print 2015. DOI: 1, 1408-1416.

43. Davis FD. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q* 1989; 13: 319.

44. Rogers EM. *Diffusion of Innovations, Fourth Edition*. 1995. Epub ahead of print 1995. DOI: citeulike-article-id:126680.

45. Karsh BT, Severtson DJ, et al. Factors affecting home care patients' acceptance of a web-based interactive self-management technology. *J Am Med Informatics Assoc*.

Epub ahead of print 2011. DOI: 10.1136/jamia.2010.007336.

46. Cicutto L, Brooks D, Henderson K. Self-care issues from the perspective of individuals with Chronic Obstructive Pulmonary Disease. *Patient Educ Couns*. Epub ahead of print 2004. DOI: 10.1016/j.pec.2003.08.012.

47. Gysels MH, Higginson IJ. Self-management for breathlessness in COPD: The role of pulmonary rehabilitation. *Chron Respir Dis*. Epub ahead of print 2009. DOI: 10.1177/1479972309102810.

48. Williams V, Price J, Hardinge M, et al. Using a mobile health application to support self-management in COPD: A qualitative study. *Br J Gen Pract*. Epub ahead of print 2014. DOI: 10.3399/bjgp14X680473.

49. West P, Van Kleek M, Giordano R, et al. Common Barriers to the Use of Patient-Generated Data Across Clinical Settings. In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. 2018. Epub ahead of print 2018. DOI: 10.1145/3173574.3174058.

50. Reading MJ, Merrill JA. Converging and diverging needs between patients and providers who are collecting and using patient-generated health data: An integrative review. *Journal of the American Medical Informatics Association*. Epub ahead of print 2018. DOI: 10.1093/jamia/ocy006.

51. Bolton CE, Waters CS, Peirce S, et al. Insufficient evidence of benefit: A systematic review of home telemonitoring for COPD. *J Eval Clin Pract* 2011; 17: 1216–1222.

52. Cruz J, Brooks D, Marques A. Home telemonitoring effectiveness in COPD: a systematic review. *Int J Clin Pract* 2014; 68: 369–378.

53. Yang F, Wang Y, Yang C, et al. Mobile health applications in self-management of patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis of their efficacy. *BMC Pulm Med* 2018; 18: 147.

54. Bautista JR. From Solving a Health Problem to Achieving Quality of Life: Redefining eHealth Literacy. *J Lit Technol*.

55. Nielsen. Usability for {Senior} {Citizens}. *Nielsen Norman Group*.

56. Mitzner TL, Rogers WA, Fisk AD, et al. Predicting older adults' perceptions about a

computer system designed for seniors. *Univers Access Inf Soc*. Epub ahead of print 2016. DOI: 10.1007/s10209-014-0383-y.

57. Doney B, Hnizdo E, Syamlal G, et al. Prevalence of chronic obstructive pulmonary disease among US working adults aged 40 to 70 years National Health Interview Survey data 2004 to 2011. *Journal of Occupational and Environmental Medicine*. Epub ahead of print 2014. DOI: 10.1097/JOM.0000000000000232.

58. Lee C, Coughlin JF. PERSPECTIVE: Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers. *J Prod Innov Manag*. Epub ahead of print 2015. DOI: 10.1111/jpim.12176.

59. Mackert M, Mabry-Flynn A, Champlin S, et al. Health literacy and health information technology adoption: The potential for a new digital divide. *J Med Internet Res*. Epub ahead of print 2016. DOI: 10.2196/jmir.6349.

60. Kayser L, Kushniruk A, Osborne RH, et al. Enhancing the Effectiveness of Consumer-Focused Health Information Technology Systems Through eHealth Literacy: A Framework for Understanding Users' Needs. *JMIR Hum Factors*. Epub ahead of print 2015. DOI: 10.2196/humanfactors.3696.

61. Petrie KJ, Weinman J. Why illness perceptions matter. *Clinical Medicine, Journal of the Royal College of Physicians of London*. Epub ahead of print 2006. DOI: 10.7861/clinmedicine.6-6-536.

62. Barton C, Effing TW, Cafarella P. Social support and social networks in COPD: A scoping review. *COPD: Journal of Chronic Obstructive Pulmonary Disease*. Epub ahead of print 2015. DOI: 10.3109/15412555.2015.1008691.

63. Whitehead L, Jacob E, Towell A, et al. The role of the family in supporting the self-management of chronic conditions: A qualitative systematic review. *Journal of Clinical Nursing*. Epub ahead of print 2018. DOI: 10.1111/jocn.13775.

64. Lawry S, Popovic V, Blackler A, et al. Age, familiarity, and intuitive use: An empirical investigation. *Appl Ergon*. Epub ahead of print 2019. DOI: 10.1016/j.apergo.2018.08.016.

65. Wiljer D, Urowitz S, Apatu E, et al. Patient accessible electronic health records: Exploring recommendations for successful implementation strategies. *J Med Internet*

Res. Epub ahead of print 2008. DOI: 10.2196/jmir.1061.

66. Hage E, Roo JP, Van Offenbeek MAG, et al. Implementation factors and their effect on e-Health service adoption in rural communities: A systematic literature review. *BMC Health Services Research*. Epub ahead of print 2013. DOI: 10.1186/1472-6963-13-19.

67. Ross J, Stevenson F, Lau R, et al. Factors that influence the implementation of e-health: A systematic review of systematic reviews (an update). *Implementation Science*. Epub ahead of print 2016. DOI: 10.1186/s13012-016-0510-7.

68. Orme MW, Weedon AE, Saukko PM, et al. Findings of the Chronic Obstructive Pulmonary Disease-Sitting and Exacerbations Trial (COPD-SEAT) in Reducing Sedentary Time Using Wearable and Mobile Technologies With Educational Support: Randomized Controlled Feasibility Trial. *JMIR mHealth uHealth* 2018; 6: e84.

69. Miyamoto SW, Henderson S, Young HM, et al. Tracking Health Data Is Not Enough: A Qualitative Exploration of the Role of Healthcare Partnerships and mHealth Technology to Promote Physical Activity and to Sustain Behavior Change. *JMIR mHealth uHealth* 2016; 4: e5.

70. Colon-Semenza C, Latham NK, Quintiliani LM, et al. Peer coaching through mhealth targeting physical activity in people with Parkinson disease: Feasibility study. *J Med Internet Res*. Epub ahead of print 2018. DOI: 10.2196/mhealth.8074.