Perspectives of patients and healthcare professionals on mHealth for asthma self-management

Andrew J Simpson[1], Persijn J Honkoop[2], Erika Kennington[3], Jiska B Snoeck-Stroband[2], Ian Smith[2], Jessica East[3], Courtney Coleman[3], Ann Caress[1], Kian Fan Chung[4], Jacob K Sont[2], Omar Usmani[4], Stephen J Fowler[1].

[1] Division of Infection, Immunity and Respiratory Medicine, School of Biological Sciences, The University of Manchester and University Hospital of South Manchester NHS Foundation Trust, UK

[2] Dept. of Medical Decision Making, Leiden University Medical Center, Leiden, the Netherlands

[3] Asthma UK, London, UK

[4] National Heart and Lung Institute, Imperial College London & NIHR Biomedical Research Unit, Royal Brompton & Harefield NHS Trust, London, UK

Correspondence to: Dr Andrew Simpson, Division of Infection, Immunity and Respiratory Medicine, University Hospital of South Manchester, Education and Research Centre (2nd Floor), Southmoor Road, Manchester M23 9LT Andrew.Simpson-2@manchester.ac.uk

Take home message

People with asthma and healthcare professionals provide strong support for mHealth for asthma self-management.

ABSTRACT

Rationale: mHealth has the potential to revolutionise the self-management of long-term medical conditions such as asthma. A user-centred design is integral if mHealth is to be embraced by patients and healthcare professionals. **Objective:** Determine the perspectives of individuals with asthma and healthcare professionals on the use of mHealth for asthma self-management. **Methods:** A sequential exploratory mixed methods design was used; focus groups informed the development of questionnaires, which were disseminated to individuals with asthma and healthcare professionals. **Results:** Focus group participants (18 asthma patients and five healthcare professionals) identified 12 potential uses of mHealth. Questionnaire results showed that individuals with asthma (n=186) most frequently requested a mHealth system to monitor asthma over time (72%) and to collect data to present to healthcare teams (70%). In contrast, a system alerting patients to deteriorating asthma control (86%) and advising them when to seek medical attention (87%) was most frequently selected by healthcare professionals (n=63). Individuals with asthma were less likely than healthcare professionals ($P<0.001$) to believe that assessing medication adherence and inhaler technique could improve asthma control. **Conclusion:** Our data provide strong support for mHealth for asthma self-management, but highlight fundamental differences between the perspectives of patients and healthcare professionals.

INTRODUCTION

Asthma affects approximately 300 million people worldwide [1]. In many cases asthma control remains suboptimal and avoidable deaths are still occurring [2]. Asthma self-management has beneficial health outcomes such as reduced hospital admissions, better lung function, fewer asthma symptoms and less use of rescue medication [3-6]. Asthma guidelines recommend that all people with asthma receive education on asthma self-management [7, 8].

Traditional asthma self-management programs utilise personal asthma action plans, which involve the monitoring of symptoms and/or peak flow, with a written action plan detailing how to recognise and respond to worsening asthma. This 'pen and paper' approach is burdensome and time consuming and neither patients nor healthcare teams are enthusiastic about their use [9]. Furthermore, action points based on rudimentary data, such as symptoms and peak flow, may be less effective than action points based on multiple personalised parameters [10]. Despite important benefits of self-management, only 27% of adults with asthma receive an asthma action plan [11] and patients' adherence to written action plans is poor [12].

Web-based systems offer less burdensome self-management support, which may improve asthma outcomes [13]. Nowadays, smartphones have become an integral part of life and mobile healthcare (mHealth) systems are promising tools that may revolutionise asthma self-management. There are over 200 mobile phone applications for asthma [14] and supplementary wearable and inhaler based devices are widely available [15]. Currently, however, the utility of mHealth for asthma self-management is unknown and a recent Cochrane review was unable to advise clinicians and the general public on their efficacy [16]. Investigations into successful mHealth systems point to user-centred design practices [17]. In terms of asthma-self management however, there is little evidence of user-centred design

practices and no data exploring the perspectives of both end-users (i.e., patients and healthcare professionals).

The current investigation is part of the myAirCoach project, supported by the European Union's Horizon 2020 Framework Program for Research and Innovation. This project aims to create a user-centred mHealth tool to support the self-management of asthma. Understanding patients' and healthcare professionals' perspectives is a fundamental step in the development of user-centred mHealth systems. Therefore, the present study was conducted to determine the perspectives of individuals with asthma and healthcare professionals on the use of mHealth systems to support asthma self-management. Specifically, we aimed to determine end-user: i) experiences and perceived uses of mHealth systems for asthma self-management; ii) views of what measurements would be useful in managing asthma; and iii) perspectives on the acceptability of and barriers to using mHealth systems for asthma self-management.

METHODS

Study design

We employed a sequential exploratory mixed methods design [18], in which qualitative exploration (using focus groups) informed instrument development for a subsequent electronic questionnaire, with findings from both data sources integrated.

Focus groups

One moderator guided each focus group, following the approach from Greenbaum [19], according to a structured schedule of topics (table 1); the content of which was determined via consultation with the myAirCoach collaborators (www.myaircoach.eu) and a patient advisory group. Three focus groups were conducted with individuals with asthma, in Manchester (UK), London (UK) and Leiden (the Netherlands), and one focus group was conducted with healthcare professionals in Manchester (UK). The focus groups were video-recorded, transcribed, translated where appropriate and underwent Framework Analysis [20]. Data were grouped under emergent themes and integrated into three pre-determined core categories, relating to the research aims. Data management was supported by NVivo qualitative analysis software (Version 10).

Individuals aged ≥ 18 years who were patients with doctor-diagnosed asthma or a healthcare professional involved in the treatment of asthma were eligible to participate in the focus groups. Patients were recruited from respiratory clinics in Manchester and Leiden, and via advertisements placed online at Asthma UK's website. Healthcare professionals were recruited from hospital respiratory departments in Manchester.

Table 1. Focus group topic guide for people with asthma and healthcare professionals

Topic 1. Experiences and perceived uses of mHealth for asthma
– Example prompts: Have you previously used mHealth systems to help manage your/your patients' asthma? What would you consider would be a useful purpose of a mHealth system with regards to your/your patients' asthma?
Topic 2. Potential useful measurements for mHealth
– Example prompts: What physiological, behavioural and environmental measurements could help you manage your/your patients' asthma?
Topic 3. Burden and barriers of mHealth
– Example prompts: What would prevent you from using mHealth systems?
Topic 4. Alerts and reminders
– Example prompts: Is there any part of your/your patients' asthma management that is often forgotten?
Topic 5. User feedback and support
– Example prompts: What type of support would you like? Examples include; intuitive interfaces with information about asthma, FAQs, access to GP, specialist asthma nurse, speak to other users
Topic 6. Privacy
– Example prompts: How would you feel about personal medical data being stored on a mobile device / being data shared with your healthcare team and/or medical researchers?
Topic 7. Product design
– Example prompts: What design aspects would you accept/find unacceptable? Would you consider carrying an additional device(s)?

Questionnaires

A long-list of questions was generated following analysis of the focus group transcripts. The clinical research team and members of the hospital's patient and public involvement team (including a patient representative) assessed the questions for face validity and bias. The importance of each question was then ranked and the number of items reduced to generate a 20-item questionnaire for people with asthma and 10-item questionnaire for healthcare professionals. The questionnaires were different for people with asthma and healthcare professionals, but contained some identical questions to allow comparisons between groups. As mHealth systems may provide multiple functions relevant to patients and healthcare

professionals, we did not impose any restrictions on the number of responses that could be selected by participants and all responses were given equal weighting.

Individuals with asthma and healthcare professionals completed the questionnaires via an online survey platform (www.surveymonkey.com), over a two-week period in December 2015. A hyperlink to the online survey was included on adverts placed online at Asthma UK and the European Commission websites and via Asthma UK's and European Federation of Allergy and Airways Diseases Patients' Associations (EFA) social media channels. Healthcare professionals from the North West Severe Asthma Network and the North West respiratory postgraduate contact list were invited via e-mail to complete the online questionnaire. For purposes of characterising the sample, individuals with asthma completed the Asthma Control Questionnaire (ACQ); a score of ≥1.5 defined uncontrolled asthma and <1.5 was classified as controlled or partly controlled asthma [21]. Chi-square tests identified differences in response frequency between individuals with asthma and healthcare professionals and between individuals with controlled (including partly-controlled) and uncontrolled asthma, using a statistical software package (SPSS, version 22.0). Significance was set at $P<0.05$.

Data integration

Qualitative focus group data and quantitative results from the questionnaires were integrated under three core categories. Focus group quotes relating to questionnaire data were identified and used to illuminate and complement and/or contrast the quantitative results.

Ethics

An NHS research ethics committee (15/EM/0360) and the ethics committee of Leiden University Medical Centre (P15.195) approved this study and participants gave informed consent.

RESULTS

Participant characteristics

Eighteen individuals with asthma (nine females) and five healthcare professionals (two medical doctors, two asthma nurses and a physiologist) participated in the focus groups. One hundred and eighty-six individuals with asthma completed the questionnaire; mean ± SD age 40 ± 16 years, 135 females, and 91 with uncontrolled asthma. Sixty-three healthcare professionals completed the questionnaire, including 31 general practitioners, 13 hospital doctors, eight asthma nurses, and 11 from other healthcare disciplines.

Core category 1: Experiences and perceived uses of mHealth for asthma self-management

The experiences of individuals with asthma of using mHealth varied considerably, with some participants reporting no experience of using mHealth for their asthma and a few participants reporting considerable experience with multiple devices. Healthcare professionals' experiences with mHealth systems were limited to their use during research projects. The types of mHealth systems that participants had experience with are presented in table 2.

Table 2. Emergent themes identified in focus groups with people with asthma (n=18) and healthcare professionals (n=5) integrated under core categories

	Emergent themes
Core category 1	
Experience of mHealth	Experience with applications for: nutrition analysis, inhaler (medication) monitoring, activity level monitoring, lung function (peak flow) monitoring, mental health, environmental monitoring (e.g., pollution and pollen), and asthma diary.
Potential uses of mHealth	Replace check-ups, advise when to seek medical attention, monitor asthma over time, collect data to present to healthcare team, alerts to deterioration in asthma control, use as an asthma action plan, provide education materials, instructions on how to manage an asthma attack, a system to call for emergency help, a system to update medical records, a system to record side-effects and a system to determine medication effectiveness.
Core category 2	
Useful measurements	Environment conditions (e.g., pollution, allergens (pollen), temp), lung function (e.g., peak flow and measurements of airway inflammation), breathing (e.g., breathing rate and details of how often you cough), heart rate and activity levels, stress level, medication adherence, inhaler technique, diet, quality of sleep, self-reported symptoms.
Useful alerts	Medication running low, using their medication too much, they have not taken their inhaler, they are using their inhaler incorrectly, lung function is getting worse, pollution level in their area is high, pollen/ allergen levels in their area are high, temperature/ humidity in their area is high/ low
Core category 3	
Acceptability and barriers	Usability, product design, privacy, time, personalisability, human contact, data usefulness (e.g., reliability, interpretation and subjectivity), cost, mobile compatibility, medication compatibility.

Focus group participants identified twelve potential uses of mHealth systems for asthma self-management (table 2). These proposed uses were developed into an item on each questionnaire relating to: i) functions individuals with asthma would like from mHealth; and ii) functions that healthcare professionals believed would be useful (table 3).

Patients most frequently requested an mHealth system to monitor asthma over time (72%) and to collect data to present to healthcare teams (70%), table 3. This may relate to difficulties that patients have recalling symptoms and conveying these to their healthcare teams, as illustrated by quote 1.1 (table 4). Discussions with healthcare professionals revealed that if a patient presented them with data on an mHealth system that they would find this useful and one healthcare professional suggested that it might empower their patients, quote 1.2 (table 4).

Functions alerting patients to deteriorating asthma control (86%) and advising when to seek medical attention (87%) were most frequently selected by healthcare professionals (table 3). Focus group data highlighted that mHealth could prompt patients to seek medical attention sooner, quote 1.3 (table 4). Support for these functions amongst individuals with asthma was also high (table 3) and comments in the focus group discussions were broadly aligned with those of the healthcare professionals, quotes 1.4 and 1.5 (table 4).

A recurring theme in the focus group discussions was the potential to incorporate asthma action plans into mHealth. The preference of mHealth over the traditional 'pen and paper' approach may be linked to the increased convenience/accessibility of mHealth, quote 1.6 (table 4). In the questionnaires, 46% of patients and 79% of healthcare professionals ($P<0.001$) answered that they would like or find it useful to have an asthma action plan incorporated into a mHealth system. The reason behind the greater support from healthcare professionals was not apparent in the focus group discussions.

Some of the proposed uses for mHealth systems that originated in the focus group discussions received less support from the questionnaires. In the focus groups several patients voiced frustrations about attending routine asthma check-ups and proposed mHealth as a possible replacement, quote 1.7. However, in the surveys only 25% of patients and 33% of healthcare professionals indicated that they would like or find it useful for a mHealth system to replace routine asthma check-ups.

Table 3. Questionnaire results: what individuals with asthma would like from a mHealth system and what healthcare professionals believe would be useful functions

Response options	Asthma (%)	HCPs (%)	P	Asthma		P
				Uncontrolled (%)	Controlled (%)	
A device/ system that could replace routine (e.g., annual) asthma check-ups	25	33	0.21	**12**	**40**	**<0.001**
A device/system that offers advice regarding when additional medical attention should be sought	**49**	**87**	**<0.001**	56	44	0.12
A device/ system to help patients monitor their asthma over time	72	81	0.14	77	66	0.12
A device/ system to collect data that patients can show their doctor/healthcare professional, to demonstrate how their asthma has been	70	78	0.30	71	67	0.57
A device/ system that detects and alerts patients and/or healthcare professionals to a deterioration in their asthma control before they would normally notice	**69**	**86**	**0.01**	75	64	0.18
A device/ system for patients to use as their asthma action plan	**46**	**79**	**<0.001**	53	40	0.08
A device/ system to offer educational materials about asthma	**22**	**73**	**<0.001**	25	17	0.21
A device/ system that provides instructions on how to manage their asthma in an emergency	**45**	**81**	**<0.001**	47	44	0.68
A device/ system that can be used to call for emergency help during an asthma attack	49	52	0.69	52	49	0.71
A device/ system that can take measurements and update a patient's medical record	53	51	0.80	56	49	0.34
A device/system to record treatment side-effects	44	37	0.29	46	44	0.79
A device/ system that can tell if changes to patient's asthma medication has improved their asthma control	**36**	**76**	**<0.001**	**45**	**28**	**0.02**

Asthma, people with asthma (n=186); HCPs, healthcare professionals (n=63); Uncontrolled, individuals with an asthma control questionnaire (ACQ) score ≥ 1.5 (n=91); Controlled, individuals with ACQ score <1.5 (n=86).

Table 4. Selection of supporting quotes

Quote Nº	Selected quotes
	Core category 1
1.1	"It would be handy having an app so that you can monitor (asthma) yourself… to show your consultant and respiratory nurse exactly how your asthma has been… because often when they ask you can't remember". [Patient #7, London]
1.2	"It's a very powerful tool to be able to show (patients) the data and say this is what is happening… rather than just saying you've got to keep taking your medication... you are empowering them with their treatment". [HCP #3]
1.3	"A little bit of a prompt to say that at these levels maybe you should be seeking medical attention, this would be helpful because then they may attend the accident and emergency department a little bit sooner". [HCP #2]
1.4	"Things sometimes get worse and I don't necessarily notice them and, therefore, I let them get worse. It would be nice if I could monitor it and see trends in different things and address them" [Patient #4, London]
1.5	"I have had that moment, where you think at what point do I call an ambulance... I would like to be able to hit a button and it says this is what you should be doing" [Patient #3, London]
1.6	"If you could have your asthma check-up and plug in your asthma action plan values into something... that's a much better way of helping people stay in control than a piece of paper, that when they come back from the doctors they put down and don't touch again until the next asthma check" [Patient #3, Manchester]
1.7	"I really dislike going to my asthma check-up when I am pretty sure it is fairly well controlled anyway…. I go and they tell me what I already know… it would be nice if a device could feedback to the nurse and they could let me know when I should get a check-up". [Patient #2, London]
	Core category 2
2.1	"My peak flow tends to go down and then I get worse… even if I don't feel bad, my peak flow will be lower than it should be" [Patient #7, London]
2.2	"On the written asthma action plans, it says if my peak flow drops below 'X' then I should do this with my medication... so it is useful for that" [Patient #3, London]
2.3	"If it's going to be a high pollen count, I will arrange to go out in the evening or very early in the morning and avoid that part of the day... air quality is something that's a bit more difficult to avoid, but it's useful to know and may influence whether I go for a run today or whether I wait until tomorrow" [Patient #4, Manchester]
2.4	"The amount of times I rush through it [taking my inhaler]… I don't feel like I am getting the benefit from it" [Patient #4, London]
2.5	"Patients are on step four or five treatment but can't take an inhaler correctly… it is frightening that they are being referred to us for more invasive treatments" [HCP #1]
	Core category 3
3.1	"Not all of the asthmatic patients have the same symptoms… I think you need to individualise the symptoms and what is measured to every patient separately" [HCP #5]
3.2	"I don't want to measure all those things… if it is one or maybe two things I might, or if you could personalise it to what is relevant to you, but I'm not going to measure all of those things" [Patient #2, London]
3.3	"If it is automatically on your inhaler and it measures and gives you feedback, perfect… if I have to get a separate device out to measure it, then I would probably use it less" [Patient #7, Leiden]

3.4	"I just don't like subjective questions. I don't remember how bad 'bad' was last time I selected bad" [Patient #2, London]
3.5	"If something is wearable and discreet, I would definitely go for something like that. If it is bulky and very visible, then maybe not" [Patient #4, London]

HCP, healthcare professional

Core category 2: Useful measurements for managing asthma

The focus group discussions highlighted many measurements that participants believed could provide support for the self-management of asthma (table 2); these were developed into items on the questionnaires (table 5).

Lung function measurements (71%) were commonly identified as being helpful to maintain asthma control (tables 5). This was linked with patients' perception of a connection between asthma control and lung function and when to take appropriate action, quotes 2.1 & 2.2 (table 4). Additional physiological parameters identified as being useful for asthma control included: resting heart rate, breathing rate, stress levels, sleep quality and diet. These measurements were given varying, but usually modest, support from the questionnaire data (table 5).

Measurements regarding environmental conditions were believed to be helpful for asthma self-management by 71% of individuals with asthma and 68% of healthcare professionals (table 5). Focus group data suggest that environmental alerts may affect individuals' behaviours, quote 2.3 (table 4).

Both individuals with asthma and healthcare professionals identified the negative impact of incorrect inhaler technique and provided support for their integration into mHealth, quotes 2.4 & 2.5 (table 4). However, survey data highlighted a notable contrast in the results, with a significantly higher proportion of healthcare professionals compared with patients believing measuring inhaler technique (87% vs. 43%, $P<0.001$) and medication adherence (89%, vs. 48%, $P<0.001$) would be helpful for asthma control.

Table 5. Questionnaire results: Which of the following measurements do you think could help you/your patients achieve better asthma control?

Response options	Asthma (%)	HCPs (%)	P	Asthma		P
				Uncontrolled (%)	Controlled (%)	
Measurements of environment conditions (e.g., pollution, allergens, temperature and humidity)	70	68	0.81	75	65	0.16
Measurements of lung function (e.g., peak flow and measurements of airway inflammation)	71	75	0.58	71	70	0.82
Measurements of breathing (e.g., breathing rate and details of how often you cough)	64	60	0.60	68	60	0.29
Measurements of heart rate and activity levels	46	37	0.18	49	43	0.39
Measurements of stress levels	**53**	**37**	**0.03**	57	49	0.27
Measurements of medication adherence	**48**	**89**	**<0.001**	52	44	0.32
Measurements of inhaler technique	**42**	**87**	**<0.001**	43	43	0.98
Measurements of diet	32	32	0.94	36	24	0.09
Measurements of quality of sleep	54	44	0.20	58	48	0.16
Measurements of self-reported symptoms	**34**	**57**	**<0.001**	40	30	0.19

Asthma, people with asthma (n=186); HCPs, healthcare professionals (n=63); Uncontrolled, individuals with an asthma control questionnaire (ACQ) score ≥ 1.5 (n=91); Controlled, individuals with ACQ score <1.5 (n=86).

Core category 3: Acceptability of and barriers to using mHealth systems for asthma self-management

Table 2 summarises perspectives on the acceptability of and barriers to the use of mHealth systems. The ability to personalise mHealth systems was a consistent subcategory across all focus groups. Discussions highlighted that different populations, e.g., children, the elderly and people with differing asthma severity, have different user-requirements. Furthermore, it was proposed that mHealth systems may need to be personalised at an individual level, quote 3.1 (table 4). One participant with asthma suggested that measuring numerous 'irrelevant' parameters might discourage their compliance with mHealth, quote 3.2 (table 4). Similarly, patients highlighted that if the burden of inputting data was too much then they would not be willing to comply with the device and emphasised that mHealth should be as automated as possible, quote 3.3 (table 4).

The topic of data usefulness was common across all focus groups and included comments regarding the reliability of data, data subjectivity and the interpretation of data. Individuals with asthma highlighted concerns with subjective measurements, such as self-reported symptoms, quote 3.4 (table 4). The interpretation of the data, either by automated systems or by the individuals themselves, was highlighted as a source of possible error and an important consideration. Consequently, only 12% of patients responding to the questionnaire indicated that they would accept all recommendations to change their medication based on feedback from mHealth. This value increased to 30% if data supporting the recommendation was also presented to the patient and to 41% if the patient's doctor endorsed the mHealth system. Similarly, only 21% of healthcare professionals would be comfortable for their patients to change their medication based on mHealth feedback. This value increased to 46% if the healthcare professional could see patient data and approve the changes. Furthermore, 22% of

healthcare professionals would like to see the patient in person before they recommended any changes to their medication.

Data security and data use was a common theme across focus groups. Patients expressed opposing views with regards to data security, with some patients unconcerned with how their data was managed and some insistent that data security is of upmost importance. Participants of the focus groups expressed unanimous support for their data to be used in an anonymous format for research purposes, whilst questionnaire results suggest just over half (58%) of patients were happy for anonymous data to be used for research purposes.

Physical properties relating to product design and compatibility were discussed as important considerations for mHealth. Questionnaire analysis revealed that 76% of individuals with asthma would be willing to carry or wear at least one additional device and 72% would be willing to keep an additional device at home. However, discussions in the focus groups indicate that this might depend on the product design, quote 3.5 (table 4).

DISCUSSION

The era of mHealth offers huge potential to enhance conventional healthcare. Asthma is an ideal candidate condition for mHealth developments, being a long-term condition that requires continuous attention from both healthcare professionals and patients. If mHealth systems are to be utilised in routine practice, they would need to be embraced by both end-users. This is the first study to comprehensively explore patients' and healthcare professionals' perspectives on the use of mHealth for the self-management of asthma. There were significant differences in opinions with regards to expectations between healthcare professionals and patients, however both end-users provide substantial support for mHealth for asthma self-management.

All people with asthma should receive a personal asthma action plan, as part of their asthma self-management strategy [7, 8]. However, only around a quarter of individuals with asthma receive such a plan [2, 11]. Our findings suggest that a large proportion of healthcare professionals believe that incorporating a personal asthma action plan into a mHealth system would be a useful function. This sentiment was commonly shared by individuals with asthma and vividly portrayed in the qualitative data, with one participant recalling the feeling of distress and indecision about how to treat their asthma and at what point to seek emergency attention. Neither patients nor healthcare professionals are enthusiastic about using written asthma action plans [9] and our data suggest the convenience of mHealth makes it an appealing alternative.

An accurate initial assessment and on-going review of patients' asthma severity and control is crucial for the appropriate management of the disease [2]. Our data suggest that people find it difficult to express asthma severity and control to their healthcare teams, and indeed it is known that patients often underestimate their asthma severity [22, 23]. Such discrepancies between perception and objective asthma severity could have drastic consequences in the

management of the disease. The UK National Review of Asthma Deaths (NRAD) suggests that poor recognition of asthma severity by patients and their healthcare teams, and subsequent long-term under-treatment, are avoidable factors related to asthma deaths [2]. One proposed use of mHealth that was well supported by both end-users, was a system that collects data over time, to assist patients in demonstrating their asthma control/severity to their healthcare teams. The selection of which parameters would be useful for this purpose merits careful consideration.

We identified a variety of physiological, environmental and behavioural measurements that individuals with asthma and healthcare professionals believe could support asthma self-management. Individuals with asthma most commonly responded that measurements of lung function would be useful for maintaining asthma control. The success of traditional asthma self-management programs, relying on regular peak flow measurements [5], would support their belief. Other physiological parameters that were identified as being useful included measurements of heart rate, respiratory rate and sleep quality. Given that heart rate variability may be associated with asthma control [24], that respiratory rate variability during sleep may differ between individuals with and without asthma [25], and that nocturnal wakening is a common complaint of individuals with asthma, the potential for these measurements to provide support for asthma self-management warrants further investigation.

Each year 5.5 million deaths can be attributed to poor air quality [26], whilst air pollution exposure is associated with increased frequency of asthma attacks in children and adults [27]. A large proportion of individuals with asthma and healthcare professionals responding to our survey believe measurements of environmental conditions could help achieve better asthma control and should be incorporated into mHealth.

Asthma is no longer seen as a single disease, but a syndrome with heterogeneous presentation

and numerous phenotypes and endotypes [28]. Participants identified that the complex and heterogeneous nature of asthma means that individuals will have differing requirements from mHealth. Whilst it is unrealistic to expect healthcare professionals to be trained in the use of multiple different mHealth systems, it was proposed by our participants that patients and their healthcare teams should be able to customise a panel of relevant functions and parameters for each patient. This poses a complex and challenging problem for mHealth developers, who should work in close partnership with a range of patients, with different levels of asthma control, and with healthcare professionals to ensure all end-user requirements are met.

Sharp contrasts were noted in the support for some mHealth functions between patients and healthcare professionals. Intriguingly, the functions that received less support from patients appear to relate to aspects that patients may be inherently aware of and therefore see no need for mHealth feedback; e.g., measurements of medication adherence, inhaler technique and self-reported symptoms. On the contrary, the well-supported functions relate to aspects whereby the patient would be somewhat blind to the information without such feedback e.g., environmental and lung function measurements. It would seem a reasonable interpretation that patients advocate functions that relate to acquiring information that would otherwise be unknown to them, not simply monitoring parameters that they could already be aware of. In contrast, functions that include 'big brother' monitoring of patients, such as medication adherence and inhaler technique, were well supported by healthcare professionals. This is reasonable given that healthcare professionals need to know that medication has been taken as prescribed in order to assess treatment efficacy, and adherence to treatment is known to be variable [29].

This research benefits from a mixed methods design, permitting themes identified in the focus groups to be quantified in the survey and integrated in the analysis to acquire a

comprehensive understanding of the perspectives of patients and healthcare professionals on mHealth for asthma self-management, However, several methodological limitations deserve consideration. Participants' responses to the questionnaires were given equal weighting in the analysis. This method fails to take into account the strength of their opinions. This study may therefore have benefitted from the ability for participants to rank their responses in order of preference. This study may have also benefited from another round of focus group discussions, to probe further into the results from the questionnaire. The majority of the participants in the survey likely came from those who visit Asthma UK's website or follow Asthma UK social media channels and, therefore, are likely to be more active and well-educated in the management of their asthma. The possibility of selection bias should therefore be considered during the interpretation of the results.

In conclusion, asthma is an ideal candidate for mHealth developments and recent times have seen a meteoric, but rather haphazard and often ill-informed [30] rise in mHealth systems for asthma self-management. A user-centred design of mHealth is integral for technology to meet end-users' expectations and may improve adherence and health outcomes. This research provides overwhelming support for mHealth to assist asthma self-management, by both individuals with asthma and healthcare professionals, but highlights fundamental differences in preferred functions between the different end-users and identified numerous factors that would need consideration during the development of new mHealth devices. Developers of new mHealth systems should consider these opinions during the development of new user-centred mHealth systems to aid the self-management of asthma.

ACKNOWLEDGEMENTS

Credits

We would like to thank Joke De Vocht for her support in organising the patient advisory group and reviewing the focus group topic guides. We would also like to thank the members of the patient advisory group for their valuable insight and guidance in developing the topic guides.

Financial contribution

This project has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement No 643607. The funder had no input in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Sponsor

The University Hospital of South Manchester NHS Trust sponsored this study. The sponsor had no input in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Competing interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) AS, PH, EK, JS-S, IS, JE, AC, CC and SF, have no conflicting interests, financial or otherwise; OU reports grants from Astra Zeneca, Chiesi, GlaxoSmithKline and Edmond Pharma and personal fees from Boehringer Ingelheim, Chiesi, Aerocrine, Napp, Mundipharma, Sandoz, Takeda, Zentiva and Cipla, outside the submitted work; JS reports grants from GlaxoSmithKline NL and Chiesi NL, outside the submitted work; KC reports grants from Pfizer, GSK, MRC, EU IMI and NIH and personal fees from GSK, Astra Zeneca, Novartis, Teva, Boehringer Ingelheim, J & J and Merck, outside of the work submitted.

Details of contributors

AS (guarantor), PH, EK, CC, KC, JS, OU and SF were responsible for the conception and design of the research; AS, EK, JS-S, IS and JE planned and conducted the focus groups; AS, JE, EK and SF produced the questionnaire; AS and SF analysed results; AS, SF and AC interpreted the results; AS drafted the manuscript; AS, PH, EK, JS-S, IS, JE, CC, AC, KC, JS, OU and SF edited and

revised the manuscript; AS, PH, EK, JS-S, IS, JE, CC, AC, KC, JS, OU and SF approved the final version of the manuscript.

Transparency declaration

AS had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. AS affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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