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

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19 **Abstract:**

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

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

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

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

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

38 Introduction

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

51 Digital health technology (DHT), including self-monitoring devices (e.g. oximeters and
52 pedometers) and healthcare ‘apps’, have been identified as an innovative model to help
53 optimize the provision of COPD care by supporting patients to enhance the knowledge and
54 sense of control they possess over self-management practices such as self-monitoring and
55 problem solving ¹²⁻¹⁴. Healthcare professionals (HCP) can benefit from longitudinal datasets
56 captured outside the clinic to inform decision-making and support self-management through
57 the personalization of treatment plans that are more aligned with patient needs and preferences
58 ¹⁵⁻¹⁸.

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

67 Such issues are generally identified through post-study user-evaluations with adoption needs
68 rarely addressed or prioritized in the design or implementation phases of digital health studies
69 in COPD²⁹. Furthermore, previous research has highlighted the tendency for digital health

70 studies to define pre-determined research goals, which often lead to the development of “one-
71 size-fits-all” solutions that prioritize clinical outcomes at the expense of accounting for
72 individual needs^{30,31}.

73 This raises questions about the value of identifying the adoption needs of COPD patients to
74 inform the design and implementation of a DHT. As Clemensen et al., suggest, understanding
75 user needs prior to the design of a digital health intervention can help researchers establish
76 patient issues before the specifications of a solution are considered³². Indeed, recent systematic
77 reviews have concluded that further qualitative research investigating the user needs of COPD
78 patients is required to highlight the ‘key ingredients’ that will better inform the development
79 of implementation and adoption strategies for digital health interventions in a patient-centred
80 manner^{19,33}. Although current COPD research in mHealth has begun focusing on patient needs
81 in the early-development phase³⁴, the literature in this space is sparse.

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

89 **Methods**

90 *Study Design*

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

92 *Recruitment and Sample*

93 Patient recruitment took place in the respiratory clinics of two university hospitals. A sample
94 of convenience was chosen for pragmatic reasons. Patients were identified by respiratory
95 consultants (MB and JC) and possible participants were then invited to partake. Exclusion
96 criteria were: any existing cognitive or psychotic disorders, or severe life-limiting co-
97 morbidities, such as lung cancer. Inclusion criteria included: a confirmed diagnosis of COPD
98 guided by the GOLD guidelines³⁵. An information leaflet and consent form were given to
99 interested patients and a 48-hour reflection period was provided prior to the researcher (PS)
100 contacting the patient to confirm participation. Upon confirmation, a date and time convenient

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

104 *Procedure*

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

110 **Table 1 Interview Topic Guide**

<i>Topic</i>	<i>Questions</i>
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?

111 *Data Analysis*

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

124 **Results**

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

131

132 **Table 2 Sample Characteristics***

<i>Characteristics</i>	<i>Data</i>
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)	

133 * Sample Characteristics data self-reported at interview

134 ** Data collected from patient medical charts

135

136 ***Barriers to Adopting DHT***

137 *Lack of Perceived Usefulness*

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

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

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

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

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

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

157 *Digital Literacy*

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

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

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

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

168

169 *Illness Perception and Social Context*

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

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

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

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

183 **Facilitators to Adopting DHT**

184 *Existing Digital Self-efficacy*

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

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

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

195

196 *Personalized Education*

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

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

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

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

208

209 *Community-based Support*

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

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

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

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

221 **Discussion**

222 This study identifies new perspectives regarding the barriers and facilitators perceived by
223 COPD patients for the adoption of DHT. The results identify three primary barriers. It is well
224 established that perceived usefulness is a core determinant to a person's intention to adopt a
225 technology^{43,44}. For self-management technology, perceived usefulness refers to the degree to
226 which a person believes the technology could improve or enhance the effectiveness of their
227 ability to manage their disease⁴⁵. However, the perceived usefulness of DHT was questioned
228 by participants in this study. Patients expressed a sentiment that due to the burden associated
229 with their existing self-management task-load^{46,47}, the addition of a DHT was not perceived as
230 appropriate. Previous research in COPD posits that self-management benefits associated with
231 DHT may not be perceived by all patients because of the commitment to actively engage in
232 long term management, however they suggest that this barrier can be addressed by assessing
233 and accounting for the patients particular self-management approaches during implementation
234⁴⁸.

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

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

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

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

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

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

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

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

305 **Limitations**

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

308 rigour demonstrated in data collection and the use of NVivo 12 software to aid analysis.
309 However, when considering the generalizability of findings, the relatively small sample size
310 should be viewed as a limitation. For instance, the mean age of this cohort is 68.2 ± 10.1 with
311 11/30 patients having no smartphone, laptop or PC which may offer a reason as to why this
312 cohort placed an emphasis on digital literacy as a barrier and the need for technology-focused
313 education as a central aspect of their perceived facilitators. Additionally, further research is
314 needed in COPD to understand the barriers and facilitators HCP perceive towards the use of
315 DHT to determine how these technologies can be most effectively integrated into their
316 workflows and clinical decision-making practices.

317 **Conclusion**

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

336

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340 **Conflict of Interests**

341 The authors have no conflicts of interest to declare.

342 **Contributorship**

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

347 **Ethical Approval**

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352 **Guarantor**

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354

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