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Features of a mobile health intervention to manage chronic obstructive pulmonary disease: a qualitative study

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Abstract

Background: The use of mobile health (mHealth) interventions has the potential to enhance chronic obstructive pulmonary disease (COPD) treatment outcomes. Further research is needed to determine which mHealth features are required to potentially enhance COPD self-management.

Aim: The aim of this study was to explore the potential features of an mHealth intervention for COPD management with healthcare providers (HCPs) and patients with COPD. It could inform the development and successful implementation of mHealth interventions for COPD management.

Methods: This was a qualitative study. We conducted semi-structured individual interviews with HCPs, including nurses, pharmacists and physicians who work directly with patients with COPD. Interviews were also conducted with a diverse sample of patients with COPD. Interview topics included demographics, mHealth usage, the potential use of medical devices and recommendations for features that would enhance an mHealth intervention for COPD management.

Results: A total of 40 people, including nurses, physicians and pharmacists, participated. The main recommendations for the proposed mHealth intervention were categorised into two categories: patient interface and HCP interface. The prevalent features suggested for the patient interface include educating patients, collecting baseline data, collecting subjective data, collecting objective data *via* compatible medical devices, providing a digital action plan, allowing patients to track their progress, enabling family members to access the mHealth intervention, tailoring the features based on the patient's unique needs, reminding patients about critical management tasks and rewarding patients for their positive behaviours. The most common features of the HCP interface include allowing HCPs to track their patients' progress, allowing HCPs to communicate with their patients, educating HCPs and rewarding HCPs.

Conclusion: This study identifies important potential features so that the most effective, efficient and feasible mHealth intervention can be developed to improve the management of COPD.

The reviews of this paper are available via the supplemental material section.

Keywords: digital health, COPD, lung disease, mhealth, telehealth, chronic disease management, smartphone

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Introduction

The significant rise in mobile phone ownership coupled with increased expectations of users' roles in managing their own care presents a unique opportunity for mobile health (mHealth) interventions.[1] The Global Observatory for

eHealth of the World Health Organization (WHO) defines mHealth as 'medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants and other wireless devices'.[2] mHealth also includes the use of medical devices compatible with smartphones. It is suggested that mHealth interventions could play a significant role in the management of chronic health conditions, including chronic obstructive pulmonary disease (COPD).[3–6]

Although COPD is preventable and treatable, WHO estimated that COPD will become the third leading cause of mortality and the seventh leading cause of morbidity worldwide.[7] Dynamic modelling has shown that any intervention that can reduce the number of exacerbations in a population, such as pharmacogenomic interventions or predictive tests for exacerbations, will have a substantial impact on the morbidity and costs associated with COPD.[8,9] Alwashmi *et al.*,[3] noted that current literature on the role of smartphones in reducing COPD exacerbations is limited, but suggested that smartphone interventions may reduce COPD exacerbations.

Chronic obstructive pulmonary disease treatment and management

Effective COPD management could delay disease progression and reduce acute exacerbations, thereby improving patients' quality of life and reducing healthcare costs.[10] There are various methods for enhancing COPD management. Smoking cessation is the most important factor that influences the natural history of COPD.[11] Lareau and Hodder[12] stressed that patient education regarding the disease and correct use of inhalers is vital for management. In addition, the synergistic effects of multiple COPD interventions, such as pulmonary rehabilitation, oxygen supplementation and physical activity, could enhance management.[11] Pharmacological and nonpharmacological management strategies are crucial in the management of COPD exacerbations. Pharmacological therapy reduces symptoms, reduces frequency and severity of exacerbations and improves health status and exercise tolerance.[11] Nonpharmacological strategies improve health status and quality of life, reduce healthcare utilization and reduce costs by preventing the frequency and severity of COPD exacerbations.[13] Effective self-management programs include written action plans that enable patients to manage exacerbations and react appropriately through the prompt initiation of prednisone or antibiotics.[14] Adherence to a COPD action plan can be effective in the management of COPD.[15,16]

Although there are effective and inexpensive treatments for COPD, adherence rates are amongst the lowest of all chronic diseases, leading to avoidable adverse medical outcomes, costs and reduced quality of life. Nonadherence in COPD is documented in the uptake of all therapies, including oxygen supplementation, physical rehabilitation and medications; it contributes to rising rates of hospitalizations, deaths and healthcare costs.[17]

mHealth for chronic obstructive pulmonary disease management

The current literature suggests the potential for smartphone integration in the management of COPD. mHealth could play a significant role in the management of modifiable risk factors, as indicated in the following studies. The application of a multifactorial intervention (COPD information, dose reminders, audio-visual material, motivational aspects and training in inhalation techniques) resulted in an improvement in therapeutic adherence in patients with COPD.[18] Wang *et al.*[19] reported that a mobile-phone-based system could provide an efficient home endurance exercise training program with improved exercise capacity, strengthened limb muscles and decreased systemic inflammation. Another study indicated that the smartphone-based collection of COPD symptom diaries enabled patients to identify exacerbations symptoms early on in the exacerbation, providing the opportunity for early intervention.[20] Other studies reported that some COPD management interventions, such as pulmonary rehabilitation and physical activity, can be delivered remotely.[10,21] And, Bender[17] stated that COPD adherence may benefit from communication and advice delivered through mobile technology, along with a larger program of education, monitoring and support.

Medical devices, such as spirometers and pulse oximeters, can obtain objective data that cannot be collected by smartphones alone. Recent advancements in technology allow for seamless integration between smartphones and medical devices. Various studies paired medical devices,

such as electronic vests, heart rate monitors, pulse oximeters and accelerometers with smartphone technology to assist in COPD management and detect exacerbations[22–29] However, these studies were focused on the technical effectiveness of these methods and there was limited involvement of patients during the design of these interventions. In addition, the studies gave limited attention to patient perceptions, usability and satisfaction.

Human-centred design in chronic obstructive pulmonary disease

The International Organization for Standardization (ISO) 9241-210 standard defines human-centred design (HCD) as 'an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques'.[30] The ISO uses the term HCD instead of user-centred design to 'address impacts on a number of stakeholders, not just those typically considered as users'.[30] However, in practice, these terms are often used synonymously.

Research on the development and evaluation of such apps is in the relatively early stages.[31] Many barriers to using telehealth can be avoided with better planning and collaboration.[29] Testing mHealth interventions with patients has revealed preferences and concerns unique to the tested population.[32–34] When developing mHealth interventions, Hopkins *et al.*[35] encouraged including insights from key users to potentially improve the process and the outcome of the intervention.

Triantafyllidis *et al.*[36] used an iterative approach to refine a tablet computer-based home monitoring system for heart failure patients. However, there was limited uptake due to usage difficulties and low levels of patient satisfaction. Thus, the authors recommended patient-centred approaches for sustainable delivery. Patient-centred care recognizes the complex, subjective and changing nature of patients' health status;[37] in addition, it links multiple episodes of care offered by diverse providers into continuous, integrated care trajectories unique to particular patients.

Although mHealth has gained popularity in recent years, patient and HCP perspectives about mHealth for COPD management are relatively unexplored.[38] The United Kingdom has recommended that apps to be 'prescribed' as part of the care for long-term conditions[39] But, few published studies address which specific features of mHealth interventions benefit patients with COPD.[40] A recent meta-analysis on the remote monitoring of patients with COPD concluded that some interventions may prove promising in changing clinical outcomes in the future, but there are still large gaps in the evidence base.[41] Noah *et al.*[41] recommended a qualitative approach to give researchers insight into which elements best engage and motivate patients and HCPs.

By obtaining the perspectives of nurses, physicians, pharmacists and patients, we aimed to understand their requirements for an mHealth intervention. Gaining a better understanding of how patients and HCPs interact with mHealth interventions will assist in developing evidence-based interventions with the potential to change behaviour over long periods of time.[41] Lessons learned will be offered as a guide for research and technology developers working with patients with COPD and their HCPs.

Methods

Purpose

To explore and develop an understanding of the perceptions of patients with COPD and their HCPs regarding the appropriate mHealth features and compatible medical devices for COPD management. The study was also intended to determine the optimal frequency of the features to ensure that patients and HCPs remain engaged with and responsive to the mHealth intervention.

Study design

We used a descriptive qualitative research design that was grounded in pragmatism.[42,43] Using a qualitative methodology to conduct semi-structured interviews allowed us to achieve an in-depth, contextualized picture of what a diverse sample of patients with COPD and their HCPs, in this case, nurses, pharmacists and physicians, think and feel about the possibility of using mHealth in COPD management.

Recruitment and study setting

HCPs involved in the treatment of patients with COPD were eligible to participate. The primary

investigator (PI) contacted the Newfoundland and Labrador Medical Association, the Association of Registered Nurses of Newfoundland and Labrador and the Pharmacists' Association of Newfoundland and Labrador. These organizations were asked to forward a recruitment email to their mailing lists or post it on their websites. Interested HCPs contacted the PI *via* email or telephone, who then scheduled appointments to complete the consent forms and conduct the interviews. Our sample consisted of 30 HCPs: 10 nurses, 10 pharmacists and 10 physicians.

Patients were recruited during routine visits to their respirologists at outpatient respirology clinics in the Eastern Health Regional Health Authority of the province of Newfoundland and Labrador, Canada. Patients received a consent cover letter for research. The cover letter included a questionnaire about technology access and use. The last section of the questionnaire included a question about the participant's interest in participating in an interview regarding the same topic. Participants were eligible for the study if they met the following inclusion criteria:

1. a COPD diagnosis (self-report),
2. aged $\geqslant$30 years at study enrolment,
3. able to answer questionnaires in English, and
4. able to provide informed consent.

Based on the demographic information collected from patients, we used purposeful sampling to identify key informants who could provide rich and diverse interview data. We used purposeful typical case sampling to gather the information that would reflect typical cases of mHealth use.[43,44] We also used a criterion-based selection[43] so that we could categorize participant characteristics such as age, familiarity with mHealth, healthcare profession and years of experience. In addition, as the interviews progressed, some participants were recruited by snowball or chain sampling, where participants suggested other possible HCPs.[43,45] Snowball or chain sampling was used to ask a few information-rich participants for additional contacts to provide confirming or different perspectives, allowing for richer data.[43]

We first contacted nurses, and after interviewing seven to eight nurses, we reached saturation, as we were not gathering new information. However, we continued interviewing until 10 nurses were interviewed. This was to strengthen the validity of inferences.[46] We used the same sampling strategy for the remaining professions and patients, with similar saturation points, as we continued to interview 10 participants for each profession and for patients. Our final sample size was comparable with similar qualitative studies.[38,47,48]

Participants were recruited from April 2018 to August 2018. Our sample consisted of 10 patients and 30 HCPs: 10 nurses, 10 pharmacists and 10 physicians. The study took place in St. John's, Canada. We conducted some interviews at Memorial University and others at the participants' offices or homes. After completing the interviews, patients were offered a CA$30 gift card.

Ethical considerations

Ethical approval for this study was obtained from the Newfoundland and Labrador Health Research Ethics Authority (2017-194). Before agreeing to participate, all subjects were informed about the nature of the research project, the possible risks and benefits and their rights as research participants. All participants completed a written consent form. They were also given a copy of the consent form.

Data collection

We conducted individual semi-structured interviews to gain an understanding of the everyday lived experiences of HCPs and patients in relation to using mHealth.[49,50] Using semi-structured interviews allowed the interviewer to begin with a broad question to direct the focus of the interview and then to provide an opportunity for the HCPs and patients to bring forth their thoughts and feelings about phenomena that they thought were important.[49,50]

Both patients and HCPs commented on the content of the patient interface as well as the HCP interface. The interface is defined as the way in which information is made available to users on the screen.[51] The interview prompts are available in Appendix 1 (for HCPs) and Appendix 2 (for patients). To facilitate discussions, the interviews were conversational in nature, and items were not asked verbatim or in the order presented. As the study progressed, emerging issues were explored with subsequent participants to refine the themes.

The prompts were informed by findings from the literature, the questionnaire results and input from the authors, who have diverse backgrounds including mHealth, pharmacy, nursing, medicine, respirology, family medicine, education and qualitative research.

The interviews were recorded to enable transparent and accurate transcription. Interview lengths ranged from 20 to 60 min. Topics included the following: demographics, mHealth usage, perceptions toward challenges of mHealth adoption, factors mHealth adoption and preferences regarding features of the mHealth intervention for COPD management. The interview included prompts about potential features, such as education and care plan, the possibility of including medical devices, the frequency of notifications and the nature of the communication between patients and HCPs. Topics also included discussions about smartphone-compatible medical devices (accelerometers, portable spirometers and pulse oximeters). Owing to a large amount of data, preferences regarding the barriers and facilitators of mHealth adoption for COPD management were presented in different articles.[52,53] HCP data consisted of more than 13 h of interview time with approximately 300 pages of transcription. Patient data consisted of about 4 h of interview time with approximately 100 pages of transcription.

Data analysis

The interviews were transcribed verbatim and compared against the digital recordings to ensure the accuracy of the content. Identifying information (names) was removed to protect anonymity. We used NVivo (version 12; QSR International) to organize the data and examine the words, including frequency counts, as in classical content analysis.[54] All data were analysed, but we only coded data that were relevant for answering the research questions, as recommended by Saldana,[55] Wolcott,[56] and Yin.[57] An audit trail was created to keep track of all analytic decisions.[57]

After using NVivo, we used first cycle coding with nurses' data. This coding was both structural and holistic,[55] meaning that we used the interview prompts and the literature to guide some of the codings. One researcher analysed the transcripts and developed a set of themes and subthemes and then obtained input from a second researcher. In the second cycle of coding, the two researchers independently coded the nurses' data using pattern coding to develop themes.[55] They then discussed commonalities and differences in their coding and theme development until a consensus was reached. The analysis of the nurses' data was mainly inductive and iterative throughout, as we went back and forth among the data, the coding and the themes.[58]

After the nursing analysis was finished, we completed the same two cycles of analysis for the pharmacist, physician and patient data. These analyses included inductive and deductive analysis. However, the analysis was more deductive in nature, as themes had already been developed from the nursing data. The iterative process continued as these analyses were conducted to find commonalities, differences and new patterns in thinking in relation to the nurses' data. Once these four sets of analyses were complete, the two researchers discussed common and different trends among the three HCP groups and patient groups to develop final themes that encompassed all the HCPs and patients.

Results

The results are organized into three sections. The first section describes the demographics of the sample. Then, the features of the patient interface will be highlighted in the second section. Lastly, the third section describes the features of the HCPs' interface.

Demographics

The sample included HCPs who worked with patients with COPD in various settings, including respirology clinics, cancer clinics, critical care, long-term care and community health. Some HCPs founded a medical technology company or had a software programming background. About half the HCPs had experience with an mHealth intervention to manage COPD. Participant demographics are outlined in Table 1.

Overall, 10 patients with COPD participated in face-to-face interviews. The mean age was 67.6 (±7.58) years, and the range was from 51 to 80 years. There were four females and six males. Based on self-report, the mean number of years living with COPD was 8.4 (±4.45) years, and the range was from 3 to 15 years.

Table 1. Participant demographics.

	Sample size	Age mean (SD)	Years of experience in working as HCP, mean (SD)
Nurses	5	47.3 (6)	19.6 (9)
mHealth* nurses	5	40.6 (10)	15.8 (10)
Physicians	5	37 (9)	8.4 (8.7)
mHealth* physicians	5	41.2 (12)	14.4 (11)
Pharmacists	7	35.7 (11)	11.4 (10)
mHealth* pharmacists	3	27.5 (4)	3.6 (2)

HCP, healthcare provider; mHealth, experience in using an mHealth intervention; SD, standard deviation.

Patient interface

We developed themes under two categories: patient interface and HCP interface. The patient interface allows patients to access features of the mHealth intervention. This section explains how patients and HCPs think these features would be beneficial in the management of COPD. The following themes give examples of how patients and HCPs can work as a team in a complementary fashion to improve patient health. Table 2 summarizes the main features recommended for the patient interface. We have also included details and examples to illustrate the HCPs' and patients' thoughts and beliefs.

The educational component is valuable. Pharmacists, nurses and physicians agreed that mHealth can have a role in educating patients with COPD. One pharmacist remarked, '… COPD is something they'll have for life. So especially when they're getting diagnosed that this is introduced as a tool for education, for making sure that it doesn't get worse'. Similarly, a physician felt confident that patients would 'learn more about their own disease and if they know more about their disease, then, like, generally speaking, they're more invested in their care'. A pharmacist raised a point that getting educational information through an app is better than 'having to Google the information and coming across misinformation'.

HCPs had strong thoughts regarding the educational content of the mHealth intervention. The majority of HCPs agreed that it should include information about the administration technique of inhaled medications. This physician statement represents the thoughts of several HCPs: 'Because if I'm giving them the best drugs but they're only getting 25% of the drug because they're not using the device properly then that may be some of the reason they're having a poor quality of life'. More generally, a pharmacist put forward the importance of patients being able 'to better understand their condition and the importance of their medications'. And, to summarize the content, one pharmacist remarked that the educational content should include 'the patient information sheet that a patient would get upon counselling'.

To deliver educational content, HCPs talked about several methods. Some HCPs recommended daily sessions, while others recommended monthly sessions. These educational sessions can be delivered *via* messages, videos, or walkthroughs, as in this pharmacist's comment: 'So if there's some sort of demonstrative capabilities where you could just click on it and have someone walk you through the technique. . . a month later if they say oh I forgot it, how did they tell me to do it again the reminders help'. In addition, some HCPs recommended making a library of the content available so patients could access it at any time.

One nurse explained how to provide educational sessions:

> *Each day when they do their health session, they get education slides within their health session. It could be just some signs and symptoms, it could be a tip of the day to help keep them healthier at home, that sort of thing. Also, on the iPad there's a 2–3-minute video on COPD to help them understand their disease process a bit better.*

Table 2. Themes with specific examples regarding the features of the patient's interface.

Theme	Specific examples for each theme
The educational component is valuable.	A source of reliable information is important.
	Topics include information about the disease, medication, inhaler techniques, and breathing exercises.
	The educational content can be delivered *via* messages, videos, or walkthroughs.
It is important to collect baseline information.	It is necessary to understand the patient and evaluate the COPD management progress. Information should include demographics, health data, psychosocial data, primary care physician, and emergency contact.
It is important to collect subjective health data.	It is necessary to understand the level of COPD management and guide pharmacological therapy. Information should include shortness of breath, cough, and sputum. Data about medication adherence, exacerbations, and hospitalizations are important.
It is beneficial to collect objective health data.	Objective data for monitoring COPD are helpful. It could reduce the reliance on healthcare resources. Medical devices could potentially include a portable spirometer, pulse oximeter, and a medication adherence monitor. Additional devices can be added, especially if the patient has a comorbidity.
Providing a COPD action plan is recommended.	It has the potential to empower patients to be a part of their management plan and reduce hospitalizations. It could use subjective and objective data to personalize COPD management.
Allowing patients to track their COPD management progress would be helpful.	This includes tracking the progress of subjective and objective data.
Providing access to family members or caregivers would be beneficial.	Family members or caregivers can assist in the delivery of the mHealth intervention.
Consider tailoring the features based on the patient's unique needs.	Differences in COPD severity level and presence of a comorbidity can affect the features required by patients.
Reminding patients to manage their COPD is a benefit.	Personalizing the features includes changing the frequency of objective and subjective data collection.
Rewarding patients for managing their COPD is a possibility.	Reminders include taking medications, refilling prescriptions, and attending hospital appointments.
There were a few features mentioned by a minority of HCPs and patients.	Using positive reinforcement messages or reward programs can be motivational.
	Features include: Using artificial intelligence. Consider visually impaired patients. Ability to share the records with any HCP. Ability to access medical records. Including a smoking cessation program.

COPD, chronic obstructive pulmonary disease; HCP, healthcare provider.

There's also videos on shortness of breath and there's a good video on showing them how to properly take deep breaths in and how to use their inhalers properly along with the importance of keeping your blood pressure under control, so it will tell them symptoms of high blood pressure and what can cause low blood pressure, heart

rate high and low along with oxygen… what a low oxygen reading could mean for them and the seriousness of breath. what can happen with a low oxygen reading.

In addition, the mHealth intervention could be used to deliver 'new research or new, you know, something has come about that they should know'.

Patients also thought that the mHealth intervention could be used to provide educational materials. All patients who were enrolled in an mHealth intervention for COPD management mentioned they read some of the content provided. One patient remarked that he particularly enjoyed the educational tips that were presented as a notification: 'They had certain hints on how, it might be on congestive heart failure or it might be on something else, but they're all helpful. You learn things from them'. However, one patient had contradictory views about using mHealth to provide educational materials, as in 'I have got so much information home now on COPD that I have not looked at'.

It is important to collect baseline information. Collecting baseline information is vital to understanding the patient and evaluating the COPD management progress. This nurse's statement represents a commonly expressed thought: 'I think the most important piece of that is to halt before you just go out and put a device in a patient's home is to understand what their normal is'.

When enrolling a new participant in the mHealth intervention, nurses supported the idea of collecting baseline data including: name, date of birth, address, who they live with, support systems, sex and age. The nurse highlighted this importance 'Definitely, we would want to know if they're a smoker or not, where they're from, any medical histories, family history'. HCPs also recommended identifying the primary care physician (PCP): 'once a month we will send out their PCP a monthly report of the biometric readings'. Emergency contact information is also important: 'if we still did not reach the patient and we felt that the result was potentially life-threatening, we need three contact people who we can call. And if we cannot reach either of them then we call the police to go in and do a well check just to be sure'.

Nurses stated that it is important to collect information on the psychosocial aspects of the patient:

What they're dealing with at home, where they live, what their environment is. In terms of whether or not they can afford their medication. Whether or not they eat healthy, whether or not they get out of their home. Do they live in an area where they're safe to get out and go for a walk or, do they live in an area where there's no sidewalks or something that might inhibit them from getting out? Are they in a basement apartment? Do they have a bunch of grandchildren? Do they have no-one? Do they have people smoking around them? Do they smoke themselves?

It is important to collect subjective data. Collecting subjective data from patients *via* surveys was recommended by the majority of HCPs. The aim is to have a record of various symptoms to understand the level of COPD management. These symptoms include shortness of breath, cough and sputum. Depending on the answers to these questions about symptoms, one nurse advocated to include 'branching questions to see what colour the sputum is and things like that'. HCPs also expressed interest in collecting data regarding medication adherence and medication side effects; for example, a pharmacist stated that 'adherence is the most important data point for everything with COPD'. Collecting the number of exacerbations and hospitalizations was also mentioned by HCPs, as in the physician's statement, 'I know there's the CAT questionnaire on COPD. You can see when there are more dyspnoeic offs. And they can also log when they have exacerbations, so when they come to the hospital'. One nurse noted the importance of taking physical activity into consideration when assessing patients with COPD, as in 'Things like activities of daily living. So, sometimes my patients would describe, relatively well, COPD management but it was because of not moving at all'. A minority of HCPs mentioned collecting data regarding smoking status, oxygen usage and depression scores.

When asked about the frequency of the survey, HCPs had conflicting opinions. Some HCPs thought a daily questionnaire would be feasible. A nurse with experience in mHealth interventions stated that a daily questionnaire did not affect the compliance rate, as in, 'whole session, from biometrics to symptom question and answers will take 5–10 min… I would say it would be probably about 90–92% compliance rate for patients who will complete their sessions'. This was also agreed upon by the patients who were part of the mHealth intervention. In addition, patients who were not

enrolled in the mHealth intervention were open to completing a daily questionnaire, as in 'If I get a notification that I need to answer some questions, it's going to take me 5 or 10 minutes, I've got no problem with that'. Alternatively, the majority of HCPs surmised that daily surveys are not feasible, as in 'I think that would make them a little turned off from the app if they had to fill out a survey every day'. Two patients were not supportive of completing a survey on a daily basis: 'I am pretty sure I would get pissed off with it and say...I am not doing it.' Some HCPs suggested that the frequency of the questionnaire should depend on the COPD severity, as in: 'I don't know the exact timeframe, but for someone who is stable and well, I think that it could be very, you know, patients could lose their sense of self-control because they're just having to do this daily thing and it's a bit tedious, but I think that for the acute patients, definitely daily, and patients should be able to recognize when they need to do that'. This was reiterated by a nurse: 'divide it into different sections depending on how complicated their health condition is'.

One pharmacist felt confident the mHealth intervention could play a role in guiding pharmacological therapy: 'If there's no improvement, then what's the point of keeping them on the drug? ...The patient can provide that information to the doctor... They can even just view it and then send a prescription into the pharmacy and the patient can go get it'.

It is beneficial to collect objective health data. It is common among mHealth interventions to use Bluetooth technology for pairing medical devices with smartphones. This is a user-friendly method that allows the transfer of results from the medical device to the smartphone and eventually to the healthcare provider platform:

> *Everything is done through Bluetooth and so they're provided with a blood pressure cuff and pulse oximeter to check their oxygen readings and they're also given weight scales and, again, all this is Bluetooth-compatible and patients have to have cellular connection or Wi-Fi in order to be in the programme, because that's how it's all transmitted into the individual nurse's monitors.*

These devices allow patients and HCPs to obtain objective data for monitoring COPD. This was observed by a nurse who uses an mHealth intervention: 'it validates that the condition is certainly stabilised and not worsening. And I think, if nothing else, it is peace of mind for the patients and so on'. In addition, pairing medical devices could reduce the reliance on healthcare resources, as stated by a pharmacist: 'I think that would be particularly valuable if you're getting meaningful medical data that doesn't necessarily require healthcare resource to be tied up. You don't have to send the client to a clinic to have these sorts of examinations or tests completed if they can do at home at their own convenience. I think that's a win-win for everyone'. HCPs voiced their opinions regarding the use of a portable spirometer, pulse oximeter and a medication adherence monitor in COPD management.

When asked about the use of a pulse spirometer to monitor COPD, most HCPs thought that it is important to measure oxygen saturation. A pharmacist, echoing other HCPs, indicated that it would 'definitely be a good idea because getting that like reinforcement of having that number come up, they might be like, okay, I'm not doing so well right now'. In terms of the frequency of measuring oxygen saturation, many physicians mentioned that measuring it daily would be a general role, but one physician recommended tailoring it to the severity of the diseases: 'I guess, it depends as well based on the severity of their disease but, I guess, on a daily basis again for somebody who's quite short of breath and has low O_2 stats, then less often for people who are better'.

Four patients who were enrolled in an mHealth intervention to manage their COPD used a portable spirometer on a daily basis. Support for this practice was voiced by others, as in this patient statement: 'everyone has to have an oximeter. And I'm very surprised that an awful lot of COPD patients don't'. It was also mentioned by another patient: 'What I found so good with that was testing your oxygen, how much oxygen you got, you know, because that was really helpful. Because if you wait until you have a hard time breathing, that's not good'. These patients were supportive of testing their blood oxygen levels daily.

When asked about the use of a spirometer to monitor COPD, HCPs had contradictory views about its use for monitoring purposes. A few HCPs thought it is important to measure the lung volume. The following physician statement supports the inclusion of a portable spirometer as part of the mHealth intervention: 'After acute

exacerbation, I think that you should, the recommendation is that you should get repeat pulmonary function tests (PFTs), like, 12–16 weeks post-discharge. And I don't think that that's being done currently...if patients had spirometers at home, that this could alleviate some of that repeat PFTs for people so that they can monitor their severity of their COPD'. This was also supported by a patient: 'my doctor generally orders it, but it's not more than once a year and sometimes I haven't had it for a year and a half, maybe 2 years. I told you I've been diagnosed about 6 years and I've probably had four'.

Alternatively, other HCPs did not recommend adding a portable spirometer to the mHealth intervention. One reason given was that patients may have trouble interpreting the results. A pharmacist noted, 'I don't know if everyone is going to be able to interpret the results properly. But that's not to say that they could just bring them to their physician'. A nurse stated that 'if the spirometry is going to go back to a respirologist then definitely. But if it's going back to a staff nurse then perhaps the nurse would rather see other biometrics'. Physicians, including respirologists, suggested that patients would not be able to perform spirometry independently, as in:

> *I feel like that would be more of a technique issue, so not all the patients have the best technique and then that's one thing, Also, there's a timing issue as well with the inhalers, so sometimes patients take inhalers right before they do it and can throw off the data a little bit and then sometimes patients don't take it. So, I think that's, it'll be more challenging to do that, personally'.*

Some HCPs thought that patients will not be interested in using the spirometer, and a pharmacist mentioned: *'The average patient is not going to see the value of it and they're not going to do it'.*

In terms of the frequency of a spirometry test, there were varying opinions among HCPs. One pharmacist recommended performing it daily: 'technically they should be doing it daily. I mean, when a patient has asthma we normally recommend doing it daily because with asthma there's also actions that need to be taken with using spirometry'. This was also mentioned by a physician who was hesitant about the frequency of testing: 'Somebody who is very mild and the spirometry results have been really good, maybe once a week. People who are more severe would probably do it more often on a daily basis'. On the other hand, a respirologist said, 'I'm not sure if it's worth the money to do something like that on a daily basis'. Other HCPs recommended using a spirometer every few weeks or months: 'if it's only a small procedure, it's not invasive, there is no reason they can't do it every few months, because if I remember right, the forced expiratory volume in 1 s (FEV_1) tends to not change massively in a short period'. One physician expressed interest in tailoring the frequency to the individual based on defined criteria: 'If you had strict clinical criteria as to when the FEV_1 would be done, as opposed to okay do it once a month or whatever it is, you know, because it's a clinical decision, it's not a time-based decision'.

A physician talked about conducting a study to determine the ideal frequency for measuring lung volumes:

> *I think the only way to know that is if you had the device and you actually studied that…So to me it would be to correlate that with the measurements and then changing their breathlessness or their sputum or other things to try to figure out is there clinical things that we could ask that would give us that information without having the technology. But as technology gets cheaper and more available then yes, it's no different than if you look at the insulin pumps and having the instantaneous monitoring now which we never had before and being able to give insulin in a much more physiological basis. So I think it could be helpful'.*

A few patients were interested in trying a portable spirometer but were not sure how often they would have to perform the test, as in 'Yes, probably once a week I'd get used to the hard blowing'. A patient shared her opinion: 'I could learn to use it. I don't think I need it as long as I'm doing what I'm doing now'.

Many HCPs thought that the use of a medication adherence monitor could be effective for COPD management, as one pharmacist said, 'That will be really good for Ventolin because then you can actually see how much they're actually using'. This was reiterated by a nurse: 'Oh yes, I think that would be very useful, because sometimes, and I hate to say it, you can't really believe the patients'. One physician suggested using a camera to promote medication adherence: 'Right now I mean most times I prescribe inhalers I don't actually watch patients take the inhaler. But if

you're able to say well take a little video of yourself and I'll look at the video of you using the puffer this evening. That ability to actually measure compliance based on the ability that if you have remote monitoring you could observe the patient using their device'. Furthermore, a pharmacist suggested adding a device to an inhaler to assess the inhalation technique: 'You can go to YouTube and you can see how to use an inhaler and they're very, very good and I don't think that the app would necessarily be able to do that unless it was somehow linked to the device and somehow knew whether you were doing it incorrectly'. Many patients were also interested in using a medication adherence device, as in 'That's a very good idea. And also, this pulmonary function test. You have to know, especially in this day and age, the reason, I guess, you're coming out with these programs, is that there's only so many doctors to go around'.

Some HCPs recommended using other devices, especially if the patient has a comorbidity. These devices could be used to measure weight, respiratory rate, blood pressure, blood glucose levels. A nurse with mHealth experience shared, 'If you were doing the oxygen, vital signs, the whole blood pressure and pulse and respiratory rate wouldn't go astray either'. One pharmacist with experience in mHealth suggested that pharmacies can offer medical devices to be used by patients that can send data from the medical device to the patient's phone.

Patients who were enrolled in an mHealth intervention to manage their COPD used a blood pressure monitor and a scale. In addition, patients with cardiovascular comorbidity used a blood pressure monitor: 'When I had a problem with blood pressure about 4 or 5 years ago I used to have to use it quite a lot because used to have to keep a record for my family doctor. So since I got it under control now, some days when I feel a bit flushed in my face well I'll check it and make sure that it's not gone up anymore'. Two patients used a glucometer to manage their diabetes comorbidity. An accelerometer, Fitbit, was used by one patient, as in:

> *I kind of slowed down a bit and I started feeling more with my joint pain. And I said what I need is for me to track what I do every day to make me feel better. So they recommended the watch so I just started from there… Normally every day I check my sleep and check how I stressed and how much I eat, how much calories I burn in a day, how much I walk and my heart rate. It's amazing.*

Providing a COPD action plan is recommended. The majority of the HCPs supported the idea of including an action plan as part of the mHealth intervention. One nurse was already using the COPD action plan in her practice, as in:

> *We promote something called COPD action plan… the whole premise of it is so they could have antibiotics and steroids on hand at their pharmacy in case they start to have a flare up. We educate them on when they should use this and the whole premise is to treat early so they don't get to the point that they end up having to go to an emergency room or be admitted. So based on that assessment is either to recommend that the patient take an extra inhaler, to use a nebuliser treatment, to increase the frequency. We may reach out to their physicians if we feel a change in their care plan is required. To get new treatment orders or, if it sounds to be a very acute situation that is not relieved with any home care measures, then we either refer to their physician, emergency department or, in some cases if they are in acute respiratory distress, we actually arrange an ambulance to come on site and visit.*

Several HCPs surmised that including an action plan had the potential to empower patients and reduce hospitalizations. One physician reinforced this notion and thought the action plan would

> *give patients the power to then be a part of their management plan, which is better when patients are empowered because they feel in control of their health. And then also would give them a couple of strategies before they need to go to the emergency department. For people with COPD it is hard for them to go out and walk to their car or take transportation to the emergency department. It can take an awful lot of effort, so it saves a patient as well as the healthcare system some resources as well.*

A pharmacist stated that patients would not lose the action plan, which is common among paper-based action plan: 'if they could customize like a COPD action plan or something like that in the app where they're not going to lose it would also be beneficial to patients.'

Most importantly, HCPs agreed that the action plan could use subjective and objective data to personalize COPD management. A physician provided the following example:

> *There could be an algorithm within the program to say, are you more short of breath, yes, are you having increased sputum production, yes, what is your oxygen saturation level, 87, what is your temperature, 37.4, and based on this information, then the application could say, you know, increase your short-acting bronchodilator, increase your short-acting agent, just based on that.*

Three patients mentioned that they have a COPD action plan. In terms of using an mHealth intervention to deliver an action plan, one patient remarked, 'I would be open to using my phone to help manage my COPD based on what that entails. If it's a few questions in terms of information gathering to develop a micro-specific COPD treatment regimen, I could absolutely see the benefit. If it would be for generic information gathering, I probably wouldn't be so open to that'.

Allowing patients to track their COPD management progress would be helpful. Some HCPs suggested providing patients with the ability to track their COPD management progress. A nurse thought that patients should be able to 'see their signs and symptoms. Is this normal? Is this abnormal? Can I manage this myself with what I have got at home or should I go to the emergency department?' Some pharmacists suggested summarizing the signs and symptoms to share with HCPs, as in 'I'd bring up my app and it would give me a simple one-page snapshot of how I'm doing. And then, from there, I could click on different areas and get some tips or whatever. It needs to be very simple. . .because if they went to their physician or to us and they hold the phone and say, here, let's have a look'.

Many patients were interested in tracking their progress, as in 'It's a critical factor. It's my health. But beyond all of this, I would really like to understand why I have COPD...I would definitely want to track my progress or regress accordingly and if the app would allow me to do that.' One patient kept a web-based record of his vital signs and medication adherence: 'I can go back five and a half years and tell you, on the third of May, that I took my pills at 08:17 in the morning'.

Providing access to family members or caregivers would be beneficial. Many HCPs mentioned that granting caregivers, family members, or homecare workers access to assist in the mHealth intervention would be beneficial. A physician stated, 'they often have children, grandchildren, homecare providers, people who can help or have it on their own phone when they're with them'. When sharing information with family members, a physician was concerned about the importance of ensuring privacy and confidentiality: 'the only issue that you'll come across there is the release of information because patients, if they're competent they don't want their family members to see their information and that could be an issue'. The majority of patients mentioned that a family member assisted them in the management of their COPD, as in 'I've got a little organizer I put my pills in there for the week. . .And if I don't, my wife gives me a smack in the back of the head'.

Consider tailoring the features based on the patient's unique needs. A recurring theme among HCPs and patients was tailoring the mHealth intervention to each patient. Differences in COPD severity level and the presence of a comorbidity can affect the features required by patients. Personalizing the features includes changing the frequency of objective and subjective data collection. For example, a physician commented, 'The question is do you want it to be individualized to the patient...You don't want to overwhelm patients with collecting all this information, right, it needs to be something that is beneficial to them and not just something else that they're having to do'. A nurse describing her monitoring approach with patients enrolled in an mHealth intervention to manage COPD: 'It would be patient-specific for sure. Somebody who is well and didn't do a session for a couple of days, maybe we'd let it slide. But somebody who you know had been unwell for a few days and if they didn't do their health session, say by mid-morning, maybe you'd might call them and say, are you okay? What's going on?'

Although this mHealth intervention is focused on COPD, many HCPs illustrated the importance of considering COPD comorbidities. A nurse gave this example: 'Often it was either coronary artery disease, diabetes, hypertension. That's the group that you tend to see most often'. This thought was reinforced by others, as in this physician statement: 'nobody has one condition, right, particularly if you're looking in your, sort of, 65 plus patients, right, they're all going to have probably, in Newfoundland anyway, a minimum of three comorbidities'. Furthermore, some

nurses supported the idea of adding a glucometer or a blood pressure monitor, based on the comorbidity, to the mHealth intervention.

The majority of patients who participated in the interview had a comorbidity. Among these comorbidities were diabetes, congestive heart failure, cancer and arthritis. A patient stated, 'I am a walking disease! I have got high blood pressure, I got high cholesterol, I have got a problem with my thyroid, I have got a problem with walking. . .I have got a problem with my eyesight and hearing'.

Reminding patients to manage their COPD is a benefit. Many HCPs rationalized that the mHealth intervention should remind patients to manage their COPD. Giving patients reminders to take their medication was most frequently suggested by HCPs, especially pharmacists, as in, 'Adherence (with medications) would be a big thing because patients are not great with that so if the app had reminders, and reminders of dealing with side effects; if they need to rinse their mouth out after, or little things like that'. One nurse reinforced this notion and thought the mHealth intervention could remind patients to manage their COPD based on objective data collected by medical devices:

> *Let's say, your respiratory rate went above 28 or 30 or whatever, whatever parameters that the nurse could set. Then the patient would get some, kind of, notification to say, what am I doing or it's time for me to sit or maybe some notification, have you taken your medications today. Little reminders maybe or something that could pick up on their heart rate. And I think that might be the way of the future.*

Lastly, one nurse talked about reminding patients about refilling prescriptions and their hospital appointments 'so they know what is coming up that they are not going to miss appointments. They are going to have their appropriate test done, they are not going to miss appointments because it is already in the app. Here we have a high percentage. On average if you have a clinic of 14 patients, sometimes 2 don't come because they didn't get notifications'.

Rewarding patients for managing their COPD is a possibility. A few HCPs suggested using a reward system to motivate patients to use mHealth for COPD management. One pharmacist with experience in mHealth commented, 'rewarding people is the best way you can get people to appreciate an app…it might be rewarding just with positive reinforcement, which is if they do 3 weeks in a row of 90% adherence to therapy, they get a notification or something to say, great job, you're doing really well'. Some HCPs elaborated on using rewards to encourage patients to stop smoking or 'to reinforce adherence, proper administration of the medication and proper timing'. A pharmacist and a physician recommended a motivational app to their patients 'I've recommended a couple of patients try this Carrot app…for patients that are trying to lose weight, they could use and record their weights and probably set goals'.

There were a few features mentioned by a minority of HCPs and patients. Additional features were mentioned by a small number of HCPs. For example, one physician pointed out the use of artificial intelligence (AI) in the mHealth intervention, as in 'they always talk about how the AI's going to be, sort of, embedded in our Electronic Health Records (EHRs), and I get that and I know that that's coming'. A pharmacist expressed interest in including a feature to include visually impaired patients: 'It would help if it could talk to you because then it could be used for people with visual impairment'. One nurse with experience in conducting mHealth interventions recommended that program administrators should conduct monthly satisfaction questionnaires with patients and healthcare providers. The questions could include 'Were you satisfied? Did you follow the nurse's advice? What was the outcome? Are you experiencing any difficulties with the device?'

One nurse suggested adding information about 'interactions between their medications if they are going to get new medications, put it in and it would give them a high alert or a low alert'. Lastly, a physician had contradictory views about allowing the patient to access their laboratory test results, such as blood work: 'if patients had access to their blood work and to their reports, that could be set up so that you could only access your own personal stuff and that would then, maybe, be helpful, because the biggest problem is if something gets missed and if you have access to your own reports, that can help. The only negative of that is it causes anxiety because for a patient when you see something or you're reading

Table 3. Themes with specific examples regarding the features of the HCP interface.

Theme	Specific examples for each theme
Allowing HCPs to track their patients' management progress is important.	Tracking data, including vital signs and medication adherence, is important.
	Tips on how to present and access the data would be beneficial.
Allowing HCPs to communicate with patients and other HCPs is beneficial.	
	Automating a monthly report to be shared with the primary care physician would be helpful.
	Ability to manage requisitions and prescriptions would be beneficial.
	Opt in to receive information regarding specified criteria or variables could be helpful.
The educational component is valuable.	
Rewarding HCPs is a possibility.	Including current best practices and guidelines on COPD management would be useful.
	Delivering existing COPD adherence programs that are funded by a third party would be beneficial.

HCP, healthcare provider.

something and you really don't know what it means'.

A pharmacist and a physician expressed interest in using the mHealth intervention to aid in smoking cessation. A pharmacist describing an mHealth intervention that she recommends to patients noted, 'you put your quit day in it and it gave you some sorts of kind of rewards and sent you congratulations messages and that sort of thing. And you could go on and see how many Dollars you've saved by quitting smoking, different things that happen every day as you quit what happens in terms of improving your lung function and that sort of thing. Also when a patient was having a craving they could actually go onto the app and play a game that would distract them for a couple of minutes to allow the craving to pass'.

Patients did not recommend many features. The following patient statement represents thoughts from several other patients: 'Really, you know far more than I do in terms of what will make for a very functional set of parameters'. Some features suggested by patients were medication and sleep tracking: 'Yes I think if I sort of keep track of what I think will be my approximate amount of sleep the night before, stress levels possibly. That could be all important'.

Healthcare provider interface

Nurses, pharmacists and physicians would require an interface to engage with the patients. One pharmacist talked about including other HCPs, 'potentially other workers in the healthcare system, social workers, you know, maybe physio. So I think everybody in the healthcare system has a role to play in it and hopefully by combining that you get a more robust outcome'. Table 3 summarizes the main features recommended to assist the HCP.

Allowing HCPs to track their patients' management progress is important. All HCPs stressed the importance of using HCP interface to access the data collected from patients. Many HCPs discussed the importance of viewing information related to the patients' signs and symptoms. A nurse suggested having the ability to view 'their vitals, their levels of activity... oxygen saturation, oxygen usage, those types of things'. Other

important information that can be accessed from the HCP interface is data regarding medication adherence, as in the following pharmacist comment: 'as a pharmacist, would be useful to explore to see if there's anything we can do to help overcome barriers or facilitate adherence'. Some pharmacists felt confident that viewing data longitudinally would be valuable in choosing the right therapy, as in 'So I see the most value in the initiation or changing of therapy…If you can actually see over a period of time, well, is that helping or not, then you can make a decision whether it's actually making a difference'. Furthermore, a physician gave this example: 'What I would appreciate as a physician is seeing longitudinal progress of my patient… because I want to know, did we just have that one acute episode, was there, kind of, many acute episodes that never actually came into me'.

The following section expands on tips suggested by HCPs to synthesize the data. The following physician statement represents thoughts from several other HCPs: 'I want all the data if I'm a research scientist because I'm trying to prove something but as a clinician, I want the data that's going to impact my patient care and quality of care'. This was supported by a pharmacist, as in 'so it's having the relevant data to make the right clinical decision rather than having all the data'. To deliver the right data to HCPs, they suggested summarizing the information, as in this physician's comment:

> *There should be a way in the app to maybe synthesize it down a little bit or else you'll just have a lot of data points without much direction… so maybe highlight areas of concern and maybe highlight, like, the averages of, say, blood pressure or saturation levels, stuff like that.*

A few HCPs rationalized the use of trends and outliers, as in 'I think in the short amount of time pharmacists and physicians learn to look for specific things…you're looking for some outliers and you're looking for trends and patterns and things like that'. Some HCPs suggested using graphs to present these trends. And, a nurse commented on her patients who were enrolled in an mHealth intervention to manage COPD: 'we would set parameters, say for the oxygen saturation, if they were less than 88 it would be red on the screen. So, of course, those would be the people that you would triage and call sooner than the others to check in on them'.

Nurses, pharmacists and physicians suggested several ways to access the data collected by mHealth interventions. Some HCPs posited that they should be able to access the data through electronic medical records (EMRs). A pharmacist proposed, 'if there's a possibility, even securely, to be able to take that information and put it in the EMR securely'. Another method of accessing mHealth data with HCPs is *via* the patient's phone. A pharmacist with experience in mHealth observed, 'I've had a couple of patients now who brought in their app and opened it up and I could look at their history and the results and I would go through it with them and it works great because I could tell them right there'.

Allowing HCPs to communicate with patients and other HCPs is beneficial. The HCP interface could be used to enhance communication between HCPs. When asked about the current practice regarding communication with physicians and specialists, one nurse who was monitoring patients through mHealth stated that patients identified their PCP during enrolment. Then, 'once a month we will send out their PCP a monthly report of the biometric readings. If a patient is going to a GP or a respirologist and there's a concern that we have regarding their current health status with their COPD, we will do that letter and fax it to their appointments along with their biometric readings'. This thought was reinforced by others, as in this pharmacist's statement, 'if a pharmacist was kind of monitoring this and they were able to kind of do up like a consult letter kind of to send to the physician before the patient went to their physician, that would definitely be beneficial'. A nurse talked about streamlining patient requisitions *via* the HCP interface: 'if we were able to have patient requisitions ahead of time… that could cut out a visit and just a follow-up phone call for results, reports, treatment, if necessary'.

Some HCPs put forward a feature that would allow them to opt in and receive a notification based on set criteria. A few HCPs stated that this could enable the HCP to 'receive the alerts if they (patients) are then outside preset parameters'. When setting parameters, one nurse with experience in mHealth stressed the importance of 'realistic parameters for readings so that our patients are not alerting constantly'. Some pharmacists recommended getting a notification for medication adherence, as in 'getting a notification, like, for 2 weeks of missed therapy, would be very interesting to me'.

To follow up on these notifications, a nurse commented on her patients who were enrolled in an mHealth intervention for COPD management

> *We would phone them or they would phone us if need be. It would be patient-specific for sure. Somebody who is well, somewhat well, who didn't do a session for a couple of days, maybe we'd let it slide. But somebody who had been unwell for a few days and if they didn't do their health session, say by mid-morning, maybe you'd might call them and say, are you okay? What's going on?*

Similarly, a physician with experience in mHealth interventions noted, 'ensure that whatever is going on with the patient there's an ability for them to have someone to have access to reassure them if they get upset'.

The educational component is valuable. A few pharmacists and physicians recommended including current best practices and guidelines on COPD management. A physician reported: 'would need to have an educational component, guidelines, you know, to remind me, of the Primary Care Guidelines. . .'.

Rewarding HCPs is a possibility. The HCP interface can be used to deliver existing COPD adherence programs that are funded by the government or insurers. For example, pharmacists in Newfoundland get a time reimbursement if they complete the COPD adherence initial and follow-up consultations. One pharmacist indicated that the program is underused because of the time required to determine eligible patients and remember to follow up with them, as in

> *This is paid intervention, but the uptake is next-to-nothing because it is so hard to manage… For us to try to remember all that and remember to go get a manual form on top of that, it's tough…I need to manually remember within two weeks and go through these lists of questions. And then, within two months afterwards, which is even harder…I don't remember what I had for breakfast, let alone in two months, to call a person and do this again.*

The pharmacist surmised that the uptake of the medication adherence program would be higher if it was automated *via* an mHealth intervention 'there's nothing like incentivizing a pharmacist to say this is a good technology for you because it will make this program very easy…if this were automated for a pharmacist, the likelihood of doing this type of a follow-up would be much higher'.

Discussion

Principal findings

This qualitative study found that HCPs and patients had several recommendations regarding the content of an mHealth intervention to assist in the management of COPD. Potential users brought forward several components that could support them in the future. The components of the patient interface include access to educational materials, COPD action plan, reminders about COPD management activities and positive reinforcement. The mHealth intervention should have the ability to collect subjective and objective data, to track COPD management and allow family members or caregivers to access the self-management information. These components should be optional, based on the patient's needs. The information collected from the patient should be shared with HCPs *via* the HCP interface. The HCP interface should have the ability to track the patient's progress, communicate with patients and positive reinforcement for HCPs. It could also include educational materials for HCPs. This interest and the numerous suggestions from HCPs and patients with COPD indicate the readiness for using mHealth for COPD management.

To optimize the successful implementation of mHealth interventions, it is important to consider the perceived facilitators and barriers to mHealth adoption for COPD management that were published by our research group.[52,53] The main facilitators to mHealth adoption are possible health benefits for patients, ease of use, educating patients and their HCPs, credibility and reducing the cost to the healthcare system. Alternatively, the barriers to adoption are technical issues, privacy and confidentiality issues, lack of awareness, lack of interest, potentially limited uptake from the elderly, potential limited connection between patients and HCPs and finances.[52,53]

Our thoughts, based on the data, are that both HCPs and patients recommend tailoring the mHealth intervention based on the patient's unique needs and preferences. The mHealth intervention could potentially enhance COPD management using several features; most

importantly, by collecting relevant subjective and objective data then using them to tailor COPD management based on the patient's unique needs. This collaborative and human-centred approach is not feasible without having an HCP interface to communicate and monitor the patients.

Comparison with prior work

Our study provides a novel and meaningful contribution to the literature. A few prior studies have specifically examined the features of mHealth among potential users, but in this case, we included HCPs and patients with COPD. We included consideration regarding an HCP interface that has not been reported previously in the context of mHealth for COPD management. In addition, we discussed the use of compatible medical devices for COPD management.

Some of the features presented in this study confirm findings by previous research, such as the importance of education, self-monitoring, reminders and communication between patients and HCPs.[38,40,59,60] In addition, we identify other potentially useful functions such as using various medical devices, including family members, and rewarding patients and HCPs. Previous researchers recommended including a larger sample of HCPs with more mHealth experience in future studies.[38]

Collecting baseline information was recommended by many HCPs. This information is vital for tracking patients' progress, and it can also be used for health research. Many researchers are utilizing smartphones for health research.[61] Data collected *via* mHealth can be paired with other data sources from the patient's medical records or genetic makeup to expand our understanding of the etiology of COPD.

As suggested by Kim and Lee,[59] patients and HCPs should support the use of medical devices that automate data generation and transmission, as this could lead to increased compliance with the mHealth intervention. We elaborate on the use and frequency of several devices relevant to COPD management, including spirometers, pulse oximeters and medication adherence devices. Nuvoair® and AioCare® are two examples of portable spirometers that could be beneficial for COPD monitoring. The use of a patch biosensor, VitalPatch®, for measuring vital signs continuously could be beneficial for continuous unobtrusive patient monitoring.[62] Other researchers are proposing the use of a vest to monitor several vital signs.[63,64]

Advancements in mobile technology have improved how we track and enhance medication adherence. Both AiCure® and emocha mobile health® utilized AI technology for facial recognition to determine if a patient takes and swallows medication.[65,66] Furthermore, a few companies such as propeller health®, Adherium® and Cohero Health® are manufacturing medication adherence devices to provide an objective measure of adherence.[67–69] These medication adherence devices have the potential to be used in assisting with improving the technique of inhaled medications.[70]

A recurrent need was that mHealth interventions can be used to deliver an action plan to assist in COPD management. However, Korpershoek *et al.*[38] stated that providing medical advice through mobile devices can be unsafe due to the large heterogeneity in patients and symptoms. Recent studies have shown that a machine-learning approach has the potential to assist in the management of COPD.[71,72] While the action plan could increase patient autonomy, it will need extensive research on its safety, efficacy and implications for COPD management.

Our findings are in agreement with Korpershoek *et al.*,[38] who stated that patients' needs regarding COPD management vary widely. The need for personalization, stemming from the individuality of patients, is an important finding. We expand on these findings by including data from both HCPs and patients about their preferences regarding the potential frequency of entering information, follow-up and performing medical tests *via* compatible medical devices.

Some HCPs recommended using the mHealth intervention to remind patients about their appointments. The mHealth intervention could be used to automate scheduling and to remind patients about their appointments. Furthermore, Leavens *et al.*[73] stated that rideshare services *via* smartphones may represent a relatively low-cost means for increasing study retention. Similarly, these ridesharing services can be integrated into the mHealth intervention to avoid missed appointments. Other researchers also found that rewarding patients *via* self-affirmations can

successfully increase adherence to recommended health goals in the context of an mHealth app.[74]

Sobnath *et al.*[40] systematically reviewed the literature and app stores to identify features that can be considered in the initial design of a COPD support tool to improve healthcare services and patient outcomes. Features such as a social networking tool, personalized education, feedback, e-coaching and psychological motivation to enhance behavioural change were found to be missing in many of the downloaded apps.[40] A recent systematic review highlighted the effectiveness of mHealth apps that use Cognitive Behavioral Therapy principles.[75] Another important feature for a COPD support tool is the self-management of physical activity. Improvement of physical activity levels can result in better physical functioning, less dyspnoea, higher quality of life and lower risks for exacerbation-related hospitalization and mortality.[40]

To stimulate information exchange between patients and HCPs, we included features of an HCP interface. Our findings echo some of the HCP interface features reported by Sobnath *et al.*,[40] which include monitoring medication adherence and other features such as device tracking, patient training, managing clinic visits and providing advice on lifestyle management. Korpershoek *et al.*[38] found that both patients and their HCPs have doubts regarding information exchange between patients and HCPs through mobile devices. However, they did not expand on these doubts. We included qualitative quotes to expand on these insights.

Strengths and limitations

This study has several strengths. First, this research is based on a diverse sample of participants. It includes various perspectives by presenting the views of patients, nurses, pharmacists and physicians, including a respirologist. This human-centred approach ensures that the needs and challenges of different people involved in the management of COPD can be considered before developing an mHealth intervention. Second, some participants had experience in using an mHealth intervention to manage COPD, which further increases the richness of the data. Third, all the interviews were conducted in a similar manner to ensure consistency during the data collection and analysis. Finally, mHealth is particularly important in geographic locations with a relatively large proportion of rural residents such as Newfoundland and Labrador. mHealth may enhance care provider access throughout sparsely populated rural areas. Newfoundland and Labrador have a substantial remote and rural population; therefore, our results may be more applicable to rural areas.

There were also several limitations. First, not all participants had experience with using mHealth. Thus, the perceptions of these participants were not based on actual interventions with patients. Second, we used only one data collection method, thus data collection was not triangulated. Conducting focus groups with some of the participants following the individual interviews could have yielded richer information, as participants would have been given the opportunity to compare their thoughts and confirm or expand upon each other's ideas. This would be a recommendation for a future study.

Implications for practice and recommendations for future research

The findings of this study provide valuable insights regarding the features of an mHealth intervention for COPD management. These findings may help various stakeholders who are planning to use mHealth interventions for COPD management.

Future studies would benefit from conducting focus groups with some of the participants following the individual interviews. Focus groups could yield richer information, as participants would be given the opportunity to compare their thoughts and confirm or expand upon each other's ideas. Furthermore, including the perspectives of allied HCPs, such as physiotherapists, social workers and occupational therapists, would be beneficial to understand the perspectives of administrators (e.g. information technology managers) who may be able to identify some of the challenges with using mHealth for COPD management. After developing a prototype of these human-centred components, the authors recommend using a mixed methods framework for usability testing.[76]

Future mHealth studies should explore the utility of the mHealth intervention in reducing exacerbations, reducing hospitalizations and improving the quality of life for patients with COPD.

Specifically, additional research is required to investigate the effectiveness and safety of the mHealth intervention in COPD management. Similar to the scoping review conducted by Hallensleben *et al.*,[77] it may be relevant to conduct scoping reviews on COPD apps in other countries. That could help in establishing guidelines to tailor components of the mHealth intervention, frequency of contact and reminders. Lastly, cost-effectiveness analysis is required to assess the impact of mHealth interventions on healthcare resources.

Conclusion

Advances in smartphones, wearables and other smart devices align well with the developing interests of using mHealth to assist in the management of COPD. Although there is interest in applying mHealth for COPD management, little attention has been paid to HCD features by future users of mHealth. The findings of this study suggest that COPD patients and their HCPs are receptive to using an mHealth intervention with multiple evidence-based components to manage COPD.

The components of the patient interface include access to educational materials, COPD action plan, reminders about COPD management activities and positive reinforcement. The mHealth intervention should have the ability to collect subjective and objective data, to track COPD management and allow family members or caregivers to access the self-management information. These components should be optional, based on the patient's needs. The information collected from the patient should be shared with HCPs *via* the HCP interface. The HCP interface should have the ability to track the patient's progress, communicate with patients and positive reinforcement for HCPs. It could also include educational materials for HCPs. These human-centred features may aid in the successful implementation of mHealth interventions for COPD management. We recommend that those who develop mHealth interventions for COPD should consider the components highlighted in this study. Lessons from this study may also be applied to other chronic diseases.

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Author contribution(s)

Meshari F. Alwashmi: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Validation; Visualization; Writing-original draft; Writing-review & editing.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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Supplemental material

The reviews of this paper are available via the supplemental material section.

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Appendix 1: HCP interview prompts

A: HCPs

- Date and place
- Age and experience from general practice
- Job title

General perceptions

- Tell me a little bit about your experience with patients with COPD.
- What are the likely treatment outcomes?
- Do you know what mHealth is?

Facilitators

- Have you used mHealth before? (if no, go to barriers).
- Tell me about a situation when you have tried to use mHealth in your practice.
  - Why this episode?
  - What did you use it for?
  - What data did you collect?
  - How often?
- What motivated you as a healthcare provider to use mHealth?
- What elements of the intervention do you think are most important?
- Did you do any preparation before using mHealth to manage COPD?
- What is necessary for you to obtain knowledge/experience and keep up to date about mHealth?

Barriers

- What is limiting you from using mHealth in your practice?
- What difficulties have you experienced when using mHealth?
- How did you solve it?
- Were there any challenges?
  - (financial, employees, technical)?
- Did you experience changes in the contact/bond with the patient?
- Do HCPs require education before use and how did that happen in the past?
- Do patients require education before use and how did that happen in the past?

mHealth in COPD management

- Do you see a role of mHealth in COPD management?
  - how do you feel about apps used in COPD management?
- Could you tell me about whether you would be interested in using it?
- How do you perceive using mHealth to manage COPD?
- What information do you want to collect from the patient?
  - Education (how often)
  - Survey (how often)
  - Care plan
  - Compatible medical devices (e.g. spirometer, pulse oximeter, medication adherence device)
- What else would you like it to do?
- What would you change, take away or add?
- What about any problems or concerns you can see with this?
- How does mHealth affect the current COPD management process?
- Did you have to do any practical changes in consultations to enable the intervention (time, follow-ups, other)?
- How about viewing large amount of data, for example, heart rate, spirometry, survey?
- Does your patients see a role of mHealth in COPD management?
- How does your patients perceive using mHealth to manage COPD?

- Who do you think can be a candidate for this intervention? (What is it about the patient that makes them suitable or not?)

Final questions

- Would you recommend mHealth to a colleague?
  - if so, what would you emphasize?
- Would you like to add anything?
- Would you like to elaborate on anything I asked?

Thank you for participating in this study, your answers to these questions are very important to us, and we really appreciate you taking the time to complete this interview. Please contact me if you have any questions or would like to discuss this topic further.

Appendix 2: Patient interview prompts

- Date
- Years living with COPD

General perceptions

- Tell me a little bit about your experience with COPD?
- How do you know if your COPD is getting worse?
- How do you manage it?
- Do you have other chronic diseases besides COPD?
- How do you manage it along with your COPD?
- How many medications do you take?
- How do you remember when to take it?
- Do you own any health devices (e.g. spirometer, blood pressure monitor)?
- How often do you use it?
- Does it connect to your smartphone?
- What type of phone do you have?
  - How did you learn how to use it?
  - Do you live with someone who knows how to use it?
  - Does your friends/ family use a smartphone?
  - Do you know what a smartphone 'app' is?
  - Do you use apps on your smartphone?
  - In the past 12 months, did you use health-related apps on your smartphone?
  - Did you access the Internet from your phone during the past 12 months?

Facilitators

- Do you know what mHealth is? (using a phone to improve your health)
- Have you used mHealth before? (if no, go to barriers).
- Tell me about a situation when you have tried to use mHealth/telehealth.
  - Why this episode?
  - What did you use it for?
  - What data did you collect?
  - How often?
- What motivated you to use mHealth?
- What elements of the intervention do you think are most important?
- Did you do any preparation before using mHealth to manage COPD?
- What is necessary for you to obtain knowledge/ experience and keep up to date about mHealth?

Barriers

- What is limiting you from using a smartphone?
- What is limiting you from using mHealth?
- What difficulties have you experienced when using mHealth?
- How did you solve it?
- Were there any challenges?
  - (financial, employees, technical)?
- Did you experience changes in the contact/ bond with your healthcare provider?

mHealth in COPD management

- Do you see a role of mHealth in COPD management?
- How do you feel about apps used in COPD management?
- What features do you want the app to include?
  - Education (how often)
  - Survey (how often)
  - Care plan
  - Compatible medical devices (e.g. spirometer, pulse oximeter, medication adherence device)
  - Health coach
- What else would you like it to do?

- How often do you think you would you use it to manage your COPD?
- Could you tell me whether you would be interested in using it?
- What about any problems or concerns you can see with this?
- Would you be comfortable allowing a family member or friend to access health-related information that you shared in an app? Why/why not?
- Would you be comfortable allowing your family doctor or other healthcare professionals to have access to your health information that you shared in an app? Why/why not?
- How does mHealth affect your current COPD management process?
- How about viewing a large amount of data, for example, heart rate, spirometry, survey?
- Does your healthcare provider see a role of mHealth in COPD management?
- How does your healthcare provider perceive using telehealth/mHealth to manage COPD?

Final questions

- Would you like to add anything?
- Would you like to elaborate on anything I asked?

Thank you for participating in this study, your answers to these questions are very important to us, and we really appreciate you taking the time to complete this interview. Please contact me if you have any questions or would like to discuss this topic further.