Planning a digital intervention for adolescents with asthma (BREATHE4T): a, theory-, evidence- and Person-Based Approach to identify key behavioural issues

Stephanie Easton BSc Hons1,2, Ben Ainsworth PhD3, Mike Thomas PhD4, Sue Latter PhD5, Rebecca Knibb PhD6, Amber Cook BSc Hons1, Sam Wilding PhD7, Michael Bahrami-Hessari MSc1, Erika Kennington PhD8, Denise Gibson PhD9, Hannah Wilkins BSc Hons9, Lucy Yardley PhD10, Graham Roberts PhD1,2\*

Affiliations:

1: Child Health, University Hospital Southampton NHS Foundation Trust, Southampton, UK. (Research primarily conducted here)1

2: Human Development and Health, Faculty of Medicine, University of Southampton, Southampton, UK. 2

3: Department of Psychology, Faculty of Humanities and Social Sciences, University of Bath, Bath, UK. 3

4: Primary Care and Population Sciences, Faculty of Medicine, University of Southampton, Southampton, UK. 4

5: School of Health Sciences, University of Southampton, Southampton, UK.

6: School of Psychology, College of Health and Life Sciences, University of Aston, Birmingham, UK.

7: Clinical Trials Unit, University Hospital Southampton, Southampton, UK.

8: Asthma + Lung UK, London, UK.

9: Physiotherapy department, University Hospital Southampton, Southampton, UK.

10: Centre for Clinical and Community Applications of Health Psychology, University of Southampton, UK.

**Funding:** ‘This work was supported by National Institute of Health Research (NIHR) grant number [PB-PG-0817-20038].’

\***Corresponding author:** Graham Roberts, Paediatric Allergy and Respiratory Medicine (Mailpoint 805), Southampton University Hospital NHS Foundation Trust, Tremona Road, Southampton SO16 6YD, United Kingdom. E-mail: g.c.roberts@soton.ac.uk. Tel. 02381206160.

**Keywords:** adolescence, asthma, breathing retraining, digital intervention, self-management

**Abbreviated title:** Planning a digital intervention for teens with asthma

**Word count:** 3800

# ABSTRACT

## Objectives

To describe a transparent approach to planning a digital intervention for adolescents to self-manage their asthma using breathing retraining (BRT), based on an existing, effective adult intervention (BREATHE).

## Methods

A theory-, evidence and Person-Based Approach was used to maximise the effectiveness and persuasiveness of the intervention. A scoping review and semi-structured interviews with target intervention users (N=18, adolescents aged 12-17yrs with asthma and parents) were carried out to explore user perspectives, barriers and facilitators towards the intended behaviours and potential intervention features. The combined evidence was used alongside and to inform theory-based activities and enabled iterative planning of the intervention.

## Results

The scoping review identified themes relating to user-specific self-management issues, content, education, training needs and features for a digital intervention. Interviews elicited potential barriers to intended behaviours such as the anticipated embarrassment of using BRT and concerns around remaining calm. Facilitators included BRT delivered by adolescents who share experiences of asthma and information for performing exercises discreetly. Relevant theoretical frameworks ensured that appropriate psychological constructs were targeted. A behavioural analysis identified six intervention functions and thirty behaviour change techniques. Logic modelling mapped the programme theory and mechanisms, which aims to improve adolescent asthma-related quality of life.

## Conclusions

This research gives a transparent insight into the approach followed to plan a self-guided BRT intervention for adolescents and has led to identification of key behavioural issues, enabling relevant intervention content to be chosen. Insight has been given into adolescent perceptions of BRT, which facilitated development of the prototype intervention.

# **BACKGROUND**

Asthma is an intermittent, long-term disorder characterised by wheeze. It affects over 339 million people globally and is the most common non-communicable disease in children and adolescents 1,2, with 1 in 14 adolescents having asthma 3. Adolescence is recognised as a challenging period of rapid change and brain development 4. During this period adolescents tend to be heavily influenced by their peers and are more likely to take health-related risks, including experimenting with drugs, alcohol and cigarettes 5,6. These physical, behavioural, and psychological adjustments can have an impact on the management of long-term conditions. For adolescents with asthma, despite the availability of effective medications, engagement with treatment is often sub-optimal and this age group tend to have poor asthma outcomes, including high mortality rates and particularly poor quality of life 7-9. In addition, adolescence presents a time of transition to adulthood as disease management shifts from parents and carers and requires greater adolescent responsibility and self-management 10. These unique factors mean that adolescent patient needs differ from adults, and thus approaches to treatments should be tailored accordingly.

An increasingly popular, adjuvant approach to asthma pharmacotherapy is breathing retraining, which is recommended to manage symptoms and to improve quality of life 11. The prevalence of dysfunctional breathing in children is currently unknown, however one study suggests it may be experienced by as many as 55% of children and adolescents with asthma 12,13. It is sometimes known as hyperventilation, vocal cord dysfunction or inducible laryngeal obstruction 12,14-16. It is characterised by increased respiratory rate, the inappropriate use of accessory muscles and paradoxical vocal cord movement 12,16. Dysfunctional breathing can exacerbate asthma symptoms, further impact quality of life and increase anxiety 11,12. Young adults with asthma often report anxiety and panic alongside asthma symptoms, in particular if medication isn’t within reach 17. Both adolescents and parents recognise the importance of staying calm and reducing panic to help control breathing 17.

Breathing exercises are traditionally taught by a physiotherapist and provide techniques to increase breathing efficiency, control and relaxation. This can be costly and requires the availability of a qualified professional. Bruton et al (2018) developed a successful and cost-effective digital intervention for self-guided breathing retraining in adults [BREATHE]18. A randomised, controlled trial demonstrated that the home-based DVD and booklet programme was as effective in improving quality of life as face-to-face therapy, in comparison to usual care 18. Despite these promising preliminary observations, systematic reviews have identified a lack of similar intervention studies exploring the effectiveness of breathing retraining in younger patients 19-22. Yet, a similar, digital, self-management approach is likely to be useful for this age group 9,23,24. Initial research and work with patient and public involvement (PPI) demonstrated that the adult BREATHE intervention needs repurposing and optimising to engage younger patients.

Strategic planning of complex interventions is important and increases their chance of success 25. The UK Medical Research Council (MRC) have recently extended their guidance to support the planning, development, feasibility and evaluation of complex interventions, emphasising overarching considerations such as context and stakeholder involvement 26,27. As the planning and development stage preceding a feasibility trial (Clinical trials, [[NCT05006703](https://clinicaltrials.gov/show/NCT05006703)]), this paper describes the process to plan and repurpose the adult BREATHE intervention into a BREATHE4T adolescent intervention. The aim was to co-develop a draft, prototype behavioural, self-management, digital intervention with adolescents with asthma. We followed the Person-Based Approach, which involves a systematic theory, evidence and Person-Based Approach to development, in line with MRC guidance 26-28. It has been used to develop several effective and cost-effective behavioural interventions to help manage various long-term health conditions 18,28-32. The iterative nature of the approach allows changes to be made throughout planning and development to maximise the intervention’s persuasiveness, relevance and potential to change behaviour, and thus leading to improved overall health outcomes 28,33.

# **METHODS AND RESULTS**

## Approach

A theory-, evidence and Person-Based Approach was used to plan, repurpose and develop an existing adult asthma intervention to be suitable and engaging for adolescents 28.

The systematic approach to planning is presented in Figure 1. Detailed intervention planning included three parts: 1) a rapid scoping review (evidence-based), 2) an in-depth qualitative interview study (person-based) and 3) behavioural analysis, logic modelling and theoretical mapping (theory-based). This combined iterative process enabled a deep insight into the perspective and experiences of the target population 33. The scoping review and qualitative interviews were combined to identify the key, context-specific, behavioural issues and needs that an adolescent breathing retraining intervention needs to address. In line with the Person-Based Approach, these methods and the other planning activities were conducted in parallel and combined to iteratively create a draft intervention prototype. This also enabled a set of guiding principles to be generated, which outline the key design objectives and key intervention features relevant to this intervention. The following behaviours are intended to be targeted by the intervention: 1) to practice breathing retraining, 2) to be able to identify when to use breathing exercises (self-manage), 3) to implement breathing exercises and 4) to engage with the intervention.

Input from stakeholders and patient and public involvement

**Figure 1.** An overview of the key elements involved in planning the Breathe4T intervention.

Key stakeholders were involved in decision-making throughout, including adolescent asthma patients and parents. Monthly development meetings were held with the core project team which consisted of clinical, psychological, and behavioural expertise, plus support from Asthma UK. These meetings predominately aimed to keep the project focused and to resolve challenges.

### Patient and public and involvement (PPI)

Two parallel panels of 6 adolescents with asthma and 5 parents were recruited at the start of the study and met with the study team quarterly. In-between meetings, regular contact was made with the adolescents via their preferred choice of communication (a social media app, WhatsApp) whilst parents communicated more traditionally via email. PPI members actively contributed in various ways by inputting to the study design, documents and recruitment activities and providing feedback on the intervention prototype and language to ensure suitability for an adolescent audience.

## Rapid scoping review (evidence)

### Purpose

To identify relevant barriers, facilitators and contextual issues that may influence engagement with a digital, behaviour change intervention for adolescents with asthma from existing evidence.

### Methods

In keeping with development timeframes, a rapid scoping review was conducted to collate existing evidence. We followed Arskey and O’Malley’s five stage framework 34. The team’s previous research had identified evidence of barriers and facilitators towards adolescent asthma self-management and were included within the review 9,17,23,35. Three further questions were identified as evidence gaps by the core study team and were used to focus the searches: i) what are the barriers and facilitators towards adolescent engagement with digital self-management interventions? ii) is breathing retraining effective as an adolescent asthma intervention? and iii) what makes an effective adolescent peer-led intervention? Searches were conducted in Medline (Ovid), Embase, Psycinfo and Cinahl. Additional studies were identified through reference lists of included papers. Endnote software was used to manage references and to remove duplicates. Data were extracted on authors, methodology, intervention type, and key findings (E-Table 1). In line with similar studies, thematic analysis was conducted on the extracted data. Potential barriers and facilitators that may influence engagement with the intervention were identified from the three areas above and organised into a summary table of key findings (Table 1) 36.

### Results

Thirty-five papers were included in the review. Three key themes were constructed from the data: 1) user-specific self-management issues 2) content, education, and training needs and 3) features of digital interventions. Barriers and facilitators were each labelled according to the search they were identified in. A full table of findings is provided in E-Table 2.

|  |  |  |
| --- | --- | --- |
| **Theme** | **Barriers** | **Facilitators** |
| User-specific self-management issues | * Forgetfulness 9,17,49-55
* Competing demands/priorities 9,49-52
* Busy or chaotic home life 20
* Too many reminders - “annoying” 55
* Embarrassment or drawing unwanted attention to asthma 9,17,35
* Reliance on parents 9,17
* Belief that already doing a good job of managing asthma 49
* Lack of motivation 9,17,47
* Negative beliefs, attitudes or perceptions towards asthma 9
* Lack of social support and poor communication 9,17,35
* Greater anxiety 35
 | * Routines and cues 9,17,20
* Appointment/medication reminders 9,17,47,49-57
* Able to customise or schedule reminders 51,53,55
* Support from peers, parents and caregivers 23,50,55,59
* Acceptance of having asthma 49,52,55
* Taking responsibility (and having the confidence to) 17
* Achieving or maintaining normalcy 47,50-52
* Feeling less limits in daily activities 47,49-52
* High self-efficacy 23
* Feeling in control of asthma symptoms 53
* Often have a smartphone available 50
* Goal setting 47,48,52
* Avoiding hospitalisation 60
 |
| Content, education and training needs  | * Lack of or inadequate asthma knowledge 17,49,51
* Not having enough information or understanding about the condition, symptoms, triggers, severity and risks 23,47,49,51,53-55,57,61
* Unrelatable peer mentors 58
* Difficulties communicating with HCPs 9,17,60,62
* Prefer not to replace advice from HCPs (supplement) 56,61
 | * Being given new ways to control asthma 17
* Greater understanding of consequences of the condition 23
* Having control over symptoms 49,51,52,55
* Interacting/hearing experiences from others with asthma 47,49-51,55,56,59,60,63,64
* Prefer advice from peers (particularly older) / change is more likely to occur is someone relatable delivers the message 63,65,66
* Prefer to learn from demographically similar other 67
* Credible/trusted source of information 51,56,57
* Reduce need for appointments with HCPs 61
* Prefer to learn breathing exercises along to a CD (than alone) 20, 68
* Using breathing exercises to relax, feel calm and fall asleep more easily at night 68
* Encouragement to contact HCPs for further information 56
 |
| Features of digital interventions | * Information cluttered/clumped 47,57
* Outdated app design 55
* Too many features 57
* Issues with login processes 55,69
* Difficulty understanding how to use an app / moving between screens 47,57
* Rewards that don’t translate into anything 54
* Poor accessibility (WiFi, devices etc.) 55,57
 | * Clean, professional and organised 54
* Use of visual aids such as colour, pictures, graphs and charts 47,54,57
* Video tutorials/picture explanations to aid understanding and teach new skills 47,49,50,53,55,57,60,70
* Ease of use 47,48,51,53,55,57,60,63
* Tracking and monitoring (symptoms and triggers) 47,49,51,53,57
* Customisable/tailored/personalised information 50,55-57,70
* Able to share information 48-50,54,55,61
* Rewards for adherence 62
* Inspirational/motivational messages 55
 |

**Table 1.** Summary of key barriers and facilitators identified in the scoping review.

HCPS = health care professionals

## Qualitative Interviews (person)

### Purpose

To elicit user views of potential intervention content and towards target behaviours, whilst exploring any further potential barriers, facilitators, or behavioural challenges that the intervention may need to address.

### Methods

Ethical approval was obtained from an NHS ethics committee (19/YH/0338). Participants were purposefully recruited from a secondary care asthma clinic. Eligible participants were between 12-17 years old with physician-diagnosed asthma, or their parent/guardian. Participants were excluded if they had co-existing respiratory conditions or were an existing PPI member. Potential participants and their parents (N=68) who had an upcoming clinic appointment were sent information about the study and 18 (9 parent and teenager dyads) chose to take part. All participants gave fully informed consent and completed a demographic questionnaire before the interview (Table 2). Semi-structured topic guides (E-Text 1) focused on target behaviours (breathing exercises) and potential intervention features (such as videos or rewards). As a prompt, participants were shown an example of the existing intervention for adults (www.breathestudy.co.uk) and asked their likes, dislikes and to suggest any improvements they would make. Interviews were recorded and transcribed verbatim. All transcripts were anonymised, and names replaced with pseudonyms. Repeated readings of transcripts and listening to the recordings ensured familiarisation with the data. Inductive, thematic analysis was used to identify views of target behaviours and any adolescent-specific behavioural challenges 37. Key issues and perceptions of potential intervention features (both positive and negative) were identified.

Most interviews took place in a hospital research setting (n=11) or, where participants preferred, their home (n=4) or via the telephone (n=3). Interviews were conducted by a research assistant (SE), and lasted an average of 32 minutes (range 16 to 56 minutes).

|  |  |
| --- | --- |
| **Participant demographics** | **N (%)** |
| **Total (adolescents)** | 9 |
| **Gender** |   |
| Female | 5 (55%) |
| **Age, years** |   |
| 12-13 | 5 (55%) |
| 14-15 | 1 (11%) |
| 16-17 | 3 (33%) |
| **Ethnicity** |   |
| White British | 8 (88%) |
| **Self-reported asthma triggers** |   |
| Weather | 5 (55%) |
| Pollen | 6 (66%) |
| Dust | 7 (77%) |
| Pets | 8 (88%) |
| Colds | 7 (77%) |
| Cigarette smoke | 4 (44%) |
| Exercise | 9 (100%) |
| **Professionals seen about asthma** |   |
| GP  | 7 (77%) |
| Primary care nurse | 4 (44%) |
| Hospital consultant | 9 (100%) |
| **Missed preventer** |  |
| Never | 3 (33%) |
| Occasionally  | 3 (33%) |
| Once a week | 2 (22%) |
| Half the time  | 1 (11%) |
| **1 or more steroids courses needed in the last year** | 4 (44%) |
| **>2 days of school missed in last year** | 6 (66%) |
| **Ever admitted to hospital because of asthma** | 5 (55%) |
| **Has eczema** | 3 (33%) |
| **Has hay fever** | 7 (77%) |
| **Food allergies** | 7 (77%) |
| **Non-smoking family** | 9 (100%) |

**Table 2.** Adolescent interview participants’ self-reported demographic information.

### Findings

Key findings arising from the adolescent and parent interviews are described below. Example quotes are presented in Table 3. Three main themes were identified: views towards practicing and using breathing exercises, preferences for the intervention features and preferences for delivering breathing retraining. Participants described various issues around anticipated embarrassment, particuarly within certain environments and this was identified as its own subtheme within practicing and using breathing exercises.

Views towards practicing and using breathing exercises: Overall, both adolescents and their parents were positive about a breathing retraining intervention. Some barriers were raised towards using the breathing exercises including time constraints, parental concerns in the ability to calm down when experiencing asthma symptoms and potential feelings of discomfort. In addition, a key issue discussed by almost all adolescents and parents were potential feelings of embarrassment or self-consciousness that may influence their ability or motivation to carry out breathing exercises. Some participants felt they’d be supported by friends or particuarly others with asthma, but a few felt they’d still be too embarrassed. Adolescents and parents felt that being able to perform the exercises discreetly or in private would be a facilitator.

Preferences for intervention features: Participants described a preference for an intervention that is easy to use, informative and visual. When shown the adult intervention, most participants felt it had too much text and both adolescents and their parents’ suggested preferences for more colour, videos, and pictures. In line with the literature, both adolescents and their parents described a challenge around forgetfulness and therefore felt reminders would be a useful and important feature of an intervention for this age group. Some participants felt they would get annoyed if they received them too often and one described wanting gentle reminders. Other features viewed positively included progress charts and breathing animations. There were mixed views on the use of rewards as some participants felt they were unnecessary and that asthma improvements would be the biggest benefit, though others suggested they might be motivated by reward systems and particuarly if it led to a physical reward, such as gift tokens.

Preferences for delivering breathing retraining: Participants suggested breathing techniques would be best demonstrated by someone closer in age to help them to connect to the examples and to recognise the exercises can work for them. Some adolescents and their parents also suggested they’d have an interest in understanding the rationale for how breathing exercises work to understand how they might help. Though, some parents suggested adolescents may require varying levels of detail. Other facilitators included the techniques being demonstrated in relatable environments such as at home or in a sports field, as opposed to a doctor’s office and the use of step-by-step instructions.

|  |  |
| --- | --- |
| **Barrier / *facilitator***  | **Participant quotes**  |
| **Theme 1: Views towards practising and using breathing exercises**  |
| *Adolescents felt positive about trying breathing exercises.* |  “I think it’s a good idea because when you are having an asthma attack if you start to breathe faster it makes your chest even worse and then, so if you start to slow down your breathing then it does help you when you’re having an asthma attack” (P17, F, 17yrs) |
| Some participants (adolescents and parents) described possible time constraints towards practising breathing retraining. | “If you’re doing it for a long time, over a long period of time every time you have to go on it then you wouldn’t want to do it if it takes half an hour” (P5, F, 13yrs)“She does play some sport as well, she’s in the first team for hockey for her year and she used to ride but she’s given that up lately because there has just been no time and what else does she do? She’s started playing netball as well and she plays the drums” (P8, mother of 13 yr old female) |
| A few adolescents had experienced discomfort after using breathing exercises previously. | “I felt it put quite an unnecessary strain on your diaphragm and your upper shoulders coz I have a problem with breathing up here [hand on chest], rather than in my stomach so I felt if you had a bit of difficulty a bit later on in the day after doing these breathing exercises, it would put quite a bad strain, you’d feel quite a lot more pain than you would if you didn’t do the breathing exercises” (P3, M, 16yrs) |
| *Some adolescents felt breathing exercises may also benefit those without asthma.* | “Breathing exercises are always going to be a good thing even if you don’t have asthma, it’s still going to be good…anybody that has a lack of breath it will be useful for” (P13, M, 12yrs)  |
| Adolescents and parents described a possible lack of motivation to practice breathing exercises. | “I wasn’t even doing them once a day, I was doing it whenever I saw the physiotherapist so it was quite infrequent, really bad, yeah, I said I would do it but I never did [laughs]” (P3, M, 16yrs)“He’s a teenager, he’s lazy isn’t he? If he’s got coursework to do, he’s got to do that hasn’t he?” (P4, mother of 16yr old male)“The most difficult group to reach I would think are boys…they won’t bother, it’s as simple as that” (P8, mother of 13yr old female) |
| Adolescents suggested their environment or location may impact their ability to use breathing exercises.  | “I think in certain lessons or if you’re with a group of people then you can’t always get a moment alone to just relax” (P11, F, 16yrs) |
| Some parents had concerns about their adolescent’s ability to calm down during an asthma attack. | “I think if you’re in the throes of an asthma attack it’s so frightening that I think it would take quite a lot of presence of mind to talk yourself into calming down and doing that and so, maybe the more mature, but not exclusively, but teenagers can actually be more needy than 5 year olds at times…” (P12, mother of 16 yr old female) |
| *Parents discussed the long-term benefits as a possible way of increasing adolescent’s motivation towards using breathing exercises.* | “With this…the long term benefits I’m guessing would be that they learn the exercises, they would be able to do more of what they want to do, do more of the PE and more of the Judo, so I guess telling him, if he learns them and pays attention to them then he might be able to do more things. He might be able to take less medicine because he can control his breathing, I mean that might work with him” (P2, mother of 15yr old male) |
| Some parents were concerned that their teenagers may lack support at school.  | “Also just the school environment is difficult because actually an awful lot of teachers don’t realise how critical asthma can be” (P12, mother of 16 year old female)“I think the teacher is the barrier…it’s actually to be able to have the confidence to go to the teacher and say I think this is about to happen, I need to step out…” (P14, mother of a 12yr old male) |
| Some adolescents felt an inhaler could relieve panic more quickly than taking the time to use breathing exercises. | “I really find it difficult…immediately the first thing you do is panic, so you reach for that blue inhaler and you need to take it there and then really, because that was my strategy and it still is but I could never calm myself down in that situation and then to focus on the breathing exercises…so I think go for the blue inhaler first and then once it’s taken the edge off, off the asthma then start going into breathing exercises” (P1, M, 15yrs) |
| **Subtheme: Anticipated embarrassment or self-consciousness** |
| Adolescents and parents anticipated feelings of self-consciousness and embarrassment in public. | “I’d have just been a bit nervous and I don’t like doing stuff that brings attention to me so it would have just made me anxious and not want to do it” (P1, M, 15yrs) “They get embarrassed, don’t they? So I know Josie gets embarrassed using her inhaler at school so she has to go and use it in the toilet, so she’d probably be embarrassed doing it in front of people, she wouldn’t be embarrassed at home but she would be embarrassed about doing it at home if she didn’t have a place to do it on her own…” (P16, mother of 13yr old female)“She does say she feels embarrassed or awkward when she uses her inhalers in public and she gets teased by other children for it” (P8, mother of 13yr old female) |
| Adolescents and parents had mixed views on the idea of using breathing exercises around friends, especially those without asthma. | “Well because none of my friends have asthma, I don’t think they would be used to it because they don’t know anyone with asthma or in their family and I think I’m the only one they know with asthma…I think they just wouldn’t really know what I’m doing and think, maybe think it’s a bit weird and it will be a bit emb-, a bit uncomfortable or something” (P15, F, 13yrs)“I also have some other friends with asthma and we all help each other out” (P13, M, 12yrs)“I don’t know that peer pressure is so much of an issue now to sort of making teenagers feel awkward about doing something because actually there much, they are very supportive of each other” (P12, mother of 16 yr old female) |
| *Adolescents and parents discussed knowing how the exercises could be performed discreetly to avoid embarrassment.* | “Just teaching the exercises in a way that you wouldn’t have to be so obvious about it so in the video they wanted you to lie down on a bed and relax your shoulders and stuff but that’s I guess that’s harder to do” (P17, F, 17yrs)“I don’t think she would do it out and about, I mean if she could do it without being noticed then maybe she would” (P18, mother of 17 yr old female) |
| *A few adolescents described coping strategies that may mitigate against their feelings of embarrassment.*  |  “If I needed to breathe and it wasn’t subtle I would do it, but I don’t think it’s that noticeable anyway because when you are breathing, I mean people don’t really look at your stomach to see how far out it is going and they don’t really look at you to see how much you are breathing but if they did ask, like if you’re not talking and breathing instead then I’d just say” (P5, F, 13yrs) |
| **Theme 2: Preferences for the intervention features**  |
| *Several adolescents and parents suggested an app would be a preferred format.* | “It would be good if it was an app, if it was an app on your phone or something then you could always have a look on it then they could get a notification when you went on” (P5, F, 13yrs)“It would be good if there was an app on her phone so if she was feeling unwell at school then she could do, follow the stuff on an app on her phone because that’s what they all do now isn’t it with their apps and stuff?” (P16, mother of a 13 yr old female) |
| Adolescents and parents suggested users wouldn’t want to read too much writing */ and had a preference to view visual content.* |  “If there’s just long bits of text then you probably aren’t going to read it and it’s just, yeah boring to read whereas if it’s just a quick video or quick pictures or something then it’s a lot easier to access and more interesting and so you are more likely to actually do it” (P17, F, 17yrs)“They are not readers these days kids, they are just not readers. There are very few and far between that are” (P8, mother of 13yr old female) |
| *Generally, participants felt a website needed to be professional, organised and easy to use.* |  “I think it just needs professionalism and it needs to look appealing to people my age, sort of thing” (P3, M, 16yrs)“If it’s easy to understand, so it’s not muddled up and everything is easy to access and just colours really, if it looks nice, if it’s old and uninteresting then people won’t want to use it” (P1, M, 15yrs) |
| *Reminders and notifications were viewed positively by participants, if not sent too frequently.* | “I think notifications are useful but I think you have sort of periodically, I always get annoyed at apps or like websites when it notifies me once an hour or something, just sort of spreading it out slightly so it’s not always nagging you, it’s just gently reminding” (P11, F, 16yrs) |
| There were mixed views on the use of rewards by both adolescents and parents.  | “Well I probably wouldn’t need a reward for just looking at a website or something, I’d just do it because it will help” (P9, M, 14yrs)“Rewards, it makes you want to do more and earn another, it entices you to keep going and achieving.” (P1, M, 15yrs)“Any reward for kids is good…book tokens, earning stuff for crafts stuff that she’s interested in, I don’t know, but anything they can get something out it” (P16, mother of 13yr old female)“I think for this, the main thing is the benefits, I mean to be able to go out with his friends and be a normal teenager” (P2, mother of 15yr old male) |
| *Adolescents liked the idea of an animation to breathe in time with.* | “It’s clear what you need to do, you need to breathe in for a bit and then out...I like that one because it’s also engaging, you can just watch it go around and it will calm you down whilst you’re watching it and relax you” (P15, F, 13yrs) |
| There were mixed views on parental involvement. Some parents felt their teenagers should start taking responsibility for their asthma, whilst others still wanted to support them. | “I think them having access to see what’s on the website but I think if they were getting notifications of what I was doing then I would kind of get annoyed if they started nagging me or I think anyone my age would get annoyed with that” (P13, M, 12yrs)“Hearing from parents helps because they have lived longer than you and have good advice that you can, a lot of people can use…if they realise I’m doing something wrong, then they can correct me which helps” (P7, F, 13yrs) “I’d like to know what he’s doing and how to do the exercises to check he is doing them properly” (P2, mother of 15yr old male)“I think he’s transitioning into adulthood now, he needs to take responsibility for it” (P4, mother of 16yr old male) |
| *Progress monitoring was viewed positively as an intervention feature.* |  “Some kids do like to chart their progress and to see that they are getting towards an end goal” (P8, mother of 13yr old female) |
| **Theme 3: Preferences for delivering breathing retraining.**  |
| *Some adolescents expressed interest in understanding why breathing exercises may help, though parents felt adolescents may vary in the level of detail they’d like to know.* | “If you see something happening and you don’t know what’s happening then you can’t really help it but if you see something happening and you know what’s happening then you can help it” (P13, M, 12yrs)“I think it would be good to know what you’re looking at. Even if it’s too technical for some, if it’s there, some kids are more into it than others, some couldn’t care less if they had whatever in their lungs, but I think someone like Aaron, he would like to see that” (P4, mother of 16yr old male) |
| *All participants felt demonstrations of breathing exercises would be more relatable by a young person that understands or has experienced asthma.*  | “Because I’m also a teenager and if I was to watch a teenager doing it then I would definitely know it works but if I was watching an adult then I could think well it might work for adults but not for kids” (P15, F, 13yrs)“I think because that is the world they access now, they learn how to put their make up on looking at other teenagers putting their make up on… it’s just their world now, they tend to listen to people on the screen far more than they do anybody else...if another teen was showing it and telling them why and how it benefits and everything else then I think that would, she’s most likely to take notice of that” (P18, mother of 17 yr old female) |
| *A few participants felt step-by-step instructions would be useful.* | “If there were pictures but they had steps under them then that would be good…maybe because if you were out and you could feel your chest being tight and you wanted to like go through the breathing exercise, you can’t really watch the video but you could just go through the steps so that would be good” (P17, F, 17yrs) |
| Both adolescents and parents felt the adult intervention videos were too clinical and suggested they’d prefer to see more relatable settings. | “Somewhere where you can get your audience’s attention, like possibly not a doctor’s office, it’s a little bit boring” (P1, M, 15yrs)“Maybe in somebody’s house or something like that in a proper bed because when you are at home is when you would feel the most safe than when you are somewhere else” (P15, F, 13yrs)“I don’t like the clinical setting, I suppose most of the videos now that seem to appeal are just young people just talking in their bedrooms, aren’t they? Just a normal everyday place, in the kitchen at home in the bedroom, down the park, just not a proper set up if you like?” (P18, mother of 17 year old female) |
| *Participants felt videos should be kept short.*  | “I’d rather just sort of like have her say ok we’re doing this and then start showing it instead of the whole talking beforehand” (P11, F, 16yrs) |

**Table 3.** Key barriers and facilitators arising from qualitative interviews with adolescents with asthma and their parents

1. Facilitators are italicised, barriers are in non-italic font.

## Behavioural analysis (theory)

### Purpose

To systematically identify and describe intervention components using behaviour change theories (behaviour change wheel (BCW)38, behaviour change techniques taxonomy (BCTv1)39 and theoretical domains framework (TDF)40), mapped onto evidence identified in the scoping review and qualitative interviews.

### Methods

Behaviour change theory uses a common language to allow comparison of behavioural techniques between interventions 38. The behaviour change wheel (BCW) is a theoretical framework that synthesises techniques found in the research literature 38. The COM-B model suggests that at least one of the following factors must be present for behaviour change to occur; capability, opportunity and motivation 38. To undertake a behavioural analysis, the intervention’s four target behaviours were specified and recorded in a table; 1) practice breathing exercises, 2) identify when to use breathing exercises (self-management), 3) implement breathing exercises and 4) effectively engage with the intervention. Potential barriers and facilitators were identified for each behaviour based on findings from the qualitative data (scoping review and interviews) and stakeholder input. Appropriate intervention components designed to elicit behaviour change were selected to address each barrier and facilitator in correspondence with the target behaviours. Each component was mapped onto the BCW to identify the constructs (e.g., physical capability) that needed to be targeted for the desired change to be achieved, in addition to the intervention functions (e.g., training) that would allow this to change. The BCTv1, consisting of 93 behaviour change techniques, was used to code each intervention component and to ensure that all relevant intervention functions had been utilised and no potentially useful techniques had been missed. Finally, each component was mapped onto the TDF, which consists of 14 domains used to combine theoretical constructs 40.

### Results

The behavioural analysis consisted of 14 pages. The analysis proposes that the intervention will target all 6 of the COM-B model components (physical capability, psychological capability, physical opportunity, social opportunity, reflective motivation and automatic motivation) and will utilise 6 of the 9 possible intervention functions: education, persuasion, training, modelling, environmental restructuring and enablement. Thirty behaviour change techniques are utilised in the Breathe4T intervention.

## Logic Modelling (theory)

### Purpose

To map intervention mechanisms of action to ensure they are appropriately targeted by intervention components.

### Methods

In line with the MRC recommendations, a logic model was created to visually map the intervention’s programme theory 26,27,41. The model combines the findings from the scoping review, behavioural analysis, and qualitative interviews to describe the underlying mechanisms of action, the intervention components expected to contribute to behaviour change and the expected outcomes.

### Results

An overview of the Breathe4T logic model is shown in Figure 2. The intervention ingredients include the main intervention components that were originally identified during the behavioural analysis included to influence intervention engagement and to target the behavioural constructs that are intended to lead to behaviour change. The logic model displays the theoretical process of intervention features and underlying mechanisms that are intended to lead to the improvement in asthma-related quality of life, such as increasing skills, competence and self-efficacy and reducing embarrassment. A measurement is provided for each mechanism, which will later be considered during a future process analysis. The underlying mechanisms are expected to lead to a decrease in symptoms, improvements in asthma control, a reduction in healthcare utilisation, reductions in stress and therefore result in overall improvements in quality of life (measured by PedsQL42 and PAQLQ43).

**Intervention ingredients**

**Mechanisms/mediators?**

**Outcomes**

**Breathing retraining (BT)**

* Peer demonstration videos of BT in a relatable context for adolescents
* Step-by-step instructions of breathing techniques
* Quick access to rescue techniques

**Supportive elements**

- Information about the rationale for BT

- Education on the benefits of BT

- Provide feedback on current BT

* Tools to support habit formation (e.g. planning/tracking/progress monitoring)
* Advice to support existing pharmacological treatments
* Addressing common barriers (e.g. concerns about other’s perceptions)
* Encouragement for parental and peer support
* Demonstrate peer success (via stories)

**Improvements in asthma-related quality of life**

*PEDSQL 3.0/ PAQLQ*

**Engagement with website app**

*Measured with usage data*

**Satisfaction with the website app**

*Measured with interview data*

**The Problem**

**To improve quality of life in adolescents with asthma**

By supporting self-management using breathing retraining.

**Reduction in healthcare utilisation**

*Measured with self-report data (steroid prescriptions, attendance at emergency department for an exacerbation of asthma and admissions for an exacerbation of asthma)*

**Improved asthma control**

*Measured with asthma control test (ACT)*

**Facilitate intervention engagement**

* Physical, customisable prompts (e.g. reminders)
* Animation to support practice
* Use of short, engaging video clips

Many adolescents have dysfunctional breathing and sub-optimal engagement with asthma treatment.

**Effective engagement with the behaviours**

**Decrease symptoms**

*Symptoms QoL sub-component*

**Provide support**

**Increase skills and competence**

*Breathing retraining questions*

**Increase self-efficacy**

*Interview data*

**Increase knowledge**

*Interview data*

**Reduce embarrassment**

*Breathing retraining questions/ interview data*

**Increase autonomy**

*Interview data*

**Reduce stress**

*Emotions/feelings QoL sub-component / interview data*

**Figure 2**. An overview of the logic model for the Breathe4T intervention.

## Theoretical mapping (theory)

### Purpose

To consider underlying theories to ensure relevant behavioural mechanisms are targeted.

### Methods

Self-determination theory (SDT) comprises of 3 basic needs considered to influence an individual’s intrinsic motivation to carry out a behaviour; autonomy (a desire to be in control of one’s own destiny), relatedness (a desire to connect or interact with others) and competency (a desire to be able to achieve a goal)44. SDT is particularly relevant for adolescents who may typically lack motivation, confidence or the skills to engage in asthma self-management 9,17. We therefore identified these determinants of motivation when developing the intervention, ensuring that intervention ingredients targeted these constructs as mechanisms. In addition, Rottman’s value-expectancy cognitive framework assumes that a patient’s beliefs, based on their own experiences with their medication, may in turn lead to cyclic pattern of non-adherence 45. We also ensured ingredients aimed to target these mechanisms, for example by increasing knowledge and encouraging self-monitoring, therefore leading to more effective behaviour change.

### Results

As represented in the logic model (Figure 2), intervention content was mapped on to SDT to ensure the theoretical constructs were targeted. For example, demonstration videos were designed to be peer-led to increase competency, but also whilst ensuring the intervention would be relatable for adolescents and enabling them to feel supported or to reduce feelings of embarrassment. Reminders, planning, and self-monitoring tools were included in the intervention to allow participants to enter their own information, scheduling and choice of modality aiming to increase autonomy. In line with Rottman’s theory, users are able to use a progress chart to self-monitor their inhaler use over time and to analyse their own patterns of behaviours in a diary section.

## The Breathe4T prototype intervention

The theory, evidence and person-based activities described above informed a draft prototype intervention, BREATHE4T. The intervention is a mobile-friendly website providing a series of peer-led training sessions to teach breathing exercises as well as providing advice and tips of how to integrate the techniques into daily living. The intervention guides users through the rationale behind breathing retraining using a combination of videos from peers and physiotherapists. The main dashboard includes other optional features such as diaries (planning, reminders, self-monitoring tools), a progress chart and a frequently asked question section addressing common concerns. Users are able to work their way through training sessions at their own pace with prompts to move on once comfortable with each exercise. A shortcut is provided on the dashboard to access exercises that may be particuarly helpful to relieve asthma symptoms, alongside advice for how to use these in conjunction with an inhaler. A full overview of the intervention is described in E-Table 3.

# **DISCUSSION**

**A statement of principle findings**

This paper describes the planning of a draft prototype intervention for adolescents with asthma following a theory-, evidence- and Person-Based Approach 28. The self-guided intervention is based on a successful adult intervention (BREATHE) and aims to teach breathing retraining. The approach enabled context-specific issues to be identified that may be particuarly relevant for this age group, and for behavioural techniques to be implemented to address these. For example, the scoping review and interviews both highlighted embarrassment as a key issue towards using breathing exercises in public and this was considered when choosing intervention features by including techniques to increase self-efficacy and relatedness, specifically by providing peer-led training videos in relevant environments. Reminders were identified as an especially relevant feature, particularly if able to be tailored to an individual’s preferences. The person-based planning activities have led to a prototype intervention consisting of selected features intended to increase motivation and reduce potential barriers.Some preferences varied between individuals, and these issues were discussed with stakeholders to best meet key user needs. Future work will enable the prototype intervention to be further optimised using think-aloud and retrospective interviews to explore a wider sample of user’s reactions to the selected intervention content and target behaviours.

**Strengths and weaknesses in relation to other studies, discussing important differences in results**

This paper is the first in our knowledge to identify the key behavioural needs of adolescents with asthma that will be used to inform and develop a digital intervention that enables self-management using breathing exercises. We provide a transparent description of the approach we took, increasing replicability. The method enabled a rich and detailed understanding of the intervention’s target users and particularly understands their views of breathing exercises, an area that currently has very limited existing evidence for this age group.

Current evidence suggests that interventions including core integrated behaviour change techniques (BCTs) also tended to have higher quality ratings. Ramsey (2020) conducted a systematic evaluation of 23 existing asthma apps to identify the presence (or absence) of BCTs 46. More than half of the apps were identified as using less than 4 BCTs. The authors concluded that two existing interventions, KissmyAsthma and AsthmaMD used the most BCTs in addition to a high-quality rating, assessed by MARS (Mobile App Rating Scale, used to assess quality of mHealth apps). KissmyAsthma study used a similar, theory- and evidence-based approach and a recent pilot study shows promising results 47,48. In the current study, our behavioural analysis used 30 BCTs, suggesting the Breathe4T intervention is in line with these current findings.

**Strengths and weaknesses of the study**

We followed a robust, theory-, evidence and person-based process that has been extensively used to develop effective interventions 33. The intervention planning used extensive co-participatory methods, working with participants and stakeholders, to maximise the likelihood of patients engaging with the intervention and thus its effectiveness 26. This will maximise the success of repurposing an effective adult intervention (BREATHE) ensuring it to be developmentally-appropriate and likely to be acceptable and engaging for this patient group 18.

The study included a small sample of local participants predominately based in Hampshire, South England. Although we aimed to recruit participants who varied across demographic measures and asthma severity as much as possible, our sample may not be fully representative of the target population. Specifically, the sample should not be considered representative of all views of all people with asthma, and further work should take care to ensure the intervention is acceptable and effective for people from a range of diverse socio-economic and ethnic backgrounds. This will be addressed in the next stages of the study, as a nationwide feasibility study will significantly expand the number of participants and feature a more diverse population where potential differential benefits in subgroups can be explored.

**Possible explanations and implications for clinicians and policymakers**

This rigorous and user-based method emphasises the possibility to engage an end user group throughout planning of an intervention, and particularly within a difficult-to-recruit teenage population. Adolescents have been receptive to the modality of an online intervention and it’s increasingly acknowledged that digital interventions are relevant and accessible for this population. In addition, this work has informed a set of guiding principles to identify key design objectives (what the intervention is trying to achieve) and key features (what the intervention must do to achieve this) within this context (see E-text 2).

**Unanswered questions and future research**

Our understanding of key, adolescent-specific behavioural issues provide insight into the views and needs of this under-served group. Along with the guiding principles informed by this work, these findings can be used to optimise interventions that address the needs of adolescents with asthma. However, care must be taken to ensure that key behavioural issues continue to be relevant within the behaviourally heterogeneous adolescent asthma population (such as those with milder asthma). Furthermore, the effectiveness and cost-effectiveness of any potential interventions should be explored prior to implementation, and thus future research should include high quality randomised controlled trials.

**Acknowledgements:** We would like to thank the Trial Steering Committee Group members (Prof Steve Turner, Prof Gary Connett, Dr Hans Michael Haitchi, Dr Daniela Ghio, Amanda-Lea Harris, Emma Ray) for their support and feedback throughout the project. We’d also like to thank the patient and public members, parents (Svetlana Inwards, Stephanie Hamm, Trevor Ward, Sheryl Ward and Lynn Tann) and teenagers (Joshua Inwards, Amy Tann, Vikram Taak, Dante Texeira, Helena Ward and Zoe Holley) for their continuing commitment and contribution to the project. Next, we’d like to thank Silverback Web-Developers for developing the prototype Breathe4T website. We’d also like to thank the NIHR CRF, and paediatric asthma team at Southampton Hospital for their support. We’d like to thank Anne Bruton for her input in conceptualising the project, based on the adult BREATHE intervention. We’d like to thank Amy Whitehead and Simone Holley, for their relevant expertise in the design of the study. Finally, we’d like to thank our colleagues at Asthma UK, and Asthma + Lung UK Centre of Applied Research (AUKCAR) for their support with the project.

**Competing interests**: Mike Thomas, Lucy Yardley and Denise Gibson were co-applicants in the adult BREATHE study. The study was funded by NIHR RfPB. Erica Kennington is employed by Asthma Lung UK.

**Data Availability Statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

# **REFERENCES**

1. Organisation WH. Asthma. 2020; https://www.who.int/news-room/fact-sheets/detail/asthma. Accessed 5th October, 2020.

2. Vos T, Abajobir AA, Abate KH, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet.* 2017;390(10100):1211-1259.

3. Kurukulaaratchy RJ, Raza A, Scott M, et al. Characterisation of asthma that develops during adolescence; findings from the Isle of Wight Birth Cohort. *Respiratory medicine.* 2012;106(3):329-337.

4. Michaud P-A, Suris J-C, Viner R. The adolescent with a chronic condition: epidemiology, developmental issues and health care provision. 2007.

5. Blakemore S-J. Avoiding social risk in adolescence. *Current directions in psychological science.* 2018;27(2):116-122.

6. Reniers RL, Murphy L, Lin A, Bartolomé SP, Wood SJ. Risk perception and risk-taking behaviour during adolescence: the influence of personality and gender. *PloS one.* 2016;11(4):e0153842.

7. Cui W, Zack MM, Zahran HS. Health-related quality of life and asthma among United States adolescents. *The Journal of pediatrics.* 2015;166(2):358-364.

8. Fleming L, Murray C, Bansal AT, et al. The burden of severe asthma in childhood and adolescence: results from the paediatric U-BIOPRED cohorts. *European Respiratory Journal.* 2015;46(5):1322-1333.

9. Holley S, Morris R, Knibb R, et al. Barriers and facilitators to asthma self‐management in adolescents: A systematic review of qualitative and quantitative studies. *Pediatric pulmonology.* 2017;52(4):430-442.

10. Netz M, Fedele DA, Sweenie R, Baker D, Light M, McQuaid EL. Asthma Management Responsibility, Control, and Quality of Life Among Emerging Adolescents. *Journal of Pediatric Psychology.* 2020;45(1):40-49.

11. Asthma GIf. *Global Strategy for Asthma Management and Prevention.* 2020.

12. Barker N, Thevasagayam R, Ugonna K, Kirkby J. Pediatric dysfunctional breathing: proposed components, mechanisms, diagnosis, and management. *Frontiers in Pediatrics.* 2020;8:379.

13. Gridina I, Bidat E, Chevallier B, Stheneur C. Prevalence of chronic hyperventilation syndrome in children and teenagers. *Archives de pediatrie: organe officiel de la Societe francaise de pediatrie.* 2013;20(3):265.

14. Newson TP, Elias A. Breathing pattern disorders (dysfunctional breathing) characteristics and outcomes of children and young people attending a secondary care respiratory clinic. *Pediatric Pulmonology.* 2020;55(7):1736-1744.

15. Soares M, Rodrigues A, Morais Almeida M. Inducible Laryngeal Obstruction in the Paediatric Population–Review of the Literature and Current Understanding. 2018.

16. Connett GJ, Thomas M. Dysfunctional breathing in children and adults with asthma. *Frontiers in pediatrics.* 2018;6:406.

17. Holley S, Walker D, Knibb R, et al. Barriers and facilitators to self‐management of asthma in adolescents: An interview study to inform development of a novel intervention. *Clinical & Experimental Allergy.* 2018;48(8):944-956.

18. Bruton A, Lee A, Yardley L, et al. Physiotherapy breathing retraining for asthma: a randomised controlled trial. *The Lancet Respiratory Medicine.* 2018;6(1):19-28.

19. Barker NJ, Jones M, O'Connell NE, Everard ML. Breathing exercises for dysfunctional breathing/hyperventilation syndrome in children. *Cochrane Database of Systematic Reviews.* 2013(12).

20. Bignall WJR, Luberto CM, Cornette AF, Haj-Hamed M, Cotton S. Breathing retraining for African-American adolescents with asthma: a pilot study of a school-based randomized controlled trial. *Journal of asthma.* 2015;52(9):889-896.

21. de Groot EP. Breathing abnormalities in children with breathlessness. *Paediatric respiratory reviews.* 2011;12(1):83-87.

22. Macêdo TM, Freitas DA, Chaves GS, Holloway EA, Mendonça KM. Breathing exercises for children with asthma. *Cochrane Database of Systematic Reviews.* 2016(4).

23. Knibb RC, Alviani C, Garriga‐Baraut T, et al. The effectiveness of interventions to improve self‐management for adolescents and young adults with allergic conditions: a systematic review. *Allergy.* 2020;75(8):1881-1898.

24. Van Buul AR, Kasteleyn MJ, Arends JM, et al. eHealth Only Interventions and Blended Interventions to Support Self-management in Adolescents with Asthma: A Systematic Review. *Clinical eHealth.* 2020.

25. O'Cathain A, Croot L, Duncan E, et al. Guidance on how to develop complex interventions to improve health and healthcare. *BMJ open.* 2019;9(8):e029954.

26. Craig P, Matthews L, Moore L, Simpson S, Skivington K, Baird J. Developing and evaluating complex interventions: draft of updated guidance. *URL: www sphsu gla ac uk/stakeholdersurvey-2019/Full% 20complex% 20guidance% 20draft% 20for% 20consultation% 20v1.* 2019;1(2026):03.19.

27. Skivington K, Matthews L, Simpson SA, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *bmj.* 2021;374.

28. Yardley L, Morrison L, Bradbury K, Muller I. The person-based approach to intervention development: application to digital health-related behavior change interventions. *Journal of medical Internet research.* 2015;17(1):e30.

29. Band R, Bradbury K, Morton K, et al. Intervention planning for a digital intervention for self-management of hypertension: a theory-, evidence-and person-based approach. *Implementation Science.* 2017;12(1):1-13.

30. Bradbury K, Steele M, Corbett T, et al. Developing a digital intervention for cancer survivors: an evidence-, theory-and person-based approach. *NPJ digital medicine.* 2019;2(1):1-13.

31. Little P, Stuart B, Hobbs F, et al. An internet-delivered handwashing intervention to modify influenza-like illness and respiratory infection transmission (PRIMIT): a primary care randomised trial. *The Lancet.* 2015;386(10004):1631-1639.

32. Little P, Stuart B, Hobbs FR, et al. An internet-based intervention with brief nurse support to manage obesity in primary care (POWeR+): a pragmatic, parallel-group, randomised controlled trial. *The Lancet Diabetes & Endocrinology.* 2016;4(10):821-828.

33. Yardley L, Ainsworth B, Arden-Close E, Muller I. The person-based approach to enhancing the acceptability and feasibility of interventions. *Pilot and feasibility studies.* 2015;1(1):1-7.

34. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *International journal of social research methodology.* 2005;8(1):19-32.

35. Vazquez‐Ortiz M, Angier E, Blumchen K, et al. Understanding the challenges faced by adolescents and young adults with allergic conditions: a systematic review. *Allergy.* 2020.

36. Greenwell K, Sivyer K, Vedhara K, et al. Intervention planning for the REDUCE maintenance intervention: a digital intervention to reduce reulceration risk among patients with a history of diabetic foot ulcers. *BMJ open.* 2018;8(5).

37. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative research in psychology.* 2006;3(2):77-101.

38. Michie S, Atkins L, West R. The behaviour change wheel. *A guide to designing interventions 1st ed Great Britain: Silverback Publishing.* 2014:1003-1010.

39. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of behavioral medicine.* 2013;46(1):81-95.

40. Cane J, O’Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation science.* 2012;7(1):1-17.

41. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. *Bmj.* 2008;337.

42. Varni J. W, et al. "The PedsQL™ in pediatric asthma: reliability and validity of the Pediatric Quality of Life Inventory™ generic core scales and asthma module." *Journal of behavioral medicine*. 2004; 27(3): 297-318.

43. Juniper E. F, et al. "Measuring quality of life in children with asthma." *Quality of life research.*1996;5(1): 35-46.

44. Deci EL, Ryan RM. Self-determination theory. 2012.

45. Rottman BM, Marcum ZA, Thorpe CT, Gellad WF. Medication adherence as a learning process: insights from cognitive psychology. *Health psychology review.* 2017;11(1):17-32.

46. Ramsey RR, Caromody JK, Voorhees SE, et al. A systematic evaluation of asthma management apps examining behavior change techniques. *The Journal of Allergy and Clinical Immunology: In Practice.* 2019;7(8):2583-2591.

47. Davis SR, Peters D, Calvo RA, Sawyer SM, Foster JM, Smith L. "Kiss myAsthma": Using a participatory design approach to develop a self-management app with young people with asthma. *Journal of Asthma.* 2018;55(9):1018-1027.

48. Davis SR, Peters D, Calvo RA, Sawyer SM, Foster JM, Smith LD. A consumer designed smartphone app for young people with asthma: pilot of engagement and acceptability. *Journal of Asthma.* 2019:1-9.

49. Carpenter DM, Geryk LL, Sage A, Arrindell C, Sleath BL. Exploring the theoretical pathways through which asthma app features can promote adolescent self-management. *Translational behavioral medicine.* 2016;6(4):509-518.

50. Koster ES, Philbert D, De Vries TW, Van Dijk L, Bouvy ML. "i just forget to take it": Asthma self-management needs and preferences in adolescents. *Journal of Asthma.* 2015;52(8):831-837.

51. Panzera AD, Schneider TK, Martinasek MP, et al. Adolescent asthma self‐management: patient and parent‐caregiver perspectives on using social media to improve care. *Journal of School Health.* 2013;83(12):921-930.

52. Peters D, Davis S, Calvo RA, Sawyer SM, Smith L, Foster JM. Young people’s preferences for an asthma self-management app highlight psychological needs: a participatory study. *Journal of medical Internet research.* 2017;19(4):e113.

53. Ramsey RR, Carmody JK, Holbein CE, Guilbert TW, Hommel KA, phd. Examination of the uses, needs, and preferences for health technology use in adolescents with asthma. *Journal of Asthma.* 2019;56(9):964-972.

54. Sage A, Roberts C, Geryk L, Sleath B, Tate D, Carpenter D. A self-regulation theory–based asthma management mobile app for adolescents: A usability assessment. *Journal of Medical Internet Research.* 2017;19(2).

55. Schneider T, Baum L, Amy A, Marisa C. I have most of my asthma under control and I know how my asthma acts: Users’ perceptions of asthma self-management mobile app tailored for adolescents. *Health informatics journal.* 2019:1460458218824734.

56. Nightingale R, Hall A, Gelder C, Friedl S, Brennan E, Swallow V. Desirable components for a customized, home-based, digital care-management app for children and young people with long-term, chronic conditions: a qualitative exploration. *Journal of medical Internet research.* 2017;19(7):e235.

57. Roberts C, Sage A, Geryk L, Sleath B, Carpenter D. Adolescent Preferences and Design Recommendations for an Asthma Self-Management App: Mixed-Methods Study. *JMIR formative research.* 2018;2(2):e10055.

58. Grape A, Rhee H, Sanchez P. Evaluation of a peer-led asthma self-management group intervention for urban adolescents. *Journal of pediatric nursing.* 2019;45:1-6.

59. Roberts CA, Geryk LL, Sage AJ, Sleath BL, Tate DF, Carpenter DM. Adolescent, caregiver, and friend preferences for integrating social support and communication features into an asthma self-management app. *Journal of Asthma.* 2016;53(9):948-954.

60. Sezgin E, Weiler M, Weiler A, Lin S. Proposing an ecosystem of digital health solutions for teens with chronic conditions transitioning to self-management and independence: exploratory qualitative study. *Journal of medical Internet research.* 2018;20(9):e10285.

61. Roberts CA, Sage AJ, Geryk LL, Sleath BL, Carpenter DM. Adolescent feedback on predisposing, reinforcing and enabling features in asthma self-management apps. *Health Education Journal.* 2019;78(7):770-783.

62. Abraham O, Wytiaz RM, Feathers AM. Paediatric use of medications and adherence apps: a qualitative analysis of the perspectives of children and parents. *Journal of Pharmacy Practice and Research.* 2019;49(2):123-129.

63. Ahola Kohut S, Stinson J, Forgeron P, van Wyk M, Harris L, Luca S. A qualitative content analysis of peer mentoring video calls in adolescents with chronic illness. *Journal of Health Psychology.* 2018;23(6):788-799.

64. Masuda JR, Anderson S, Letourneau N, Sloan Morgan V, Stewart M. Reconciling preferences and constraints in online peer support for youth with asthma and allergies. *Health promotion practice.* 2013;14(5):741-750.

65. Al-sheyab N, Gallagher R, Crisp J, Shah S. Peer-led education for adolescents with asthma in Jordan: a cluster-randomized controlled trial. *Pediatrics.* 2012;129(1):e106-e112.

66. Stinson J, Kohut SA, Forgeron P, et al. The iPeer2Peer program: a pilot randomized controlled trial in adolescents with juvenile idiopathic arthritis. *Pediatric Rheumatology.* 2016;14(1):48.

67. Carpenter DM, Alexander DS, Elio A, DeWalt D, Lee C, Sleath BL. Using tailored videos to teach inhaler technique to children with asthma: results from a school nurse-led pilot study. *Journal of pediatric nursing.* 2016;31(4):380-389.

68. Chiang L-C, Ma W-F, Huang J-L, Tseng L-F, Hsueh K-C. Effect of relaxation-breathing training on anxiety and asthma signs/symptoms of children with moderate-to-severe asthma: a randomized controlled trial. *International Journal of Nursing Studies.* 2009;46(8):1061-1070.

69. Odom L, Christenbery T. There is an “app” for that: Designing mobile phone technology to improve asthma action plan use in adolescent patients. *Journal of the American Association of Nurse Practitioners.* 2016;28(11):583-590.

70. Fedele DA, McConville A, Graham Thomas J, et al. Applying Interactive Mobile health to Asthma Care in Teens (AIM2ACT): Development and design of a randomized controlled trial. *Contemporary Clinical Trials.* 2018;64:230-237.

71. Burbank AJ, Lewis SD, Hewes M, et al. Mobile-based asthma action plans for adolescents. *Journal of asthma.* 2015;52(6):583-586.