Augmented Reality to Enhance Educational Resources to Improve Inhaler Technique for Young People with Asthma

---

Antonia Hai-Ting O'Connor

A thesis submitted in fulfilment of the requirements for the Degree of

Doctor of Philosophy

School of Medicine

Faculty of Health and Medical Sciences

University of Adelaide

South Australia

July 2022

Table of Contents

Publications

Submitted for Publication

1. **O'Connor A**, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework. Pediatric Pulmonology
2. **O'Connor A**, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. Co-design of an augmented reality asthma inhaler educational intervention for children: Development and usability study. Journal of Medical Internet Research – Pediatrics and Parenting
3. **O'Connor A**, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study. Journal of Medical Internet Research - Pediatrics and Parenting

Published Works

4. **O'Connor A**, Tai A, Carson-Chahhoud K. Isn't There an App for That? The Role of Smartphone and Tablet Applications for Asthma Education and Self-Management in Adolescents. Children. 2021; 8(9):786.
5. **O'Connor A**, Tai A, Kopsaftis Z, Carson-Chahhoud K. Qualitative Study Protocol: Augmented Reality Technology to Deliver Asthma Inhaler Technique Training for Children and Adolescents With Asthma. International Journal of Qualitative Methods. January 2021.

Editorial Review (accepted for publication)

6. **O'Connor A**, Hasan M, Stovold E, Carson-Chahhoud KV, Dennett EJ. Home-based educational interventions for children with asthma. Cochrane Database of Systematic Reviews TBD, Issue TBD.

In Press

7. **O'Connor A**, Sharrad KJ, Kopsaftis ZA, King CM, Carson-Chahhoud K. Is there potential to use augmented reality technology to provide demonstrative inhaler technique education for asthma patients? A qualitative study. Journal of Medical Internet Research – Formative Research.

Thesis Summary

In Australia, 90% of people with asthma are not using their inhalers correctly, yet inhaled medications (inhalers) are first-line pharmacotherapeutic treatment, targeting symptom control and airway inflammation. Incorrect inhaler technique contributes to the 80% of avoidable asthma hospitalisations in Australia, where almost half occur in children. This is of particular concern given asthma is the leading cause of disease burden for youth aged 5-14 years. Therefore, novel and technology-enhanced interventions to improve asthma management are being called for by experts in the field and the asthma community. One such technology is augmented reality, which utilises mobile devices to create an immersive experience, and may provide a solution for effective asthma inhaler technique education in young people. However, no studies to date have developed an augmented reality mechanism to deliver asthma inhaler technique education in young people with asthma.

The objective of this thesis is to address these issues by creating a novel technology-enabled intervention, that will provide a foundation for a sustainable asthma inhaler technique model for young people. This thesis will show that augmented reality is perceived to be a useful tool for education delivery by asthma stakeholders and healthcare professionals (Chapter 5).

To inform the setting for the evaluation of the augmented reality-enabled intervention, a Cochrane systematic review has been undertaken (Chapter 6). Current literature on home-based asthma educational interventions was synthesised. This showed no significant difference in health outcomes when education was delivered in the home compared to standard care.

Based on results from Chapter 6, the hospital setting was chosen for evaluation of the AR-enhanced resource. Mixed-method investigation has been undertaken to determine perceived barriers and facilitators of asthma education delivery amongst healthcare professionals, asthmatic children and their caregivers within the hospital (Chapter 7). Time pressures and uncertainty of healthcare professional roles in delivering education have been identified as barriers, whilst the use of technology-based interventions have been perceived as a facilitator, supporting the development of an augmented reality-enhanced educational intervention.

Given the novelty of augmented reality, the slow adoption rate of healthcare professionals to digital interventions, and the importance of end user feedback on successful uptake, this thesis describes the use of an iterative co-design process (Chapter 8). Qualitative and quantitative investigation were also performed for the developed augmented reality intervention in Chapters 8 and 9. Children with asthma, their caregivers and healthcare professionals identified the intervention to have good acceptability and usability.

The research performed for this thesis enabled a novel augmented reality technology-enabled prototype intervention to be developed for children for the delivery of asthma inhaler education. This is now being incorporated into a comprehensive asthma model of care which combines multiple technology-enhanced asthma education and self-management tools into one package to test clinical effectiveness in a hospital environment. Results from this thesis including the co-design process, design outcomes and qualitative investigation, produce new evidence to inform development and delivery of technology-enabled asthma inhaler technique education interventions, more likely to be capable of improving inhaler technique, reducing the burden of asthma on Australians.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

I give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

Signed Date 3/7/22

Acknowledgements

Words cannot express my gratitude to all the incredible people who have been a part of this PhD journey with me.

First and foremost, I would like to express my deepest appreciation to my supervisors. The immense support I received from A. Prof. Kristin Carson-Chahhoud, Dr. Andrew Tai, Dr. Malcolm Brinn and Dr. Zoe Kopsaftis was unwavering to which I am so grateful.

To A. Prof. Kristin Carson-Chahhoud - when I first decided to do a PhD, the overwhelming advice I received was to make sure I had a supportive primary supervisor. I am so incredibly lucky that I can say I definitely had that from you, and more. You have remained such a patient, generous, encouraging supervisor throughout this process and I have learnt so much from you. Also - your ability to fit 25 hours in a day with your dedication to your work, students and family is truly inspirational!

To Dr. Andrew Tai - thank you for pushing me to do a PhD, and to get it done! The mentorship you have, and undoubtedly will continue to provide me has been tremendous and I certainly would not be in the position I am in today without all your encouragement.

To Dr. Malcolm Brinn – thank you for stepping in as a supervisor so graciously and willingly when I asked! Even prior to this, you gave me words of encouragement when we ran into each other, you offered so much of your time and advice, and I feel so incredibly lucky to have learnt so much from you.

To Dr. Zoe Kopsaftis – your kind, encouraging words from the beginning have always made me feel like I could (hopefully) do this! Your support and guidance when I was first starting was just what I needed and it has been such a privilege getting to meet and know you.

I am also so incredibly grateful for my collaborators and those who helped with my research over the last few years. A huge thank you to Dr. Amy Hoang and Dr. Daniele Cataldi for helping me with my data entry and analysis - for people who are already so busy, giving up your time to help me with this was so appreciated and I can't thank you enough. Thank you also to Nick Marlow and Kelsey Sharrad, who kindly answered any silly questions I had when I emailed you out of the blue – even when we hadn't met yet!

This endeavour also would not have been possible without my colleagues at The Women's and Children's Hospital, especially the Respiratory and Sleep Department. I am incredibly lucky to be able to work alongside such a great team, with not only colleagues but mentors and friends. Your clinical input, patience, and moral support were so valued, and I will be forever grateful to you all.

I'd also like to extend my sincere thanks to all the children and families of South Australia, and the many healthcare professionals who so generously gave up their time and thoughts. This research could not have been done without you. I have learnt so much from you and I will forever be indebted to you!

To my incredible family and friends, thank you for joining me on this wild journey, even when you didn't really ask to be on it. To my dad, Francis, thank you for all the unconditional support, encouragement and love you have provided throughout life. To my brother, Bosco, thank you for not only being a sibling and roommate through this, but also a true friend. Not only did you provide proof reading support, your cooking, comedic relief and encouragement were greatly appreciated.

Lastly, but most definitely not least, I would like to thank my husband, Matthew for your patience, support, and truly deep love. Whilst I'm sure you weren't anticipating dealing with me whilst heavily pregnant, working and trying to finish this thesis at the same time, the immense care and kindness you have shown Clarry and I has been unbelievable and I'm so excited for what's about to come.

Abbreviations

ACTRN	Australian New Zealand Clinical Trials Registry Number
AIHW	Australian Institute of Health and Welfare
Approx.	Approximately
App	Application
AR	Augmented reality
BC	Before Christ
CHW	Community health worker
DPI	Dry powder inhaler
DOI	Digital object identifier
e.g.	*Exempli gratia* (for example)
EOI	Expression of interest
HCP	Healthcare professional
HREC	Human research ethics committee
GINA	Global initiative for asthma
i.e.	*Id est* (in other words)
MDI	Metered dose inhaler
MRFF	Medical Research Future Fund
NHMRC	National Health and Medical Research Council
PhD	Doctor of Philosophy
RCT	Randomised controlled trial
SA	South Australia
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SUS	System Usability Scale
TDF	Theoretical Domains Framework
TFA	Theoretical Framework of Acceptability
USD	US Dollar
WCHN	Women's and Children's Health Network
WHO	World Health Organisation

Note: Abbreviations listed above are those used within the thesis, excluding those in the manuscripts/publications which are reported within

Background

Chapter 1. Introduction

Hippocrates first described asthma between 460-377 BC, with the origins of the word 'asthma' derived from the Greek word 'asthmaino', meaning 'short of breath' (1, 2). This could be applied to both cardiac and pulmonary disorders. In the 16th century, the association between environmental factors and airway symptoms was first described, with miners noted to have improvement with symptoms when masks were worn (3). During this time, cold baths were also part of the mainstay of asthma therapy (3). Asthma was refined in 1860 by Henry Salter who defined asthma as 'paroxysmal dyspnoea of a peculiar character with intervals of health respiration between attacks' (4). Soon after in 1892, Sir William Osler described the inflammatory component to asthma, of which the link was made between various stimuli and bronchospasm (1, 2).

Over the last century, the increasing understanding and knowledge of asthma and its pathophysiology has led to targeted, evidence-based approaches to treatment (5). Despite this, asthma remains the most common chronic non-communicable disease in children worldwide and there have not been any improvements over the last decade in hospitalisation rates or mortality, signifying childhood asthma management must remain an ongoing priority in research (5, 6).

1.1 Asthma

Asthma is defined by the Global Initiative for Asthma (GINA) as 'a heterogenous disease, usually characterised by chronic airway inflammation, defined by a history of respiratory symptoms, such as wheeze, shortness of breath, chest tightness and cough, that vary over time and in intensity, together with variable expiratory airflow limitation' (7). It is estimated to effect 300 million people worldwide, with this expected to increase to 400 million by 2025 (5, 8). In Australia, it is one of the two leading chronic conditions in children under 14 years old, with an estimated prevalence of 10%. (9). Approximately 80% of asthma hospitalisations in Australia are avoidable, and almost half occur in children, with asthma remaining the leading cause of disease burden in those 5-14 years (9, 10). The primary goal for management and treatment is to achieve asthma control (11). This is defined by both control of symptoms, and control of the underlying airway inflammation

which aims to minimise the future risk of poor asthma outcomes such as asthma exacerbations, lung function decline, or medication-related side effects (12, 13). When paediatric asthma is uncontrolled, it is associated with not only increased exacerbations, but also poorer quality of life for children and their families and chronic airway remodelling which can lead to persistent bronchial obstruction (14, 15). Uncontrolled, or poorly controlled asthma is estimated by the Centres for Disease Control and Prevention to occur in approximately 50% of children with asthma, but has been reported in studies to range from 16% to 84% (16, 17). Multiple factors can influence asthma control, including co-morbidities such as rhinosinusitis or gastro-oesophageal reflux disease, recurrent respiratory tract infections poor adherence to treatment and/or medication issues, severity of asthma, environmental and psychosocial factors (17-20).

1.2 Asthma inhalers

The foundation of pharmacological management to achieving asthma control are inhaled medications (inhalers) which are also used for acute symptomatic relief (11, 21). Inhalers are devices which deliver and deposit asthma medication to the bronchial epithelium, where pharmacological action occurs. They have a more rapid onset of action and require smaller doses compared with other routes of administration (e.g., oral medications), decreasing the incidence of systemic side effects (22). There are multiple inhaler devices including pressured metered-dose inhalers (MDI), dry powder inhalers (DPI) and breath-actuated MDIs, of which all require different techniques (23). The successful deposition of the medication relies on correct inhaler device technique, however, if this is achieved, the effectiveness between devices is comparable (24, 25). The use of a spacer or valved holding chamber is also recommended to improve delivery and reduce side effects of an inhaled corticosteroid, with approximately 50% of children that do not use one with their MDI having minimal clinical benefits from their medication (26). Prior to the prescription of an inhaler, current guidelines state that technique education must be provided, and patients must demonstrate satisfactory technique (21). In addition, inhaler technique should be reviewed and re-checked by clinicians at every opportunity (7, 27).

Correct technique requires the inhaler to be used over sequential steps, with deviations from the steps labelled as errors (28). Errors which are commonly made include the inability to hold the breath for long enough, not taking a breath deep enough, or taking a breath too deep (29-32). The paediatric population faces particular challenges, with poorer

coordination abilities between dose actuation and inhalation (either inhaling too late or early), difficulty in performing fast inhalation, and inhalation through the nasal passage rather than mouth in younger children (22, 33). Poor technique correlates with suboptimal control and poorer clinical outcomes, with increased utilisation of healthcare, requirements for higher medication dosages or oral corticosteroids to treat exacerbations, and poorer quality of life (34-41). These consequences are preventable, with corrections in inhaler use able to achieve immediate clinical improvements (42, 43).

1.3 Asthma inhaler technique educational interventions in young people

Educational interventions can significantly improve asthma inhaler technique, as supported by a 2017 systematic review by Klijn et. al (44). From the 39 included studies, 37 of the educational interventions included demonstrated a statistically significant improvement in inhaler technique (indicated most frequently as the number of correctly performed steps) (44). The majority (89%) of these interventions included a demonstration of inhaler use (video or in-person), with or without asthma disease education embedded within. In a Cochrane systematic review which was also published in 2017, educational interventions on inhaler technique was also identified as having some benefits, such as improvements in asthma control and quality of life (although studies were small with variable results and therefore results were not statistically significant) (41). Within the 29 included studies, educational interventions included face-to-face training, multi-media-delivered training (e.g. games, videos) and technique feedback devices. In both systematic reviews, studies which were included that involved children were smaller in number and size compared to adults. The importance of educational interventions designed for children and their caregivers should be emphasised, given the inherent challenges described above which are more unique to this population. Educating children on the correct steps of their inhaler device has been shown to improve inhaler technique (reported by the number of steps performed correctly), regardless of where this education takes place and by whom (26). Inhaler technique may be taught to young people by a variety of means, in a variety of locations, by a range of people (e.g. medical staff, allied health professionals, lay persons). In a recent scoping review article published in 2022, approaches for educational interventions for children were broad and mostly encompassed provision of verbal and written instructions (most common modality) or continued education until the child could physically demonstrate correct technique (45). Often this also included physical demonstration from educators which was also supplemented by videos (either tailored to

patient or standardised), written instruction, and practice inhaler devices. Physical demonstration may have also occurred remotely. This review did not compare the effectiveness between interventions.

Despite knowing overall that educational interventions can be successful in improving patients' inhaler technique and international guidelines recommending frequent inhaler technique review, 70-80% of patients are still unable to use their inhaler correctly and are unaware they have a problem (7). The prevalence in the paediatric population for incorrect inhaler technique is even higher, with recent studies reporting 86-92% of children do not use their MDI correctly (46-48). This prompts new approaches for educational interventions on asthma inhaler technique to be considered (49).

1.4 Requirement for novel interventions for asthma inhaler technique education and use of technology-based interventions

Technology-based interventions are one such approach that are already employed in healthcare for multiple purposes including accessing of services and information, delivery of treatment and monitoring, patient self-management and education (50). This may be via such means as websites and internet utilisation, telemedicine as well as the use of smartphone and tablet devices. The use of mobile devices for improvement of healthcare and public health is known as 'mHealth' (51). mHealth technologies include smartphone and tablet devices, wearable technology such as sensors or medication pumps, and the use of information communication tools within healthcare (such as electronic medical records) (52). Most commonly, mobile devices are used in mHealth via mobile applications (apps) (52). Whilst the potential role of mHealth and other technology-based interventions has become increasingly apparent during the SARS-CoV-2 pandemic, its use and effectiveness in chronic disease management (including self-management behaviours and health outcome measures) has already been established over the last decade (53-56). These include for chronic non-communicable diseases such as diabetes mellitus, mental health disorders, cardiovascular disease and lung diseases (57).

For adults with asthma, the use of mobile technology-based interventions to deliver asthma education and self-management skills has been shown in multiple systematic reviews to improve quality of life as well as asthma control when compared with routine care (58-61). Delivery via this modality is advantageous in its accessibility, convenience and cost-

effectiveness (62). Apps may be utilised to deliver education on disease pathophysiology and provide self-management tools including the ability for symptom monitoring, personalised asthma action plans and medication reminders (63).

Unfortunately, only 5-10% of the 210 currently available asthma-related apps are targeted towards children (62, 64). With over 90% of children and adolescents having access to a smartphone or tablet in Australia, the age of the introduction of digital technology dropping and the increased familiarity of mobile devices over books, this presents an unmissable opportunity for a technology-based modality for asthma inhaler education delivery (65, 66). Moreover, young Australians have indicated they are more likely to seek support from an online source over healthcare professional advice in regards to stress management in recent surveys, highlighting their preference for technology-based solutions (67). This, in combination with the growing body of evidence which suggests technology-delivered interventions and asthma education programs can improve knowledge, treatment adherence and health outcomes for asthmatic children, again emphasises the need for novel technology-based solutions for education, particularly inhaler technique, in an aim to improve engagement and uptake, and subsequently health-related outcomes (68-70).

An invitation was extended to contribute to an issue in the journal *Children*, which specifically addressed asthma and its impact in adolescents. *Children* is a peer-reviewed, international journal which focuses on the clinical, epidemiological and translational science which is relevant to paediatrics. Given the increasing importance placed on technology for education and the potential for an in-depth review of the current use of smartphone and tablet devices in asthma, specifically in young people, the invitation was accepted. This was seen as an opportunity to contribute to the current evidence base and guide intervention development for this research and the research of others. This publication is presented next as part of the background for this thesis (Chapter 1.4.1).

Chapter 1.4.1

Isn't there an app for that? The role of smartphone and tablet applications for asthma education and self-management in adolescents

(Invited review article)

Antonia O'Connor[1,2], Andrew Tai[1,2,3], Kristin V Carson-Chahhoud[2,4,5]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2] School of Medicine, University of Adelaide, Adelaide, South Australia, [3]Robinson Research Institute, University of Adelaide, [4]Translational Medicine and Technology Group, University of South Australia, [5]Australian Centre for Precision Health, South Australian Health and Medical Research Institute

Children 2021

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Isn't There an App for That? The Role of Smartphone and Tablet Applications for Asthma Education and Self-Management in Adolescents

---

Publication status: Published

Publication details: O'Connor A, Tai A, Carson-Chahhoud K. Isn't There an App for That? The Role of Smartphone and Tablet Applications for Asthma Education and Self-Management in Adolescents. Children. 2021; 8(9):786.

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Identified topical area of clinical importance for summary, designed methodological approach to review evidence, consolidated literature to answer questions to inform future research, conceived and designed manuscript and made critical revisions. Approved final version. Acted as corresponding author.		
Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Andrew Tai		
Contribution to the paper	Invited to write review, assisted in identification of clinical question, contributed to writing the manuscript, agree with manuscript results and conclusions, made critical revisions, approved final version and supervised the process. Co-supervision of primary author.		
Signature		Date	21/06/2022

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Assisted in identification of clinical question and chosen methodological approach to address this through supervision of primary author. Contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process (primary supervisor)		
Signature		Date	21/06/2022

children

MDPI

Review

Isn't There an App for That? The Role of Smartphone and Tablet Applications for Asthma Education and Self-Management in Adolescents

Antonia O'Connor [1,*], Andrew Tai [1,2] and Kristin Carson-Chahhoud [3,4,5]

1 Respiratory and Sleep Department, Women's and Children's Hospital, 72 King Williams Road, North Adelaide, SA 5006, Australia; andrew.tai@sa.gov.au
2 Robinson Research Institute, University of Adelaide, Ground Floor, Norwich Centre, 55 King William Road, North Adelaide, SA 5006, Australia
3 Adelaide Medical School, University of Adelaide, Adelaide Health and Medical Sciences Building, Corner of North Terrace & George Street, Adelaide, SA 5000, Australia; Kristin.Carson-chahhoud@unisa.edu.au
4 Translational Medicine and Technology Group, Australian Centre for Precision Health, University of South Australia, Level 8 South SAHMRI Building, North Terrace, Adelaide, SA 5000, Australia
5 Australian Centre for Precision Health, South Australian Health and Medical Research Institute, North Terrace, Adelaide, SA 5000, Australia
* Correspondence: antonia.chan@sa.gov.au; Tel.: +61-8-8161-7234

Abstract: Asthma is one of the most common chronic diseases worldwide, with a substantial proportion of the asthma population being children and adolescents. Self-management is recognized as a key component to asthma management, with multiple international guidelines emphasizing the need for adequate self-management skills for good asthma control. Unfortunately, the uptake amongst young people and adolescents is low, with often suboptimal engagement to self-management education and skills contributing to poor adherence to medication as well as poor perception of asthma symptoms. Innovative solutions to deliver education and self-management to adolescents are clearly needed. mHealth is the use of mobile devices such as smartphones and tablet devices to improve healthcare and has been used in multiple chronic diseases. This review articles explores the current use of mHealth in asthma, specifically smartphone and tablet applications as a generation-appropriate, accessible delivery modality for provision of asthma education and self-management interventions in adolescents. Current evidence gaps are also highlighted, which should be addressed in future research.

Keywords: bronchial asthma; asthma impact; adolescents; self-management; mobile health; technology; smartphone; tablet

Citation: O'Connor, A.; Tai, A.; Carson-Chahhoud, K. Isn't There an App for That? The Role of Smartphone and Tablet Applications for Asthma Education and Self-Management in Adolescents. *Children* **2021**, *8*, 786. https://doi.org/10.3390/children8090786

Academic Editor: Roberto W. Dal Negro

Received: 31 July 2021
Accepted: 7 September 2021
Published: 9 September 2021

1. Introduction

Asthma is one of the most prevalent chronic diseases worldwide, with an estimated 330 million people diagnosed [1]. Despite the increasing knowledge surrounding pathophysiology and treatment of the disease, prevalence is still estimated to be increasing, with 100 million more people anticipated to have asthma by 2025 [2]. Children and adolescents make up a substantial proportion of this group, with the paediatric population having a higher incidence and prevalence than adults [3]. Children and adolescents who have poorly controlled asthma contribute significantly to health care systems and government costs with an estimated 5.35 billion dollars per year in the United States alone spent on managing the disease within this population [4]. Asthma self-management programs have been shown to assist in achieving asthma control, improving quality of life, reducing health care utilisation and are recommended in management guidelines [5–9]. However, among young people and adolescents with asthma, there is often poor adherence to medication

and a poor perception of symptoms, which may be a reflection of suboptimal engagement in asthma self-management and education [10–12]. Innovative solutions for delivery of education and self-management in this age group have been more recently explored via the use of smartphone and tablet devices. The use of these technologies to enhance health and chronic disease management is known as mobile health (mHealth) [13]. This review article aims to be a rapid review of the current evidence and use of smartphone and tablet devices as a specific modality of mHealth, as a generation-appropriate and readily available delivery modality for self-management among adolescents, to identify current evidence gaps which should be addressed in future research.

2. Asthma Self-Management

Whilst there are many pharmacological agents proven to be efficacious in asthma, self-management programs and self-management skills are also recognised as a key component in disease management. Self-management can be defined as 'the tasks that individuals must undertake to live with one or more chronic conditions' and is an important component in all chronic disease management [14]. Broadly, self-management programs aim to overall change behaviours, and develop skills specific to the condition with techniques including improving knowledge of the disease, encouraging active participation in care, empowering the patient and supporting adherence to strategies which may prevent complications and symptoms [15–17]. Asthma self-management programs commonly include information regarding asthma pathophysiology, training on self-monitoring of symptoms, information regarding avoidance of triggers, as well as frequent medication and device technique reviews [6,8,9,15,18]. As well as education, guided self-management should also include a written action plan which is personalised and be regularly reviewed by health professionals [9,19]. The personalised plan supports self-management for those with asthma, containing information such as symptom recognition, instructions on use of prescribed inhalers, and immediate management guidance for an acute exacerbation such as inhaler use and triggers to seek urgent health care review [19]. Multiple randomised controlled trials have shown that self-management education programs are effective in the paediatric asthma population in improving lung function, decreasing missed school days, as well as decreasing unplanned healthcare visits [20–23]. The evidence for self-management programs is also robust in adults with asthma, with a Cochrane systematic review reporting reduced hospitalisations, reduced urgent healthcare utilisation, reduced missed work or school days and improved quality of life in those with self-management education involving interventions such as asthma plans, self-monitoring of symptoms and frequent review by health professionals [24]. To be effective, however, sufficient time is required from trained healthcare professionals to help deliver self-management education, and patients must be receptive to the development of these skills, which may be difficult among the adolescent cohort.

3. Adolescents and Self-Management

Adolescence, in which there are significant physical, emotional, and social changes in the transition to adulthood, makes for a particularly challenging period for the self-management of chronic diseases [12,25,26]. It is a time of increasing independence and desire for autonomy. However, this is juxtaposed with an ongoing dependence on health professionals and medications. As such, adolescents may experience emotions such as resentment towards their asthma and their 'sick' role [12,26]. Adherence to treatment may be affected by competing interests in their day-to-day lives including schooling, new opportunities for employment and social activities. Adolescents are estimated to only take up to 50% of their prescribed medications [26,27]. This transition period also marks a time where there is an increase in risk-taking behaviours, among which smoking cigarettes is common [28]. Adolescents may also be embarrassed or feel different to their peers if needing to take reliever medications in public and hence be more likely to have untreated symptoms [12]. In a cross-sectional study of 126 adolescents with

asthma, these indeed were some of the most common barriers to asthma self-management in which it was reported that there was an unwillingness to give up behaviours which doctors had asked them to, forgetfulness of medications, and a sense of 'trying to forget' their diagnosis were commonly identified [27]. Although effective communication and education remains crucial in this period, traditional self-management programs may not be as successful [5]. With the known decline of adherence to effective disease management during adolescence, it is clear that there is a need for innovative strategies to approach asthma self-management education in the adolescent population [29]. Positively, childhood and early adolescence has been shown to be an optimal time for skills acquisition and reinforcement learning [30,31]. Combined with the increasing drive for independence, there is an opportunity for engagement and ownership over asthma self-management during this period.

4. Smartphone and Tablet Application Use in Self-Management and Education of Chronic Diseases

Information and communication technologies (ICTs) have been increasingly used for medical purposes as a strategy to improve communication between patients and health care professionals, as well as to provide information and education to patients, and track health data across healthcare professions [32,33]. ICTs are defined as tools that are able to 'communicate, manipulate and store data by electronic means' and include both smartphone and tablet devices [34]. The use of these mobile devices to improve healthcare and public health is known as 'mHealth' [33]. These devices can remind patients of appointments with text messages, but most commonly, they are used in mHealth through mobile applications (apps) [5,15]. Telemedicine has also been employed, allowing improved patient access to support and an encouragement of adherence [26,35].

Over the past decade, mHealth has been adopted by multiple chronic diseases for behaviour change and self-management. These chronic diseases include diabetes mellitus, asthma and cancer and employ strategies such as encouraging increasing frequency of blood glucose monitoring, which has been shown to be effective in behaviour change for both adults and adolescents [36,37]. In addition, there are numerous studies identifying improved outcomes such as decreased healthcare utilisation when self-management is delivered via telemedicine [38,39]. Smartphones and tablets offer a convenient, easily accessible, cost-effective mode of self-management tool delivery with the benefit of being capable of patient-specific tailoring, and is readily updated as the evidence changes [5,26,40,41]. As technology continues to rapidly evolve and improve, mHealth and the use of smartphone and tablet technology will no doubt be a communication disrupter to the delivery of self-management tools for education.

Health-related mobile apps are rapidly increasing, with a recent digital health trend report stating there are over 325,000 apps available worldwide currently, and more than 90,000 new health apps were added to major smartphone app stores in 2020 alone [42–44]. The focus on health-related mobile apps has also shifted, with an increasing focus on the management of specific health conditions rather than overall wellness [44]. The increasing use of ICTs for management of chronic illnesses and for healthcare promotion is likely multifactorial, with an increasing number and quality of devices and apps, a decrease in the cost of devices and mobile data, as well as a population which is becoming more technology-proficient all contributing [15,45].

5. Smartphone and Tablet Applications in Asthma Self-Management and Education

As described previously, asthma self-management education is known to be an important component of management. However exactly how delivery should occur is not explicit in the guidelines. Whilst information delivered face-to-face and on paper-based resources will always have its place, the convenience and accessibility has allowed self-management interventions and education delivered via smartphone and tablet devices to become increasingly attractive and acceptable options [40]. Apps created for asthma include varied combinations of disease information provision, social support and self-management tools

such as asthma action plans, symptom diaries, medication reminders and information regarding environmental triggers (e.g., pollen count) [5]. It may also allow for self-entry of data to allow the clinicians involved to monitor their health remotely to ensure timely intervention if required [46].

Recently, there has been multiple systematic reviews surrounding the use of mHealth and technology-based interventions that have shown improved adherence and quality of life; however, there have been few which have reviewed the use of smartphone and tablet apps specifically comparative to usual care [47–53]. In 2013, Belisario et al. identified two randomised controlled trials which compared mobile-based self-management to paper-based self-management but were unable to draw any conclusions in their systematic review, with insufficient studies and heterogeneity within the included studies. Since then, there have been two systematic reviews identified examining the use of smartphone and tablet applications in asthma self-management and its beneficial impact on outcomes [18]. A meta-analysis conducted in 2016 by Hui et al. reviewed mobile apps as a delivery method for self-management support for adult asthmatics, showing improved asthma control (using the Asthma Control Questionnaire), as well as improved quality of life over 6–30 months in half of the interventions [54]. In 2017, Farzandipour et al. identified 10 studies reviewing the effect of mobile apps on asthma self-management with most of the included studies (90%) reporting a positive impact of the intervention on outcomes assessed. Overall, there were statistically significant improvements in asthma control as well as a positive impact on quality of life, though mixed effects on medication adherence and healthcare utilisation were observed [55].

6. Can Smartphone and Tablet Applications Improve Education and Self-Management in the Adolescent Asthma Population and Where Are the Current Gaps in the Evidence?

The use of smartphone and tablet applications for asthma is particularly promising as a self-management and educational tool in the adolescent age group. Adolescents not only have increasing access to smartphone and tablet devices, but they also use the internet more frequently than ever before. In a survey of teenagers in the United States in 2018, 95% of youths aged 13–17 years reported that they either had a smartphone or could access one, and 45% of teenagers reported almost constant use of the internet [56]. This internet usage had almost doubled since the 2015 survey [56]. Therefore, with the ability of smartphones, tablets and the internet to engage this demographic, it is logical that health interventions should be tailored towards these modalities to provide a generation-appropriate and accessible platform [57], especially for disease self-management.

For asthma self-management, engagement is particularly important at this stage, as strong beliefs regarding their asthma and medication usage will be formed during adolescence. These beliefs may be long-lasting, and as previously mentioned, adherence rates also decrease in this time [58]. Therefore, innovative solutions for delivery of self-management should be a priority. Unfortunately, despite the combination of numerous asthma apps being available and adolescents being early adopters of technology, with smartphones and tablets almost always at their fingertips, only seven out of 157 asthma apps identified in a systematic review in 2015 were targeted towards children or their parents, with none targeted specifically towards adolescents [40]. Since this systematic review in 2015, there have been only a small numbers of applications which have been designed for adolescents and young people identified in the literature [11,55,59–61]. Moreover, despite adolescents perceiving the use of smartphone and tablets as beneficial, particularly for symptom monitoring, and findings that it can be a feasible delivery mechanism for self-management skills and communication assistance with health-care professionals, adolescents with asthma are not commonly involved in the design process of many of these apps, with only one study clearly involving young people in the design process from the outset [5,58,59].

In a survey conducted in 2016 of over 1000 teenagers, 21% had downloaded a health-related app, however almost half (47%) of this group hardly ever or never used them [57]. This may be reflective of the level of difficulty in app use, or low interest and tailoring for the user. Involving adolescents in the creation is vital for a user-based perspective

to ensure it is appealing and engaging. A recent systematic review in 2019 reviewed adolescents' preferences for app features in health-related applications and identified an ability to customise, enhanced engagement through gamification, social media linking and observing their health trends were important to this population [62]. To our knowledge, only five studies over the last five years have reviewed adolescents' preferences for content and features of health technology in asthma (Table 1) [4,5,26,63,64]. The use of tracking capabilities of symptoms and medications, medication reminders to promote adherence, and specific knowledge surrounding individual action plans and medication use have been identified as important components for teenagers with asthma [26].

Table 1. Adolescents' preferences for content and features of apps in asthma.

Author	Year	Study Design	Key Preferences Identified
Carpenter et al.	2016	Observational—usage of two asthma self-management apps over one week period by adolescents	Ability to increase self-observation and self-judgement via reminders, self-check quizzes, charting and tracking features such as symptoms and triggers Ability to share data and information from app with family, healthcare providers, school
Schneider et al.	2016	Observational—usage of two asthma apps over 7–10 days by adolescents	Ability to receive messages through the app, including reminders for medications, measuring peak flow, attend appointments Ability to receive alerts if deteriorating peak flow Motivational and supportive messages Visual aids (graphs/charts) to monitor trends of asthma status Ability to enter data such as peak flow Ability to share information and communicate with healthcare providers and others Customisation (e.g., 'personally designed avatar') and age-appropriate graphics Gamification
Roberts et al.	2018	Observational—usage of two asthma apps over one week by adolescents	Ease of use Simple layout Visual aids such as graphs and pictures Customisation—including medication lists, triggers, visuals and graphics of apps Gamification Ability to track asthma control Medication reminders Appointment reminders Information with videos
Ramsey et al.	2019	Qualitative	Ability to track symptoms Ability to track treatment and medications Reminders for medications, appointments Ability to deliver information on asthma and self-management (personalised medications and asthma plans) Be customisable to fit with daily life Ability to share data and information with health care providers and parents
Schneider et al.	2020	Qualitative, exploratory—asthma self management app trialled for 3 months by adolescents	Reminders for medications or checking peak flow Option to share information with health care provider Ability to review asthma patterns over time Age friendly visuals and graphics of app including backgrounds, fonts Ability to customise Availability of asthma training material e.g., videos on self-management strategies Ability to interact and communicate with others (healthcare providers, other teenagers, technological support) 'Fun' elements including gamification and incentives

Despite the lack of apps created specifically for adolescents, there are a small number of recent studies assessing the effects of apps for smartphone and tablet devices on adolescents with asthma, which have identified this as a feasible method to deliver education and self-management interventions [11,55,61,65,66]. Burbank et al. in 2015 found statistically significant improvement in asthma control in adolescents with uncontrolled asthma from baseline with the use of a personalised mobile asthma action plan on a smartphone app. This app provided feedback based on their personalised action plan in real time, based on the participants' current symptoms or peak flow measurements. After using the personalised mobile asthma action plan for eight weeks, median Asthma Control Test (ACT) scores improved from 16 to 18 [11]. Perry et al. also reviewed the effects of a smartphone-based asthma action plan on a smartphone app, and found a statistically significant improvement in asthma control in those with uncontrolled asthma post-intervention, also using ACT scores [55]. In addition to a personalised asthma action plan on the app, medication and prescription refill reminders, as well as self-management tips and symptom/peak flow diaries were also available [55]. A proof-of-concept study by Mosnaim et al. in 2015, also showed promising results, with an electronic medication monitor and smartphone asthma app designed for a low health literacy population. The app in this study used gamification techniques and offered rewards such as monetary incentives for inhaled corticosteroid use by the participant. From baseline compared with completion of the eight-week treatment phase, the study found improvements in medication adherence (using an electronic medication monitoring device) as well as asthma control (using ACT scores) [61]. In 2019, a randomised controlled trial with an interactive app in which participants randomised to the intervention had access to for six months also showed improvement in adherence to inhaled corticosteroids in patients with a low baseline adherence [66]. This app had multiple features including disease control scoring, reminders for medication, informative videos, the ability to chat to peers in the study or a pharmacist, as well as fortnightly questions surrounding adherence [66]. Lastly, in 2021, Davis et al. undertook a short pilot study (six weeks) on an asthma application designed for young people (15–24 years old) and reported on significant changes in the 'emotional function' domain score of asthma quality of life (using the Mini Asthma Quality of Life Questionnaire) with no other statistically significant changes in other domains.

There has been only one systematic review to our knowledge, which reviews smartphone applications for asthma self-management specifically in adolescents by Alquran et al. in 2018. This combined interventional, observational and qualitative studies and identified smartphone apps as being able to have a positive effect on adolescents' control and adherence to medications as well as self-efficacy; however, due to the small number and heterogeneity of included studies, no definitive conclusion on effect could be made [15].

7. Future Directions

mHealth may be a generation-appropriate, widely accessible and cost-effective solution for self-management interventions and education for adolescents, which is a known period for poorer asthma control. We have identified the following gaps in the current literature which we believe require addressing in order for successful implementation and use of smartphone and tablet apps used for self-management in adolescents with asthma.

7.1. Smartphone and Tablet Applications Designed Specifically for Adolescents Required

Several studies have demonstrated usefulness of smartphone and tablet applications for self-management in other chronic diseases, and in adults with asthma. Recent studies have also identified the feasibility of using smartphone and tablet devices as educational and self-management interventions in the adolescent asthma population. However, only five reports in the literature describe applications specifically designed for the adolescent asthma population. This infers a lack of evidence-based applications for adolescents are available. For successful implementation within the adolescent population, applications must be designed to be specific to the user [11,55,59–61].

7.2. Incorporation of Adolescents' Preferences for Content and Features of Smartphone and Tablet Applications in Asthma Required and Co-Design Process Utilised

To ensure successful design, qualitative research must be undertaken to determine preferences, acceptability, and usability. Only one study to date has described implementing the co-design process, i.e., with contributions from the adolescent population, from the outset of application development, which we have identified as a major gap in development [59]. Intervention developers should be designing mHealth technology using co-design, and using existing evidence of adolescents' preferences which we have highlighted in this review paper, to ensure successful engagement.

7.3. Larger Efficacy Studies Required

As mentioned, there has only been one systematic review to date which has analysed smartphone applications for asthma self-management in adolescents. Within the review, the included studies had a small number of participants with heterogeneity in both the study methods themselves, as well as in the intervention applied. Given the heterogeneity, no definitive conclusion could be made [15]. In view of this, larger efficacy studies are needed to identify the impact that this technology can have on asthma-related health outcomes for young people and to establish an evidence base that can launch a revolution in asthma self-management education.

mHealth creates an exciting opportunity for engaging adolescents during a busy time of their lives, using devices that the majority would have daily access to and use frequently. The incorporation of the co-design process to develop adolescent specific smartphone and tablet applications for self-management in asthma requires further attention, as we look to improve health outcomes in this vulnerable population.

Author Contributions: Conceptualization, A.O., K.C.-C. and A.T.; writing—original draft preparation, A.O.; writing—review and editing, K.C.-C. and A.T.; supervision, K.C.-C. and A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: Women's and Children's Health Library for administrative support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Braman, S.S. The Global Burden of Asthma. *Chest* **2006**, *130*, 4S–12S. [CrossRef] [PubMed]
2. Masoli, M.; Fabian, D.; Holt, S.; Beasley, R.; Global Initiative for Asthma (GINA) Program. The global burden of asthma: Executive summary of the GINA Dissemination Committee Report. *Allergy* **2004**, *59*, 469–478. [CrossRef] [PubMed]
3. Dharmage, S.; Perret, J.L.; Custovic, A. Epidemiology of Asthma in Children and Adults. *Front. Pediatr.* **2019**, *7*, 246. [CrossRef] [PubMed]
4. 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 Form. Res.* **2018**, *2*, e10055. [CrossRef]
5. 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 Inform. J.* **2019**, *26*, 342–353. [CrossRef] [PubMed]
6. British Guideline on the Management of Asthma. *Thorax* **2014**, *69*, i1–i192.
7. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention. 2020. Available online: www.ginasthma.org (accessed on 15 July 2021).
8. Powell, H.; Gibson, P.G. Options for self-management education for adults with asthma. *Cochrane Database Syst. Rev.* **2002**, *2010*, CD004107. [CrossRef] [PubMed]

9. Lougheed, M.D.; Lemière, C.; Dell, S.D.; Ducharme, F.M.; FitzGerald, J.M.; Leigh, R.; Licskai, C.; Rowe, B.H.; Bowie, D.; Becker, A.; et al. Canadian Thoracic Society Asthma Management Continuum—2010 Consensus Summary for Children Six Years of Age and Over, and Adults. *Can. Respir. J.* **2010**, *17*, 15–24. [CrossRef]
10. Banzett, R.B.; Dempsey, J.A.; O'Donnell, D.E.; Wamboldt, M.Z. Symptom Perception and Respiratory Sensation in Asthma. *Am. J. Respir. Crit. Care Med.* **2000**, *162*, 1178–1182. [CrossRef]
11. Burbank, A.J.; Lewis, S.D.; Hewes, M.; Schellhase, D.E.; Rettiganti, M.; Hall-Barrow, J.; Bylander, L.A.; Brown, R.H.; Perry, T.T. Mobile-based asthma action plans for adolescents. *J. Asthma* **2015**, *52*, 583–586. [CrossRef]
12. Macdonald, P. Understanding and treating asthma in adolescents. *Paediatr. Nurs.* **2003**, *15*, 34–36. [CrossRef] [PubMed]
13. Wu, A.C.; Carpenter, J.F.; Himes, B.E. Mobile health applications for asthma. *J. Allergy Clin. Immunol. Pr.* **2015**, *3*, 446–448.e16. [CrossRef] [PubMed]
14. Taylor, S.J.; Pinnock, H.; Epiphaniou, E.; Pearce, G.; Parke, H.L.; Schwappach, A.; Purushotham, N.; Jacob, S.; Griffiths, C.J.; Greenhalgh, T.; et al. A rapid synthesis of the evidence on interventions supporting self-management for people with long-term conditions: PRISMS—Practical systematic RevIew of Self-Management Support for long-term conditions. *Health Serv. Deliv. Res.* **2014**, *2*, 1–580. [CrossRef] [PubMed]
15. Alquran, A.; Lambert, K.A.; Farouque, A.; Holland, A.; Davies, J.; Lampugnani, E.R.; Erbas, B. Smartphone Applications for Encouraging Asthma Self-Management in Adolescents: A Systematic Review. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2403. [CrossRef]
16. Mansouri, M.P.; Ghadami, M.M.; Najafi, M.S.S.; Yektatalab, P.S. The effect of Self-Management Training on Self-Efficacy of Cirrhotic Patients Referring to Transplantation Center of Nemazee Hospital: A Randomized Controlled Clinical Trial. *Int. J. Community Based Nurs. Midwifery* **2017**, *5*, 256–263.
17. Creer, T.L. Behavioral and Cognitive Processes in the Self-Management of Asthma. *J. Asthma* **2008**, *45*, 81–94. [CrossRef]
18. Marcano Belisario, J.S.; Huckvale, K.; Greenfield, G.; Car, J.; Gunn, L.H. Smartphone and tablet self management apps for asthma. *Cochrane Database Syst. Rev.* **2013**, *11*, CD010013. [CrossRef]
19. Pinnock, H. Supported self-management for asthma. *Breathe* **2015**, *11*, 98–109. [CrossRef]
20. Guevara, J.P.; Wolf, F.M.; Grum, C.M.; Clark, N.M. Effects of educational interventions for self management of asthma in children and adolescents: Systematic review and meta-analysis. *BMJ* **2003**, *326*, 1308. [CrossRef]
21. Guan, Z.; Sun, L.; Xiao, Q.; Wang, Y. Constructing an assessment framework for the quality of asthma smartphone applications. *BMC Med. Inform. Decis. Mak.* **2019**, *19*, 1–17. [CrossRef]
22. Wolf, F.; Guevara, J.P.; Grum, C.M.; Clark, N.M.; Cates, C. Educational interventions for asthma in children. *Cochrane Database Syst. Rev.* **2002**, *4*, CD000326. [CrossRef]
23. Boyd, M.; Lasserson, T.J.; Mckean, M.C.; Gibson, P.; Ducharme, F.M.; Haby, M. Interventions for educating children who are at risk of asthma-related emergency department attendance. *Cochrane Database Syst. Rev.* **2009**, *2009*, CD001290.
24. Gibson, P.G.; Powell, H.; Wilson, A.; Abramson, M.; Haywood, P.; Bauman, A.; Hensley, M.J.; Walters, E.; Roberts, J.J. Self-management education and regular practitioner review for adults with asthma. *Cochrane Database Syst. Rev.* **2002**, *2002*, CD001117. [CrossRef]
25. De Benedictis, D.; Bush, A. The Challenge of asthma in adolescence. *Pediatric Pulmonol.* **2007**, *42*, 683–692. [CrossRef]
26. Ramsey, R.R.; Carmody, J.K.; Holbein, C.E.; Guilbert, T.W.; Hommel, K.A. Examination of the uses, needs, and preferences for health technology use in adolescents with asthma. *J. Asthma* **2018**, *56*, 964–972. [CrossRef] [PubMed]
27. Rhee, H.; Belyea, M.J.; Ciurzynski, S.; Brasch, J. Barriers to asthma self-management in adolescents: Relationships to psychosocial factors. *Pediatr. Pulmonol.* **2009**, *44*, 183–191. [CrossRef] [PubMed]
28. Price, J.F. Issues in adolescent asthma: What are the needs? *Thorax* **1996**, *51*, S13–S17. [CrossRef] [PubMed]
29. Bitsko, M.J.; Everhart, R.S.; Rubin, B.K. The Adolescent with Asthma. *Paediatric Resp. Rev.* **2014**, *15*, 146–153. [CrossRef] [PubMed]
30. Janacsek, K.; Fiser, J.; Nemeth, D. The best time to acquire new skills: Age-related differences in implicit sequence learning across the human lifespan. *Dev. Sci.* **2012**, *15*, 496–505. [CrossRef]
31. Davidow, J.Y.; Foerde, K.; Galván, A.; Shohamy, D. An Upside to Reward Sensitivity: The Hippocampus Supports Enhanced Reinforcement Learning in Adolescence. *Neuron* **2016**, *92*, 93–99. [CrossRef]
32. Calderón, J.; Cherrez, A.; Ramón, G.D.; Jove, O.L.; Baptist, A.; Matos, E.; Maciel, B.M.; Calero, E.; Sanchez-Borges, M.; Cherrez, S.; et al. Information and communication technology use in asthmatic patients: A cross-sectional study in Latin America. *ERJ Open Res.* **2017**, *3*. [CrossRef] [PubMed]
33. Free, C.; Phillips, G.; Felix, L.; Galli, L.; Patel, V.; Edwards, P. The effectiveness of M-health technologies for improving health and health services: A systematic review protocol. *BMC Res. Notes* **2010**, *3*, 1–7. [CrossRef]
34. Perron, B.E.; Taylor, H.O.; Glass, J.; Margerum-Leys, J. Information and Communication Technologies in Social Work. *Adv. Soc. Work.* **2010**, *11*, 67–81. [CrossRef]
35. Mammen, J.R.; Schoonmaker, J.D.; Java, J.; Halterman, J.; Berliant, M.N.; Crowley, A.; Reznik, M.; Feldman, J.M.; Fortuna, R.J.; Frey, S.M.; et al. Going mobile with primary care: Smartphone-telemedicine for asthma management in young urban adults (TEAMS). *J. Asthma* **2020**, 1–13. [CrossRef]
36. Majeed-Ariss, R.; Baildam, E.; Campbell, M.; Chieng, A.; Fallon, D.; Hall, A.; McDonagh, J.E.; Stones, S.R.; Thomson, W.; Swallow, V. Apps and Adolescents: A Systematic Review of Adolescents' Use of Mobile Phone and Tablet Apps That Support Personal Management of Their Chronic or Long-Term Physical Conditions. *J. Med. Internet Res.* **2015**, *17*, e287. [CrossRef]

37. Cafazzo, J.A.; Casselman, M.; Hamming, N.; Katzman, D.K.; Palmert, M.R. Design of an mHealth App for the Self-management of Adolescent Type 1 Diabetes: A Pilot Study. *J. Med. Internet Res.* **2012**, *14*, e70. [CrossRef] [PubMed]
38. McLean, S.; Chandler, D.; Nurmatov, U.; Liu, J.; Pagliari, C.; Car, J.; Sheikh, A. Telehealthcare for asthma: A Cochrane review. *Can. Med. Assoc. J.* **2011**, *183*, E733–E742. [CrossRef] [PubMed]
39. Brown, W.; Odenthal, D. The uses of telemedicine to improve asthma control. *J. Allergy Clin. Immunol. Pract.* **2014**, *3*, 300–301. [CrossRef] [PubMed]
40. Huckvale, K.; Car, M.; Morrison, C.; Car, J. Apps for asthma self-management: A systematic assessment of content and tools. *BMC Med.* **2012**, *10*, 144. [CrossRef]
41. Farzandipour, M.; Nabovati, E.; Arani, M.H.; Akbari, H.; Sharif, R.; Anvari, S. Enhancing Asthma Patients' Self-Management through Smartphone-Based Application: Design, Usability Evaluation, and Educational Intervention. *Appl. Clin. Inform.* **2019**, *10*, 870–878. [CrossRef] [PubMed]
42. Research2Guidance. mHealth App Economics 2017/2018—Current Status and Future Trends in Mobile Health. How Digital Intruders Are Taking Over the Healthcare Market November 2017. Available online: https://research2guidance.com/product/mhealth-economics-2017-current-status-and-future-trends-in-mobile-health/ (accessed on 25 July 2021).
43. Kagen, S.; Garland, A. Asthma and Allergy Mobile Apps in 2018. *Curr. Allergy Asthma Rep.* **2019**, *19*, 1–13. [CrossRef] [PubMed]
44. Aitken, M.N.D. *Digital Health Trends 2021*; IQVIA Institute: Danbury, CT, USA, 2021.
45. Betz, C.L.; Lewinter, K.; Kysh, L.; Hudson, S.; Espinoza, J. Smart devices for the management of pediatric asthma: A scoping review protocol. *JBI Database Syst. Rev. Implement. Rep.* **2019**, *17*, 2308–2316. [CrossRef] [PubMed]
46. Mosnaim, G.; Safioti, G.; Brown, R.; DePietro, M.; Szefler, S.J.; Lang, D.M.; Portnoy, J.; Bukstein, D.A.; Bacharier, L.B.; Merchant, R.K. Digital Health Technology in Asthma: A Comprehensive Scoping Review. *J. Allergy Clin. Immunol. Pract.* **2021**, *9*, 2377–2398. [CrossRef]
47. Biblowitz, K.; Bellam, S.; Mosnaim, G. Improving Asthma Outcomes in the Digital Era: A Systematic Review. *Pharm. Med.* **2018**, *32*, 173–187. [CrossRef]
48. Miller, L.; Schüz, B.; Walters, J.; Walters, E.H.; Ryan, D. Mobile Technology Interventions for Asthma Self-Management: Systematic Review and Meta-Analysis. *JMIR mHealth uHealth* **2017**, *5*, e57. [CrossRef]
49. Tran, N.; Coffman, J.M.; Sumino, K.; Cabana, M.D. Patient reminder systems and asthma medication adherence: A systematic review. *J. Asthma* **2014**, *51*, 536–543. [CrossRef]
50. Doshi, H.; Hsia, B.; Shahani, J.; Mowrey, W.; Jariwala, S.P. Impact of Technology-Based Interventions on Patient-Reported Outcomes in Asthma: A Systematic Review. *J. Allergy Clin. Immunol. Pract.* **2021**, *9*, 2336–2341. [CrossRef] [PubMed]
51. Jeminiwa, R.; Hohmann, L.; Qian, J.; Garza, K.; Hansen, R.; Fox, B.I. Impact of eHealth on medication adherence among patients with asthma: A systematic review and meta-analysis. *Respir. Med.* **2019**, *149*, 59–68. [CrossRef]
52. Morrison, D.; Wyke, S.; Agur, K.; Cameron, E.J.; Docking, R.I.; MacKenzie, A.M.; McConnachie, A.; Raghuvir, V.; Thomson, N.; Mair, F.S. Digital Asthma Self-Management Interventions: A Systematic Review. *J. Med. Internet Res.* **2014**, *16*, e51. [CrossRef]
53. Ramsey, R.R.; Plevinsky, J.M.; Kollin, S.R.; Gibler, R.C.; Guilbert, T.W.; Hommel, K.A. Systematic Review of Digital Interventions for Pediatric Asthma Management. *J. Allergy Clin. Immunol. Pract.* **2020**, *8*, 1284–1293. [CrossRef]
54. Hui, C.Y.; Walton, R.; McKinstry, B.; Jackson, T.; Parker, R.; Pinnock, H. The use of mobile applications to support self-management for people with asthma: A systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. *J. Am. Med. Inform. Assoc.* **2016**, *24*, 619–632. [CrossRef]
55. Perry, T.T.; Marshall, A.; Berlinski, A.; Rettiganti, M.; Brown, R.H.; Randle, S.M.; Luo, C.; Bian, J. Smartphone-based vs paper-based asthma action plans for adolescents. *Ann. Allergy Asthma Immunol.* **2017**, *118*, 298–303. [CrossRef]
56. Anderson, M.J. *Teens, Social Media & Technology 2018*; Pew Research Center: Washington, DC, USA, 2018.
57. Wartella, E.; Rideout, V.; Montague, H.; Beaudoin-Ryan, L.; Lauricella, A. Teens, Health and Technology: A National Survey. *Media Commun.* **2016**, *4*, 13–23. [CrossRef]
58. Kosse, R.C.; Bouvy, M.L.; De Vries, T.W.; Koster, E.S. Evaluation of a mobile health intervention to support asthma self-management and adherence in the pharmacy. *Int. J. Clin. Pharm.* **2019**, *41*, 452–459. [CrossRef] [PubMed]
59. Davis, S.R.; Peters, D.; Calvo, R.A.; Sawyer, S.M.; Foster, J.M.; Smith, L. "Kiss myAsthma": Using a participatory design approach to develop a self-management app with young people with asthma. *J. Asthma* **2018**, *55*, 1018–1027. [CrossRef]
60. Sage, A.; Roberts, C.; Geryk, L.; Sleath, B.; Tate, D.; Carpenter, D.; Furberg, R.; Gaytán-Lugo, L.; Mayora, O. A Self-Regulation Theory–Based Asthma Management Mobile App for Adolescents: A Usability Assessment. *JMIR Hum. Factors* **2017**, *4*, e5. [CrossRef] [PubMed]
61. Mosnaim, G.; Li, H.P.; Martin, M.; Richardson, D.; Belice, P.J.; Avery, E.; Leigh, J.; Kenyon, R.; Jones, S.; Bender, B.; et al. A tailored mobile health intervention to improve adherence and asthma control in minority adolescents. *J. Allergy Clin. Immunol. Pract.* **2015**, *3*, 288–290.e1. [CrossRef]
62. Jeminiwa, R.N.; Hohmann, N.S.; Fox, B.I. Developing a Theoretical Framework for Evaluating the Quality of mHealth Apps for Adolescent Users: A Systematic Review. *J. Pediatr. Pharmacol. Ther.* **2019**, *24*, 254–269. [CrossRef] [PubMed]
63. Carpenter, D.M.; Geryk, L.L.; Sage, A.; Arrindell, C.; Sleath, B.L. Exploring the theoretical pathways through which asthma app features can promote adolescent self-management. *Transl. Behav. Med.* **2016**, *6*, 509–518. [CrossRef]

64. Schneider, T.; Panzera, A.D.; Couluris, M.; Lindenberger, J.; McDermott, R.; Bryant, C.A. Engaging Teens with Asthma in Designing a Patient-Centered Mobile App to Aid Disease Self-Management. *Telemed. e-Health* **2016**, *22*, 170–175. [CrossRef] [PubMed]
65. Mayoral, K.; ARCA Group; Garin, O.; Caballero-Rabasco, M.A.; Praena-Crespo, M.; Bercedo, A.; Hernandez, G.; Castillo, J.; Barrantes, C.L.; Pardo, Y.; et al. Smartphone App for monitoring Asthma in children and adolescents. *Qual. Life Res.* **2021**, 1–18. [CrossRef]
66. Kosse, R.C.; Bouvy, M.L.; de Vries, T.W.; Koster, E.S. Effect of a mHealth intervention on adherence in adolescents with asthma: A randomized controlled trial. *Respir. Med.* **2019**, *149*, 45–51. [CrossRef] [PubMed]

1.5 Potential of augmented reality

The use of technology-based interventions in asthma is rapidly growing, with one leading new technology being augmented reality (AR). This digital technology has the ability to deliver information and education via videos, animations and graphics on smartphone and tablet devices. Augmented reality is defined as 'technology which is able to superimpose virtual objects into a real-world setting so that the virtual objects seem to co-exist in the same space in real time' (71). By allowing the real and virtual world to be blended, an immersive experience for users is created. The rapid uptake and incorporation of this technology into multiple sectors such as education, gaming and retail earnt it the title of one of the most 'disruptive' emerging technologies in 2021 (72). In essence, 'disruption' is a process in which a smaller company with less resources can successfully challenge already established businesses (73). Within the medical and healthcare industry, augmented reality is currently one of the top novel technological innovations (74).

Augmented reality already has proven efficacy in other industries for teaching purposes and as a behaviour change tool (75-80). In educational settings, augmented reality has been seen as effective by increasing participation, motivation, attention, and enjoyment (75, 81-83). Higher levels of educational achievement, increased positive attitudes and improved long-term retention in education on science topics has been reported in students (84, 85). There is also evidence it has the ability to enhance collaborative learning and allows information to be received quickly (86, 87). In children with disabilities, augmented reality has been used to teach navigation and work-related skills, vocabulary, and has shown the ability to encourage faster rates of concept understanding (77, 88). The use of augmented reality in educational settings is supported by two systematic reviews in the last decade in which students who used augmented reality-based approaches had improved learning effectiveness compared to those who did not (80, 89). For behaviour change, augmented reality has the capability of providing immediate visual feedback and instantaneous reminders or recommendations on behaviour, with self-motivation and action shown to increase with its use (90). It has been shown to be efficacious for changes in dietary habits within nutrition, and consumer behaviours in the retail sector (78, 79, 91). In the tourism industry, the use of games which incorporate augmented reality has shown to increase the intentions of users to visit tourist destinations (92).

In healthcare, augmented reality has been predominantly used for education and training purposes of healthcare professionals and students, and for surgical planning (76, 93-95). With its efficacy already demonstrated in other industries, its ability to allow for tailoring to individual populations (e.g. age, language), the increased engagement proven in education and accessibility offered through delivery via mobile devices, the concept of using augmented reality to deliver healthcare education to patients and their families should be strongly considered (71, 96-98). For young people, augmented reality may provide a generation appropriate and engaging modality for asthma education. Apart from a single study which demonstrated improved asthma inhaler technique in a non-asthmatic paediatric cohort, augmented reality has not yet been explored in asthma education for children (98).

In 2015, Deloitte Access Economics was commissioned by Asthma Australia and the National Asthma Council of Australia to perform an analysis on the economic and burden of disease costs to Australia (99). Incorporating multiple components including the direct costs of asthma to the Australian health system, productivity losses (which included both productivity losses of people who had asthma and costs of informal care) and burden of disease, it was estimated to cost the Australian economy a total of $28 billion Australian dollars in 2015 (99). Based on this, and with relevant asthma key stakeholder involvement, major recommendations were made. These included increasing the uptake of low-cost interventions such as improving inhaler technique and patient education, as well as research focused on novel therapies and effective interventions. The use of augmented reality to deliver asthma inhaler technique to young people with asthma may provide a solution to address both of these recommendations.

1.6 Summary

Despite the increasing knowledge of asthma pathophysiology and advancing phenotypic-specific treatments, asthma remains to be one of the most common chronic non-communicable diseases worldwide (5). Worldwide, it is ranked 28th for burden of disease, however, amongst young people in Australia, it is ranked first (5, 100). Incorrect inhaler technique is common in children and adolescents and contributes to this burden by impacting asthma control. Despite the awareness that educational interventions are effective in improving inhaler use, technique has not improved over time.

The overall aims of this thesis are to provide a novel, suitable solution for asthma inhaler technique education delivery for young people through the development of a prototype augmented reality technology-enabled intervention. The research in this thesis produces new evidence to inform development and delivery of technology-enabled asthma inhaler technique education interventions which are more likely to be capable of improving asthma inhaler technique, reducing the burden of asthma on young Australians.

Aims and Hypothesis

Chapter 2. Overview of aims and hypothesis

2.1 Objective

To address the substantial proportion of children who still do not use their asthma inhalers correctly, new interventions are required for the delivery of asthma inhaler technique education. A possible suitable solution for the paediatric population may be development of a novel technology-delivered educational resource. This is supported by a growing body of evidence that technology-delivered interventions are efficacious for improving knowledge, treatment adherence and health outcomes in children with asthma. The overall objective of this thesis was to create a prototype augmented reality technology-enabled intervention to provide a foundation for a sustainable asthma inhaler technique educational model for young people.

2.2 Overview of aims

A summary of the aims for each manuscript presented in this thesis are below.

2.2.1 Augmented reality technology to provide demonstrative inhaler technique education for asthma patients: a qualitative study (Chapter 5)

The aim of this study is to explore the perspectives of healthcare professionals, asthma patients and key community stakeholders on the potential use of augmented reality technology to improve upon the existing education for asthma inhaler technique.

2.2.2 Home-based educational interventions for children with asthma (Chapter 6)

The aim of this Cochrane systematic review is to assess the effects of educational interventions for asthma, which is delivered in the home to children, their caregivers, or both, on asthma-related outcomes. This review also aims to make the education interventions accessible to readers by summarising the contents and components.

2.2.3 Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework (Chapter 7)

The aim of this mixed-methods study is to identify the barriers and facilitators of delivering and receiving asthma inhaler education for children in a hospital setting. This study also aims to explore the use of technology-based innovations for asthma education in children to guide and inform development of an augmented reality-based educational intervention for inhaler technique.

2.2.4 Co-design of an augmented reality asthma inhaler educational intervention for children: development and usability study (Chapter 8)

The aims of this study are to describe the co-design process, development and design outcomes of a smartphone/tablet application which incorporates augmented reality technology to deliver asthma inhaler technique education to children with asthma. This study also aims to provide a usability evaluation of the designed intervention to inform future research, and to provide recommendations for others performing similar work.

2.2.5 The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study (Chapter 9)

The aim of this study is to evaluate the acceptability of augmented reality as a delivery mechanism for asthma inhaler technique education, from the perspectives of children with asthma, their caregivers and healthcare professionals.

2.3 Hypothesis

A co-designed augmented reality-enabled prototype which delivers asthma inhaler technique education to children will be usable and acceptable within a hospital-based setting by children with asthma, their caregivers and healthcare professionals with experience in delivering asthma education.

Methods

Chapter 3. Overview of study methodologies

An overview of the methodology for each publication/manuscript presented in this thesis are described below. A detailed description of methodology is provided within each manuscript, including the reason we chose each specific design, the specific framework to analyse it and the specific approach taken to do this. A detailed published protocol of qualitative methods is also presented in Chapter 4. Formatting of manuscripts which have been submitted for publication are in accordance with journal specific requirements. Information pertaining to ethics approvals for this thesis are provided in the appendix (Appendices 1 and 2). References for the thesis are provided at the end without unnecessary duplication from references within publications and submitted manuscripts.

3.1 Overview of study methods

3.1.1 Augmented reality technology to provide demonstrative inhaler technique education for asthma patients: a qualitative study (Chapter 5)

A poster of 22 asthma inhaler devices, which when triggered by augmented reality technology via a smartphone application, launched instructional videos of correct technique for each inhaler was designed for qualitative investigation. Semi-structured one-on-one interviews were undertaken with healthcare professionals, people with asthma and key community stakeholders to explore the perspectives of participants on the use of augmented reality to improve asthma inhaler technique education. Deductive thematic analysis was informed by the Triandis model of interpersonal behaviour.

3.1.2 Home-based educational interventions for children with asthma (Chapter 6)

Two independent researchers undertook a Cochrane systematic search using records from the Cochrane Airways Group Trials Register, Cochrane Central Register of Controlled Trials, MEDLINE, Embase and clinical trials registries. The Education Resources Information Centre database and grey literature was also searched. Studies which were included were randomised controlled trials (RCT) of asthma education delivered in the home to children, their caregivers or both. Two independent researchers selected trials and

assessed the quality of each trial. Recommended Cochrane methodology was utilised for data extraction, evidence synthesis and reporting of results.

3.1.3 Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework (Chapter 7)

Qualitative interviews and questionnaires underpinned by the Theoretical Domains Framework (TDF) were developed for participants (children with asthma, their caregivers and healthcare professionals who provide asthma education) to explore their experiences, knowledge, beliefs and recommendations about asthma education delivery. The TDF was also used to provide a framework for deductive thematic analysis.

3.1.4 Co-design of an augmented reality asthma inhaler educational intervention for children: development and usability study (Chapter 8)

An augmented reality asthma inhaler intervention was developed using an iterative co-design process which incorporated suggestions and feedback from likely end users and key stakeholders. A multi-stage process was required for the design. Qualitative interviews and usability testing were undertaken over multiple rounds with children with asthma, their caregivers and healthcare professionals who regularly manage children with asthma. From the initial prototype, ideation of content and feedback was used for re-design of the prototype and has been used to develop a final augmented reality-enabled asthma inhaler technique educational intervention for clinical setting evaluation.

3.1.5 The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study (Chapter 9)

Using the augmented reality-enabled asthma educational resource co-designed as described in Chapter 9, qualitative investigation was undertaken with likely end users to evaluate the acceptability of augmented reality technology as an educational delivery mechanism. Children with asthma, their caregivers and healthcare professionals who regularly manage asthmatic patients participated in semi-structured interviews to obtain data. The

Theoretical Framework of Acceptability (TFA) informed questions for the moderator guides (Appendix 3) for the interviews, as well as for deductive thematic analysis.

3.2 Ethics approval

Ethics approval for the studies presented in Chapters 7, 8 and 9 was obtained from the Women's and Children's Hospital Human Research Committee on the 21st of August 2020 (HREC20/WCHN/74). The acceptance of approval was obtained by the University of Adelaide on the 20th of October 2021. Site specific assessment for the Women's and Children's Health Network was authorised in October 2020 (Appendices 1 and 2).

Chapter 4.

Qualitative study protocol: Augmented reality technology to deliver asthma inhaler technique training for children and adolescents with asthma

---

Antonia O'Connor[1,2], Andrew Tai[1,2,3], Zoe Kopsaftis[4,5], Kristin V Carson-Chahhoud[5,6,7]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2]School of Paediatrics and Reproductive Health, Faculty of Medicine, The University of Adelaide, South Australia, [3]Robinson Research Institute, University of Adelaide, [4]Respiratory Medicine Department, The Queen Elizabeth Hospital, Adelaide, South Australia, [5] School of Medicine, University of Adelaide, Adelaide, South Australia, [6]Translational Medicine and Technology Group, University of South Australia, [7]Australian Centre for Precision Health, South Australian Health and Medical Research Institute

International Journal of Qualitative Methods 2021

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Qualitative Study Protocol: Augmented Reality to Deliver Asthma Inhaler Technique Training for Children and Adolescents with Asthma

---

Publication status: Published

Publication details: O'Connor A, Tai A, Kopsaftis Z, Carson-Chahhoud K. Qualitative Study Protocol: Augmented Reality Technology to Deliver Asthma Inhaler Technique Training for Children and Adolescents With Asthma. International Journal of Qualitative Methods. January 2021.

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Identification of gap in evidence, conceived idea of investigation and developed study methodology to address the gap, planned and designed the manuscript to describe study methodology, wrote the first draft and made critical revisions, approved final version. Acted as corresponding author.		
Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Andrew Tai		
Contribution to the paper	Assisted in identification of clinical question and approach to address evidence gap. Contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Zoe Kopsaftis		
Contribution to the paper	Assisted in methodology design. Contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	29/6/22

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Assisted in identification of gap in knowledge, design methodology to answer question and act in a supervisory role to primary author. Contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process (primary supervisor).		
Signature		Date	21/06/2022

International Journal of Qualitative Methods
Volume 20: 1 9
© The Author(s) 2021
DOI: 10.1177/16094069211042229
journals.sagepub.com/home/ijq
SAGE

Qualitative Study Protocol: Augmented Reality Technology to Deliver Asthma Inhaler Technique Training for Children and Adolescents With Asthma

Antonia O'Connor, MBBS[1,2], Andrew Tai, MBBS, FRACP, PhD[1,2,3], Zoe Kopsaftis, PhD[4,5], and Kristin Carson-Chahhoud, PhD, MSPPM[5,6,7]

Abstract

Asthma is a chronic inflammatory condition of the airways with a heterogenous symptom profile. When symptoms are poorly controlled and frequent, asthma sufferers are impacted regularly, with limitations on physical activities and sleep disturbances, significantly impairing quality of life. Asthma is highly prevalent and the leading cause of disease burden in young people. Those aged 0–14 contribute to over half of the asthma hospitalisations within Australia. Asthma education and self-management remains a key component of care; however, challenges remain in the paediatric population with difficulties of engagement. Augmented reality (AR) may provide a novel and effective solution with its ability to superimpose virtual objects into a real-world setting. Using a smartphone or tablet to deliver AR makes this modality accessible to much of the population. AR is a growing field in technology and has already established uses in education and training. The ability to increase motivation, enhance enjoyment and encourage faster concept understanding in the educational setting is encouraging and supports our proposal that AR technology can provide a generation appropriate education delivery modality for young people with asthma. To ensure successful implementation of an AR asthma educational resource on a large scale, the usability, acceptability, barriers and enablers of its use must be investigated. Using an iterative co-design process, an asthma resource utilising AR to deliver education on inhaler technique will be created. Qualitative research will be undertaken using semi-structured interviews with moderator guides to obtain mixed-method data on the AR resource. Participants will be key members of the asthma community including children and adolescents with asthma (8–17 years old), caregivers of children and adolescents with asthma, and health professionals. Understanding the usability, acceptability, barriers and enablers of the AR resource will enable us to improve our alpha version and test an optimal version in a planned feasibility study.

Keywords

augmented reality, asthma, education, inhaler, qualitative

[1]Respiratory and Sleep Department, Women's and Children's Hospital, North Adelaide, SA, Australia
[2]School of Paediatrics and Reproductive Health, Faculty of Medicine, The University of Adelaide, Adelaide, SA, Australia
[3]Robinson Research Institute, University of Adelaide, Adelaide, SA, Australia
[4]Respiratory Medicine Department, The Queen Elizabeth Hospital, Woodville South, SA, Australia
[5]Adelaide Medical School, University of Adelaide, Adelaide, SA, Australia
[6]Translational Medicine and Technology Group, Australian Centre for Precision Health, University of South Australia, Adelaide, SA, Australia
[7]Australian Centre for Precision Health, South Australian Health and Medical Research Institute, Adelaide, SA, Australia

Corresponding Author:
Antonia O'Connor, Respiratory and Sleep Department, The Women's and Children's Hospital, 72 King William Road, North Adelaide, SA 5006, Australia.
Email: Antonia.chan@sa.gov.au

Background/Study Justification

Asthma

Asthma has been defined as chronic inflammation of the airways which can result in bronchial hyper-responsiveness and limitation in airflow (Braman, 2006). It is a heterogenous disease, with varying symptoms including coughing, wheezing, shortness of breath and chest tightness in susceptible individuals (Braman, 2006; Mims, 2015). Symptoms can range in severity from mild to life threatening

(Licari et al., 2018). The airway hyper-responsiveness and variable airflow limitation is usually reversible, either with pharmacological intervention or spontaneously, and may be triggered by a variety of stimuli such as pollen, temperature changes, exercise and viral respiratory tract infections (Mims, 2015). The main aim for management of asthma is to control the inflammation and symptoms, as well as reduce the risk of exacerbations (Global Initiative for Asthma, 2020; James & Lyttle, 2016). Those who have poor symptom control suffer frequent symptoms and/or require frequent use of a reliever, have activity which is limited by their asthma and can experience nocturnal waking due to their symptoms. Asthma is defined as 'uncontrolled' when there is either poor symptom control and/or frequent exacerbations (two or more per year) which requires oral corticosteroids or having a serious exacerbation more than once or more per year, which requires hospitalisation (Global Initiative for Asthma, 2020; Papaioannou et al., 2015). Those who have uncontrolled or poorly controlled asthma with frequent symptomatology may be impacted on a daily basis, including having limitations in their physical activities and sleep disturbances (Papaioannou et al., 2015). They suffer from impaired quality of life, including poorer health and mental well-being, heightened psychological distress and increased symptoms of anxiety and depression (Drapeau et al., 2012; Goldney et al., 2003; Janson et al., 1994; Vollmer et al., 1999; Welfare, 2013; Yonas et al., 2013).

Impact of Asthma

Asthma is a highly prevalent disease, estimated to effect over 330 million people worldwide (Braman, 2006). This is especially true in the paediatric population, in which asthma is the most common chronic condition globally (Braman, 2006; Poulos et al., 2005; Woolcock et al., 2001). There is increasing knowledge surrounding the disease and its pathogenesis, as well as growing evidence-based treatment options. Despite this, prevalence is increasing with an estimation of over 100 million more people to be diagnosed with asthma by 2024, and there are still approximately 180,0000 deaths which are related to asthma per year worldwide (Masoli et al., 2004; Nunes et al., 2017).

In Australia, asthma is the leading cause of disease burden in young people aged 5–14 years (AIHW, 2018; Braman, 2006). It is one of the most common hospital emergency department presentations, and half of the asthma hospitalisations in Australia are in young people aged 0–14 years old (AIHW, 2018; Poulos et al., 2005). For children, poorly controlled asthma has a significant impact on daily living for the child themselves, as well as the whole family unit, with sleep disturbances due to symptoms, missed schooling and restrictions on activities compared to their healthy peers all contributing (Gustafsson et al., 2006; Poulos et al., 2005).

Asthma also significantly affects healthcare systems and governments, with direct costs (those related to asthma management, investigations, and treatments) and indirect costs (losses related to not being at work and school resulting in reduced productivity). In recent years, this has been estimated to cost the Australian economy $AUD 24.7 billion in 2015 and the US economy $USD 56 billion in 2011 (Deloitte, 2015; Nunes et al., 2017).

Asthma Self-Management Education

Asthma education and guidance on self-management remains an essential part of care and is recognised as an important aspect of treatment in asthma management guidelines (Global Initiative for Asthma, 2020; National Asthma Council Australia, 2020). A systematic review by Gibson et al. (2003) reviewed 36 trials and compared self-management programmes with usual care and found that self-management education was effective in reducing hospitalisations, emergency department visits, days off work or school, symptoms and also improved quality of life. A systematic review looking specifically at the paediatric population and the efficacy of asthma self-management on health outcomes also found that asthma self-management programmes in children reduced missed school days, emergency department visits and symptoms (Wolf et al., 2003).

Despite recognition of education as important, studies show that limited health literacy resulting in low treatment adherence, poor asthma knowledge and limited engagement in self-management contribute to many Australians still having poor asthma control (Holley et al., 2017; Mackey et al., 2016; O'Connor et al., 2015). Children and adolescents are an especially vulnerable population in which engagement may be challenging; however, having increased knowledge about asthma and asthma medications has been associated with higher medication adherence rates (Koster et al., 2015; Mosnaim et al., 2014).

Health professionals are expected to provide adequate information for asthmatic patients; however, in a recent 2018 systematic review, overall, the inhaler technique was correct in only 15% of over 6000 healthcare professionals (Plaza et al., 2018). This is reflective of data suggesting that 10–30% of people with asthma use their inhalers correctly, and over the last 40 years, there has been no significant improvement in technique (Basheti et al., 2008; Sanchis et al., 2016).

New Interventions Required for Asthma Self-Management Education

In 2015, Blanchard et al. reported on the 'National Young People and Asthma Survey' to provide a current picture on asthma control and evaluate the national asthma strategy currently in place in Australia which aims to improve asthma self-management. This survey identified that majority of young people aged 12–25 had poorly controlled asthma and a key recommendation was made that new interventions for education were required, especially surrounding the use of preventative medications (Blanchard et al., 2014).

In Australia, approximately 92% of the population has access to a smartphone, and over 80% of young people with asthma use a smartphone daily, making education delivered via this modality accessible (Blanchard et al., 2014; Corbett et al., 2020). Asthma smartphone self-management apps have been studied in meta-analysis and shown to be effective in improved adherence with medications compared to standard treatment, improved asthma control and the potential for improving quality of life; however, this has been predominantly in adult based populations (Farzandipour et al., 2017; Hui et al., 2017; Miller et al., 2017). It is also still unclear as to which specific features are associated with the engagement and adoption of self-management apps, and studies considering the education delivery to children specifically are lacking (Hui et al., 2017; Iio et al., 2020; Miller et al., 2017).

Augmented Reality in Educational Settings and for Behaviour Change

Augmented reality (AR) can be delivered by a smartphone or tablet device and has been defined as technology able to superimpose virtual objects into a real-world setting so that the virtual objects seems to co-exist in the same space in real time (Akcayir & Akcayir, 2017). AR allows information to be delivered via videos, animations and graphics which can be a generation appropriate modality for children and adolescents.

AR has already been applied to educational and training settings as well as in the business world (Lee, 2012). In the healthcare clinical setting, it has been predominantly applied to allow medical practitioners the ability for surgical planning and is used for both treatment and training purposes (Eckert et al., 2019). In the educational sphere, there is evidence that AR can increase self-learning opportunities (Akcayir & Akcayir, 2017), increases motivation (Bacca et al., 2018), has the ability to encourage faster concept understanding in children with disabilities (Hrishikesh & Nair, 2016) and also can enhance collaborative learning (Phon & Halim, 2014). There is also evidence it enhances enjoyment (Ibáñez et al., 2014), provides a positive attitude (Rafał Wojciechowski, 2013) and enables users to receive information quickly (Chiang et al., 2014). Previous research has also shown that AR can assist in memorisation when digital information is presented within a real-world environment (Fujimoto et al., 2013). This may be reflected in the findings of a meta-analysis in which the performance of students who used AR based approaches had an improvement of a moderate effect size compared to those who used non-AR based approaches (Santos et al., 2014).

The efficacy of AR for behaviour change has also been explored over recent years, especially in relation to nutrition and dietary habits as well as in the retail sector for consumer behaviours (Lavoye et al., 2021; McGuirt et al., 2020; Suzuki et al., 2015). With the ability of AR for immediate delivery of visual feedback and the ability for 'in the moment' behavioural reminders or recommendations, this has been shown to increase self-motivation and action and highlights the ability of AR as a behaviour change intervention for the future (Khan et al., 2019).

Augmented Reality as a Delivery Modality for Asthma Self-Management Education

AR may provide an exciting, effective new modality for delivering asthma education for young people. It also may be an effective strategy for education delivery to parents with low literacy levels, which is a particularly important area to address as this is known to be associated with poorer asthma control and lower adherence to asthma treatment (Koster et al., 2011; Lasmar et al., 2009).

AR has already established itself as a growing field in technology with rapid growth patterns in areas such as media, entertainment and marketing. This is expected to contribute to the estimated market value in 2025 to be greater than US $140 billion (ABI Research-Augmented Reality Total Market Value Will Surpass US$140 Billion in 2025, 2021). It has been described as a 'disruptive' technology, as it displaces already well-established practices by its growth and uptake by users (Siddhpura et al., 2020).

To our knowledge, there has been only one other educational resource for children which utilised AR for asthma self-management education via gamification (Suha et al., 2021). Promisingly, there was increased engagement in the educational programmes and improved inhaler technique in those randomised to using the AR application, compared with children using a video or leaflet. This study, however, did not have participants with a diagnosis of asthma and did not assess asthma related health outcomes, nor conduct any qualitative investigation for the acceptability and usability of the resource to users.

Aims

This article outlines the protocol for a qualitative study, which aims to evaluate the acceptability, usability, barriers and enablers of an AR educational resource for inhaler technique, using an iterative co-design process to create an optimal tool for future feasibility studies. This will occur over two stages:

1. Development of an AR resource which can be delivered via a smartphone or tablet as an educational tool for children and adolescents with asthma
2. Determine the acceptability and usability of the developed resource and identify the barriers and enablers in delivering self-management education to children and adolescents, their caregivers and relevant health professionals

Explanation and Justification of Method

As AR technology is a novel concept for delivering asthma self-management education for young people with asthma, the

acceptability and usability of the resource is crucial for successful implementation. This research will determine the acceptability and usability using semi-structured interviews with moderator guides to obtain mixed method data. Deductive thematic analysis using the domains of the Theoretical Domains Framework (TDF) and the Theoretical Framework of Acceptability (TFA) will inform both the semi-structured moderator guide and coding for analysis, and the System Usability Scale will also be integrated to ensure acceptability, usability and barriers and enablers of the resource are all analysed (Sekhon et al., 2017).

The TDF has been validated in its use for research involving behavioural change and implementation problems (Cane et al., 2012). It provides an understanding of behaviour change and forms a basis for exploring implementation problems allowing for our intervention design and application in the real world to be successful (Atkins et al., 2017).

Acceptability has been defined as a 'multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experienced cognitive and emotional responses to the intervention' (Sekhon et al., 2017). The TFA has seven constructs of which can be used as a guide to both prospectively and retrospectively assess the acceptability of an intervention (Sekhon et al., 2017).

Usability testing is important in intervention development prior to examining its efficacy in the real-world clinical setting, so the effectiveness, efficiency and satisfaction of its goals from users can be optimised (Susan Alexander and Haley, 2019). The System Usability Scale has been validated as a versatile and reliable scale for products and systems and will also be used to determine usability of our resource (Bangor et al., 2008).

Phase 1 Augmented Reality Resource Development

The development of the AR resource will be underpinned by current resources which have used similar technology including the Lung Foundation Australia 'Stepwise Management of Stable COPD' reference guide (Lung Foundation, 2020) and in conjunction with input from health professionals. The application will function via pattern recognition of a paper-based poster, to trigger educational videos to be activated and initiate the paper-based poster to come to life on either a smartphone or tablet.

This project will use an iterative co-design process with likely end-users, for the development of the AR educational resource. Iterative co-design is an important process in the implementation of any intervention as it places the user at the centre of the design process (Susan Alexander and Haley, 2019). The design process involves identification of users with a specific context for use of the resource initially, an understanding of the requirements of the user, production of a design, then evaluation of this with users and stakeholder involvement (Alwashmi et al., 2019). The process is repeated with improvement of the resource over time. This enables the intervention designed to be best suited for the likely end-users and increases likelihood of successful uptake (Alwashmi et al., 2019).

Phase 2 Determine the Acceptability, Usability, Barriers and Enablers for the AR Resource to Deliver Asthma Self-Management Education to Young People

One-on-one interviews will be conducted to identify acceptability, usability, barriers and enablers for the use of the AR resource by children and adolescents with asthma aged 8–17 years old, their caregivers, as well as health professionals, including paediatric respiratory physicians, general paediatricians, nursing staff, general practitioners, pharmacists and asthma educators.

The interviews will be of approximately 45–60 minutes in duration per participant. During the session, participants will receive a demonstration of the resource from a study investigator and be asked to trial the use of it themselves as a one-off.

Semi-structured moderator guides will be used to assist in collecting the qualitative data which will specifically address the research aims. The moderator guides will form the basis of the interviews which have been developed specifically for each of the three participant groups described previously and will be framed by the TDF and TFA.

Interviews will take place in the respiratory department of the major tertiary paediatric hospital in Adelaide, South Australia (S.A.).

Interviews will be recorded and transcribed by an automated transcription service, with participants being contacted at a later date to validate the content if required.

Sampling/Recruitment

Three groups of likely end users will be recruited to allow for wider generalisation of data (Cote & Turgeon, 2005). Health professionals, children and adolescents with asthma, and caregivers of children and adolescents with asthma will be chosen based on their identification as information-rich cases. To cover the varying opinions of the asthma community, this study will interview participants from two categorised groups: children and adolescents with asthma, and parents of children and adolescents with asthma. We identified six different health professions that cover asthma treatment, management and education: respiratory specialists, paediatric general medicine specialists, general practitioners, nurses, pharmacists and asthma educators.

Asthma Community

Purposive sampling will be used through recruitment flyers inviting potential participants of the asthma community to join the study. These flyers will be displayed in wards and

offices of the tertiary paediatric hospital the study will be undertaken in, where there is a high exposure to our target sample. Potential participants will contact researchers via email or the telephone number provided on the recruitment flyer. Asthma patients may also be recruited through existing contacts throughout the Respiratory Department at The Women's and Children's Hospital, S.A., via the respiratory specialists and asthma educators during clinical appointments, with a letter of invitation for the study provided to the family.

Potential participants will be screened to ensure they meet inclusion criteria, and if screening is successful, they will then be invited to participate in an interview. A Participant Information Sheet and Consent Form will be emailed or posted to the potential participant, and they will be given an opportunity to read through and ask any questions either through the provided contact details or at the beginning of the interview. They will be asked to bring the Consent Form to the interview to have it signed and witnessed by a member of the research team.

Qualitative data will be obtained through interviews with participants from the following categories:

i. Children and adolescents with a clinical diagnosis of asthma – aged 8–17
ii. Parent/guardians of asthmatic children and adolescents aged 8–17

Non-English speaking participants have been excluded due to logistical difficulties around the need for interpreters as well as the cost and delays this may present. Those unable to consent have also been excluded.

Health Professionals

Purposive sampling will be used through a recruitment email inviting potential participants to participate in the study. These will be distributed by email via relevant managers at the tertiary paediatric hospital where the study will be undertaken. Health professionals may also be recruited through existing contacts of the Respiratory Department of this hospital.

Initial contact with potential participants will be via email and the telephone number provided on the recruitment email. Potential participants will be screened to ensure they meet inclusion criteria and, if screening is successful, they will then be invited to an interview at a suitable time and date. A Participant Information Sheet and Consent Form will be emailed or posted to the potential participant, and they will be given an opportunity to read through and ask any questions either through the provided contact details or at the beginning of the interview. They will be asked to bring the Consent Form to the interview to have it signed and witnessed by a member of the research team.

Qualitative data will be obtained through one-on-one interviews from health professionals in the following categories:

i. Nursing Staff
ii. Paediatric General Medicine Doctors
iii. General Practitioners
iv. Respiratory Specialists
v. Pharmacists
vi. Asthma Educators

Inclusion criteria for the above participants include having worked in their profession in S.A. and having treated asthma patients regularly for >12 months in the last 5 years. They will be excluded if they are aged <18 years old, unable to consent or are non-English speaking.

Qualitative research requires sample sizes which are both large enough to ensure broad views and depth, however, also small enough for intensive meaningful analysis, and there are no prespecified criteria in determining sample size (Cleary et al., 2014). An approximate total sample size of 15–20 has been determined in being helpful in exploring the potential use of AR technology as an education tool for this study, allowing documentation of diversity and understanding variation among participants (Patton, 2002). This also is in line with experts who advocate for there to be less than five users per round of iterative design, as 85% of usability problems with the resource is detected within the five users, with more users not being cost or time effective (Susan Alexander and Haley, 2019).

Data Handling/Analysis

Deductive thematic analysis will be used as the coding method to categorise participant responses from interviews into the domains of the theoretical domains framework. The analysis of the data will be coded by two independent researchers to improve inter-rater reliability. Disagreements will be resolved with discussion. Coded data will be entered and analysed using NVivo software. A kappa co-efficient will be calculated to examine the degree of inter-rater reliability between the two coders (NVivo, 2020).

All research documentation will be treated as confidential and will be securely stored. Hard copy documents and audio recordings will be stored in a secure office. Audio recordings which will be taken from the interview sessions will be kept for 30 years after transcription. All transcriptions will be de-identified. Electronic data will only be accessible to study investigators on hospital network servers in secure folders.

Ethics

Anonymity and Confidentiality: All audio recordings which are taken from interview sessions and transcribed will be de-identified. Storage of hard copy data will be secure and stored securely in an area with only staff access within the tertiary hospital. Electronic data will be stored on hospital servers in secure folders which will only be accessible to study investigators. We will ensure all data is de-identified.

Research within a vulnerable population group: As this research involves participants aged 8–17 years old, all investigators and research assistants involved have a current Working with Children Check or a Child-Related Employment Screen clearance which has been issued through the S.A. government. As this research is purely seeking opinions from participants, we anticipate this to be low risk in terms of causing any negative impact on children and young people safety, emotional and psychological security. Moderator guides have been designed specifically for this age group to minimise confusion or distress from a lack of comprehension.

Informed consent: Participation will be voluntary. Potential participants will contact researchers via email or the telephone number provided on the recruitment flyer and will be screened to ensure they meet inclusion criteria. A Participant Information Sheet and Consent Form will be emailed or posted to the potential participants, and they will be given an opportunity to read through and ask any questions either through the provided contact details or at the beginning of the interview. The Consent Form will need to be signed and witnessed by a member of the research team. A specific Participant Information Sheet for children and adolescents has been developed to ensure information is conveyed in an age-appropriate manner. For children under 18, consent will need to be provided from their parent/guardian. To ensure communication is effective in the consent process, the exclusion criteria for this study also include being non-English speaking.

Beneficence: If asthma community participants (i.e., children and adolescents with asthma or their caregivers) choose to withdraw from the study, there will be no implications to their clinical care. This is made clear to them as part of the consent process.

This study will also be conducted with the principles of the 'Declaration of Helsinki', Good Clinical Practice, the National Statement on Ethical Conduct in Human Research (National Statement on Ethical Conduct in Human Research, 2007). It will also comply fully with the Australian Code for the Responsible Conduct of Research (2007) and within the laws and regulations of Australia.

This study has been reviewed by Human Research Ethics Committee of The Women's and Children's Hospital Network in Adelaide, S.A., and been approved (approval number HREC/20/WCHN/74).

Rigour

Rigour will be ensured during all steps of this research.

Participants will be enrolled from key stakeholders in the asthma community (being children and adolescents with asthma, their caregivers, and health professionals) to ensure transferability. We will use purposive sampling of members of the asthma community to be able to optimise participants able to answer our research question.

Using semi-structured interviews with moderator guides, we will increase dependability, credibility and conformability. As they will be audio-recorded, we will undergo member checking to also increase both credibility and confirmability with the participant being able to validate the interview. Research investigators and assistants will also be trained in doing qualitative interviews for further dependability.

Triangulation of data sources will be possible by using both interviews and questionnaires, so as to be able to optimise accuracy, support and confirmability in themes. Pilot coding between two independent researchers will also ensure consistency and minimise bias.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study has been supported through funding from the National Health and Medical Research Council (NHMRC) provided to Kristin Carson Chahhoud (GNT1141521).

ORCID iD

Antonia O'Connor https://orcid.org/0000 0001 8938 3842

References

ABI Research Augmented Reality Total Market Value Will Surpass US$140 Billion in 2025 (2021). ENP Newswire.

AIHW, A. I. o. H. a. W. (2018). *Asthma snapshot*. Canberra: AIHW.

Akcayir, M., & Akcayir, G. (2017). Advantages and challenges associated with augmented reality for education: a systematic review of the literature. *Educational Research Review*, *20*, 1 11. doi: 10.1016/j.edurev.2016.11.002.

Alwashmi, M. F., Hawboldt, J., Davis, E., & Fetters, M. D. (2019). The iterative convergent design for mobile health usability testing: mixed methods approach. *JMIR mHealth and uHealth*, *7*(4), e11656. doi: 10.2196/11656.

Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., Foy, R., Duncan, E. M., Colquhoun, H., Grimshaw, J. M., Lawton, R., & Michie, S. (2017). A guide to using the theo retical domains framework of behaviour change to investigate implementation problems. *Implementation Science*, *12*(1), 77. doi: 10.1186/s13012 017 0605 9.

Bacca, J., Baldiris, S., Fabregat, R., & Kinshuk (2018). Insights into the factors influencing student motivation in augmented reality learning experiences in vocational education and training. *Frontiers in Psychology*, *9*, 1486. doi: 10.3389/fpsyg.2018.01486.

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. *International Journal of Human Computer Interaction*, *24*(6), 574 594. doi: 10.1080/10447310802205776.

Basheti, I. A., Armour, C. L., Bosnic Anticevich, S. Z., & Reddel, H. K. (2008). Evaluation of a novel educational strategy,

including inhaler based reminder labels, to improve asthma inhaler technique. *Patient Education and Counseling*, *72*(1), 26 33. doi: 10.1016/j.pec.2008.01.014.

Blanchard, M., Morris, J., Birrell, E., Stephens Reicher, J., Third, A., Burns, J. J. M. Y., & Centre, W. C. R. (2014). *National Young People and Asthma Survey: Issues and Opportunities in Sup porting the Health and Wellbeing of Young People Living With Asthma*. https://asthma.org.au/wp content/uploads/Resources/Blanchard 2015 AsthmaSurvey 2 1.pdf.

Braman, S. S. (2006). The global burden of asthma. *Chest*, *130*(1 Suppl), 4S 12S. doi: 10.1378/chest.130.1 suppl.4S.

Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science*, *7*(1), 37. doi: 10.1186/1748 5908 7 37.

Chiang, T. H. C., Yang, S. J. H., & Hwang, G J. (2014). Students' online interactive patterns in augmented reality based inquiry activities. *Computers and Education*, *78*, 97 108. DOI: 10.1016/j.compedu.2014.05.006.

Cleary, M., Horsfall, J., & Hayter, M. (2014). Data collection and sampling in qualitative research: does size matter? *Journal of Advanced Nursing*, *70*(3), 473 475. doi: 10.1111/jan.12163.

Corbett, P. P. R., & Herman, J. (2020). *Digital consumer trends 2020*. https://www2.deloitte.com/au/en/pages/technology media and telecommunications/articles/digitalconsumertrends.html.

Cote, L., & Turgeon, J. (2005). Appraising qualitative research ar ticles in medicine and medical education. *Medical Teacher*, *27*(1), 71 75. doi: 10.1080/01421590400016308.

Deloitte (2015). *The hidden cost of asthma* (pp. 1 120). Deloitte Access Economics Pty Ltd.

Drapeau, A., Marchand, A., & Beaulieu Prevost, D. (2012). *Epi demiology of psychological distress. Mental Illnesses Under standing, Prediction and Control*. IntechOpen.

Eckert, M., Volmerg, J. S., & Friedrich, C. M. (2019). Augmented reality in medicine: systematic and bibliographic review. *JMIR Mhealth Uhealth*, *7*(4), e10967. doi: 10.2196/10967.

Farzandipour, M., Nabovati, E., Sharif, R., Arani, M. H., & Anvari, S. (2017). Patient self management of asthma using mobile health applications: a systematic review of the functionalities and effects. *Applied Clinical Informatics*, *8*(4), 1068 1081. doi: 10.4338/ACI 2017 07 R 0116.

Fujimoto, Y., Yamamoto, G., Taketomi, T., Miyazaki, J., & Kato, H. (2013). Relation between displaying features of augmented reality and user's memorization. *Transactions of the Virtual Reality Society of Japan*, *18*(1), 81 91. doi: 10.18974/tvrsj.18.1 81.

Gibson, P. G., Powell, H., Coughlan, J., Wilson, A. J., Abramson, M., Haywood, P., Bauman, A., Hensley, M. J., & Walters, E. H. (2003). Self management education and regular practitioner review for adults with asthma. *The Cochrane Database of Systematic Reviews Electronic Resource*, *1*, CD001117. doi: 10.1002/14651858.CD001117.

Global Initiative for Asthma (2020). *Global strategy for asthma management and prevention*. www.ginasthma.org.

Goldney, R. D., Ruffin, R., Fisher, L. J., & Wilson, D. H. (2003). Asthma symptoms associated with depression and lower quality of life: a population survey. *The Medical Journal of Australia*, *178*(9), 437 441. https://www.ncbi.nlm.nih.gov/pubmed/12720509.

Gustafsson, P. M., Watson, L., Davis, K. J., & Rabe, K. F. (2006). Poor asthma control in children: evidence from epidemiological surveys and implications for clinical practice. *International Journal of Clinical Practice*, *60*(3), 321 334. doi: 10.1111/j.1368 5031.2006.00798.x.

Holley, S., Morris, r., Knibb, R., Latter, S., Liossi, C., Mitchell, F., & Roberts, G. (2017). Barriers and facilitators to asthma self management in adolescents: a systematic review of quali tative and quantitative studies. *Pediatric Pulmonology*, *52*, 430 442.

Hrishikesh, N., & Nair, J. J. (2016). Interactive learning system for the hearing impaired and the vocally challenged. In International Conference on Advances in Computing, Communications and Informatics (ICACCI), Jaipur, India, 21 24 September 2016, 1079 1083. doi: 10.1109/ICACCI.2016.7732188.

Hui, C. Y., Walton, R., McKinstry, B., Jackson, T., Parker, R., & Pinnock, H. (2017). The use of mobile applications to support self management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. *Journal of the American Medical Informatics Association: JAMIA*, *24*(3), 619 632. doi: 10.1093/jamia/ocw143.

Ibáñez, M. B., Serio, Á. D., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: impact on flow student experience and educational effective ness. *Computers and Education*, *71*, 1 13. DOI: 10.1016/j.compedu.2013.09.004.

Iio, M., Miyaji, Y., Yamamoto Hanada, K., Narita, M., Nagata, M., & Ohya, Y. (2020). Beneficial features of a mHealth asthma app for children and caregivers: qualitative study. *JMIR Mhealth Uhealth*, *8*(8), e18506. doi: 10.2196/18506.

James, D. R., & Lyttle, M. D. (2016). British guideline on the man agement of asthma: SIGN clinical guideline 141, 2014. *Archives of Disease in Childhood. Education and Practice Edition*, *101*(6), 319 322. doi: 10.1136/archdischild 2015 310145.

Janson, C., Bjornsson, E., Hetta, J., & Boman, G. (1994). Anxiety and depression in relation to respiratory symptoms and asthma. *American Journal of Respiratory and Critical Care Medicine*, *149*(4), 930 934. doi: 10.1164/ajrccm.149.4.8143058.

Khan, T., Johnston, K., & Ophoff, J. (2019). The impact of an augmented reality application on learning motivation of stu dents. *Advances in Human Computer Interaction*, *2*, 1 14. doi: 10.1155/2019/7208494.

Koster, E. S., Philbert, D., Winters, N. A., & Bouvy, M. L. (2015). Adolescents' inhaled corticosteroid adherence: the importance of treatment perceptions and medication knowledge. *Journal of Asthma*, *52*(4), 431 436. doi: 10.3109/02770903.2014.979366.

Koster, E. S., Wijga, A. H., Koppelman, G. H., Postma, D. S., Brunekreef, B., De Jongste, J. C., Smit, H. A., Hoekstra, M. O.,

Raaijmakers, J. A., & Maitland van der Zee, A. H. (2011). Uncontrolled asthma at age 8: the importance of parental per ception towards medication. *Pediatric Allergy and Immunology: Official Publication of the European Society*, *22*(5), 462 468. doi: 10.1111/j.1399 3038.2011.01150.x.

Lasmar, L., Camargos, P., Bousquet, J., Goulart, E., Sakurai, E., & Carvalhais, M. (2009). Factors related to lower adherence rates to inhaled corticosteroids in children and adolescents: a pro spective randomized cohort study. *Journal of Tropical Pedi atrics*, *55*(1), 20 25. doi: 10.1093/tropej/fmn067.

Lavoye, V., Mero, J., & Tarkiainen, A. (2021). Consumer behavior with augmented reality in retail: a review and research agenda. *The International Review of Retail, Distribution and Consumer Research*, *31*(3), 299 329. doi: 10.1080/09593969.2021. 1901765.

Lee, K. (2012). Augmented reality in education and training. *Tech Trends*, *56*(2), 13 21.

Licari, A., Brambilla, I., Marseglia, A., De Filippo, M., Paganelli, V., & Marseglia, G. L. (2018). Difficult vs. severe asthma: defi nition and limits of asthma control in the pediatric pop ulation. *Frontiers in Pediatrics*, *6*, 170. doi: 10.3389/fped. 2018.00170.

Lung Foundation (2020). Stepwise management of stable COPD Reference guide. *Lung Foundation Australia*.

Mackey, L. M., Doody, C., & Werner, E. L. (2016). Self management skills in chronic disease management: what role does health literacy have? *Medical Decision Making*, *36*(6), 741 759.

Masoli, M., Fabian, D., Holt, S., & Beasley, R., Global Initiative for Asthma, P. (2004). The global burden of asthma: ex ecutive summary of the GINA dissemination committee report. *Allergy*, *59*(5), 469 478. doi: 10.1111/j.1398 9995. 2004.00526.x.

McGuirt, J. T., Cooke, N. K., Burgermaster, M., Enahora, B., Huebner, G., Meng, Y., Tripicchio, G., Dyson, O., Stage, V. C., & Wong, S. S. (2020). Extended reality technologies in nutri tion education and behavior: comprehensive scoping review and future directions. *Nutrients*, *12*(9), 1 14. doi: 10.3390/ nu12092899.

Miller, L., Schuz, B., Walters, J., & Walters, E. H. (2017). Mobile technology interventions for asthma self management: sys tematic review and meta analysis. *Journal of Medical Internet Research: mHealth and uHealth*, *5*(5), e57. doi: 10.2196/ mhealth.7168.

Mims, J. W. (2015). Asthma: definitions and pathophysiology. *In ternational Forum of Allergy and Rhinology*, *5*(Suppl 1), S2 S6. doi: 10.1002/alr.21609.

Mosnaim, G., Li, H., Martin, M., Richardson, D., Belice, P. J., Avery, E., Ryan, N., Bender, B., & Powell, L. (2014). Factors asso ciated with levels of adherence to inhaled corticosteroids in minority adolescents with asthma. *Annals of Allergy, Asthma & Immunology: Official Publication of the American*, *112*(2), 116 120. doi: 10.1016/j.anai.2013.11.021.

National Asthma Council Australia (2020). *The Australian asthma handbook*. http://www.asthmahandbook.org.au/.

National Statement on Ethical Conduct in Human Research. (2007). *(Updated May 2015)*. Canberra: The National Health and Medical Research Council, the Australian Research Council and the Australian Vice Chancellors' Committee. Commonwealth of Australia.

Nunes, C., Pereira, A. M., & Morais Almeida, M. (2017). Asthma costs and social impact. *Asthma Research and Practice*, *3*, 1. doi: 10.1186/s40733 016 0029 3.

NVivo (2020). *QSR international pty Ltd*. https://www.qsrinternational. com/nvivo qualitative data analysis software/home.

O'Connor, R., Wolf, M. S., Smith, S. G., Martynenko, M., Vicencio, D. P., Sano, M., Wisnivesky, J. P., & Federman, A. D. (2015). Health literacy, cognitive function, proper use, and adherence to inhaled asthma controller medications among older adults with asthma. *Chest*, *147*(5), 1307 1315.

Papaioannou, A. I., Kostikas, K., Zervas, E., Kolilekas, L., Papiris, S., & Gaga, M. (2015). Control of asthma in real life: still a valuable goal? *European Respiratory Review: an Official Journal of the European Respiratory Society*, *24*(136), 361 369. doi: 10.1183/16000617.00001615.

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods*. Thousand Oaks: Cal: Sage Publications.

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014). Collaborative augmented reality in education: a review. In International Conference on Teaching and Learning in Computing and En gineering, Kuching, Malaysia, 11 13 April 2014. 78 83. doi: 10.1109/LaTiCE.2014.23.

Plaza, V., Giner, J., Rodrigo, G. J., Dolovich, M. B., & Sanchis, J. (2018). Errors in the use of inhalers by health care professionals: a systematic review. *The Journal of Allergy and Clinical Im munology: In Practice*, *6*(3), 987 995. doi: 10.1016/j.jaip.2017. 12.032.

Poulos, L. M., Toelle, B. G., & Marks, G. B. (2005). The burden of asthma in children: an Australian perspective. *Paediatric Respiratory Reviews*, *6*(1), 20 27. doi: 10.1016/j.prrv.2004. 11.004.

Rafał Wojciechowski, W. C. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers and Education*, *68*, 570 585. DOI: 10.1016/j. compedu.2013.02.014.

Sanchis, J., Gich, I., & Pedersen, S., Aerosol Drug Management Improvement (2016). Systematic review of errors in inhaler use: has patient technique improved over time? *Chest*, *150*(2), 394 406. doi: 10.1016/j.chest.2016.03.041.

Santos, M. E. C., Chen, A., Taketomi, T., Yamamoto, G., Miyazaki, J., & Kato, H. (2014). Augmented reality learning experiences: survey of prototype design and evaluation. In IEEE Transactions on Learning Technologies, January March 2014, *7*(1), 38 56. doi: 10.1109/TLT.2013.37.

Sekhon, M., Cartwright, M., & Francis, J. J. (2017). Acceptability of healthcare interventions: an overview of reviews and devel opment of a theoretical framework. *BMC Health Services Re search*, *17*(1), 88. doi: 10.1186/s12913 017 2031 8.

Siddhpura, A., Indumathi, V., & Siddhpura, M. (2020). Current state of research in application of disruptive technologies in

engineering education. *Procedia Computer Science*, *172*, 494 501. doi: 10.1016/j.procs.2020.05.163.

Suha, A. N., Peter, B., Thomas, A., Chris, J., Fandi, I., & Mohamed, A. M. (2021). Examining the efficacy of a novel augmented reality mobile delivery platform for the enhancement of asthma care education for children. *International Journal of Interactive Mobile Technologies*, *15*(7), 47 68. doi: 10.3991/ijim.v15i07.20379.

Susan Alexander, K. F., & Haley, H. (2019). *Applied clinical informatics for nurses*. Jones and Bartlett Learning, LLC.

Suzuki, E., Narumi, T., Sakurai, S., Tanikawa, T., & Hirose, M. (2015) *Changing Drinking Behavior and Beverage Consumption Using Augmented Reality.* Paper presented at The Human Interface and the Management of Information. Information and Knowledge Design: Cham.

Vollmer, W. M., Markson, L. E., O'Connor, E., Sanocki, L. L., Fitterman, L., Berger, M., & Buist, A. S. (1999). Association of asthma control with health care utilization and quality of life. *American Journal of Respiratory and Critical Care Medicine*, *160*(5), 1647 1652. doi: 10.1164/ajrccm.160.5.9902098.

Welfare, A. I. o. H. a (2013). *How does asthma affect quality of life?* Chronic respiratory conditions.

Wolf, F. M., Guevara, J. P., Grum, C. M., Clark, N. M., & Cates, C. J. (2003). Educational interventions for asthma in children. *The Cochrane Database of Systematic Reviews Electronic Resource*, *1*, CD000326. doi: 10.1002/14651858.CD000326.

Woolcock, A. J., Bastiampillai, S. A., Marks, G. B., & Keena, V. A. (2001). The burden of asthma in Australia. *The Medical Journal of Australia*, *175*(3), 141 145. https://www.ncbi.nlm.nih.gov/pubmed/11548080.

Yonas, M. A., Marsland, A. L., Emeremni, C. A., Moore, C. G., Holguin, F., & Wenzel, S. (2013). Depressive symptomatology, quality of life and disease control among individuals with well characterized severe asthma. *Journal of Asthma*, *50*(8), 884 890. doi: 10.3109/02770903.2013.810750.

Results

Chapter 5.

Augmented reality technology to provide demonstrative inhaler technique education for asthma patients: a qualitative study

---

Antonia O'Connor[1,2], Kelsey J Sharrad[3], Zoe A Kopsaftis[2,4], Charmaine M King[3], Kristin V Carson-Chahhoud[2,3,5,6]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2] School of Medicine, University of Adelaide, Adelaide, South Australia, [3]University of South Australia, Allied Health and Human Performance, Australian Centre for Precision Health, Adelaide, [4]Respiratory Medicine Unit, The Queen Elizabeth Hospital; Central Adelaide Local Health Network, Adelaide, [5]Cancer Research Insititute, University of South Australia, Adelaide, [6]South Australian Health and Medical Research Institute, Adelaide

JMIR Formative Research 2022

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Augmented reality technology to provide demonstrative inhaler technique education for asthma patients: a qualitative study

---

Publication status: In press

Publication details: O'Connor A, Sharrad KJ, Kopsaftis ZA, King CM, Carson-Chahhoud K. Is there potential to use augmented reality technology to provide demonstrative inhaler technique education for asthma patients? A qualitative study. Journal of Medical Internet Research – Formative Research.

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Data analysis and interpretation for qualitative findings, synthesis of evidence into the theoretical framework, interpretation of findings within the context of clinical service delivery and future research, updated the evidence within background and discussion with revisions to manuscript.		
Overall percentage (%)	30%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Kelsey Sharrad		
Contribution to the paper	Interpretation of data, updating the evidence for background and discussion, revisions of manuscript.		
Signature		Date	24/6/2022

Name of co-author	Zoe Kopsaftis		
Contribution to the paper	Co-supervision of honours student, drafting of ethics application, supervision of data collection and analysis, interpretation of results.		
Signature		Date	29/6/22

Name of co-author	Charmaine King		
Contribution to the paper	Drafting and submission of ethics application, recruitment, data collection and analysis. Contribution to first draft.		
Signature		Date	21/6/22

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Primary supervisor of honours student, conceptualisation of study, supervisions of ethics/data collection, training of student for data analysis, contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process		
Signature		Date	21/6/22

Asthma in Australia affects 1 in 10 people, almost triple the global prevalence (101). Despite severity of symptoms declining over the last two decades, there is an increase in children or adolescents who have ever had asthma (102). Gold standard for pharmacological management are asthma inhalers, however incorrect inhaler technique amongst children occurs in over 90% and is not improving over time. Therefore, new strategies for educational interventions which are targeted at inhaler technique are required to ensure engagement and effectiveness in the paediatric population.

Through discussions between colleagues, it was identified that the now primary supervisor of this PhD (Associate Professor Kristin Carson-Chahhoud) had undertaken research in this space in an adult setting. In 2016, an honours student commenced qualitative investigation under the supervision of Associate Professor Carson-Chahhoud into the use of augmented reality technology for asthma inhaler technique education for adult asthma patients. Twenty-one semi-structured interviews were undertaken with healthcare professionals who had experience in asthma education delivery, people with asthma and community stakeholders to explore their perspectives on the use of augmented reality to improve asthma inhaler technique education. This was not prepared for publication at the time however given the relevance to the clinical gap identified, this work resurfaced. An opportunity was identified for review of the data, interpretation of the qualitative findings and an update and synthesis of the evidence which I undertook for publication.

Healthcare professional participants felt confident in their delivery of asthma inhaler education however the irregular frequency of inhaler technique assessment of their patients was also identified. Beliefs from asthmatic patients confirmed this with reports that healthcare professionals rarely provided inhaler technique education. Barriers to the regular review of inhaler technique included time constraints and lack of resources. Results from this study identified that the use of augmented reality was believed to have the ability to improve inhaler technique by all participant groups by increasing availability of asthma education and as a prompter for healthcare professionals to discuss and review inhaler technique during consultations. Concerns it would be challenging for older people in terms of both access and appropriateness were raised as a potential barrier for augmented reality technology.

Despite being a relatively novel technology, the use of augmented reality in educational and training settings has been described. There is evidence it increases self-learning opportunities; facilitates faster concept understanding and enhances enjoyment when used in an educational setting. Augmented reality has also been used and proven to be

efficacious in behaviour change interventions with its ability to increase self-motivation and action by providing immediate visual feedback, reminders, and recommendations. Results from this study suggested that healthcare professionals and key asthma community stakeholders perceived that augmented reality could be a useful tool for asthma inhaler technique education. With paediatric respiratory being an area of expertise of myself and being mindful of the novelty and accessibility of this technology, the possibility was raised that augmented reality could provide a solution to address the identified issue of poor inhaler technique in the paediatric population.

Title: Augmented reality technology to provide demonstrative inhaler technique education for asthma patients: a qualitative study.

O'Connor A[1,3], Sharrad KJ[4], Kopsaftis ZA[1,2], King CM[4], Carson-Chahhoud KV[1,4,5,6]

Co-authors:

[1]Adelaide Medical School; The University of Adelaide; Adelaide, Australia

[2]Respiratory Medicine Unit; The Queen Elizabeth Hospital; Central Adelaide Local Health Network; Adelaide, Australia

[3]Department of Respiratory and Sleep Medicine, Women's and Children's Hospital; Adelaide, Australia

[4]University of South Australia; Allied Health and Human Performance; Australian Centre for Precision Health; Adelaide, Australia

[5]Cancer Research Institute; University of South Australia; Adelaide, Australia

[6]South Australian Health and Medical Research Institute; Adelaide, Australia

Corresponding author: Assoc. Prof Kristin Carson-Chahhoud

The University of South Australia; Allied Health and Human Performance; Australian Centre for Precision Health; University of South Australia Cancer Research Institute

Kristin.Carson-Chahhoud@unisa.edu.au; Ph: 08 8302 0453; Mb: 0412 708 879

Abstract

Background: Many people with asthma use incorrect inhaler technique resulting in sub-optimal disease management and increased health service utilisation. Novel ways of delivering appropriate instructions are needed.

Objective: This study explores stakeholder perspectives on the potential use of augmented reality (AR) technology to improve asthma inhaler technique education.

Methods: Based on existing evidence and resources, an information poster displaying the images of 22 asthma inhaler devices was produced. Using AR technology via a free smartphone application, the poster launched video demonstrations of correct inhaler technique for each device. Twenty-one semi-structured, one-on-one interviews with health professionals, people with asthma and key community stakeholders were conducted and data was analysed thematically using the Triandis model of interpersonal behaviour.

Results: A total of 21 participants were recruited into the study and data saturation was achieved. People with asthma were confident with inhaler technique (mean score of 9.17 out of 10 and standard deviation (SD) of 1.33). However, health professionals and key community stakeholders identified that this perception was misguided (mean 7.25, SD 1.39 and mean 4.5, SD 0.71 for health professionals and key community stakeholders respectively) and facilitates persistent incorrect inhaler use and sub-optimal disease management. Delivering inhaler technique education using augmented reality was favoured by all participants, particularly around ease of use, with the ability to visually display inhaler techniques for each device. There was a strongly held belief that the application/technology has the capacity for improving inhaler technique across all participant groups (mean 9.25 (SD 0.89) for participants, 9.83 (SD 0.41) for health professionals, and 9.5 (SD 0.71) for key community stakeholders). However, all participants identified some barriers, particularly for access and appropriateness of AR for older people.

Conclusion: Augmented reality technology may be a novel means to address poor inhaler technique among certain cohorts of asthma patients and serve as a prompt for health professionals to initiate review of inhaler devices. A randomised controlled trial design is needed to evaluate efficacy of this technology for use in the clinical care setting.

Keywords

Augmented Reality, Asthma, Disease Management, Smartphone, Inhaler technique

Introduction

Asthma is a chronic respiratory disease affecting one in nine Australians and 262 million people globally [1, 2]. Current asthma management guidelines recommend that all patients are provided with guided self-management education [3]. This includes monitoring of symptoms and/or lung function, having a written asthma action plan, and regular review by a health professional, which may involve the use of pamphlets with pictures and demonstrations of inhaler devices [3, 4]. However, the literature suggests patients who do access health professional support do not necessarily receive an explanation about their disease, or correction of management missteps during these encounters [5-7]. A study by AL-Jahdali, Ahmed [8], found more than 50% of asthma patients had no formal education about the disease, and a further 40% had no official education about the medications or inhaler devices from any health professionals. This is evidenced by an estimated 70-80% of people with asthma unable to use their inhaler medication correctly [9]. Common mistakes in inhaler technique include: inability to hold the breath long enough, breathing in too deep or not deep enough and the inability to coordinate inhaler use [10-13]. Preventable consequences of poor understanding of asthma and/or inhaler technique include treatment failure, leading to poor clinical outcomes, increased healthcare utilisation, increased morbidity, higher medication dosages, as well as poorer quality of life [14-17].

Improving poor disease control can occur through review of inhaler technique, with health professionals correcting mistakes as they observe [10-12]. However, they may not be able to provide this level of support [6, 7, 18, 19]. Health professionals are time-poor, overburdened, and have variable uptake of evidence-based guidelines in clinical practice [5-7, 20]. Literature also suggests that healthcare professionals may not have adequate knowledge of asthma and inhaler technique themselves [17]. A systematic review by Plaza et al [21] looked at 55 studies with more than 6300 participants identified as healthcare professionals, and results showed only 15.5% of participants were considered proficient in inhaler technique. Furthermore, a study by Basheti, Hamadi [6] explored 200 health professionals and determined there was significant association between poor asthma knowledge and inhaler technique. Additionally, perceptions held by asthma patients about health professionals can impact the range of mistakes being made, as well as impact the amount of information available to them [22, 23]. Qualitative research indicates some patients perceive General Practitioners (GPs) as the only avenue of support, or believe that alternate health professionals, particularly pharmacists, are unable to deliver medication advice [22]. A study by Cheong, Armour [22] interviewed 47 asthma patients to determine how their perceptions and choices may impact multidisciplinary care. In particular, they looked at perceptions participants held on the role of health professionals, the convenience of accessing health advice and asthma itself [22]. Furthermore, many people with asthma who perceive themselves to be adept in using their inhaler, make more or as many mistakes as those identifying as less confident [23, 24]. Contributing to confusion, in Australia, people with asthma

may use one or more of the 22 different inhaler devices available, depending on the device they are prescribed, they would therefore need to master one of six different techniques [25]. One way to address poor inhaler knowledge and technique, and increase use of prescribed medications, is through improving education for patients and healthcare professionals [15, 17].

A simple stepwise video demonstration may enhance education, as proper inhaler technique may not be portrayed sufficiently from manufacturer leaflets [26, 27]. Advantages of multimedia education are noted from as early as 1983 and include: takeaway resources allowing independent application, entertaining audio-visual for patients, and a modality that is less reliant on those with limited literacy skills [27-30]. A review by Abed, Himmel [27] discovered three asthma studies that found multimedia useful for asthma education, with participants in 10 of the 20 included studies showing improvement following video-assisted patient education. Studies assessing the effect multimedia and technology have on inhaler technique all showed improvement in skill and knowledge following short and long-term interventions [27, 31-35]. Studies have also shown multimedia to be effective for improving self-efficacy in children with asthma and their caregivers [36, 37].

Technology known as augmented reality, utilised as interactive print (an innovative medium allowing dissemination of educational advice), allows for digital enhancement of paper-based resources. AR technology can: overcome issues of limited health literacy [38, 39]; allow for tailoring to individual populations (e.g. age, language); increase engagement [40]; increase accessibility of education [41]; and allow for real-time updates of content as new evidence becomes available. While multimedia has shown to be able to improve inhaler technique compared to traditional standard print, utilisation in the form of augmented reality has not been tested before. Additionally, as with any new technology or innovation, it is necessary to ensure that it meets the demands of the main user - for example; health professionals, asthma patients and key community stakeholders such as the Asthma Foundation of South Australia. Therefore, the aim of this study is to obtain health professional, asthma patient and key community stakeholder perspectives on the feasibility of innovative technology in the form of augmented reality. In particular; current inhaler technique education level, technology use level and potential of augmented reality.

Methods

Ethical approval

The Human Research Ethics Committee (HREC) of The Queen Elizabeth Hospital (TQEH) granted both ethical (13th July 2016) and governance approval (29th July 2016), Q20160614. Acceptance

of approval (25th July 2016) and relevant insurance (26th July 2016) from the HREC and Legal and Risk Branch of The University of Adelaide were also obtained.

Development of paper-based resource

Following review of research evidence, in addition to recommendations from national and international asthma guidelines [8, 9, 12, 24, 25, 42], a prototype poster (*see multimedia appendix 1*) for patient information around inhaler technique was developed. A senior scientist on the Medical and Scientific Advisory Committee for the Asthma Foundation of South Australia (MASAC) examined the prototype for relevance and applicability for use by health professionals and asthma patients. The final approved version of the poster was then transformed into interactive print using Layar software [43]. A digital version of the poster was uploaded to an online Layar server and superimposed with educational inhaler technique videos provided by the Lung Foundation of Australia [42]. After publishing the interactive print version of the poster, the free Layar application could be used to scan printed versions of the paper-based poster, triggering pattern recognition. The educational videos were then activated, thereby initiating the print-based poster to "come to life" on a smartphone screen. Layar allows digital media to be added to paper-based resources, augmenting them and providing the observer with a direct view of correct inhaler technique video demonstration [43]. The free smartphone application allowed demonstration of the technology throughout interviews and further aided in gaining perspectives from participants and potential users.

Participant enlistment in the study

Inclusion criteria for all participants were based on the current gap in the literature for inhaler technique. Participant recruitment commenced in August 2016 and continued until sufficient data saturation was achieved in September 2016. Names of all potential participants were contacted to assess willingness of participation. Participant information sheets and consent forms were distributed following agreement for consideration with 24 hours allowed to discuss enrolment in the study with friends and/or family members. Interviews were scheduled following reading and understanding of participant information sheets as well as verbal and written agreement of participation.

Health professional recruitment

Health professionals were recruited through existing contacts of the Respiratory Medicine Department at TQEH, SA Health and the Asthma Foundation of South Australia. Health professionals intended for interviewing included respiratory specialists, general practitioners, respiratory nurses and pharmacists, currently consulting asthma patients [5, 6, 44, 45]. Eight semi-structured, one-on-one interviews (two with each profession) were anticipated feasible to

reach data saturation inclusively with asthma patient and key community stakeholder interviews [46]. Health professionals who did not meet inclusion criteria were excluded from participation. Specific health professional inclusion criteria comprised:

1) Providing consults/assistance for asthma patients over a minimum 12-month period with at least one consult per week or equivalent

Asthma patient recruitment

Recruitment of asthma patients occurred through existing contacts throughout the Respiratory Department at TQEH via respiratory specialists. Three male and three female semi structured, one-on-one interviews were anticipated feasible for data saturation, inclusively with health professionals and key community stakeholders [46]. Asthma patients were recruited through purposive selection ensuring diversity of demographic characteristics and in particular, sourcing patients who experience difficulty with inhaler technique [47]. For example, recruiting someone who is regularly admitted to hospital for inadequate asthma management, at least once per year, compared to someone with well controlled asthma [9]. Asthma patient inclusion criteria comprised:

1) Over the age of 18 years
2) Formal diagnosis of asthma
3) No diagnosis of chronic obstructive pulmonary disease (COPD)

Patients with COPD can use different inhalers to manage their condition compared to patients who purely have asthma [25]. Therefore, to avoid confusion COPD-Asthma Overlap Disease was excluded.

Key community stakeholder recruitment

Four key community stakeholders, identified through existing contacts of the principal investigator, were anticipated for recruitment from the Asthma Foundation of South Australia. They were chosen as their key role in delivering resources and training is particularly focused on health professionals and asthma patients. Semi-structured, one-on-one interviews were conducted with participants involved in asthma education including asthma researchers, policy makers and asthma health workers. Four interviews were considered feasible in obtaining data saturation inclusively with health professional and asthma patient interviews. Key community stakeholder inclusion criteria comprised:

1) Involved with people with asthma or community consultation capacity for a minimum 12-month period over the past five years

Data analysis

Interview data was de-identified for coding and analysis, and publication purposes. Participants were also given the opportunity to review their transcript prior to publication and dissemination.

QSR NVivo Pro 11 allowed qualitative data (interview transcripts) to be analysed by two independent coders. Analysis and coding occurred under thematic categories based on the Triandis model of interpersonal behaviour (explained below), and further divided into positive and negative participant perspectives in attempt to reduce confirmation bias [48].

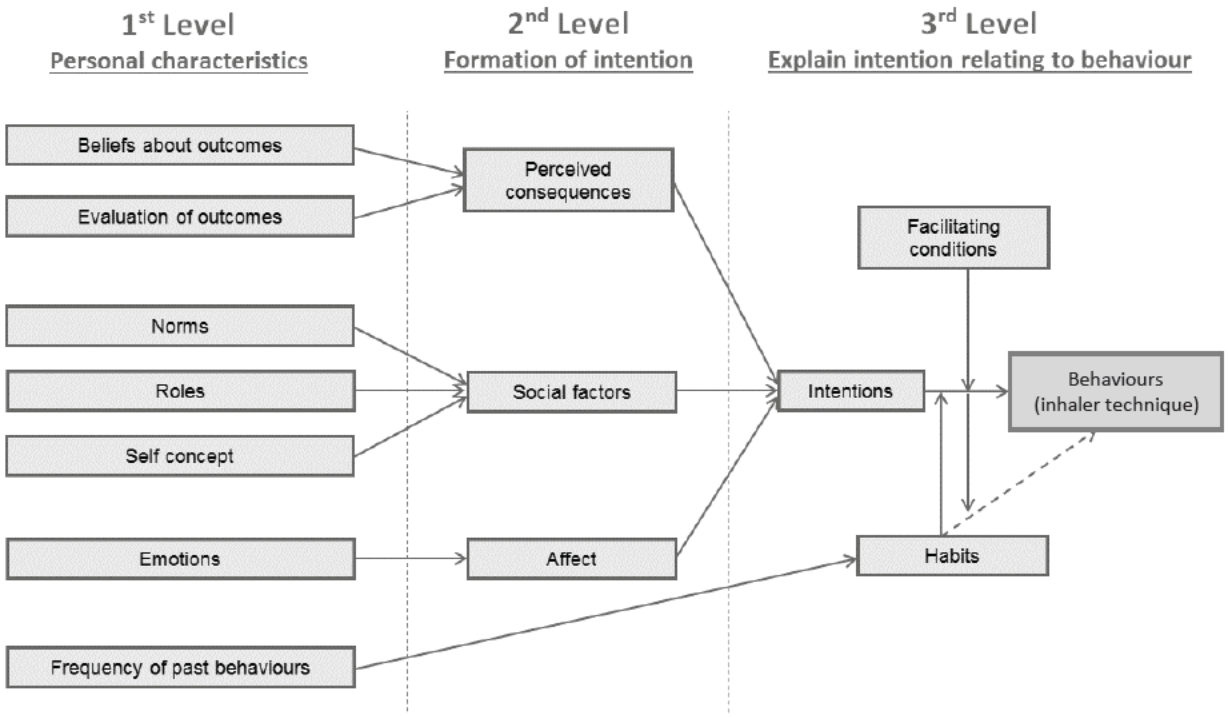
10-point Likert scales assessing attitudes, knowledge, perceptions and beliefs of inhaler use and education were collected during interviews and expressed as means and standard deviations (SD) (*see Table 3*). Other quantitative data including demographics, inhaler use, asthma education and more (*see Table 1*) were also collected. Using both qualitative and quantitative data enhances triangulation of information which is important to improve strength and dependability of findings [49]. Moreover, it allows comparison of the three participant groups responses through three levels of the Triandis model leading to improved reliability and validity [49, 50].

Theoretical underpinning

The Triandis model of interpersonal behaviour belongs to a school of cognitive models and considers intentions and habits as immediate precursors of behaviour. Both are influenced by facilitating conditions [50]. According to Triandis, facilitating conditions including social and affective factors as well as rationale considerations (e.g. incorrect inhaler technique causing decreased asthma management, leading to patients stopping use of their inhalers) all influence intentions [51]. This can indicate no action is either fully deliberate or automatic and behaviour is therefore believed to be influenced by intentions, habits and facilitating conditions. The impact of this can be further limited by both emotional and cognitive function [50].

An alternative way to consider the influences within the Triandis model is the tri-level explanation developed by Egmond and Bruel [48]. The study applied this form of the model throughout [48]. The model starts with investigating the behaviour (inhaler technique) itself and working backwards from that point. The third level explains intentions when influenced by facilitating conditions i.e., difficulty in understanding written instructions. It also explains habits such as using inhaler incorrectly to predict whether or not an individual will perform a particular behaviour. The second level considers how cognition, affect (being pure emotion) and personal normative beliefs influence the creation of intentions regarding a specific or general behaviour. Finally, the first level relates to personal characteristics that focus on past experiences which shape perceived consequences, affect and social factors related to behaviour. Ultimately, the Triandis model offers model framework that provides explanations to understand complex human behaviours, particularly those influenced by affective and social factors (*see Figure 1*).

Figure 1: *Modified representation of the Triandis model of Interpersonal Behaviour by Egmond and Bruel [48, 52]*



Results

A total of 21 participants were recruited into the study and data saturation was achieved. The sample consisted of n=7 males and n=11 females, aged between 21 and 64 years. The characteristics of all participants are reported in *Table 1*, though raw age and gender information has been removed for confidentiality purposes.

Table 1. Participant characteristics

	Occupation	Education	Years teaching/ using inhaler	No. asthma consultations	Education provided in consultation	Access to smart phone/device
HP 1	Respiratory Specialist	FAACP – Post Grad	7	0-3 per day	Briefly	Yes
HP 2	Respiratory Specialist	Bachelor of Medicine & surgery	4	2 per month	Yes	Yes

HP 3	General Practitioner	University Degree	32	1-2 per day	Sometimes	Yes
HP 4	General Practitioner	University Degree	6	1-2 per day	Not always	Yes
HP 5	Respiratory Nurse	Degree & Post Grad	20	2-5 per month	Yes	Yes
HP 6	Respiratory Nurse	University Degree	15	15-20 per month	Yes	No
HP 7	Pharmacist	University Degree	6	1 per day	Yes	Yes
HP 8	Pharmacist	University Degree	10	2 per day	Yes	Yes
AP 1	Labourer	Year 11	3	2-3 per year	Yes	Yes
AP 2	Research Officer	Tafe	19	1 per 1-2 years	No	Yes
AP 3	Senior Medical Scientist	Post Grad Diploma	8	1 per year	Yes	Yes
AP 4	Doctor	Bachelor of Medicine & Surgery	29	1 per 1-2 years	No	Yes
AP 5	Baker	Tafe Diploma	22	2 per month	Sometimes	Yes
AP 6	Medical Scientist	PhD	15	2 per year	Yes	Yes
KCS 1	Chief Executive	Master's Degree	N/A	N/A	N/A	Yes
KCS 2	Health services manager	N/A	N/A	N/A	N/A	Yes
KCS 3	Health Promotion Coordinator	Bachelor Degree	9	2 per month	Yes	Yes
KCS 4	Health Promotion	Bachelor Degree	6	6-12 per day	Yes	No

AP = Asthma Patient; F= Female; HP= Health Professional; KCS= Key Community Stakeholder; M= Male; N/A= Not Applicable; PhD= Doctor of Philosophy

Positive perspectives to inhaler technique technological interventions

1st level of Triandis – Personal characteristics

A patient's normal inhaler technique behaviour is reviewed by health professionals. In particular, respiratory nurses and respiratory specialists pursued this evaluation prior to critique of inhaler technique. Hence, there appears to be a standard approach taken by health professionals when evaluating patient inhaler use, however, all health professionals indicated this does not always occur. An approach used by health professionals involves observing current technique before evaluating practice to ensure medication is administered correctly. Two respiratory specialists

(HP 1 and 2) and general practitioners (HP 3 and 4) reported involving pharmacists, respiratory nurses and key community stakeholders in providing correct inhaler technique education. This is conducted internally as well as externally from the clinic or hospital, allowing more time to consult asthma patients in a more comfortable setting.

> *"I will get them to show me what they do first and then I will demonstrate…the correct technique if it's something they are already on. If it's something they've never used I will demonstrate first and then I will get them to show me how they do it." HP 5; "In an inpatient setting they all will be educated by a pharmacist." HP 2*

2nd level of Triandis – Formation of intention

Introduction of augmented reality to help improve asthma inhaler technique education was perceived positively. All participants perceived it would have positive impact on improving inhaler technique. However, there was a divergence in views between groups with all except five asthma patients perceiving it may require further support resources such as written information on how to use the technology. Participants believed this would be particularly the case for elderly users. Furthermore, two asthma patients agreed the technology would be a great resource for children aged seven years and over to utilise, due to their perceived high level interest in technology. Health professionals perceived the technology would be particularly useful as an inhaler initiation tool for new users as well as a helpful refresher for those who may need to update their technique. All key community stakeholders and asthma patients agreed it would be preferred as a refresher tool. Attention was further drawn to ease of technology use and all participants agreed it would be useful throughout an asthma patient's time with the disease. Furthermore, all participants gave positive responses regarding practicality of the technology, however, questioned if potential operators would utilise it. The nine asthma patients interviewed agreed they would use it, however, could only report hope that others would.

> *"It's a good start…cause that's the question I'm asking myself…how correct am I in teaching the patient." HP 6; "On initial diagnosis I would imagine…or when they are sort of unsure about what to do then they could go back and refresh every so often to make sure their actually doing it correctly." KCS 3*

3rd level of Triandis – Explain intention relating to behaviour

Health professionals and key community stakeholders believe habits and intentions play crucial roles in how a patient learns the behaviour of inhaler technique. In particular, two pharmacists agreed most asthma patients have the right intentions. However, throughout a technique check-up some demonstrate incorrect inhaler technique that appears to have developed from previous habits. On the contrary, asthma patients interviewed all perceived themselves using their inhalers correctly, leading to development of good and bad habits in relation to inhaler use. All asthma patients agreed they were questioning their confidence in utilising their inhaler correctly

following the interview. Furthermore, introduction of augmented reality technology was believed to be a facilitating condition. All participants perceived it would help improve inhaler technique and re-assure all potential handlers to use their inhalers correctly.

> *"I think some customers are afraid…to ask me again if they are unsure about something. The first time they are very receptive and…appreciate that you spend the time…I think they're a bit embarrassed about asking again." HP 8; People don't have to be able to read information and they've got a visual cue and they can come back and watch the demo again." HP 5; "There's people that that take it seriously and want to get the best care, I think they will find that very useful." AP 6*

Negative perspectives to inhaler technique technological interventions

1st level of Triandis – Personal characteristics

The study by AL-Jahdali, Ahmed [8] was mentioned during the interviews to determine how the results of the study made participants feel. Responses indicated health professionals were aware of deficient education about asthma and inhaler devices. However, the health professionals also reported this absence being identified when concerns or problems with technique were raised by patients during consultation. In particular, two health professionals, through their experience practicing in a hospital, learnt to question patients in order to understand what information was required. Furthermore, the two health professionals believed with time restraints and other health concerns taking priority, inhaler technique and asthma education were often forgotten or missed during consultation. Two pharmacists added time as a barrier for demonstrating correct inhaler technique. Moreover, pharmacist's evaluation of outcomes determined there is a lack of notification from other health professionals and patients regarding when inhaler technique education is necessary. This leads to asthma patients, in particular three interviewed, conceptualising they were never educated about the disease or inhaler devices until a serious event, hospitalisation or exacerbation had occurred.

> *"I think we've all been guilty of just prescribing someone…a device…and just assuming that the patient's going to read the instructions…when your pushed for time it's a bit like, just make sure you read the instructions…and if you have any questions then contact me." HP 3; "I even still don't fully understand the scientific side of asthma and the disease…I was basically just given a puffer and told this will fix it…" AP 2*

2nd level of Triandis – Formation of intention

A particular question regarding whose responsibility it is to deliver correct inhaler technique education was put forward throughout the interviews. Health professionals and key community stakeholders all perceived it to be a combined effort from all involved to consequently improve inhaler technique, however this does not always occur. Interviewed asthma patients had alternate perspectives. For example, they perceived general practitioners or respiratory

specialists to be responsible for delivery of the education. This indicates most patients do not perceive there are other available sources for education and consequently leading to outcomes where patient problems are not being resolved and intentions become negative.

> *"I s'pose it'd be…respiratory doctors" AP 1; "I've only ever been to see my GP about my asthma…I expect it would be my GP" AP 2; "Well it's combined responsibility…if they had some education at the GPs or the practice nurse that does education, then again at the pharmacists…they come into us and have more education hopefully we can get them on the right path." KCS 3*

3rd level of Triandis – Explain intention relating to behaviour

Barriers perceived by interviewed participants include bad habits that were formed many years ago, and patients believing themselves to be proficient with their inhalers, but upon observation using it incorrectly. Another barrier is with the technology itself. Although interviewed participants agreed they would use it providing they had access to it, many health professionals believed some patients would not be able to work the technology. From here they perceived they would be the ones to implement the technology therefore, further reducing consult time. In particular, one health professional brought up concerns about the technology initially requiring internet until the video was downloaded as not all asthma patients have or can access this. Another mentioned it being reliant on smartphones or other capable devices and not all asthma patients having access to technology. One asthma patient interviewed did not have a smart phone and agreed it was problematic.

> *"One in cognitive function, memory, language fluency, literacy. So these are all potential barriers." KCS 4; "They understand but it's their condition…" HP 6; "I think one of the challenges for us in particular is that people generally don't take the asthma seriously." KCS 2; "Not having smartphone maybe, this is dependent on a smartphone." HP 1; "I haven't got the technology." AP 7*

Additional findings related to attitudes, knowledge, beliefs around inhaler technique and technology, in the form of augmented reality, for each of the three levels of behaviour is reported in *Table 2*.

Table 2. Sub-themes and quotes identified under the Triandis model.

Positives		
Triandis	**Subcategory**	**Quote**
1st level	Demonstration of device	*"Well he dug out the spacer and out the thing on the end and said well what you do is you know,*

		press, breathe in and he watched me do it and he said yeah that's fine." AP 6 *"...if I do have a demo inhaler in my clinic I'll show them how to use it or sometimes I feel it's easier to just play a video on YouTube if time permits as well during the clinic session."* HP 2
	Inhaler technique check	*"Well the best way and the one that I prefer the most is hands on...we actually sit in with the person with either a placebo or their own puffers and actually doing it, re-enacting, so an aesthetic approach."* KCS 4 *"Not every time but some of the times when I've been back for a prescription renewal and they've said make sure you do this and wash your mouth out afterwards and more often than not they remind me."* AP 3
	Teaching correct inhaler technique	*"We provide inhaler technique education beyond asthma...we do it to all your respiratory chronic diseases and that would be part of most of our consults...that would be...making sure that people are using their devices correct. "* HP 5
2nd level	Confidence in delivery of education	*"I think I've got the knowledge, I feel confident with it...because I've been asthmatic...and I deal a lot...with some of these asthma kids from up at the hospital...I feel pretty good with that because I've seen enough of it."* HP 4
	Responsibility for delivery of inhaler technique education	*"Probably doctors but the lung specialist at the moment has probably been the best one"* AP 5 *"At the moment the practice nurse would be the one that would do it."* AP 6 *"It would be good if firstly the doctor could explain that to them and pharmacists as well. If you have more people teaching in a collaborative manner*

		that will help reinforce the techniques because I think people learn by repetition." HP 8
	Applicability of technology	*"Most people are able to press a few buttons… most people would use it. If you've got a young mum out there…she's concerned about her child that has asthma and this can show her exactly…how to use the puffer which makes it brilliant."* KCS 1
3rd level	Development of habit	*"For some people like they may develop habit but it may be that it's working for them, they are still getting that benefit from the medications… their symptoms are controlled, they're taking it, taking their medications at the regular intervals that is required."* HP 7
	Level of care patients have	*"I think most patients that I've seen…they do care…especially mums with young children that are just starting it."* HP 7 *"If I get a new puffer I can check it up or and see if the doctors not actually lying to me or something."* AP 5
	Good habits	*"I believe that if the first time they've already been taught the right way then it becomes a habit of them."* HP 6 *"Like a golf swing, it's like if you…have a good teacher initially uhm a doctor or a pharmacist that shows you how to do it properly and you repeat that…good habits will develop and your asthma as a result of that will be better controlled."* HP 8
Negatives		
1st level	Formal education about disease, medications & devices	*"I think some pharmacists won't check that it's new or their dispense techs don't tell them that it is new and then it just gets missed…"* HP 7

		"I even still don't really fully understand the scientific side of asthma and the disease. I know the basics but it's never, I've never attended anything that's really explained to me what it mean…how it impacts my body…I was basically just given a puffer and told this will fix it not knowing whether I was going to have it for life." AP 2
	Beliefs about outcomes	*"Time is a major barrier. So obviously clinics are full packed and jammed so don't have much time."* HP 1 *"Honestly not everyone I'd talk to about inhaler technique… it's super important, like I know I've gotta get better at it…but I think we all take it for granted that they know what to do"* HP 4
	Assumptions regarding confidence with using an inhaler correctly	*"I think patients just assume they're using their inhalers correctly…because it's a bit, oh how hard could this be…but there might be subtle things that are not right."* HP 3 *"Cause you get lazy at these things…people take shortcuts."* HP 4 *"People tend to think they know everything and sometimes they're not that willing to listen so often…you'll say to somebody, can you show me how you use your medication, and they'll tell you, oh I know how to use it, I use it correctly and…you can't tell them anything that they don't already know."* KCS 3
2nd level	Responsible for inhaler education delivery	*"It's a shared responsibility… I just wouldn't probably delegate it to the prescriber necessarily… but because we don't make it someone's absolute responsibility therefore patients fall between the cracks…"* HP 3

	Abundance of varying instructions	*"People are just giving different instructions…this is how I've been told, this is how the doctor so that's how I give and then there's other staff coming into follow up and it's a different technique."* HP 6 *"There's different opinions between different doctors and then some doctors stick with only one type and then it , you don't even know, I mean how the hell is someone like me supposed to know."* AP 2
	Importance of inhaler technique	*"When you've got busy lives and everything, the importance of medication sort of forgets put to the, you know, background or whatever and you're not really thinking about it until now."* HP 5 *"It's a big issue because you've got to get the drugs into your lungs and if you don't get the drugs into your lungs you don't have good control."* AP 6
3rd level	Beliefs inhalers are not working	*"I feel that people neglect the use of preventer's because they don't give immediate benefit from shortness of breath…education on the underlying inflammation…and the benefits of using a corticosteroid inhaler…knowing that…preventers…prevent the onset of asthma attacks…"* HP 8
	Age of diagnosis and effect on inhaler technique education	*"Maybe people like myself who get diagnosed really young and perhaps they're…not personally educated. Their parents have been educated and then there's no sort of update on them being educated."* AP 4
	Problems facilitating proper inhaler technique	*"Their health literacy's like and things like that come into play as well…if they're not understanding so much about how important all these things are…if they can't follow instructions…"* HP 5

		"A lot of people just think I manage my asthma by using my Ventolin…I don't like using my preventer and I certainly wouldn't use a spacer…so there are a lot of issues when for people when we're trying to extend outreach and impact actually get them to take their condition quite seriously." KCS 2

Questionnaire data

Triangulation of the data is observed with similarities in the quantitative and qualitative results between the three groups and three levels of the Triandis model. There is a strongly held belief that the application/technology has the capacity for improving inhaler technique. Furthermore, it's believed all users of the technology would benefit by using it due to the importance of patient inhaler technique.

Table 3. Quantitative questionnaire variables separated by the three levels of Triandis identifying participant attitudes, knowledge and beliefs around inhaler technique[a].

1st level: Personal characteristics	**Health professionals**		**Asthma patients**		**Key community stakeholders**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sufficient education/help available regarding patient inhaler use	5.5	2.07	7.83	2.71	5.5	0.71
Application/technology will be helpful for inhaler technique	9	0.93	9.17	1.33	9.5	0.71
Healthcare professionals benefit from technology like this	8.88	0.64	9.5	1.22	9.5	0.71
2nd level: Formation of intention	**Health professionals**		**Asthma patients**		**Key community stakeholders**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Patients experience stress/anxiety/worries when using their inhaler	5.38	1.19	1.5	2.51	5	1.41
The technology has the capacity to improve inhaler technique	9.25	0.89	9.83	0.41	9.5	0.71

Importance of patient correct inhaler technique	9.88	0.35	9.67	0.52	10	0

3rd level: Intention relating to behaviour	Health professionals		Asthma patients		Key community stakeholders	
	Mean	SD	Mean	SD	Mean	SD
Patient confidence when using their inhaler	7.25	1.39	9.17	1.33	4.5	0.71
Repeated use of technology	7.63	0.92	4.67	1.75	8.25	0.35

[a]Mean = average score (out of 10)

As per the evidence in *Table 3* and responses from the qualitative results, asthma patients are all very confident with their inhaler technique represented by the mean score of 9.17 out of 10 and standard deviation (SD) of 1.33. Health professionals and key community stakeholders, however, believe that asthma patients are typically not confident (mean 7.25, SD 1.39 and mean 4.5, SD 0.71 for health professionals and key community stakeholders respectively). Further adding to this incongruency, asthma patients do not believe they experience stress, anxiety or worries when using their inhalers (mean 1.83, SD 2.51), while health professionals and key community stakeholders report that asthma patients do stress, are anxious or report being worried when using their inhaler device (mean 5.38, SD 1.19 and mean 5 SD 1.41 respectively). Frequency of smartphone technology use is another instance where a divergence in views between groups can be observed, as shown in *Table 3*. Health professionals and key community stakeholders see themselves using the technology more often (mean 7.63, SD 0.92 and mean 8.25, SD 0.35 respectively) than the asthma patients (mean 5.17, SD 1.75). The final discrepancy reported between the three groups was in relation to the amount of education and/or help available for patient's inhaler use. Asthma patients believed there was sufficient education or help available with a mean score of 6.5 (SD 2.71) while health professionals and key community stakeholders believed there could be more education (mean 5.5 for both and SD 2.07 and 0.71 respectively). Additional findings related to attitudes, knowledge and beliefs around inhaler technique for each of the three groups of participants are reported in *Table 3.*

Discussion

This study used a qualitative interviewing approach to investigate the potential use of augmented reality to improve upon existing education for asthma inhaler technique. The 21 participants were all from Adelaide, South Australia, with varying occupations, gender, age, experience of teaching or using an inhaler, and technology use. Results from all participants reflect the

importance of correct inhaler technique education, with three key factors being identified: 1) health professional and patient confidence with inhaler use as well as stress, anxiety or worries experienced by patients while using their inhalers; 2) the amount of education and help available for patients' inhaler use and 3) potential frequency of augmented reality technology use. These core findings are discussed further below.

Confidence, stress and anxiety when using inhaler(s):

Despite a lack of knowledge and confidence being mentioned throughout the literature [5, 7, 21, 23, 24, 26, 53, 54], it did not appear to be a problem among the health professionals and key community stakeholders interviewed. All health professionals and key community stakeholders who were interviewed expressed confidence in delivering correct inhaler technique and having sufficient knowledge about both the disease and medications. However, during the interviews, all health professionals were questioning themselves as to how adept they really were in communicating this to patients. This suggests that there may be insufficient education readily available and easily accessible for both health professionals and asthma patients. An incidental yet important finding is the irregular frequency in assessment of inhaler technique with patients, which may not be fully identified as an issue among health professionals until probed. While health professionals are confident, when quizzed about actual clinical practice, their hesitation suggests that inhaler technique is not addressed often enough during consultations.

Following concerns about lack of knowledge and confidence within the health professional community, all interviewed participants were asked specifically about asthma patients' confidence while using their inhaler(s). From the results, health professionals and key community stakeholders perceived asthma patients as having low levels of confidence during inhaler technique evaluation. However, contrary to these results, asthma patients all reported feeling confident in using their inhaler(s). The literature has identified that asthma patients can be highly confident in performing inhaler technique, despite doing so incorrectly [23, 24, 55]. A high level of confidence is not a good indicator that inhaler technique will be performed correctly as highly confidence patients make mistakes more or as often as patients who are less confident [23, 24]. This suggests even though patients may appear to be confident, health professionals or key community stakeholders still need to regularly review device use. This is likely to lead to more patients who correctly use their asthma inhaler.

Similarly, as asthma patients perceive themselves as being adept with their inhaler use, they also believe they do not experience stress, anxiety or worries while using their medication devices. However, health professionals and key community stakeholders reported that approximately half of the asthma patients they see will experience some kind of stress, anxiety or worry related to use of their device at some point in time. This finding may also be linked back to the high

confidence level perceived by the asthma patient, compared to the level observed by the health professionals and key community stakeholders. Patients who do not receive any or insufficient education may be unaware of potential issues with their technique [5, 6, 18, 19, 56].

Education and ongoing assistance for patient inhaler technique:

Health professionals agreed that the frequency of inhaler technique education occurred only on a 'when required' basis. Four health professionals reported using the assistance of available practice nurses or pharmacists when discussing inhaler technique, to navigate the issues relating to time constraints. On the contrary, asthma patients reported that health professionals rarely provided any education related to inhaler technique. Furthermore, four of the asthma patients were unaware of alternative help avenues available for inhaler technique education such as online resources and those available via the Asthma Foundation of South Australia. This finding is consistent with the literature [22], suggesting that the limited awareness of available alternative resources stems from asthma patient's perception that they do not need additional help. These results support findings in the literature [23, 24], suggesting that asthma patients do not believe that assistance is required and therefore do not seek help. However, opportunities may arise with use of the augmented reality technology resource, not only as a means to increase the amount of available education but also to act as a prompt for patients to intermittently confirm their inhaler technique.

Barriers to regularly reviewing inhaler technique were raised as a concern among all individuals. Similar to previously published research [5-7, 18, 19], key barriers around improving inhaler technique included limited appointment time, and lack of resources (e.g. pamphlets, books, etc.) and availability of placebo devices to aid in education. Although the published literature points to time constraints as the greatest limiting factor on correcting inhaler technique, asthma patients in this study mentioned that other health issues often require attention, leaving minimal or no time to discuss inhaler technique. With this in mind, all participants believed that the augmented reality technology resource could be introduced and implemented during consultation, and potentially used as a refresher tool with the intention of reducing these barriers.

Frequency of smartphone technology use

All participants believed the technology would be beneficial for health professionals and asthma patients as a means of delivering inhaler education. Following demonstration of the innovative technology, all participants agreed that the hand-held resource provides a physical cue that health professionals, asthma patients and key community stakeholders are familiar with. Health professionals and key community stakeholders felt it would be a useful inhaler initiation tool used

in conjunction with other support materials. However, asthma patients believed the smartphone application would be sufficient without the need for a poster or accompanying physical resource to deliver inhaler technique education as a refresher tool. In this qualitative study, a frequently reported limitation impeding regular use was that some asthma patients may not use smartphones, and that the elderly in particular would find it difficult to navigate.

Future research

A randomised controlled trial is needed to evaluate the effectiveness of the augmented reality resource in the clinical care setting. Combined with a brief training program, the physical poster-based resource overlayed with augmented reality technology should be compared to implementation of usual care across multiple sites. Outcomes to evaluate include: assessment of correct inhaler technique among patients, number of patients shown inhaler technique by their health professional at each visit, asthma exacerbations, need to use reliever medication, emergency department presentation or hospitalisation and reported use of the electronic resource outside of outpatient/hospital visits.

Limitations

Recruitment was more difficult than initially predicted due to the paucity of asthma patients admitted to The Queen Elizabeth Hospital who met all the inclusion criteria and were willing to participate. Therefore, more subjects with well-controlled asthma were recruited. These participants had fewer exacerbations and better controlled asthma than those originally targeted, however, in the final phase of recruitment, three subjects fulfilling all of the original inclusion criteria were identified and agreed to participate, improving generalisability of the findings. For these reasons the number of asthma patients recruited is a larger cohort than initially intended. While unexpected, this broadens the scope of the research to include asthma patients with well controlled symptoms as well as those with frequent hospitalisations.

Another limitation for this study includes the limited representation of diversity in the sample. The sample included people who resided within urban areas of Adelaide with limited ethnic diversity, had English as a first language, middle to high socio-economic status and were employed. This study would be strengthened with recruitment of a more diverse range of participants from across multiple hospitals and different locations (urban, regional and rural as well as across states/territories). Of note, subjects were not excluded based on smoking status or time of last lung function assessment. Therefore, a potential exists for some recruited asthma subjects to have undiagnosed early-stage COPD. However, it is unlikely that having undiagnosed COPD will affect the results of the evaluation as patient's self-identity as an asthma sufferer will not change.

Purposive sampling used throughout recruitment of asthma patients poses a risk of subject selection bias that is difficult to measure or control [57]. However, considering that the purpose of this evaluation was to gain insight into specific populations, the targeted sample cohort evaluated in this study is typical of qualitative research. An attempt was made to reduce researcher bias by using two independent researchers to code the qualitative data.

As the scope of the paper was limited to themes directly related to the use of new technology as an intervention to improve inhaler technique, it only indirectly addressed the broader strategies for improving asthma inhaler technique, such as pamphlets, face to face assessments and other resources or dynamics used when educating patients.

Methodology employed within this study did not incorporate quantitative assessment of asthma patient inhaler technique according to guidelines. Moreover, interviews were conducted using a semi-structured guide permitting flexibility in wording and flow of interview. Throughout initial interviews with health professionals, asthma patients and key community stakeholders, responses were not as expected in some cases. In these instances, adjustments to the moderator guides occurred, generating more in-depth responses that better addressed the gap in evidence. Counts could not be conducted to quantify responses on any one particular issue. Supplementing this, 10-point Likert scales were used to provide quantitative outputs or key issues that were also used to triangulate data collection.

Conclusion

Inhaler technique is an important part of asthma management that is frequently overlooked. There is a widely held perception of confidence in inhaler technique among the majority of asthma patients that may be masking issues of incorrect technique. These perceptions lead to a false sense of security as patient's do not ask their health professionals to check inhaler technique, they do not seek resources for confirmation, and health professionals request to see inhaler technique less often. These factors may be exacerbating the high rates of incorrect inhaler technique that are contributing to sub-optimal disease management and subsequently escalating hospital utilisation. Augmented reality technology was perceived by all participants to be a potentially valuable tool to aid in the education of correct inhaler technique, and as a means of prompting health professionals to check inhaler use. The ability to easily and cost-effectively update the digital content without the need to change the printed document is a valuable asset, as is the capacity for videos to negate issues surrounding poor health literacy. Barriers to uptake were identified for the older population who may not know how to use the technology, and for people without smartphones. Under-evaluation of poor inhaler technique by health professionals was also identfiied as a potential barrier resulting in reduced uptake of the

technology by asthma patients. As this is a qualitative study, research data cannot be generalised beyond the sample. Therefore, a randomised controlled trial to evaluate efficacy in the clinical setting is required.

Acknowledgements

This study was funded by an NHMRC TRIP Fellowship awarded to KCC, and resources provided by The Queen Elizabeth Hospital, Respiratory Medicine Department.

Conflicts of Interest

The author team have no conflicts of interest to declare.

Abbreviations

AR: Augmented reality

AP: Asthma patient

COPD: Chronic obstructive pulmonary disease

HP: Health professional

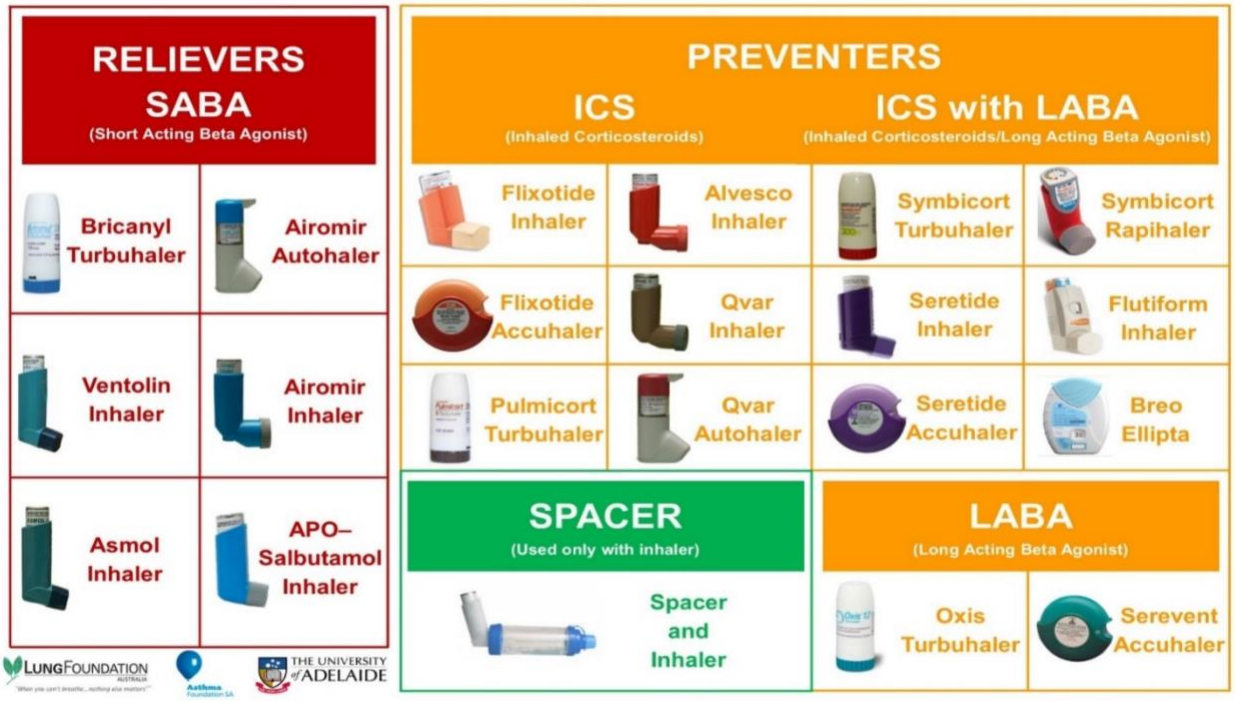
KCS: Key community stakeholder

MASAC: Medical and Scientific Advisory Committee for the Asthma Foundation of South Australia

SD: Standard deviation

Multimedia Appendix 1: Prototype inhaler education poster with augmented reality functionality

Which inhaler do you use for asthma?



REFERENCES

1. Australian Bureau of Statistics. Asthma. Canberra: Australian Bureau of Statistics; 2018 [cited 2021 1/11/21]; Available from: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/asthma/latest-release#endnotes.
2. Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. 2020;396(10258):1204-22.
3. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention (2021 update). 2021.
4. Scichilone N. Asthma Control: The Right Inhaler for the Right Patient. Adv Ther. 2015;32(4):285-92. doi: 10.1007/s12325-015-0201-9.
5. Self TH, Arnold LB, Czosnowski LM, Swanson JM, Swanson H. Inadequate skill of healthcare professionals in using asthma inhalation devices. Journal of Asthma. 2007;44(8):593-8.
6. Basheti IA, Hamadi SA, Reddel HK. Inter-professional education unveiling significant association between asthma knowledge and inhaler technique. Pharmacy Practice. 2016;14(1).
7. Miles C, Arden-Close E, Thomas M, Bruton A, Yardley L, Hankins M, et al. Barriers and facilitators of effective self-management in asthma: systematic review and thematic synthesis of patient and healthcare professional views. npj Prim Care Respir Med. 2017 2017/10/09;27(1):57. doi: 10.1038/s41533-017-0056-4.
8. AL-Jahdali H, Ahmed A, AL-Harbi A, Khan M, Baharoon S, Bin Salih S, et al. Improper inhaler technique is associated with poor asthma control and frequent emergency department visits. Allergy Asthma Clin Immunol. 2013;9(1). doi: 10.1186/1710-1492-9-8.
9. Global Initiative for Asthma. Global strategy for asthma management and prevention. 2016.
10. Zambelli-Simões L, Martins MC, Possari JCC, Carvalho GB, Coelho ACC, Cipriano SL, et al. Validation of scores of use of inhalation devices: Valoration of errors. J Bras Pneumol. 2015;41(4):313-22. doi: 10.1590/S1806-37132015000004435.
11. Vanderman AJ, Moss JM, Bailey JC, Melnyk SD, Brown JN. Inhaler misuse in an older adult population. Consultant Pharmacist. 2015;30(2):92-100.
12. Sadowski CA, Cor K, Cave A, Banh HL. Administration Technique and Acceptance of Inhaler Devices in Patients With Asthma or COPD. The Annals of pharmacotherapy. 2015;49(6):639-48.
13. Price DB, Roman-Rodriguez M, McQueen RB, Bosnic-Anticevich S, Carter V, Gruffydd-Jones K, et al. Inhaler Errors in the CRITIKAL Study: Type, Frequency, and Association with Asthma Outcomes. J Allergy Clin Immunol Pract. 2017 Jul - Aug;5(4):1071-81 e9. PMID: 28286157. doi: 10.1016/j.jaip.2017.01.004.
14. Basheti IA, Armour CL, Bosnic-Anticevich SZ, Reddel HK. Evaluation of a novel educational strategy, including inhaler-based reminder labels, to improve asthma inhaler technique. Patient Educ Couns. 2008;72(1):26-33. doi: 10.1016/j.pec.2008.01.014.
15. Crane MA, Jenkins CR, Goeman DP, Douglass JA. Inhaler device technique can be improved in older adults through tailored education: Findings from a randomised controlled trial. npj Prim Care Respir Med. 2014;24. doi: 10.1038/npjpcrm.2014.34.
16. Hammerlein A, Muller U, Schulz M. Pharmacist-led intervention study to improve inhalation technique in asthma and COPD patients. Journal of Evaluation in Clinical Practice. 2011;17(1):61-70.
17. Normansell R, Kew KM, Mathioudakis AG. Interventions to improve inhaler technique for people with asthma. Cochrane Database of Systematic Reviews. 2017 (3). PMID: CD012286. doi: 10.1002/14651858.CD012286.pub2.

18. Torjesen I. Two thirds of deaths from asthma are preventable, confidential inquiry finds. British Medical Journal. 2014;348:g3108. doi: http://dx.doi.org/10.1136/bmj.g3108
19. Levy M, Andrews R, Buckingham R, Evans H, Francis C, Houston R, et al. Why asthma still kills: The National Review of Asthma Deaths (NRAD). Confidential Enquiry report. Royal College of Physicians, 2015 May 2014. Report No.
20. Gagne ME, Boulet LP. Implementation of asthma clinical practice guidelines in primary care: A cross-sectional study based on the Knowledge-to-Action Cycle. J Asthma. 2018 Mar;55(3):310-7. PMID: 28548896. doi: 10.1080/02770903.2017.1323919.
21. Plaza V, Giner J, Rodrigo GJ, Dolovich MB, Sanchis J. Errors in the Use of Inhalers by Health Care Professionals: A Systematic Review. J Allergy Clin Immunol Pract. 2018 May - Jun;6(3):987-95. PMID: 29355645. doi: 10.1016/j.jaip.2017.12.032.
22. Cheong LH, Armour CL, Bosnic-Anticevich SZ. Patient asthma networks: understanding who is important and why. Health Expectations. 2015;18(6):2595-605.
23. Chorão P, Pereira AM, Fonseca JA. Inhaler devices in asthma and COPD–an assessment of inhaler technique and patient preferences. Respiratory medicine. 2014;108(7):968-75.
24. Press VG, Arora VM, Shah LM, Lewis SL, Charbeneau J, Naureckas ET, et al. Teaching the use of respiratory inhalers to hospitalized patients with asthma or COPD: a randomized trial. Journal of general internal medicine. 2012;27(10):1317-25.
25. National Asthma Council Australia. Australian Asthma Handbook. Melbourne: National Asthma Council Australia; 2015.
26. Leung J, Bhutani M, Leigh R, Pelletier D, Good C, Sin DD. Empowering family physicians to impart proper inhaler teaching to patients with chronic obstructive pulmonary disease and asthma. Canadian respiratory journal : Journal of the Canadian Thoracic Society. 2015;22(5):266-70.
27. Abed MA, Himmel W, Vormfelde S, Koschack J. Video-assisted patient education to modify behavior: A systematic review. Patient Educ Couns. 2014;97(1):16-22.
28. Wilson EA, Makoul G, Bojarski EA, Bailey SC, Waite KR, Rapp DN, et al. Comparative analysis of print and multimedia health materials: a review of the literature. Patient Educ Couns. 2012;89(1):7-14.
29. Wilson M. Readability and patient education materials used for low-income populations. Clinical Nurse Specialist. 2009;23(1):33-40.
30. Self T, Brooks J, Lieberman P, Ryan M. The value of demonstration and role of the pharmacist in teaching the correct use of pressurized bronchodilators. Canadian Medical Association Journal. 1983;128(2):129.
31. King TL, Kho EKY, Tiong YH, Julaihi SNB. Comparison of effectiveness and time-efficiency between multimedia and conventional counselling on metered-dose inhaler technique education. Singapore Med J. 2015;56(2):103-8. doi: 10.11622/smedj.2015024.
32. Navarre M, Patel H, Johnson CE, Durance A, McMorris M, Bria W, et al. Influence of an interactive computer-based inhaler technique tutorial on patient knowledge and inhaler technique. Annals of Pharmacotherapy. 2007;41(2):216-21.
33. Savage I, Goodyer L. Providing information on metered dose inhaler technique: is multimedia as effective as print? Family practice. 2003;20(5):552-7.
34. Van Der Palen J, Klein JJ, Kerkhoff AHM, Van Herwaarden CLA, Seydel ER. Evaluation of the long-term effectiveness of three instruction modes for inhaling medicines. Patient Educ Couns. 1997;32(SUPPL. 1):S87-S95.
35. Mulhall AM, Zafar MA, Record S, Channell H, Panos RJ. A Tablet-Based Multimedia Education Tool Improves Provider and Subject Knowledge of Inhaler Use Techniques. Respir Care. 2017 Feb;62(2):163-71. PMID: 28108685. doi: 10.4187/respcare.05008.

36. Zarei AR, Jahanpour F, Alhani F, Razazan N, Ostovar A. The Impact of Multimedia Education on Knowledge and Self-efficacy among Parents of Children with Asthma: A Randomized Clinical Trial. J Caring Sci. 2014 Sep;3(3):185-92. PMID: 25276762. doi: 10.5681/jcs.2014.020.
37. Iio M, Hamaguchi M, Narita M, Takenaka K, Ohya Y. Tailored Education to Increase Self-Efficacy for Caregivers of Children With Asthma: A Randomized Controlled Trial. Comput Inform Nurs. 2017 Jan;35(1):36-44. PMID: 27606790. doi: 10.1097/CIN.0000000000000295.
38. Bacca J, Baldiris S, Fabregat R, Graf S. Augmented reality trends in education: a systematic review of research and applications. 2014.
39. Kim H, Xie B. Health literacy in the eHealth era: A systematic review of the literature. Patient Education and Counseling. 2017;100(6):1073-82.
40. Akcayir M, Akcayir G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review. 2017;20:1-11.
41. Porter ME, Heppelmann JE. How smart, connected products are transforming companies. Harvard Business Review. 2015;October(R1510G):1-19.
42. Lung Foundation Australia. Asthma. 2016; Available from: http://lungfoundation.com.au/patient-support/other-lung-conditions/asthma/.
43. Blippar Group. Layar. 2016; Available from: https://www.layar.com/.
44. Cloutier MM. Asthma management programs for primary care providers: increasing adherence to asthma guidelines. Current opinion in allergy and clinical immunology. 2016;16(2):142-7.
45. Basheti IA, Qunaibi EA, Hamadi SA, Reddel HK. Inhaler technique training and health-care professionals: effective long-term solution for a current problem. Respir Care. 2014;59(11):1716-25.
46. Malterud K, Siersma VD, Guassora AD. Sample Size in Qualitative Interview Studies Guided by Information Power. Qualitative health research. 2015:1049732315617444.
47. Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Administration and Policy in Mental Health and Mental Health Services Research. 2015;42(5):533-44.
48. Egmond C, Bruel R. Nothing is as practical as a good theory. Analysis of theories and a tool for developing interventions to influence energy-related behaviour. 2007.
49. Patton MQ. Enhancing the quality and credibility of qualitative analysis. Health services research. 1999;34(5 Pt 2):1189.
50. Darnton A. Reference report: An overview of behaviour change models and their uses. UK: Government Social Research Behaviour Change Knowledge Review. 2008.
51. Bamberg S, Schmidt P. Incentives, morality, or habit? Predicting students' car use for university routes with the models of Ajzen, Schwartz, and Triandis. Environment and behavior. 2003;35(2):264-85.
52. Robinson J. Triandis' theory of interpersonal behaviour in understanding software piracy behaviour in the South African context 2010.
53. Fink JB, Rubin BK. Problems with inhaler use: A call for improved clinician and patient education. Respir Care. 2005;50(10):1360-74.
54. Lindh A, Theander K, Arne M, Lisspers K, Lundh L, Sandelowsky H, et al. Errors in inhaler use related to devices and to inhalation technique among patients with chronic obstructive pulmonary disease in primary health care. Nurs Open. 2019 Oct;6(4):1519-27. PMID: 31660180. doi: 10.1002/nop2.357.
55. Usmani OS, Lavorini F, Marshall J, Dunlop WCN, Heron L, Farrington E, et al. Critical inhaler errors in asthma and COPD: a systematic review of impact on health outcomes. Respir Res. 2018 Jan 16;19(1):10. PMID: 29338792. doi: 10.1186/s12931-017-0710-y.
56. Soones TN, Lin JL, Wolf MS, O'Conor R, Martynenko M, Wisnivesky JP, et al. Pathways linking health literacy, health beliefs, and cognition to medication adherence in older adults with asthma. J Allergy Clin Immunol. 2017 Mar;139(3):804-9. PMID: 27555454. doi: 10.1016/j.jaci.2016.05.043.

57. Acharya AS, Prakash A, Saxena P, Nigam A. Sampling: Why and how of it. Indian Journal of Medical Specialties. 2013;4(2):330-3.

Chapter 6.

Home-based educational interventions for children with asthma

(Systematic review and meta-analysis)

Antonia O'Connor[1], Maryam Hasan[2], Elizabeth Stovold[3], Kristin V Carson-Chahhoud[4], Emma J Dennett[3]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, Adelaide, [2]St. George's University of London, London, [3]Population Health Research Insititute, St. George's, University of London, London, [4]School of Health Sciences, University of South Australia, Adelaide

Submitted and accepted for publication, Cochrane Systematic Reviews

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Home-based educational interventions for children with asthma

---

Publication status: Submitted for publication, accepted for publication, editorial review

Publication details: O'Connor A, Hasan M, Stovold E, Carson-Chahhoud KV, Dennett EJ. Home-based educational interventions for children with asthma. Cochrane Database of Systematic Reviews TBD, Issue TBD.

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Updated the Cochrane protocol including additional methodology, creating and coordinating Covidence database for streamlined screening, screening searches based on titles and abstracts and full text review of shortlist studies to identify for inclusion, extracted data for characteristics, risk of bias and results, analysed the data, synthesised and interpreted results, drafted manuscript		
Overall percentage (%)	65%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Maryam Hasan		
Contribution to the paper	Developed protocol from 2011 publication, drafted and edited original manuscript, screening searches to identify studies for inclusion, extracted data for characteristics		
Signature		Date	20/06/2022

Name of co-author	Elizabeth Stovold		
Contribution to the paper	Literature searches, organised workflow, drafted PRISMA diagram, updated manuscript		
Signature		Date	20/06/2022

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Updated Cochrane protocol including additional methodology, screening searches based on titles and abstracts and full text review of shortlist studies to identify for inclusion, edited manuscript and supervised principal author (primary supervisor)		
Signature		Date	

Name of co-author	Emma Dennett		
Contribution to the paper	Developed protocol from 2011 publication, lead in first version of review as primary author. Updated the Cochrane protocol including additional methodology, screening searches based on titles and abstracts, second full text screening to identify studies for inclusion, extracted data for characteristics, risk of bias and results, analysed the data, edited manuscript.		
Signature		Date	20/06/2022

Provision of asthma education is a long-standing key component of asthma management. Education is multi-faceted, with information on the disease process, instruction on self-management skills as well as treatment principles required. For children, education may be provided to the individual, their family, or within a group setting. Education delivery can be provided by a variety of asthma educators in a range of settings.

To help guide the study protocol for evaluation of augmented reality technology for inhaler education in children and adolescents, reviewing asthma inhaler technique education interventions and settings for interventions was deemed necessary. In 2017, Fortescue et. al published a Cochrane systematic review for interventions to improve inhaler technique for people with asthma however given the lack of studies in children, evidence was not clear for the effectiveness of the interventions on improved technique and the intervention on asthma-related health outcomes (41). In 2019, Harris et. al published a Cochrane systematic review for self-management interventions for asthma in children and adolescents delivered at school however effectiveness of interventions on improvement of self-management were not definitive (103).

Results from Chapter 5 highlighted augmented reality technology could be a useful delivery mechanism for asthma inhaler technique education delivery in adults with asthma with this research was carried out in a hospital-based setting. In paediatrics, there is an increasing awareness of the importance of environmental factors such as family and the neighbourhood on health outcomes. Asthma education delivered in the home may have several advantages over delivery in a clinical or school environment including the ability to address home-based triggers, educate other family members and improve reach to socioeconomically disadvantaged children where barriers such as lack of transport may be present. The evaluation of the efficacy of home-based educational interventions was last reviewed over a decade ago in a Cochrane review. Given the importance of home-based care on children with asthma, and with the SARS-CoV-2 pandemic recently stressing the need for alternative strategies and models of care for healthcare delivery, this highlighted the need to update the evidence on asthma home-based education.

Cochrane systematic reviews have long been recognized as the gold standard for evidence synthesis with its rigorous, reproducible methodology to answer specific research questions. There is an emphasis on minimization of bias to ensure increased reliability of findings which is essential for decision makers and other researchers. An evaluation of the current literature surrounding home-based educational interventions for children with asthma, conducted through a Cochrane systematic review and meta-analysis was therefore thought necessary to consolidate the determine if a home-based setting would be

appropriate for the delivery of a technology-based educational intervention for inhaler training.

Twenty-five studies involving 4923 children were included. There was little to no difference in the primary outcomes of asthma exacerbations requiring emergency department visits and asthma exacerbations requiring a course of oral corticosteroids when comparing home-based asthma educational interventions compared to standard care, education delivered outside the home or a less intensive educational intervention delivered at home. Other outcomes such as quality of life, symptom free days and days missed from school or work also had little or no difference between groups. Due to the considerable diversity of the included studies, many of the results were unable to be pooled for meaningful interpretation and provision of recommendations for clinical care.

Circulation and Breathing Network

Home-based educational interventions for children with asthma

--Manuscript Draft--

Manuscript Number:	
Full Title:	Home-based educational interventions for children with asthma
Article Type:	Update: Intervention Review
Section/Category:	Airways
Corresponding Author:	Antonia Chan AUSTRALIA
Corresponding Author's Institution:	
Order of Authors:	Antonia Chan
	Maryam Hasan
	Elizabeth Stovold
	Kristin Carson-Chahhoud
	Emma Dennett
Abstract:	Background During the SARS-CoV-2 pandemic over the recent years, it has become increasingly important for healthcare policy makers to think more broadly as to how and where care is delivered. While guidelines recommend that children with asthma should receive asthma education, it is not known if education delivered in the home is superior to usual care or the same education delivered elsewhere. Inconsistent evidence for home-based education interventions was found in the previous Cochrane systematic review published in 2011. The home setting allows educators to reach populations (such as the economically disadvantaged) that may experience barriers to care (such as lack of transportation) within a familiar environment, and also allows for avoidance of attendance at healthcare settings. This is a review update. Objectives 1. To assess the effects of educational interventions for asthma, delivered in the home to children, their caregivers, or both, on asthma-related outcomes. 2. To make the education interventions accessible to readers by summarising the contentand components. Search methods We searched the Cochrane Airways Group Trials Register, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, Embase, and clinical trials registries. We also searched the Education Resources Information Center database (ERIC), reference lists of trials and review articles (last search 13 September 2021). Selection criteria We included randomised controlled trials of asthma education delivered in the home to children, their caregivers or both. In the first comparison, eligible control groups were provided usual care or the same education delivered outside the home. For the second comparison, control groups received a less intensive educational intervention delivered in the home. Data collection and analysis Two authors independently selected the trials, assessed trial quality and extracted the

	data. We contacted study authors for additional information. We pooled dichotomous data with fixed-effect odds ratio and continuous data with mean difference (MD) using a fixedeffect where possible. We used GRADE and methods recommended by Cochrane. The primary outcomes were the number of patients with exacerbations requiring emergency department (ED) visits and exacerbations requiring a course of oral corticosteroids (OCS). Main results A total of 25 studies involving 4923 children were included. Twenty studies were conducted in North America. Participants were predominantly from low socioecononomic areas. Participants differed markedly in terms of age, severity of asthma, context and content of the educational intervention leading to substantial clinical diversity. The aims of the studies varied from reducing healthcare utilisation (such as ED visits and readmission rates) to improving adherence to medications or quality of life. This is reflected in diversity in the control group event rates which highlights the differences in the included populations. A table summarising some key components of the education programmes is included in the review. The studies were overall of good methodological quality, although they are all at risk of bias because the intervention could not be blinded.
Secondary Abstract:	
Additional Information:	
Question	Response
All authors have read the Cochrane Conflict of interest policy on Cochrane Library content, and when prompted by email, will submit Declaration of interest forms via the online Global Disclosure System, Convey.	I/We confirm
All authors meet the criteria for authorship.	I/We confirm
All people who have provided input to the article, and who don't meet criteria for authorship, have been offered the opportunity to be acknowledged in the acknowledgments section.	I/We confirm
All people who have agreed to be acknowledged in the acknowledgments section have provided evidence of permission to be publicly acknowledged. Authors must submit evidence from each person acknowledged, such as an email, or a signed copy of the acknowledgments section from the person.	I/We confirm
All figures included in the article are original, or any figures that have been reproduced from elsewhere have been reproduced with permission. Authors must submit evidence of permissions to reproduce figures, such as an email, signature or publisher's form.	I/We confirm
For intervention reviews, authors have	I/We confirm

prepared the article following the guidance outlined in the Cochrane Handbook for Systematic Reviews of Interventions, and for all other review types, authors have prepared the article following appropriate methodological guidance available from Cochrane.	
The article is not under consideration for publication elsewhere, without prior discussion with Cochrane editors.	I/We confirm

RevMan: review – intervention; 6326090908202822 86 (version 4.18)

Status: UNPUBLISHED DRAFT

Home-based educational interventions for children with asthma

Editors: Cochrane Airways Group

Contact Person: Antonia O'Connor (antonia.chan@sa.gov.au)

Adelaide, Australia

Antonia O'Connor[1]Maryam Hasan[2]Elizabeth Stovold[3]

Kristin V Carson-Chahhoud[4]Emma J Dennett[3]

[1] Department of Respiratory and Sleep Medicine, Women's and Children's Hospital, North Adelaide, Australia

[2] St George's University of London, London, UK

[3] Population Health Research Institute, St George's, University of London, London, UK

[4] School of Health Sciences, University of South Australia, Adelaide, Australia

Citation

O'Connor A, Hasan M, Stovold E, Carson-Chahhoud KV, Dennett EJ. Home-based educational interventions for children with asthma. Cochrane Database of Systematic Reviews TBD, Issue TBD. Art. No.: CD008469. DOI: 10.1002/14651858.CD008469.pub3.

Dates

Revision published: Issue TBD, TBD (TBD)

Version published (citation changed): Issue TBD, TBD (TBD)

Review first published: Issue 10, 2011

Protocol first published: Issue 4, 2010

Abstract

Background

During the SARS-CoV-2 pandemic over the recent years, it has become increasingly important for healthcare policy makers to think more broadly as to how and where care is delivered. While guidelines recommend that children with asthma should receive asthma education, it is not known if education delivered in the home is superior to usual care or the same education delivered elsewhere. Inconsistent evidence for home-based education interventions was found in the previous Cochrane systematic review published in 2011. The home setting allows educators to reach populations (such as the economically disadvantaged) that may experience barriers to care (such as lack of

transportation) within a familiar environment, and also allows for avoidance of attendance at healthcare settings. This is a review update.

Objectives

1. To assess the effects of educational interventions for asthma, delivered in the home to children, their caregivers, or both, on asthma-related outcomes.

2. To make the education interventions accessible to readers by summarising the content and components.

Search methods

We searched the Cochrane Airways Group Trials Register, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, Embase, and clinical trials registries. We also searched the Education Resources Information Center database (ERIC), reference lists of trials and review articles (last search 13 September 2021).

Selection criteria

We included randomised controlled trials of asthma education delivered in the home to children, their caregivers or both. In the first comparison, eligible control groups were provided usual care or the same education delivered outside the home. For the second comparison, control groups received a less intensive educational intervention delivered in the home.

Data collection and analysis

Two authors independently selected the trials, assessed trial quality and extracted the data. We contacted study authors for additional information. We pooled dichotomous data with fixed-effect odds ratio and continuous data with mean difference (MD) using a fixed-effect where possible. We used GRADE and methods recommended by Cochrane. The primary outcomes were the number of patients with exacerbations requiring emergency department (ED) visits and exacerbations requiring a course of oral corticosteroids (OCS).

Main results

A total of 25 studies involving 4923 children were included. Twenty studies were conducted in North America. Participants were predominantly from low socioecononomic areas. Participants differed markedly in terms of age, severity of asthma, context and content of the educational intervention leading to substantial clinical diversity. The aims of the studies varied from reducing healthcare utilisation (such as ED visits and readmission rates) to improving adherence to medications or quality of life. This is reflected in diversity in the control group event rates which highlights the differences in the included populations. A table summarising some key components of the education programmes is included in the review. The studies were overall of good methodological quality, although they are all at risk of bias because the intervention could not be blinded.

Home-based education versus usual care, wait list or less intensive education programme delivered outside the home

Home-based education may result in little to no difference in exacerbations leading to ED visits. One study reported fewer ED visits in the intervention group compared to the control group and one reported more, while no clear difference was shown in other studies (608 participants, 4 RCTs, low certainty evidence). There was too much clinical diversity and statistical heterogeneity to pool this outcome. It is not clear whether an increase or decrease in ED visits is the desirable outcome. Three studies contributed to our other primary outcome, exacerbations requiring a course of oral corticosteroids. There may be little or no difference in the number of courses of OCS (MD -0.18, 95% CI -0.63 to 0.26, 250 participants, 1 study, low certainty evidence).

For secondary outcomes, 8 studies (1679 participants, low certainty evidence) reported children's QoL, these were not pooled due to differences in instrument scores and missing data. Two small studies showed an improvement in caretaker's quality of life, but three were uncertain. Mean symptom free days, days missed from school or work and exacerbations leading to one or more hospitalisation also showed considerable uncertainty and there may be little or no difference in these outcomes.

Home-based education versus less-intensive home-based education for children with asthma

One study reported fewer exacerbations leading to ED visits in the more intensive education group (OR 0.46; 95% CI 0.25 to 0.84, N = 181). We were unable to meta-analyse the remaining studies, but they reported no clear difference. No difference in OCS prescriptions was reported (752 participants, 2 RCTs, low certainty evidence).

For secondary outcomes, there was again considerable uncertainty for symptom free days, days missed from school or work and exacerbations leading to one or more hospitalisations.

Adverse events was not an outcome in the review, though some outcomes are considered to be adverse events.

Authors' conclusions

We found uncertain evidence for home-based asthma educational interventions compared to standard care, education delivered outside the home or a less intensive educational intervention delivered at home. Education remains a key component of managing asthma in children. This review does not contribute further information on the fundamental content and optimum setting for such educational interventions. Considerable diversity meant we were unable to pool many of the results and derive any meaningful interpretation across the diverse studies. It is still possible that home-based education may be beneficial, especially in vulnerable populations.

Further studies should use standard outcomes from this review and design trials to tease out what components of an education programme are the most important to include.

Plain language summary

How useful is it to deliver asthma education to children, or their caregivers, or both, in the home?

Key message

Asthma education is important, but we were unable to show whether education delivered in the home is better or worse. For some children, it may be the best option e.g. if children are unable to reach a healthcare setting.

What is asthma?

Asthma is a chronic (long term) lung condition. People with asthma have inflammation in the airways in the lungs. The symptoms are wheeze, shortness of breath, chest tightness, and cough.

What is asthma education?

Asthma education aims to give children and caregivers education and skills to manage their asthma. This should be a partnership between the patient and the healthcare professionals. Components of asthma education are skills in how to use inhalers effectively, encouraging adherence with medications, an agreed management strategy,

information about asthma and training in self-management including monitoring such as with a peak flow meter and regular reviews with a healthcare professional. (This paragraph is based on the Gina Asthma Report 2021)

Why do we think the home might be a good place to give children asthma education?

The home setting allows educators to reach populations (such as the economically disadvantaged) that may experience barriers to care (such as lack of transportation) within a familiar environment, and also allows for avoidance of attendance at healthcare settings.

This review update is timely because since the SARS-CoV-2 pandemic, healthcare policy makers are thinking more broadly about how and where care is delivered.

What did we want to find out?

While guidelines recommend that children with asthma should receive asthma education, it is not known if education delivered in the home is superior to usual care or the same education delivered elsewhere.

What did we do?

We searched for trials delivering home-based education about asthma to children or their caregivers. The education had to be compared to something – either no education, or education delivered at a healthcare centre, or a less-intensive education delivered in the home.

We used standard Cochrane methods to evaluate the trials we found.

What did we find?

We found 25 studies involving 4923 children. Most of the studies were done in North America. Most families were from low socioeconomic areas. Children differed in terms of age, severity of asthma, context and content of the educational intervention.

Key results

* We found home-based education may result in little to no difference in exacerbations leading to ED visits.

* There may be little or no difference in the number of courses of oral steroids prescribed.

* Mean symptom free days, days missed from school or work, and exacerbations leading to one or more hospitalisation also showed considerable uncertainty and there may be little or no difference in these outcomes.

What are the limitations of the evidence?

The studies were overall of good methodological quality, although they are all at risk of bias because the intervention could not be blinded.

There was a lot of difference between their children’s asthma severity, the types of education delivered and other factors. This makes it hard to tell whether there is a real difference between the interventions because there is so much difference in the studies.

The aims of an intervention might be different too. For some children whose families have little asthma knowledge, they may be wanting to improve their knowledge of symptoms and encourage them to go to the emergency department more often. However, some children who have poorly controlled asthma and may be going to the emergency department a lot, you might want to improve their asthma control by teaching them how to use their medications properly, and this would hopefully decrease the number of emergency department visits. This makes thinking about the evidence more complicated.

How up to date is this evidence?

The information is current to 13 September 2021.

Summary of findings

Summary of findings 1

Home-based education compared to usual care or less-intensive education for children with asthma

Patient or population: children with asthma
Intervention: Home-based education
Comparison: Usual care or less-intensive education delivered outside the home

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with usual care or less-intensive education	Risk with home-based education				
Exacerbations leading to ED visits. Follow-up: range 3 to 6 months	One study reported fewer ED visits in the intervention group compared to the control group and one reported more, while no clear difference was shown in other studies. There was too much clinical heterogeneity to pool this outcome.			608 (4 RCTs)	⊕⊕⊖⊖ Low[a,b]	Home-based education may result in little to no difference in exacerbations leading to ED visits. It is not clear whether an increase or decrease in ED visits is the desirable outcome.
Mean exacerbations requiring a course of OCS. Follow-up: 6 months	The mean exacerbations requiring a course of OCS was **1.3** exacerbations	MD **0.18 exacerbations lower** (0.63 lower to 0.26 higher)	-	250 (1 RCT)	⊕⊕⊖⊖ Low[b,c]	There may be little or no difference in the number of courses of OCS
Quality of life. Follow-up: range 3 to 12 months	Studies reporting on children's QoL were not pooled due to differences in instrument scores and missing data. Two small studies showed an improvement in caretaker's quality of life, but three were uncertain.			1679 participants (8 studies)	⊕⊕⊖⊖ Low[a, b]	The evidence of an effect on quality of life is uncertain
Mean symptom-free days in the last 2 weeks. Follow-up: 12 months	The mean symptom-free days was **1.9** days	MD **1.45 days higher** (0.12 lower to 3.01 higher)	-	682 (2 RCTs)	⊕⊖⊖⊖ Very low[a,b,d,e]	Other studies reported symptom-free days in a variety of ways and results were uncertain.
Days missed from school or work Follow-up: 6 to 12 months	Studies were not pooled owing to heterogeneity and data not being in a format appropriate for meta-analysis. No studies reported a significant intervention effect.			807 participants (3 RCTs)	⊕⊖⊖⊖ Very low[b,c,f]	
Exacerbations leading to one or more hospitalisations. Follow-up: 6 months	Studies were not combined due to clinical heterogeneity, follow-up periods and outcome definitions.		Not estimable	618 participants (2 RCTs)	⊕⊕⊖⊖ Low[a,b]	Evidence for this outcome is uncertain.

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: confidence interval; **ED:** emergency department; **MD:** mean difference; **OCS:** oral corticosteroids; **OR:** odds ratio; **QoL:** quality of life; **RCTs:** randomised controlled trials

GRADE Working Group grades of evidence
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

[a] Downgraded 1 point for risk of bias. All studies unclear risk of bias for blinding as blinding not possible in educational trials, and many were uncertain for a number of domains.

[b] Downgraded 1 point for inconsistency. There was heterogeneity in the study populations, outcome definitions, follow-up time and differences in the control group event rate.

[c] Downgraded 1 point for imprecision. There was only 1 small study.

[d] Downgraded 1 point for imprecision. Two small studies with wide confidence intervals.

[e] Downgraded 1 point for risk of bias. Unclear risk of bias for blinding as not possible in educational trials, uncertain for a number of domains, and outcome self-reported.

[f] Downgraded 1 point for risk of bias. High risk of bias for attrition bias and uncertainty for all other domains.

Summary of findings table: Home-based education compared to usual care or less-intensive education for children with asthma

Summary of findings 2

Home-based education compared to less intensive home-based education for children with asthma

Patient or population: Children with asthma
Intervention: Home-based education
Comparison: Less intensive home-based education

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with Less intensive home based education	Risk with Home-based education				
Exacerbations leading to ED visits. Follow-up: 12 months	One study reported fewer exacerbations in the more intensive education group (OR 0.46; 95% CI 0.25 to 0.84, N = 181). We were unable to meta-analyse the remaining studies, but they reported no clear difference.			960 (5 RCTs)	⊕⊕⊖⊖ Low[a,b]	
Mean exacerbations requiring a course of OCS. Follow-up: 12 months	No difference in OCS prescriptions reported.			752 participants (3 RCT)	⊕⊕⊖⊖ Low[a,b]	
Quality of life. Follow-up: 12 months	No difference in QOL reported.			315 participants (2 RCTs)	⊕⊕⊖⊖ Low[b,c]	Evidence is uncertain for this outcome
Mean symptom free days in the last 2 weeks. Follow-up: 12 months	The mean symptom free days was **9.74 days**	MD **0.59 days lower**(1.77 lower to 0.59 higher)	-	274 (1 RCT)	⊕⊖⊖⊖ Very low[c,d,e]	
Days missed from school or work. Follow-up: 12 months	No change in missed school days reported.			43 (1 RCT)	⊕⊕⊖⊖ Low[f,g]	Evidence is uncertain for this outcome
Exacerbations leading to one or more hospitalisations. Follow-up: 12 months	Studies were not combined due to clinical heterogeneity, follow-up periods and outcome definitions.			960 participants (5 RCTs)	⊕⊕⊖⊖ Low[b,c]	Evidence is uncertain for this outcome

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
Abbreviations: CI: confidence interval; **ED:** emergency department; **MD:** mean difference; **OCS:** oral corticosteroids; **OR:** odds ratio; **QoL:** quality of life; **RCTs:** randomised controlled trials

GRADE Working Group grades of evidence
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

[a] Downgraded 1 for risk of bias. Several domains were unclear, there were issues such as high drop-out rates, lack of published protocol and the intervention cannot be blinded.

[b] Downgraded 1 for imprecision. We were unable to pool owing to lack of reported data.

[c] Downgraded 1 for risk of bias. Several domains unclear, lack of published protocol, outcomes were all caregiver self reported however could have been verified, intervention cannot be blinded.

[d] Downgraded 1 for imprecision. Few patients, few events and wide confidence interval.

[e] Downgraded 1 for risk of bias. Outcomes in the NCT record differed from those reported in the primary publication.

[f] Downgraded 1 for risk of bias. Several domains unclear, no prespecified protocol, unclear if allocation was concealed and intervention unable cannot be blinded.

[g] Downgraded 1 for imprecision. Small study with few patients and few events.

Summary of findings table: Home-based education compared to less intensive home-based education for children with asthma

Background

Description of the condition

Asthma is a chronic condition affecting the airways causing wheezing, coughing and difficulty in breathing. The 2019 Global Burden of Disease study identified 262.4 million prevalent cases of asthma (Safiri 2022). There are over 1000 deaths per day from asthma globally, making asthma an ongoing significant health problem (Asher 2019). Although a cure does not currently exist, multiple guidelines report on recommendations in which symptoms can be controlled (GINA 2021; SIGN158 2019). Despite this, a substantial number of children are still experiencing asthma symptoms, with a recent global cross-sectional study indicating 10% of school-aged children having had wheeze within the previous year, with over half of this population having symptoms classified as severe (Asher 2021). In children, poor symptom control results in missed school, restriction on physical activities and increased healthcare utilistion (Isik 2017). Asthma symptoms can impact the quality and enjoyment of life, with asthma sufferers at a higher risk of mood disorders including depression, psychological stress, eating disorders and alcohol abuse, compared to people without asthma (Oh 2019; Lee 2022).

People across all spectrums of economic development are affected, however lower socioeconomic groups have a higher prevalence of asthma, as well as higher levels of asthma-related morbidity and mortality (SIGN158 2019; Sinharoy 2018; Gaffney 2021; Asher 2021). Along with those from minority groups, they also have poorer asthma outcomes and secondary healthcare utilisation, typically making more asthma-related visits to emergency departments, having more hospitalisations and more readmissions as a result of their asthma (Tran 2020; Redmond 2021). This places a financial burden on both patients and the economy, through direct medical costs such as hospitalisations, and indirect costs from reduced productivity resulting from days lost at work or school. If nothing changes, models estimate the economic cost of uncontrolled asthma in the United States (US) to be US$936 billion, between the period 2019 to 2038 (Yaghoubi 2019).

Description of the intervention

Asthma education has long been recommended as an essential and integral part of asthma management (SIGN158 2019; GINA 2021). Education involves not only information on the disease process itself, but also development of self-management skills such as recognising triggers, self-monitoring their disease and treatment principles, with the goal of behaviour change and symptomatic control.

Specific components of education interventions may affect behaviour change by:

- reinforcing basic information about asthma to embed understanding;
- emphasising adherence to prescribed long-term controller medication;
- emphasising the importance of avoiding environmental triggers;

- providing self-monitoring techniques to help patients identify and respond appropriately to worsening asthma;
- providing written action plans to help patients respond correctly to exacerbations; and
- improving communication between patients and clinicians.

The way this education can be delivered to encourage patient involvement in the management of their asthma is variable. It may be delivered to an individual, their family, or in a group setting from various educators including clinicians, nurses, allied health professionals, and community health workers among others. Many with asthma will receive personalised written asthma action plans, whilst some may receive education delivered via other modalities, such as through interactive games, workshops, booklets, and lectures. It is likely there is a combination of education modalities in use across many settings, where these combined efforts are needed to produce the most benefit.

How the intervention might work

Asthma education can be delivered in multiple settings. Asthma education delivered in the home is distinct from that delivered in a clinical setting or school, in factors relating to the educator, the family members receiving it, and the environment. Delivery of education in a familiar and relaxed setting, such as the home, may be more comforting, and therefore have several advantages over other environments such as clinical settings.

Advantages may include the ability to educate multiple family members within the household, the ability to address individual home-based environmental triggers and improve the reach of education to children who face early adversity through removal of barriers such as lack of transport, costs of travel or care required for other siblings (Fernandes 2019). Families who are time-poor or lack motivation to attend an educational session may also be more readily reached (Boulet 2015).

The home setting may also provide additional benefits over the clinical setting where time pressures, competing clinical priorities and variable knowledge levels or preferences of individual educators may impact the ability for full adherence of asthma self-management education as recommended by guidelines (Akinbami 2020). Pressures on families within an acute inpatient setting may also impact the ability for full understanding and comprehension. There is also evidence to support uptake of skills is more successful when being taught in a setting they would be likely to occur in, such as within the home (Guastaferro 2018).

Community health workers may also provide education (Uchima 2019). Although their expertise in asthma management may not be as extensive as that of health professionals, the families may be more responsive to these workers who often share the same socioeconomic status, language and/or culture. Additionally, the use of community health workers has been shown to be cost-effective and improve health system efficiency (Shaak 2022; Scott 2018).

Why it is important to do this review

Over the last few years during the SARS-CoV-2 pandemic, in-person consultations and patient visits have markedly reduced for paediatric asthma services in response to social distancing, community lockdowns, and concerns for increasing infection risk (Papadopoulos 2020). The importance of alternative strategies for service delivery of asthma education has become increasingly apparent. Delivery of asthma education within the home setting is one such approach to enable families to still access a crucial component of their asthma management. Whilst telehealth is shown to be non-inferior to in-person reviews in the clinical setting for asthma health outcomes, including asthma control (Portnoy 2016), the benefits described above about being within the patients' home setting for asthma self-management education, cannot be necessarily replicated through this delivery mechanism.

There has also been increasing research into complex interactions involving biological, psychological, and social factors, that may collectively influence asthma severity and morbidity (Stempel 2019; Sharrad 2021). Whilst biological factors such as the patient's genetics have long been known to play a role, awareness of factors relating to a child's environment such as their family and neighbourhood are becoming increasingly apparent in contributing to health outcomes in children. Home-based education can offer a unique opportunity for health care workers to review and address potentially modifiable factors such as environmental allergens, suboptimal housing, barriers to care, and difficulties with access to healthcare, medications, and education. Whilst school-based delivery of asthma education may capture some families who experience barriers such as lack of transport or childcare for siblings, it does not have the capacity to improve access to preschool aged children and their caregivers.

Asthma education delivered at home to children and/or their caregivers, and its efficacy to influence health outcomes, was last evaluated in 2011. Since then, the SARS-CoV-2 pandemic has highlighted the importance and need for alternative strategies for health care delivery, and there is increasing awareness for asthma care interventions to be targeted towards multiple components of the biopsychosocial model, which interplay and impact asthma morbidity and mortality. A review of home-based education is vital in providing updated evidence to inform policy, clinical care, and patient outcomes for children with asthma.

Objectives

1. To assess the effects of educational interventions for asthma, delivered in the home to children, their caregivers or both, on asthma-related outcomes.
2. To make the education interventions accessible to readers by summarising the content and components.

Methods

Criteria for considering studies for this review

Types of studies

We included randomised controlled clinical trials (RCTs). We planned to include quasi-randomised trials (e.g. participants allocated by day of week or hospital number). We included studies reported in full text, those published as an abstract only and unpublished data.

Types of participants

We included children and adolescents between two and 18 years of age with an existing diagnosis of asthma. We accepted both doctor-diagnosed asthma or asthma identified against objective criteria for asthma symptoms based on the Global Initiative For Asthma (GINA) criteria for making a diagnosis of asthma (GINA 2021). We excluded studies on mixed-disease populations.

Types of interventions

Inclusion criteria

We included any type of self-management education programme delivered in the home of the child or adolescent. We included self-management programmes delivered to children, their caregivers or both. We only included interventions aimed at changing behaviour including one or more of the following methods: providing information about asthma symptoms, medication and inhaler technique; symptom or lung function monitoring; provision or development of personalised action plan; development of coping strategies; improving communication between clinician and patient. Interventions involving at-home

technology (smartphones, tablets, computers, internet) were included only if there was a face-to-face component delivered in real-time in the home.

We used control groups to form 2 comparisons, as follows

1. Control groups that received either usual care, waiting list or a less intensive education programme delivered outside the home.
2. Control groups that received a less intensive home-based educational intervention.

Exclusion criteria

We excluded education that provided only information with no face-to-face education programmes, e.g. just giving the child or caregiver a booklet, smoking cessation programmes for caregivers and education interventions delivered to physicians, nurses or other healthcare providers rather than the child or carer. We excluded programmes primarily aimed at, and providing, environmental modification (i.e. provision of vacuum cleaners with high-efficiency particulate air (HEPA) filters, HEPA air purifiers, ventilation fans, remediation of mould-contaminated carpet or wallboard, professional pest control, roach or rodent traps, anti-allergy mattress or pillow covers) to reduce exposure to indoor allergens. Although this kind of environmental remediation may have a positive effect on asthma outcomes, these studies tend to focus on remediation with education as a secondary measure and may be better addressed as a separate review rather than as a subgroup of this review. We did not exclude trials based on language.

Types of outcome measures

Outcome measures were not a criterion for exclusion in the review.

Primary outcomes

1. Exacerbations leading to emergency department visits
2. Exacerbations requiring a course of oral corticosteroids

Secondary outcomes

1. Functional health status
    a. Quality of life
    b. Days of restricted activity
    c. Nights of disturbed sleep
    d. Day symptoms
2. Days missed from school or work
3. Exacerbations leading to hospitalisation
4. Lung function (FEV1 (forced expiratory volume in one second) and PEF (peak expiratory flow)).
5. Withdrawals from intervention or usual care.

Search methods for identification of studies

Electronic searches

We identified studies from searches of the following databases and trial registries:

1. Cochrane Airways Trials Register (Cochrane Airways 2022), via the Cochrane Register of Studies, all years to 13 September 2021;
2. Cochrane Central Register of Controlled Trials (CENTRAL), via the Cochrane Register of Studies Online, all years to 13 September 2021;
3. MEDLINE (Ovid) ALL 1946 to 13 September 2021;
4. Embase (Ovid) 1974 to 13 September 2021;

5. Education Resources Information Center (ERIC), all years to 13 September 2021;
6. US National Institutes of Health Ongoing Trials Register ClinicalTrials.gov (www.clinicaltrials.gov);
7. World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch)

The database search strategies are listed in Appendix 1. The search strategies were developed and run by the Cochrane Airways Group Information Specialist (ES), in collaboration with the other authors. All databases and trials registries were searched from their inception to 13 September 2021 and were not restricted by language or type of publication. Hand-searched conference abstracts and grey literature were searched for through the Cochrane Airways Trials Register, Embase, and the CENTRAL database.

Searching other resources

We reassessed the excluded studies, ongoing studies and studies awaiting classification listed in the 2011 version of this review. We used the Web of Science to identify articles that cited the 2011 version or the individual included studies. This citation search was carried out on 17 June 2020. We also reviewed the reference lists of all primary studies and related review articles for references to additional studies. We contacted authors of identified trials where possible and asked them to identify other published and unpublished studies.

Data collection and analysis

Selection of studies

For the current update we used Cochrane's Screen4Me workflow to help assess the search results. Screen4Me comprises three components: known assessments – a service that matches records in the search results to records that have already been screened in Cochrane Crowd and been labelled as an RCT or as Not an RCT; the RCT classifier – a machine learning model that distinguishes RCTs from non-RCTs; and if appropriate, Cochrane Crowd (http://crowd.cochrane.org) – Cochrane's citizen science platform where the Crowd help to identify and describe health evidence. More detailed information about the Screen4Me components can be found in the following publications: Marshall 2018, McDonald 2017, Noel-Storr 2018, Thomas 2017.

Following this initial assessment, two review authors (KVCC, AOC, EJD) screened the titles and abstracts of the remaining search results independently in Covidence, and coded them as 'retrieve' (eligible or potentially eligible/unclear) or 'do not retrieve'. We retrieved the full-text study reports of all potentially eligible studies and two review authors (KVCC, AOC, EJD) independently screened them for inclusion, recording the reasons for exclusion of ineligible studies. We resolved disagreements through discussion and consensus. We identified and excluded duplicates and collated multiple reports of the same study so that each study, rather than each report, was the unit of interest in the review. We recorded the selection process in detail to complete a PRISMA flow diagram and 'Characteristics of excluded studies' table.

Data extraction and management

We extracted information from each study for the following characteristics.

1. Design (design, total duration study, number of study centres and location, withdrawals, date of study).
2. Participants (N, mean age, age range, gender, asthma severity, diagnostic criteria, baseline lung function, sociodemographics, caregivers' education, ethnicity, inclusion criteria, exclusion criteria).
3. Interventions (total number of intervention and control groups. For each intervention or control group*:* treatment, programme topics, setting, session type, number of sessions, session length, educator, time span of intervention, self-management

strategy, educational strategy, instructional methods/tools, additional information and net treatment, incentives, cost).

4. Outcomes (outcomes specified and collected, time points reported).
5. Aims.
6. Risk of bias.

For the new trials included in the updated review, a combination of two authors (KVCC, AOC, EJD, MH) independently extracted data from the studies and resolved any discrepancies by discussion and consensus, or by consulting a third party where necessary. For each trial, one author (AOC) transferred data from data collection forms into Review Manager 5.3 and this was checked by the other.

Assessment of risk of bias in included studies

Two review authors (KVCC, AOC, EJD, MH) assessed risk of bias independently for each study using the criteria outlined in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins 2019). Disagreements were resolved by discussion or by involving another author (KVCC, EJD). We assessed the risk of bias according to the following domains:

- random sequence generation;
- allocation concealment;
- blinding of participants and personnel;
- blinding of outcome assessment;
- incomplete outcome data;
- selective outcome reporting;
- other bias.

We judged each potential source of bias as high, low or unclear and provided a quote from the study report together with a justification for our judgement in the 'Risk of bias' table. We summarised the risk of bias judgements across different studies for each of the domains listed. We considered blinding separately for different key outcomes where necessary (e.g. for unblinded outcome assessment, risk of bias for all-cause mortality may be very different than for a patient-reported pain scale). Where information on risk of bias relates to unpublished data or correspondence with a trialist, we noted this in the 'Risk of bias' table.

When considering treatment effects, we took into account the risk of bias for the studies that contributed to that outcome.

Measures of treatment effect

We analysed dichotomous data as odds ratios (OR) and continuous data as the mean difference (MD) or standardised mean difference (SMD). Data from rating scales were combined in a meta-analysis to ensure they were entered with a consistent direction of effect (e.g. lower scores always indicate improvement).

Meta-analyses were only undertaken when considered meaningful; that is, if the treatments, participants and the underlying clinical question are similar enough for pooling to make sense.

We described skewed data narratively in the results under 'Effects of interventions'.

Where multiple trial arms were reported in a single study, only the relevant arms were included. When there were two comparisons combined in the same meta-analysis, the active arms were either combined the active arms or the control group was halved to avoid double-counting.

When adjusted analyses were available (ANOVA or ANCOVA) these were used as a preference in our meta-analyses. If both change from baseline and endpoint scores were

available for continuous data, we used change from baseline.

We used intention-to-treat (ITT) or 'full analysis set' analyses when they were reported instead of completer or per protocol analyses.

Unit of analysis issues

Studies that compare two types of education intervention with a control may yield important comparison results between two education types (Wolf 2002). We therefore entered both intervention arms separately in the meta-analyses and split the control group in half (to avoid double-counting) rather than combining the two arms (Higgins 2019). Data was analysed from cluster randomised controlled trials only if available data had been or could be adjusted for potential clustering effects. Adjustments for clustering would be made by contacting original study authors to identify intra-cluster correlation coefficients.

Dealing with missing data

We requested additional data including missing numerical data and information required for the risk of bias assessment from trialists.

Analyses based on change scores were preferred, but we used final values where change scores were not available.

Loss of participants that occurred prior to baseline measurements was assumed to have no effect on the eventual outcome data of the study. An intention-to-treat approach was taken as the measure for assessment with losses after baseline measurements reported in characteristics table and in the discussion. When data was only presented in abstract or protocol form and attempts to contact authors (on two occasions) were unsuccessful, studies were classified as excluded but relevant.

Assessment of heterogeneity

A combination of tests, including visual inspection of the data and the I^2 statistic were used to assess statistical heterogeneity. Thresholds for the I^2 statistic were determined according to the Cochrane Handbook for Systematic Reviews (Higgins 2019). This includes:

- 0% to 40%: might not be important
- 30% to 60%: may represent moderate heterogeneity
- 50% to 90%: may represent substantial heterogeneity
- 75% to 100%: considerable heterogeneity

A random-effects model was considered for all analyses in the presence of substantial heterogeneity (> 50% based on the I-squared statistic).

Assessment of reporting biases

We reported the proportion of participants contributing to each outcome in comparison to the total number randomised. . Funnel plots were to be applied as well if there had been 10 or more studies included. We considered the Der-Simonian and Laird method of analysis presented with a p-value of less than 0.05 as statistically significant.

Data synthesis

We planned to combine dichotomous data using the Mantel-Haenszel fixed-effect odds ratio using 95% confidence intervals. We planned to combine continuous data with either mean difference (MD) or standardised mean difference (SMD) using a fixed-effect model and 95% confidence intervals.

Subgroup analysis and investigation of heterogeneity

We planned to investigate heterogeneity based on the following predefined subgroups.

1. Children (2 to 12) versus adolescents (12 to 18).
2. Mild/moderate versus severe asthma.
3. Short time frame trials < 6 months versus long time frame > 6 months.
4. Physician or nurse versus community health worker.
5. Doctor-diagnosed asthma versus asthma identified against objective criteria for asthma symptoms (GINA 2021)
6. Web and internet based delivery versus face-to-face delivery.

We planned to apply a test for interaction between subgroup estimates (Altman 2003).

Sensitivity analysis

We planned to assess the sensitivity of our primary outcomes to the degree of risk of bias. We planned to compare the results of fixed and random-effects models. If combining change scores and final value scores we planned to look at baseline imbalance.

Summary of findings and assessment of the certainty of the evidence

We created a 'Summary of findings' table using the following outcomes: exacerbations leading to emergency department visits; exacerbations requiring a course of oral corticosteroids; quality of life; mean symptom free days; days missed from school or work and exacerbations leading to hospitalisation. We used the five GRADE considerations (risk of bias, consistency of effect, imprecision, indirectness and publication bias) to assess the quality of a body of evidence as it relates to the studies that contribute data for the prespecified outcomes. We used the methods and recommendations described in Chapter 14 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2019), using GRADEpro software (GRADEpro GDT 2015). We will justify all decisions to downgrade the quality of studies using footnotes and we will make comments to aid the reader's understanding of the review where necessary.

Results

Description of studies

Results of the search

In this update, a total of 5143 references were identified through database searches on 13 September 2021. A total of 2772 records were screened once 2703 duplicate records were identified and removed. Screen4Me excluded a total of 1023 records, leaving a remaining 1758 for manual screening for inclusion. 1697 reports were excluded based on title and abstracts. 52 full texts were retrieved for further evaluation. 16 were excluded as they did not meet inclusion criteria (predominantly due to wrong intervention of wrong trial design, for full information see Table Characteristics of excluded studies). We identified one reference for an included study from contacting the author for published results (Martin 2021). A total of 2581 participants from 13 studies were included. One study included (Krieger 2009) had been previously excluded from the 2011 review as mattress encasements had been provided to the participants, however after discussion between authors, the decision was made to include the study in this update as both intervention and control groups received the mattress encasements and it was evident that the home-based intervention was what was primarily being investigated. Therefore there were a total of 13 new included studies and overall this update includes a total of 25 studies. A PRISMA diagram can be found in Figure 1.

Two studies were identified as awaiting classification in this update (NCT03335046, ChiCTR1800014551). Seven studies which were awaiting classification in the 2011 review remain in this section as they did not appear to have been published. There are nine studies awaiting classification in this current review.

Included studies

There were 25 included randomised controlled trials reporting data on children who had received education delivered in the home. There were a total of 4923 participants. Full details can be found in Characteristics of included studies. Key characteristics of the participants and education programme content are summarised in Table 1 and Table 2.

Setting and populations

Twenty studies took place in the USA (Baek 2019; Brown 2002; Brown 2006; Butz 2006; Butz 2010; Butz 2014; Campbell 2015; Celano 2012; Eakin 2020; Fisher 2009; Galbreath 2008; Gorelick 2006; Jonas 2020; Kamps 2008; Krieger 2009; Martin 2015; Martin 2021; Naar-King 2014; Otsuki 2009; Seid 2010), one in Canada (Dolinar 2000), one in Brazil (Bresolini 2020), one in Turkey (Altay 2013), one in the United Kingdom (Carswell 1989) and one in New Zealand (Mitchell 1986). The latter study divided the population into two ethnic groups; Polynesian and European children (Mitchell 1986).

Patients were recruited mostly from the Emergency Department (ED) in five studies (Brown 2006; Gorelick 2006; Otsuki 2009; Butz 2010; Butz 2014), mostly outpatient clinics in eight studies (Dolinar 2000; Brown 2002; Butz 2006; Kamps 2008; Seid 2010; Altay 2013; Bresolini 2020; Jonas 2020) and following a hospital admission in two studies (Mitchell 1986; Fisher 2009). There were five studies which recruited from the community such as at schools, preschool programs, family centres and community based clinics (Baek 2019; Carswell 1989; Eakin 2020; Krieger 2009; Martin 2021). Four studies recruited patients by other methods such as reviewing patient lists, community or physician based referrals and the media (Galbreath 2008; Naar-King 2014; Campbell 2015; Martin 2015). One study recruited from mostly the children's hospital, however did not report where specifically (Celano 2012). Twenty-three of the studies were conducted between 2000 and 2021, while two were much older (Mitchell 1986; Carswell 1989). The studies varied in size from 15 to 473 participants.

Eleven studies reported participants with a range of asthma severity from mild to severe, with the latter group varying from 4% to 66% (Brown 2002; Butz 2006; Brown 2006; Gorelick 2006; Galbreath 2008; Krieger 2009; Butz 2010; Seid 2010; Butz 2014; Martin 2015; Martin 2021). Kamps 2008 and Naar-King 2014 enrolled participants with moderate to severe persistent asthma, Bresolini 2020 enrolled participants with severe or difficult to control asthma, while Dolinar 2000 described the participants as having stable asthma. The Mitchell 1986 cohort had frequent asthma attacks and Otsuki 2009 and Jonas 2020 enrolled patients prescribed an asthma controller medication. Campbell 2015 did not report severity, and based eligibility on control of asthma with inclusion criteria including asthma which was either not well controlled or poorly controlled. Carswell 1989 did not report severity or inclusion criteria around severity. Celano 2012 included poorly controlled asthma in the inclusion criteria, and this was defined as one or more ED visits or hospitalisations for asthma or prescription of more than one oral corticosteroid (OCS) burst within the past year. Dolinar 2000 included children with stable asthma and who had a diagnosis for at least six months, and excluded patients with an exacerbation requiring a visit to the ED in the previous year (in contrast to most other studies that required an ED visit). A table of control group rates for ED visits and hospitalisations provides an indicator of severity and can be found in Table 3. 59% of children in Eakin 2020 had uncontrolled asthma as measured by the Test for Respiratory and Asthma Control in Kids (TRACK) score. Fisher 2009 recruited children after a hospitalisation for asthma. Jonas 2020 reported that 90% of children has poorly or very poorly controlled asthma.

The trials enrolled participants with a range of age groups. Four trials included infants less than two years which was outside of the inclusion criteria for this review. However, we included them as the majority of participants would have been over two years (Dolinar 2000; Brown 2002; Brown 2006; Baek 2019). The majority of participants were children (up to 12 years old), but in the update 11 studies included some teenage participants (Altay 2013;Baek 2019; Bresolini 2020; Brown 2006; Campbell 2015; Carswell 1989; Galbreath 2008; Gorelick 2006; Martin 2015; Martin 2021; Naar-King 2014).

The studies were predominantly conducted in urban or suburban settings involving vulnerable populations. The exceptions were Dolinar 2000 where the majority of families

were above the low-income level in Canada and Mitchell 1986 who recruited and analysed data for European and Polynesian children separately, since the Polynesian children were previously reported to have lower socioeconomic status and differences in asthma management and outcomes (Mitchell 1981; Mitchell 1984). Carswell 1989, Altay 2013 and Bresolini 2020 did not describe any socioeconomic indicators. Eleven studies reported high levels of participants on Medicaid or public insurance (Brown 2002; Butz 2006; Gorelick 2006; Galbreath 2008; Fisher 2009; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Butz 2014; Campbell 2015) or attending subsidised community clinics (Seid 2010). Eighteen studies included greater than 50% participants from ethnic minorities (Brown 2002; Butz 2006; Gorelick 2006; Galbreath 2008; Fisher 2009; Krieger 2009; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Butz 2014; Naar-King 2014; Campbell 2015; Martin 2015; Baek 2019; Eakin 2020; Jonas 2020; Martin 2021), one study was conducted in a predominantly white population (Brown 2006) while the remaining six trials did not report the ethnic groups of participants.

Interventions

A summary of the educational interventions for each study is displayed in Table 2. Fourteen studies included predominantly four to six-weekly home visits, which lasted 30 to 60 minutes each (Mitchell 1986; Butz 2006; Gorelick 2006; Galbreath 2008; Kamps 2008; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Altay 2013; Butz 2014; Campbell 2015; Martin 2015; Jonas 2020). Six studies delivered shorter interventions of one to three sessions (Baek 2019; Bresolini 2020; Brown 2006; Butz 2014; Dolinar 2000; Fisher 2009). Three studies delivered a longer program of 8 to 10 sessions (Altay 2013; Brown 2002; Martin 2021). One study (Naar-King 2014) based the number of sessions on clinical need and had a mean of 27 sessions over an average of 5.14 months. Five studies (Gorelick 2006; Galbreath 2008; Fisher 2009; Krieger 2009; Eakin 2020) included additional telephone sessions, and one study allowed two telephone contacts in lieu of a home visit (Campbell 2015). The educator who provided the home sessions assisted in one or more primary care clinic visits in three studies (Brown 2006; Butz 2010; Butz 2014).

The shortest follow-up was three months (Dolinar 2000; Baek 2019; Bresolini 2020) followed by one trial with five months follow up (Altay 2013), two trials with six months follow-up (Brown 2006; Gorelick 2006), and one trial with seven months follow up (Naar-King 2014), while the remaining nine studies collected follow-up data for nine to 24 months from initial enrolment.

Eight studies employed nurses to deliver asthma education (Mitchell 1986; Carswell 1989; Dolinar 2000; Brown 2002; Brown 2006; Butz 2006;Butz 2014; Bresolini 2020) and ten studies involved either trained community health workers (CHWs), nurses, social workers or health educators (Gorelick 2006; Fisher 2009; Krieger 2009; Otsuki 2009; Butz 2010; Campbell 2015; Martin 2015; Baek 2019; Jonas 2020; Martin 2021). The study investigator who had a master's degree in nursing delivered the intervention in Altay 2013. Galbreath 2008 used nurses for the telephonic intervention and employed pulmonary therapists for the home visits, while Kamps 2008 employed licensed psychologists or master's level psychology students. Naar-King 2014 used either a psychologist or social worker. Seid 2010 provided in-home asthma education through bachelor’s level, bilingual, bicultural home visitors, and the problem-skills training intervention component was delivered by bilingual and bicultural bachelor’s or master’s level health educators. Two studies specifically reported on employing those who shared ethnic and racial backgrounds with participants (Krieger 2009, Jonas 2020).

All programmes provided basic education on the concepts of asthma, such as pulmonary anatomy and physiology as well as the disease process. Ten studies provided printed materials (such as booklets) and/or homework to complete after the educational sessions (Dolinar 2000; Brown 2002; Gorelick 2006; Kamps 2008; Otsuki 2009; Seid 2010; Altay 2013; Butz 2014; Martin 2015; Jonas 2020). All programmes reviewed asthma medications along with inhaler technique and reviewed strategies for self-management of the disease. One study used electronic devices to provide objective feedback to inform patients and families on medication adherence (adherence monitoring arm of Otsuki 2009), while another study kept track of nebuliser use electronically to measure study

outcomes (Butz 2006). Galbreath 2008 provided active disease monitoring and management via scheduled telephone calls and access to a 24-hour hotline. Written action plans were reviewed and/or provided in 16 out of 24 studies (Dolinar 2000; Brown 2002; Butz 2006; Brown 2006; Gorelick 2006; Galbreath 2008; Fisher 2009; Krieger 2009; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Butz 2014; Naar-King 2014; Jonas 2020; Martin 2021). All but two studies (Carswell 1989; Otsuki 2009) specifically mentioned educational interventions that reviewed asthma triggers, measures to reduce environmental allergens or both.

Most interventions were based on already-existing asthma educational programmes, some founded on theories of learning. Brown 2002 used the Wee Wheezers programme (Wilson 1996b), developed using principles of social learning theory by a team of paediatricians, pulmonologists, psychologists, public health educators and educational video specialists. Brown 2002 modified the scripts and handouts to make them culturally appropriate and to target low-literacy level caregivers. Jonas 2020 utilised content from the Wee Wheezers and Wee Wheezers at home curricula similarly for their intervention, which involved delivery of asthma education in the home by a CHW who shared the participants' racial and ethnic backgrounds. Butz 2006 also made use of Wee Wheezers as well as the A+ Asthma Club Programme (Schneider 1997), the latter of which uses the PRECEDE (Predisposing, Reinforcing, Enabling Constructs in Educational Diagnosis and Evaluation) planning model. Additional programmes included the Air Force Asthma Program developed by the Ontario Lung Association (Dolinar 2000), the National Jewish Asthma Disease Management Program and Pulmonary Therapies LLC programme (Galbreath 2008), the Fight Asthma Milwaukee Allies (Gorelick 2006), and the Air Wise Program and The Clubhouse Kids Learn Asthma interactive computer program (Kamps 2008). Butz 2010 designed an asthma communication education programme based on the chronic care model (Wagner 2001; Bodenheimer 2002) and other studies examining clinician-caregiver-child communication (Halterman 2001; Tates 2001). The CHWs in Fisher 2009 used the Transtheoretical Model to assess participants' readiness for change and adopted asthma management behaviours accordingly. They also used a "nondirective supportive style" in their interactions. Krieger 2009 also used the Transtheoretical Stages of Change Model however this was utilised for intervention development, Kamps 2008 used behaviour management techniques to promote adherence, specifically the Exchange Program for Improving Medication Adherence (Rapoff 1999). Similarly, Seid 2010 employed problem-solving skill training based on a concept by D'Zurilla (D'Zurilla 1971; D'Zurilla 1986) and a protocol previously tested on mothers of children with cancer (Varni 1999). Seid 2010 based the care co-ordination component of their intervention on the Robert Wood Johnson Foundation's Allies Against Asthma CHW model (Friedman 2006). The NHLBI guidelines were explicitly stated as the basis of asthma management in five trials (Brown 2002; Brown 2006; Galbreath 2008; Fisher 2009; Seid 2010), while the Air Wise Program used in Kamps 2008 was affiliated with the NHLBI. Campbell 2015 modified the already developed evidence-based home visiting program of Krieger 2009, the Healthy Homes program. The initial Healthy Homes study had an emphasis on environmental remediation, and hence has not been included in this study (Krieger 2005). In the second Healthy Homes project, Krieger 2009, an average of 4.5 follow up home visits over 12 months were made, however Campbell 2015 developed a streamlined version of the program in which four home visits in approximately three and a half months were made. Baek 2019 included content from the Asthma and Healthy Homes curriculum which had been certified by state health services, as well as from the Seven Principles of Healthy Homes program. The Seven Principles of Healthy Homes program involved education on keeping the household trigger free (Neltner 2010). Naar-King 2014 used multisystemic therapy, a home and community based family therapy which was originally used and validated for treatment of severe behaviour problems in youth, which was then adapted in the healthcare setting to target challenging management in adolescents with chronic medical conditions (Henggeler 2009). Eakin 2020 based their asthma educational content on NAEPP guidelines and used a family asthma education program which had previously demonstrated efficacy in a previous study (Otsuki 2009). They combined these at home educational sessions with a pre-existing national program in the United States 'Head Start' for their intervention. Head Start is targeted at low-income families with children in preschools, and provides

preventive health services in a community setting to this vulnerable population (Head Start 2021).

Three studies involved two intervention and one control group (Gorelick 2006; Otsuki 2009; Seid 2010). All intervention groups were included in this review except the intensive primary care linkage arm of the Gorelick 2006 trial, since there was no home education component.

Control groups

Control groups received usual care, wait list or a less intensive education programme delivered outside the home in 19 trials (Altay 2013; Baek 2019; Bresolini 2020; Brown 2002; Brown 2006; Campbell 2015; Carswell 1989; Dolinar 2000; Eakin 2020; Fisher 2009; Galbreath 2008; Gorelick 2006; Jonas 2020; Krieger 2009; Martin 2015; Martin 2021; Mitchell 1986; Otsuki 2009; Seid 2010), and form the basis of the first comparison in this review. The remaining six studies provided controls with home-based general asthma education which were less intensive than the study intervention group. These six studies form the basis of our second comparison of education versus a less intensive educational intervention. One study (Celano 2012) provided the control group with a single home visit to design a written action plan, with the intervention group receiving four to six sessions over four months. The remaining five studies provided additional education for specific therapies or skills in the intervention group (nebuliser therapy education, asthma communication education and strategies to improve adherence to inhaled corticosteroids for Butz 2006, Butz 2010 and Kamps 2008, respectively), more intensive educational strategies (the use of multi-systematic therapy focusing on behavioural change in Naar-King 2014) or additional support to improve preventative asthma care (accompaniment of trained nurse or asthma health educator to one primary care provider visit in Butz 2014) .

Compliance

The proportion of the sessions attended by participants varied. In three studies (Carswell 1989, Dolinar 2000, Kamps 2008) 100% of participants completed the full education program, however in Campbell 2015, only 6.6% of participants in the intervention group received all visits. One study (Altay 2013) did not report on compliance to the intervention. Participant completion rates can be seen in Table 4.

Outcomes

The primary outcomes of the trials varied. For Brown 2006, it was time to first relapse for asthma (ED or unscheduled visit for asthma). Butz 2010 defined caregiver reported symptom days and nights over the past 30 days as the primary outcome. Jonas 2020 also reported on caregiver reported symptom days however this was defined as over the past 14 days. Two studies defined their primary outcomes as adherence to asthma medication adherence, with Kamps 2008 reporting adherence to inhaled corticosteroids using an electronic monitor (MDILog) and Martin 2015 also using a medication monitor (DOSER) fitted on metered dose inhalers (and if unable to be fitted, medication counter number was recorded). Eakin 2020 defined asthma controlled measured by the TRACK score as their primary outcome, and whilst Martin 2021 also had asthma control as a primary outcome, this was measured by the ACT or cACT score depending on participant age, as well using self-reported asthma-related activity limitation over the past 14 days as a primary outcome. Krieger 2009 and Campbell 2015 used asthma symptom-free days, caregiver quality of life and asthma-related urgent health service utilisation as their primary outcomes. Butz 2006 looked at asthma severity, number of ED visits and medication usage (*email communication with author*); Dolinar 2000 used parental coping, caregiver perception of change and quality of life; Fisher 2009 reported hospitalisations at 12 months; Galbreath 2008 chose time to first asthma-related events, quality of life and rates of healthcare utilisation; Gorelick 2006 used proportion of patients experiencing an ED visit over six months; Butz 2014 used number or preventive asthma care visits with a primary care provider; Otsuki 2009 chose ED visits; Naar-King 2014 used lung function (measured with FEV1) and Seid 2010 measured health-related quality of life. One study (Bresolini 2020) used inhalation technique as their primary outcome, using a checklist

developed specifically for the study. Six studies did not define primary outcomes (Mitchell 1986; Carswell 1989; Brown 2002; Celano 2012; Altay 2013; Baek 2019).

For full details of outcomes reported in each study, see Characteristics of included studies.

We obtained additional data from three trialists (Butz 2006; Gorelick 2006; Butz 2010).

Aims

The overall aims of the studies varied (Table 5), testing different interventions to improve various outcomes (listed in the section above).

Excluded studies

We recorded the reasons for exclusion of 176 studies after retrieving the full-text documents. The most common reasons for exclusion included studies which were not home-based, studies aimed primarily at environmental remediation, studies conducted only on adults or those which were identified as not being randomised controlled trials. Reasons for exclusion are summarised in the Characteristics of excluded studies table.

Risk of bias in included studies

Full details of risk of bias judgements can be found in Characteristics of included studies. Graphical representations of our judgements of the risk of bias can be found in Figure 2.

Allocation

Eighteen studies reported full details of adequate sequence generation and we judged them to be of low risk of bias (Dolinar 2000; Butz 2006; Brown 2006; Gorelick 2006; Galbreath 2008; Kamps 2008; Fisher 2009; Krieger 2009; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Butz 2014; Campbell 2015; Martin 2015; Bresolini 2020; Eakin 2020; Martin 2021). Five studies were reported as randomised, but gave no description of the methods used and we therefore judged them to be at unclear risk of bias (Mitchell 1986; Carswell 1989; Brown 2002; Naar-King 2014; Baek 2019). Two studies were judged to be at high risk of bias without adequate random sequence generation (Altay 2013; Jonas 2020).

Eleven studies were low risk of bias with full details of allocation sequence concealment reported (Brown 2006; Butz 2006; Gorelick 2006; Galbreath 2008; Krieger 2009; Otsuki 2009; Butz 2010; Seid 2010; Butz 2014; Campbell 2015; Eakin 2020). The author confirmed allocation concealment in one study (Butz 2006). There were insufficient details for twelve studies for us to reach a firm conclusion, so we judged them to be at unclear risk of bias (Mitchell 1986; Carswell 1989; Dolinar 2000; Brown 2002; Kamps 2008; Fisher 2009; Celano 2012; Naar-King 2014; Martin 2015; Baek 2019; Bresolini 2020; Martin 2021). The remaining two studies were deemed high risk of bias with allocation based on when presenting to outpatients in Altay 2013; and open label randomisation in Jonas 2020.

Blinding

The nature of the intervention precludes the possibility of blinding patients or the educator and therefore all the studies were judged to be at unclear risk of performance bias. However, it is possible to blind the people who collected or analysed the data. We judged 14 studies to be at low risk of bias with respect to blinding of data collectors (Carswell 1989; Brown 2002; Butz 2006; Gorelick 2006; Fisher 2009; Otsuki 2009; Butz 2010; Seid 2010; Celano 2012; Butz 2014; Naar-King 2014; Martin 2015; Eakin 2020; Martin 2021). Nine studies did not describe blinding, so we judged them to be at unclear risk of bias (Mitchell 1986; Brown 2006; Galbreath 2008; Kamps 2008;Krieger 2009; Campbell 2015; Baek 2019; Bresolini 2020; Jonas 2020). Dolinar 2000 was high risk of bias as it was described as non-blinded. The lack of blinding would likely have a greater impact on the more subjective outcomes (e.g. quality of life) than more objective measures (e.g. ED visits). Altay 2013 was also deemed high risk of bias as the primary investigator made all

the home visits for intervention delivery as well as administered questionnaires for data collection.

Incomplete outcome data

We judged 12 studies to be at low risk of bias due to incomplete outcome data as indicated by withdrawals/losses to follow-up in Table 4 (Baek 2019; Bresolini 2020; Butz 2010; Butz 2014; Campbell 2015; Celano 2012; Dolinar 2000; Galbreath 2008; Krieger 2009; Otsuki 2009; Martin 2021; Naar-King 2014). Martin 2021; Butz 2014; Celano 2012; Krieger 2009; Butz 2010 and Dolinar 2000 had similar losses to follow-up in both education and control groups, Galbreath 2008 obtained comprehensive health care utilisation data for 99% of participants and Otsuki 2009 had consistent losses to follow-up across treatment arms which averaged around 10%. We judged seven studies to be at high risk of bias with respect to incomplete outcome data (Altay 2013; Brown 2002; Brown 2006; Butz 2006; Gorelick 2006; Mitchell 1986; Seid 2010). Brown 2002 had a high number of withdrawals from the treatment arm (n = 6) compared to none on the control arm, Butz 2006 had unbalanced losses of pharmacy records, Brown 2006 had 21% lost to follow-up in the intervention group at six months compared to six percent in the control group, Gorelick 2006 reported the baseline characteristics of those lost to follow-up or with incomplete data (22%) but there were more lost in the treatment versus the control group, while Seid 2010 had high and unbalanced losses to follow-up and refusal to comply, which we assume was related to the nature of the interventions. Mitchell 1986 and Altay 2013 did not mention how many people contributed data, so we judged this to be at a high risk of bias. The remaining two studies were at unclear risk of bias (Carswell 1989; Eakin 2020; Fisher 2009; Jonas 2020; Kamps 2008; Martin 2015). Fisher 2009 unbalanced follow-up survey data but reviewed hospital records for all patients. The risk of bias was unclear because records were only available from one hospital in the city, albeit the latter was where the majority of admissions likely occurred. Kamps 2008 was a small pilot study with poor follow-up, so although the losses were balanced between arms, the reported data were on limited participants. Carswell 1989 did not clearly report on attrition for outcomes aside from peak expiratory flow assessment and in Martin 2015; there was falsified data mentioned in the study however it was unclear where the missing data went and how this was analysed. In Eakin 2020, there was an unclear withdrawal definition as well as reasons for withdrawal and in Jonas 2020 there were up to 16% of the participants lost to follow up at each time point, with no clear reasons as to why some participants did not complete, which may have put these results at risk of bias.

For consideration of the number of patients withdrawing and those lost to follow-up, please see Effects of interventions and Characteristics of included studies.

Selective reporting

We judged 17 studies to be at unclear risk of bias for selective outcome reporting since there was no published protocol (Altay 2013; Baek 2019; Brown 2002; Brown 2006; Butz 2006; Butz 2010; Carswell 1989; Campbell 2015; Celano 2012; Dolinar 2000; Fisher 2009; Galbreath 2008; Kamps 2008; Mitchell 1986; Krieger 2009; Otsuki 2009; Seid 2010). Six trials (Butz 2006; Butz 2010; Butz 2014; Galbreath 2008; Otsuki 2009; Seid 2010) were registered in clinicaltrials.gov but all had one or more secondary outcomes in the protocols that were not reported in the final publications, and were therefore deemed unclear risk of bias. One trial (Naar-King 2014) was also registered in clinicaltrials.gov and had hospital and emergency department utilisation for asthma exacerbations at 7 months and 12 months stated to be a primary outcome, however in the final publication was listed as a secondary outcome with missing data from the seven month time point so was deemed high risk for reporting bias. Martin 2021 reported on measuring asthma medication type, technique and adherence as a secondary outcome however this was not reported on in published results, however the corresponding author was emailed and was able to provide data for these outcomes and so this was deemed unclear risk rather than high risk for reporting bias. The final study (Gorelick 2006) measured hospital admissions but did not report this in the results and the trialists were unable to provide these data

through correspondence. We therefore judged Gorelick 2006 at high risk of selective reporting bias.

Other potential sources of bias

The main additional source of bias identified in these studies was recall bias for outcomes where the patient or caregiver had to report the number of events experienced over time. We judged 12 studies to be at low risk of recall bias (Altay 2013; Butz 2010; Butz 2014; Brown 2002; Celano 2012; Dolinar 2000; Gorelick 2006; Galbreath 2008; Kamps 2008; Martin 2021; Mitchell 1986; Naar-King 2014). Dolinar 2000 and Kamps 2008 only reported outcomes that by their nature have to be measured by self report and we therefore judged them to be at low risk of bias. Six studies reviewed medical records for healthcare utilisation (Brown 2002; Butz 2010; Celano 2012; Galbreath 2008; Martin 2021; Mitchell 1986; Naar-King 2014) while Gorelick 2006 collected both self reported ED visits as well as those in their computerised tracking system. We judged Fisher 2009 to be an unclear risk, once again due to the retrieval of hospitalisations from one hospital only. We judged four studies to be at high risk of bias for outcomes that were self reported, but could have been verified (e.g. ED visits, hospitalisations; Butz 2006; Brown 2006; Krieger 2009; Otsuki 2009; Seid 2010; Campbell 2015; Baek 2019; Eakin 2020; Jonas 2020). Otsuki 2009 compared self reported adherence to pharmacy records for inhaled corticosteroid usage and showed that the self reports overestimated adherence compared to pharmacy records, which highlights the potential for recall bias in these situations and the need for collecting accurate data where possible. In Martin 2015, there was falsification of data from a CHW reported, with the full extent of the implications for this unclear.

There were two cluster randomised controlled trials included (Carswell 1989; Baek 2019). In both, recruitment bias was deemed unclear with recruitment not clearly described in either, including in terms of allocation concealment. They did appear to be both balanced in baseline characteristics however the adjustment for clustering in analysis was not mentioned in either.

Effects of interventions

Home-based education versus usual care or a less intensive, non-home-based education

Primary outcome: Exacerbations leading to emergency department visits

Eleven studies involving 2292 patients reported the number of patients with one or more asthma exacerbations resulting in ED visits (Mitchell 1986; Dolinar 2000; Brown 2006; Gorelick 2006; Fisher 2009; Seid 2010; Campbell 2015; Baek 2019; Eakin 2020; Jonas 2020; Martin 2021). The studies were not pooled due to diversity in the study populations, outcome definitions, follow-up time and differences in the control group event rate (Table 3). Brown 2006 reported unscheduled urgent visits to a physician office and ED visits for asthma as a single outcome and Fisher 2009 reported the subset of ED visits that did not result in hospitalisations. Two studies reported on health care utilisation over the previous 12 months as a single outcome, and combined the sum of hospitalisations, ED visits and urgent clinic visits (Campbell 2015; Jonas 2020). Jonas 2020 did not report on results of the intervention group and the control group separately but stated there was no significant difference in change over time in the odds of health care utilisation between groups at 12 month follow up. Campbell 2015 however did report a significant intervention effect over with 1.31 events fewer over 12 months in the intervention group (95%CI -2.10 to 0.52; p = 0.001). Martin 2021 also combined health care utilisation as a single outcome, however only combined ED visits and hospitalisations. They reported on this at 12 and 24 months post baseline, with significant lower odds of any ED visits or hospitalisations for asthma in the intervention group at 24 months compared to the control (OR 0.52; 95% CI 0.24 to 1.10).

Two studies measured outcomes at three months (Dolinar 2000; Baek 2019), three reported data at six months (Mitchell 1986; Brown 2006; Gorelick 2006), one at 12

months (Eakin 2020) and one at 24 months (Fisher 2009). Only one study (Mitchell 1986) showed a significant effect favouring controls over the intervention for the European children subgroup (Analysis 1.1). Seid 2010 reported the number of patients experiencing asthma exacerbations at three months and nine months from baseline. Seid 2010 also reported odds ratios for patients with ED visits adjusted for the baseline level of the outcome and covariates (including age, race/ethnicity, Spanish language and mother's education), which were not significant for either of the intervention groups compared to controls. Eakin 2020 reported the total count of ED visits in the previous 3 months and reported at three, six, nine and 12 month time points from baseline. This was reported as a percentage of participants. There was no statistical analysis provided for this outcome, however it was stated that there were no change in ED visits over time for each group.

Four studies involving 815 patients reported the mean number of acute visits for asthma (Brown 2002; Gorelick 2006; Otsuki 2009; Baek 2019). The pooled data for two studies on 430 people at six months was not statistically significant (mean difference (MD) -0.07; 95% confidence interval (CI) -0.31 to 0.16; Analysis 1.2). Brown 2002 reported only means without standard deviations and incorporated ED and clinic visits for acute asthma as a single outcome, so we could not pool these data. Although there was a significant decrease over time in the mean number of acute asthma visits at 12 months in both groups, there was no significant net treatment effect. Otsuki 2009 reported mean ED visits in the previous six months at six-month intervals from 0 to 18 months of follow-up. At 18 months, the results (for the previous six months) revealed no significant difference between either intervention groups (basic asthma education or intervention with additional adherence monitoring with feedback) and the control group (MD -0.72, 95%CI -1.51 to 0.07). However, the authors analysed the decrease in ED visits over the entire 18-month period, and showed that the rate of decrease in ED visits over time was faster in both the combined treatment groups and the adherence feedback group alone than the control group (Otsuki 2009). Baek 2019 reported on the number of emergency room visits, and change scores evaluating four weeks pre-baseline and the three months post baseline. Data was collected from the Children's Health Survey for Asthma (validated and standardised tool) completed by participants. There was a reduction in the intervention group for emergency room visits but the changes between baseline and follow-up was not statistically significant between the two groups. Butz 2014 reported the mean number of ED visits in both groups, but with no measure of variance and no between group differences.

Galbreath 2008 reported an adjusted annual asthma exacerbation rate per patient leading to ED visits showing no significant difference between groups.

Primary outcome: Exacerbations requiring a course of oral corticosteroids

Three studies involving 783 patients reported results on exacerbations requiring a course of oral corticosteroids (Otsuki 2009; Eakin 2020; Martin 2021). Otsuki 2009 reported on the mean number of exacerbations requiring a course of oral corticosteroids every six months from baseline to 18 months. At six months, the pooled results for the two intervention arms (basic education and adherence monitoring) were not statistically significant (MD -0.18; 95% CI -0.63 to 0.26; Analysis 1.3). However, the authors once again demonstrated that the rates of decrease in mean courses of OCS over 18 months follow-up were faster for either intervention groups compared to usual care (Otsuki 2009). Martin 2021 reported on the odds of courses of OCS in the past 12 months at baseline, 12 months and when combined with Otsuki 2009 there may be little or no difference (MD -0.08; 95%CI -0.02 to 0.05; Analysis 1.3). Galbreath 2008 reported no statistically significant difference in the number of oral corticosteroid bursts, but the numbers were not provided to allow pooling of results.

Eakin 2020 reported on total number of courses of OCS within the participants, every three months from baseline to 12 months. At 9 months, there was a significant intervention effect (β = −0.61; 95%CI, −1.13 to −0.09; P = 0.02).

Secondary outcome: Functional health status

Quality of life

Eight studies on 1679 participants measured quality of life (Dolinar 2000; Brown 2002; Gorelick 2006; Galbreath 2008; Krieger 2009; Seid 2010; Campbell 2015; Eakin 2020). Given the difference in instrument scores and missing data in some trials, we present a narrative summary below.

Six studies involving 1283 patients used the Paediatric Asthma Caregiver's Quality of Life Questionnaire (PACQLQ) to assess quality of life (Dolinar 2000; Brown 2002; Galbreath 2008; Krieger 2009; Campbell 2015; Eakin 2020). Juniper et al developed both the PACQLQ (Juniper 1996a) and Paediatric Quality of Life Questionnaire (PAQLQ; Juniper 1996b), which were validated as evaluative and discriminative instruments for children seven to 17 years old. The PAQLQ contains 23 items in the domains of activity limitation, symptoms and emotional function, administered to the child (Juniper 1996b) while the PACQLQ contains 13 items concerning activity limitations and emotional function administered to the caregiver (Juniper 1996a). Brown 2002 reported improvement in PACQLQ scores among the caregivers of both intervention and control arms. However an intervention effect was only noted in the younger patient subgroup (one to three years old). Krieger 2009 and Campbell 2015 both reported an improvement in caretakers' quality of life as measured by the PACQLQ in both the control group and the intervention group from baseline to 12 months post baseline and we pooled these data (MD 0.37, 95% CI 0.04 to 0.71, 2 studies, 682 participants, Analysis 1.4). The MD was lower than the MCID for the scale of 0.5 points. Three studies did not show a significant effect of the intervention as measured by the PACQLQ (Dolinar 2000; Galbreath 2008; Eakin 2020) although in Galbreath 2008 and Eakin 2020 the quality of life improved over time in all groups.

Galbreath 2008 also administered the PAQLQ to children. Galbreath 2008 reported no statistically significant group differences in the quality of life scores at follow-up (adjusted for baseline differences in demographics; P = 0.40), although quality of life improved from baseline in both groups. Seid 2010 reported overall health-related quality of life in 165 children using the PedsQL Total (23 items on physical and psychosocial health) administered to the caregiver and, if applicable, the child. Seid 2010 also reported quality of life using the PedsQL Asthma (28 items on asthma symptoms, treatment problems, worry and communication) administered to the caregiver and, if applicable, the child. There was no statistically significant difference in the primary outcome PedsQL Total for caregiver -reported symptom scores for control versus either intervention groups at three months. At nine months, there was no statistically significant difference between control versus the care co-ordination intervention, but there was a statistically significant difference in control versus care co-ordination with additional problem-solving skills training in the PedsQL Total administered to caregivers (adjusted MD 4.05; 95% CI 0.63 to 7.4).

Gorelick 2006 had caregivers complete the Integrated Therapeutics Group Child Asthma Short Form (ITG-CASF), containing 10 items specific to asthma, at baseline and six months. This tool was previously validated for use in the ED (Gorelick 2004). The mean change in scores from baseline improved in both intervention and control groups, but the difference between groups was not statistically significant.

Days of restricted activity

Three studies involving 865 participants reported on number of days with restricted activity (Campbell 2015; Krieger 2009; Martin 2021). Both Krieger 2009 and Campbell 2015 measured days with activity limitation per two weeks from baseline compared to 12 months post baseline. The intervention group and the control group had a reduction in the number of days with activity limitation per two weeks from baseline to 12 months post baseline in both studies. This reduction was found to be statistically significantly more in the intervention relative to the control group, with a decrease of 0.6 days more (95% CI -1.27 to 0.02; p = 0.044) in Campbell 2015. There was no significant intervention effect in Krieger 2009. Martin 2021 also measured days with activity limitation over the past 14 days from baseline compared to 12 and 24 months post baseline. Activity limitation improved in both the intervention and control group. At 12 months, the intervention group had a 37% reduction in days of activity limitation (b = 0.63; 95% CI 0.40, 1.00) and at 24

months, the intervention group had a 42% reduction in days of activity limitation relative to the control group (b = 0.58; 95% CI 0.35, 0.96).

Nights of disturbed sleep

Only one study involving 333 participants reported on nights of disturbed sleep (Campbell 2015). Campbell 2015 reported on nighttime awakening due to asthma as a component of one of their primary outcomes, being self-reported asthma symptom-free days during the prior two weeks (which also considered wheeze, tightness in chest, cough, shortness of breath and a decrease in usual activities because of asthma). This was self-reported. They also reported on nights with symptoms as a secondary outcome. Both the intervention and the control groups had improvements in nights with symptoms per two weeks (i.e. had a reduction in the number of nights with symptoms). There was a significant difference in improvement in the intervention group compared to the control group with a decrease in 1.1 nights more per two weeks; from baseline to approximately one year after baseline (95% CI -1.70 to -0.48; p < 0.001).

Day symptoms

Eight studies involving 1590 participants reported information relating to asthma symptoms (Carswell 1989; Brown 2002; Galbreath 2008; Krieger 2009; Otsuki 2009; Seid 2010; Campbell 2015; Jonas 2020). However, only two studies (Campbell 2015; Krieger 2009) were pooled due to missing data, the diversity of the tools used to measure symptoms and underlying differences in the control group exacerbation rate (Table 3). Brown 2002 reported the mean for asthma symptom score (using a sub-scale of the PAQLQ) and the mean symptom-free days. Although follow-up analyses were able to show that there was a benefit for symptoms and symptom-free days in the younger children (one to three years old) and not in the older children, overall there was no treatment effect on either outcome. Krieger 2009 and Campbell 2015 also reported mean asthma symptom-free days, defined as the self-reported number of 24 hour periods during the prior two weeks without having symptoms of wheeze, chest tightness, cough or shortness of breath, a decrease in usual activities because of asthma, or nighttime awakening because of asthma. In both studies this showed a significant treatment effect with the intervention group having 2.1 days more symptom free days over two weeks comparative to the control group (95% CI 1.17, 3.05; p < 0.001) in Campbell 2015, and the intervention group having 0.94 more symptom free days in Krieger 2009 (95% CI 0.02 to 1.86; p = 0.046). These data were pooled (MD 1.45, 95% CI -0.12 to 3.01, 2 studies, 682 participants, Analysis 1.5).

Conversely, Jonas 2020 reported on mean asthma symptom days during the prior two weeks. They defined this as the maximum of the number of days when the child had daytime symptoms such as wheezing, chest tightness or cough; the number of days the child had to slow down or stop activities because of the asthma, and the number of nights the child woke up to do asthma. At 12 months from baseline, there was a reduction in mean asthma symptom days in both the control and intervention group, with a significant intervention effect (β = -0.47; 95% CI -0.92 to 0.03; p=0.038).

Galbreath 2008 measured symptom scores using the Lara Asthma Symptom Scale (LASS) and stated that symptom scores decreased over time in all groups, but did not show a significant treatment effect. Otsuki 2009 measured caregiver reports of symptoms every six months (baseline, 6, 12 and 18 months), calculating the mean asthma symptoms in the previous 30 days. None of the mean values for symptom scores were different at each time point between either intervention groups versus controls, but Otsuki 2009 reported differences in the rate of improvement in symptoms over time for the asthma basic care versus control group - the intervention improving faster than the control group over the first 12 months. Using ordinal scales, Seid 2010 reported the percentage of children experiencing daytime symptoms (< twice a week, three to six times a week and every day) and night-time symptoms (< once/week, > once/week) at baseline, three months and nine months after baseline. The odds ratios adjusted for baseline levels and covariates showed no significant different between either intervention groups compared with controls for daytime symptoms, but statistically improved night-time symptoms at three months but not nine months for the care co-ordination/problem-

solving skills group compared to controls (odds ratio (OR) 0.33; 95% CI 0.13 to 0.82; Seid 2010).

Carswell 1989 reported on asthma symptoms over four separate one week periods in six months, based on family reported symptoms. There was no data available however they reported they did not find a significant difference between intervention and control groups when symptoms were compared.

Secondary outcome: Days missed from school or work

Three studies on 807 participants reported on child days missed from school and/or caregiver days missed from work (Mitchell 1986, Brown 2006; Krieger 2009). One study with 259 participants reported no statistically significant difference between groups in the number of school days missed (Mitchell 1986; Analysis 1.6). One study combining 239 adults and children reported on days missed from school or work, also showing no group difference (Brown 2006). Krieger 2009 reported on children and caregivers separately. Both children and caregivers had significant improvements from baseline to 12 months (i.e. a decrease in missed school or work days) however there was no differences between the group (missed school intervention effect coefficient 0.81; 95% CI 0.35 to 1.88, missed work intervention effect coefficient 0.6; 95% CI 0.2 to 1.78). Two studies did not report data in a format appropriate for meta-analysis.

Secondary outcome: Exacerbations leading to hospitalisations

Ten studies on 2319 participants reported the number of patients experiencing one or more hospitalisations (Mitchell 1986; Dolinar 2000; Fisher 2009; Otsuki 2009; Seid 2010; Campbell 2015; Baek 2019; Eakin 2020; Jonas 2020; Martin 2021). However, the data were not combined due to clinical heterogeneity and follow-up periods (Analysis 1.7). Fisher 2009 demonstrated reduced hospitalisations at 24 months in the intervention group in (OR 0.4; 95% CI 0.22 to 0.71) and the Europeans in Mitchell 1986 had increased admissions between six and 18 months (OR 2.45; 95% CI 1.25 to 4.83). All the other studies reported no group difference. None of the patients in Dolinar 2000 had a hospital admission.

Three studies on 859 participants reported the mean hospitalisations, although we did not pool due to diversity in the studies(Mitchell 1986; Galbreath 2008; Baek 2019). Mitchell 1986 had diversity between study populations, so we did not pool this outcome (Analysis 1.8). Mitchell 1986 reported mean hospital admissions at both six months and between six and 18 months. Only the European children showed a significant effect favouring controls in the latter time period. Galbreath 2008 reported no significant treatment effect for the adjusted rates of hospital admissions per patient per year. Baek 2019 reported mean hospitalisations at three months and the change in hospitalisations over the previous four weeks from baseline to three months post baseline. Data was collected from the Children's Health Survey for Asthma which was completed by participants. There was a reduction in the intervention group for mean number of hospitalisations in the prior four weeks (MD -0.03; 95% CI 0.08 to 0.02) and in the control group there was no change (MD 0.0, 95% CI -0.02 to 0.02), however the changes between baseline and follow-up was not statistically significant between the two groups.

Eakin 2020 reported on cumulative hospitalisation per participant between groups comparing 12 months before and after randomisation. In this study, participants in the intervention group were found to be significantly less likely to have a hospitalisation in the 12 month follow-up period (OR 0.36; 95%CI 0.21 to 0.61; $p < 0.001$). Eakin 2020 also reported a graph showing the number of hospitalisations at 12 months follow-up - there were 24 in the headstart group and 8 in the ABC plus headstart group, but it was not clear whether this was the total number of hospitalisation or the number of people experiencing one or more hospitalisations. .

As mentioned in our primary outcome 'Exacerbations leading to ED visits', Jonas 2020 and Campbell 2015 combined ED visits, hospitalisations and urgent clinic visits as a single outcome of 'Health care utilisation'. There was a significant intervention effect in Campbell 2015, with 1.31 events fewer over 12 months in the intervention group (95% CI

-2.10 to 0.52; p=.001), however Jonas 2020 did not find any significant results for this outcome when comparing intervention to control.

Also as mentioned in our primary outcome 'Exacerbations leading to ED visits', Martin 2021 also combined health care utilisation as a single outcome, combining ED visits and hospitalisations. At 24 months post baseline, there were significantly lower odds of any ED visits or hospitalisations for asthma in the intervention group compared to the control group (OR 0.52; 95% CI 0.24 to 1.10).

Secondary outcome: Lung function

Carswell 1989 was the single study with 86 participants who reported lung function. Mean peak expiratory flow (PEF) rates in a week, measured over seven consecutive days at baseline then over three further separate weeks in a six month period during the intervention period were measured. Exact time points were not provided. Mean PEF was reported to improve from baseline to the final assessment in both groups with a significant difference reported (p = 0.04). Naar-King 2014 reported mean change within group for FEV1 (intervention 0.20 (SD 0.43), control 0.07 (SD 0.40)) .

Home-based education versus a less-intensive home-based education

Six studies reported on a home-based education intervention compared to another, less intensive type of home-based education as a control group (Butz 2006; Kamps 2008; Butz 2010; Butz 2014; Celano 2012; Naar-King 2014).

Primary outcome: Exacerbations leading to emergency department visits

Five studies on 960 participants reported information about exacerbations, but only one reported the data that we could potentially meta-analyse. Butz 2006 showed fewer patients in the nebuliser-targeted education group (27/95) reporting at least one ED visit at six months compared to the less intensive education group (40/86), which was statistically significant result in favour of the more intensive home-based education (OR 0.46; 95% CI 0.25 to 0.84; Analysis 2.1). Butz 2010 reported no statistically significant difference between groups for the decrease in mean number of ED visits at 12 months. Butz 2014 reported no statistical significant difference between groups for mean total ED visits over 12 months (Analysis 2.2). Naar-King 2014 also reported no statistically significant difference between groups, although both groups had mean ED visits over the previous 12 months decline. Celano 2012 reported on number of ED visits during the year after postintervention, and number of ED visits between baseline and 1 year after postintervention, but with with no statistically significant differences between groups and no measures of variance reported (no measures of variance reported for any outcomes - symptoms, days missed from school and hospitalisations).

Primary outcome: Exacerbations requiring a course of oral corticosteroids

Three studies on 752 participants reported on exacerbations requiring a course of OCS. Butz 2006 reported no statistical differences between intervention and control groups for the mean number of oral corticosteroid prescriptions at 12 months. Butz 2010 and Butz 2014 reported no significant differences for the mean number of oral corticosteroids filled at 12 months (Analysis 2.3).

Secondary outcome: Functional health status

Quality of life

Two studies in 315 participants reported on quality of life. Kamps 2008 measured physical function and psychosocial health with the generic PedsQL and asthma-related quality of life with the PedsQL Asthma Module (with sections on asthma symptoms, treatment problems, worry, and communication) administered to both child and caregiver. No significant treatment effects were observed using repeated measures analyses of covariance and pooled time series analysis using data from baseline (n = 15), two (n = 10), six (n = 6) and 12 months (n = 5) (Kamps 2008). Butz 2014 measured quality of life using the Activity Limitations Scale of the PACQLQ. It was reported that the QOL scores improved with statistically significant differences from baseline and 6 months, and

baseline and 12 months, however there was no comparison data between intervention and control groups in terms of determining any intervention effect.

Days of restricted activity

Not reported.

Nights of disturbed sleep

No study reported on nighttime awakening, however Butz 2014 reported on asthma symptom free nights over the previous two weeks, with no difference between groups of mean symptom free nights at 12 months.

Day symptoms

Four studies on 587 participants reported on symptoms using various scales. Kamps 2008 measured caregiver-reported and child-reported asthma symptoms using PedsQL Asthma Module and found no significant difference in treatment effect at baseline and two, six and 12 months. Repeated-measures ANCOVAS did not yield significant interactions or main effects for symptom scores. Butz 2010 reported no statistically significant differences between groups for the decrease in mean number of symptoms during both the day and at night measured with a Likert-type scale at 12 months. Butz 2014 reported on asthma symptom free days over the previous two weeks, with no difference between groups in mean change in symptom free days over a 12 month follow up period (Analysis 2.4). Celano 2012 measured asthma symptom days as the greatest number of days the child experienced wheezing, coughing, chest tightness or shortness of breath over the last 14 days according to caregiver report at baseline, post intervention and at 6 months after the intervention. It was reported there was a significant decrease in symptom days from baseline to post, however not at 6 months follow up from intervention. However there was no significant intervention effect. We did not pool the data due to differences in measurement tools.

Secondary outcome: Days missed from school or work

One study of 41 participants reported on the number of school days missed (Celano 2012) (zero days missed vs. one or more days missed in last four weeks at baseline, post intervention and six months post intervention) however there was no significant intervention effect.

Secondary outcome: Exacerbations leading to hospitalisations

Five studies reported on hospitalisations for asthma (Butz 2006; Butz 2010; Butz 2014; Celano 2012; Naar-King 2014). A single study on 181 participants reported the number of patients experiencing at least one hospitalisation for the previous six months at 12 months follow-up (Butz 2006). There were fewer hospitalisations in the group receiving the additional nebuliser use training compared to the less intensive education, which was a statistically significant difference (OR 0.30; 95% CI 0.09 to 0.98; Analysis 2.5). Naar-King 2014 reported on mean number of hospitalisations over previous 12 months comparing at enrolment with 12 months post enrolment. Both groups had a lower mean number in the 12 months post-baseline with a significant intervention effect (β = −0.882; P = .04; incidence rate ratio = 0.414; 95% CI = 0.175 to 0.978). Celano 2012 reported on the total number of hospitalisations between baseline and one year after intervention in participant groups. Using Chi-square analyses, there was a significant group difference with only one child (5%) in the intervention group, compared to seven (35%) in the control group having a hospitalisation (p=0.02). Both Butz 2010 and Butz 2014 reported no difference in the mean number of hospitalisations at 12 months (Analysis 2.6).

Secondary outcome: Lung function

Two studies reported on lung function as an outcome (Kamps 2008; Naar-King 2014). A single study of 167 participants reported on mean forced expiratory volume in one second (FEV1) changes from baseline to 7 and 12 months post baseline (Naar-King 2014). Those in the intervention control had greater improvements in FEV1 over time than those in the attention control group at both seven and 12 months (β = 0.097; t[164.27] = 2.52; P

= 0.01).
Kamps 2008 did not report any significant differences in lung function (FEF (forced expiratory flow) 25% to 75%) using repeated measures analyses of covariance and pooled time series analysis at two months (n = 10), six months (n = 6) and 12 months (n = 6).

Cost

Galbreath 2008 reported the cost of the four home visits to be USD 206 and USD 531 for the telephonic intervention, totalling USD 737 per participant. Carswell 1989 also calculated the cost per patient, with each home visit costing 4.30 pounds, equating to 15 pounds/patient/6 month period. Campbell 2015 estimated the cost of each home visit to be USD 205.20 and for asthma control supplies to be USD 210, totalling a minimum of USD 415.10 per participant in the intervention group, dependent on how many home visits they received. Martin 2021 compared the cost of the home visit intervention to the cost of an asthma educator delivering educator within clinic sessions and which were reported as $74 per home visit and $135 per clinic session respectively.

Withdrawals

We decided not to pool these data due to diversity in the trial design (such as the number of education sessions) and reporting of the number of withdrawals. Instead, we created Table 4 to reflect the number of patients who completed all or some of the education, patients lost to follow-up and those who withdrew. This table should be viewed and interpreted with caution. Each study had its own definition of completing the programme and in some cases people may have missed some sessions yet still be registered as completing the programme. The programmes also varied in number of sessions.

Subgroup analysis

We were unable to perform any of the prespecified subgroup analyses due to the lack of studies. We could not subgroup by age as almost half of the studies were on two to 12 year olds, aside from two studies who had only included adolescents (Altay 2013, Naar-King 2014). The remaining studies included a range of ages spanning childhood and adolescence (Carswell 1989; Brown 2006; Gorelick 2006; Galbreath 2008; Krieger 2009; Celano 2012; Campbell 2015; Martin 2015; Baek 2019; Bresolini 2020; Martin 2021). We could not subgroup by asthma severity as only one study (Bresolini 2020) included participants with severe asthma, whilst the remaining studies which reported on severity included children with a range of asthma severities (i.e. mild, moderate and severe). There were only four studies with interventions which ran longer than six months (Fisher 2009; Krieger 2009; Eakin 2020; Martin 2021). We had planned to subgroup by physician or nurse versus CHW. However, over one third of the studies employed both a nurse combined with either a social worker, a trained health educator or a pulmonary therapist, or did not have a physician, nurse or CHW delivering the intervention at all (Gorelick 2006, Galbreath 2008, Kamps 2008, Otsuki 2009, Butz 2010, Seid 2010, Celano 2012, Naar-King 2014, Eakin 2020). Kamps 2008 used a psychologist or a psychology graduate student, Otsuki 2009 and Eakin 2020 an asthma educator, Seid 2010 employed bilingual, bicultural graduate asthma visitors, Celano 2012 used trained asthma counsellors and Naar-King 2014 used either a psychologist or social worker.

We were unable to subgroup by how participants had been diagnosed with asthma (i.e. doctor-diagnosed vs. asthma identified against objective criteria for asthma symptoms) as the majority of studies did not specify how participants had been diagnosed, rather they predominantly reported on severity and control. Lastly, we could not subgroup by web and internet based delivery of education vs. face to face delivery as we did not identify any studies which utilised these modalities to deliver education. This may have been a reflection on our inclusion criteria in which we only included interventions which involved at-home technology only if there was also a face-to-face component delivered in real-time within the home.

Discussion

Summary of main results

This update included 13 new studies and 2581 participants, with a total of 4923 patients from 25 studies for this review. Of these, 20 trials were conducted in North America. Twenty studies were in urban or suburban settings involving vulnerable populations. We summarised the components of the home-based educational interventions in Table 1. As with the 2011 review, we were unable to pool many of the outcomes due to diversity of the populations, interventions, and timing of outcome assessment. The control event rates for Emergency Department (ED) visits and hospitalisations were quite different between trials as previously noted, however, the majority of new studies that were included did not report this outcome. It is possible that trials with a higher control group event rate (poorly controlled asthma) would be more likely to achieve a decrease in admissions/ED visits, leading to difficulties in pooling results (see Table 3 and further discussion below). Overall, the effect of home-based education was difficult to interpret and derive any meaningful outcomes over these studies due to variable contexts within each trial.

Overall completeness and applicability of evidence

Implementation, feasibility and applicability of home-based educational interventions

Many of the included studies tested commercially-available asthma educational interventions covering similar programme topics, though these were delivered differently and with different emphasis on each component of education. These studies showed that while home-based interventions are feasible, additional resources and trained personnel are required, which may not be easily applied in real-world settings, especially without adequate financial support. Only Martin 2021 analysed cost-effectiveness, comparing per session cost of education delivered at home via a community health worker (CHW) to education delivered via asthma education within clinic sessions and found at home sessions were $61 USD less than clinic sessions. Having economic data may strengthen the case for such interventions to be included in policy and healthcare budgets, concurrent with more evidence supporting clinical effectiveness. Administrators and policy-makers may want to consider whether children with asthma and their caregivers are able to attend asthma clinics to receive education or whether some families can only be reached by visiting their home.

Our review also draws attention to another issue pertaining to the feasibility of interventions: the ability to retain participants. Although the participants who provided follow-up data generally completed most of the education sessions, there appeared to be a higher attrition rate in the education group compared to the control groups in studies reporting lost to follow-up. While high and unbalanced withdrawal rates are common in trials with high demands on participants' time, unbalanced withdrawal rates may also provide a biased indication of the effectiveness of home-based education, depending on whether the intervention retained children who were more or less likely to benefit than those who dropped out.

In the previous review, the use of lay workers from the community to deliver education sessions to improve feasibility and reduce costs of interventions were suggested, with one included study in the review (Fisher 2009) demonstrating reduced hospitalisations in asthma patients with the use of CHWs. This updated review includes six studies that have employed the use of CHWs (Krieger 2009; Campbell 2015; Martin 2015; Baek 2019; Jonas 2020; Martin 2021). With at least 75% of participants in the intervention groups partially completing the intervention, which was similar or better than those interventions employing health professionals, successful implementation and maintenance of the intervention is suggested. The majority of these studies employing CHWs showed significant intervention effects in one or more of our primary or secondary outcomes

including combined healthcare utilisation and indicators of functional health status (quality of life, asthma day and night symptoms), demonstrating its effectiveness as an intervention and an overall reduction in direct and indirect health care system medical costs.

Three studies in our review require careful interpretation in regard to the applicability of the interventions and results (Mitchell 1986; Carswell 1989; Butz 2006). Butz 2006 was focused on a population of children using nebulisers to deliver medications at home, which is not currently standard practice for most children with asthma and is not usually recommended in current guidelines (SIGN158 2019; GINA 2021). Butz 2006 was the only trial among three with a home-based control education group that showed a significant treatment effect for reducing ED visits and hospital admissions. This may relate to more severe asthma in children enrolled who were using nebulisers, and hence the greater likelihood of needing ED visits or hospital admissions for acute asthma (nearly half of the control group had ED visits in this study). Mitchell 1986 and Carswell 1989 were conducted more than two decades ago when asthma management practices and treatments were quite different from what we use today, including the use of regular short-acting beta-agonists and the use of regular inhaled corticosteroids which were not part of recommended guidelines (Reddel 2019; Nannini 2020).

Quality of the evidence

GRADE

Our GRADE ratings ranged from low to very low. The reasons for downgrading included for risk of bias because the studies could not be blinded owing to the nature of the intervention and some studies were high risk of bias for attrition. There was substantial clinical diversity in the PICOs of the included studies, meaning we decided not to pool several outcomes, and this is explored in detail below. Furthermore, most outcomes had few studies and participants increasing the uncertainty.

Diversity leading to statistical heterogeneity

Our review has highlighted the diversity present in the PICOs of randomised trials of home-based educational interventions, resulting in difficulties extracting and deducing key components of programmes that may be most effective. Several sources of diversity, which lead to statistical heterogeneity in the forest plots, are highlighted below.

Diversity in educational programmes

As with the previous version of this review, the educational programmes were diverse (e.g. focus, intensity and duration of education), the education received in control groups were varied, and methods of outcome assessment differed, resulting in substantial statistical heterogeneity. Because of this, we could not pool many of the data and were unable to draw definite conclusions from the narrative syntheses.

The aims of the studies varied from reducing healthcare utilisation (such as ED visits and readmission rates) to improving adherence to medications or quality of life. Some studies focused on one aspect of education (e.g. adherence to steroids or improving nebuliser use) or more specifically on improving an outcome (e.g. reducing readmissions or increasing primary care follow-up), whilst other studies were broader (e.g. improve asthma management). It is possible that the differences in the aims may have impacted the education delivered and the outcomes however the extent of this is unknown. The aims of the trial are summarised in Table 5.

Whilst most trials reported programmes covering comparable education topics (e.g. basic asthma education and instruction on inhaler technique), there was variation in the person delivering the education (e.g. trained psychologists, CHWs, nurses) as well as variation on what formed the basis of the educational program (e.g. different behavioural theories, family interventions, chronic care model concepts). We captured differences in Table 1 however we were unable to draw any conclusions of effect of interventions based on specific educational components.

The majority of trials in our review provided between four and six sessions of a similar intensity, with a few exceptions. Three studies delivered only a single education session (Dolinar 2000; Brown 2006; Gorelick 2006; Baek 2019) while more intense intervention provided visits over a greater length of time (e.g. every three months for two years in Fisher 2009) or more frequently in a shorter length of time (e.g. Naar-King 2014 provided sessions based on clinical need with an average of 27 sessions to participants over an average of five months). Although the latter, more intense studies demonstrated significantly reduced hospital admissions, there are many other possible explanations for this (e.g. Fisher 2009 also had the highest control group event rate, Naar-King 2014 provided sessions based on clinical need and hence targeting patients with possible more severe asthma). Therefore, we cannot draw definitive conclusions on the effect of programme intensity.

Diversity in control group event rates and populations

The majority of studies were performed in an urban or suburban setting with participants from vulnerable populations, such as those in lower socioeconomic groups and minority groups, although some studies did not report on ethnicity or socioeconomic demographic characteristics of their cohorts. Baseline asthma severity in participants differed between trials and this may be a reflection of trials having differing inclusion criteria, or different institutions having different standards of care. Although not an outcome in our review, there were three deaths in the trial by Butz 2006, two in Otsuki 2009 and two adults died in Galbreath 2008, which may be an indication of asthma severity or a higher-risk population. We attempted to capture differences between baseline characteristics of populations in Table 1.

Children with asthma are likely to have different levels of access to care, which may affect outcomes. For example, a child may benefit from education if the caregiver learns when to seek medical attention before an exacerbation becomes too severe, but if a primary care provider is not accessible they may end up having to make a non-urgent ED visit. The end result is an educational intervention that has outcomes that become difficult to interpret. To investigate this further we looked at the event rates for ED visits and hospitalisations in the control groups (Table 3). From the trials reporting ED visits as an outcome, four had relatively high control group ED visit rates (38% to 54%; Butz 2006; Brown 2006; Gorelick 2006; Fisher 2009) and these trials may be more likely to show a decrease in ED visits than the three reporting lower rates of ED visits (5% to 23%; Mitchell 1986; Dolinar 2000; Seid 2010; Eakin 2020). However, most of the individual trial results were not statistically significant for ED visits (except Butz 2006 and Mitchell 1986, with their unique populations and limited applicability of results, as previously described) and we were unable to draw conclusions. The statistically significant difference in hospitalisations observed in Fisher 2009 may be explained by the high hospitalisation control group event rate (59%) compared to the lower event rates for the other studies (8% to 33%; Table 3).

In the case of the six trials with a home-based education control group (Butz 2006; Kamps 2008; Butz 2010; Celano 2012; Butz 2014; Naar-King 2014), there may have been a decreased ability to detect a difference between groups due to the controls receiving less intense education in the home setting.

Some outcome measures improved over time in both intervention and control groups

In many of the included studies, patient-centred outcomes such as quality of life scores, days of restricted activity and day and night symptoms improved in both groups over the trial period (Brown 2002; Gorelick 2006; Galbreath 2008; Krieger 2009; Seid 2010; Campbell 2015; Jonas 2020). This may be due to recruitment factors (patients are enrolled after an ED visit or hospital admission, when they are potentially at their sickest and the majority will get better), the natural evolution of the disease (younger children getting better with age) or the nature of subjective reporting of outcome measures by recruited patients in trials. This highlights the importance of observing data over extended periods of time to assess whether change is truly due to the intervention and whether the effects are long-lasting after the trial period.

Potential biases in the review process

Although we attempted to apply a systematic process for including and excluding studies in this review and followed the criteria prespecified in our protocol, the final decisions are open to interpretation or criticism. In order to reduce heterogeneity, we excluded some trials that had mixed interventions, such as those with more education delivered outside of the home (e.g. Flores 2009), those with a greater focus on environmental allergen reduction (e.g. Jones 2001), or interventions based on asthma coordination of care (e.g. Everhart 2020; see Characteristics of excluded studies for more information).

Agreements and disagreements with other studies or reviews

Updated research supports the already strong foundation for asthma self-management education in improving health outcomes such as reducing health care utilisation, improving quality of life, improving symptomatic control, as well as improving knowledge and skills in children and their caregivers (Pinnock 2017; Isik 2019).

This systematic review adds 13 new trials to the preceding review and brings new trials that have not been included in previous systematic reviews. Since the 2011 review, no further systematic reviews to our knowledge have reviewed the impact of specifically home-based educational interventions for children with asthma, although systematic reviews looking at the effects of asthma education in general, and school and community based-interventions for children with asthma have been added to the literature (Harris 2019; Isik 2019; Chan 2021; Ramdzan 2021; Liu 2022). These systematic reviews do not include any of our new included trials.

Liu 2022 included 15 longitudinal studies for meta-analysis in children receiving an asthma educational intervention in a variety of settings, by a variety of instructors with no limit on tools. Those who received asthma education had a lower risks for hospitalisation (RR = 0.46; 95% CI 0.32-0.66) and ED visits (RR = 0.69, 95% CI 0.59 – 0.81). They also identified that education to both the child and the caregiver was more effective than education which only targeted children or their caregivers in reducing hospitalisations, however, were not able to report whether education within a hospital setting vs. community setting was superior. Whilst it is important to re-emphasise the importance of asthma education in children on asthma-related health outcomes and healthcare utilisation, as with our study, an inability to identify specific components of education and optimum setting may not help policymakers and health care administrators.

Similarly, Chan 2021 reviewed 21 studies examining comprehensive community-based asthma educational interventions (i.e. involving multiple components) and found there were significant intervention effects in regards to health care utilisation (reductions in ED visits OR = 0.26; 95% CI 0.20 – 0.35 and hospitalisations OR = 0.24; 95% CI 0.15 – 0.38) and asthma control (significant reductions in day and night symptoms as well as the use of bronchodilators). This encompassed education delivered over a range of settings including at home, in schools or with primary care providers, with multiple studies included extending over multiple settings. Due to the nature of the study and inclusion criteria involving studies that included multiple components of education, as with our systematic review, the optimum components and combination of elements is unable to be identified. Positively, this study supports education delivered outside the hospital setting.

Isik 2019 performed a systematic literature review of school and community-based nurse-led asthma interventions for children and their caregivers. There were eight studies included of which there were none from our review with the majority of the interventions conducted in a school setting. Overall, this review reported identifying that asthma knowledge and skills could be improved by intervention programs not within the clinical inpatient setting, however, it did not appear that any statistical analysis was done to compare studies and review for any intervention effects.

Whilst our study was unable to identify the key components to educational interventions which were important, Pinnock 2017 suggested in a systematic review of supported self-management strategies that education on self-monitoring, as well as regularly reviewed

written action plans were key. Harris 2019 has identified interventions that have been driven by an underpinning theoretical framework were more likely to be successfully implemented, as well as interventions that had caregiver involvement, child satisfaction, and interventions based around the child's schedule. This differs from Ramdzan 2021 which identified only substantial caregiver involvement to be important. In comparison to the educational intervention programs in our systematic review, many of our included programs involved both education on self-monitoring and asthma action plans, education not clearly discriminatory to targeting either the child, caregiver or both, and were underpinned by a theoretical framework, making it difficult for us to have been able to clarify the importance of each of these components individually.

Authors' conclusions

Implications for practice

We included 4923 patients from 25 trials in this review. Most of the participants involved a vulnerable urban population of North American children with asthma, a group of individuals hypothesised to benefit from home-based asthma educational interventions. As with our findings from the previous review over decade ago, there was still too much diversity which meant we were unable to pool many of the results and derive any meaningful interpretation. It is still possible that home-based education may be beneficial, especially in vulnerable populations.

Implications for research

The evidence from RCTs of education delivered to children with asthma in the home was uncertain. The following important questions that could benefit from well-designed trials to address the following issues remain:

1. Defining the exact components of education that are linked with improved asthma knowledge and outcomes. This will involve addressing the heterogeneity of trials and may involve:
    a. comparing similar programmes or programmes with slight variations (for example, with differences in duration, number of visits, types of educators, length of follow-up);
    b. designing trials with multiple intervention arms to tease out which components of education are effective;
    c. standardising reporting of outcomes - for example, reporting a minimum set of outcomes (such as those specified in this review) and using the same validated quality of life questionnaire(s).
2. Cost-effectiveness: while cost data were not well-reported in the included trials, further work is needed to establish whether the extra costs of delivering education in homes ties in with a reduction in costly outcomes such as acute health care visits. With trials that report on healthcare utilisation such as ED visits and hospitalisations, this may demonstrate cost-effectiveness, along with clinical effectiveness, which would support the widespread adoption of such programmes and strengthen the case for such interventions to be included in policy and health care budgets.

Highlighting the increasing utilisation of community health workers, this study also suggests that well-designed trials exploring efficacy of the community health worker (e.g. comparing community health workers to nurses or other educators) and the cost-effectiveness of programmes who employ the use of lay workers would also be beneficial.

Acknowledgements

We thank Susan Hansen who helped design the search strategy, and the editors and peer referees who provided helpful comments. We thank Dr Butz, Dr Gorelick, Dr. Carrillo and Dr. Martin, for providing additional information and Dr Galbreath and Dr Seid for providing copies of their publications in print.

CRG Funding Acknowledgement: The National Institute for Health Research (NIHR) is the largest single funder of the Cochrane Airways Group.

Disclaimer: The views and opinions expressed therein are those of the authors and do not necessarily reflect those of the NIHR, NHS or the Department of Health.

Data and analyses

Comparison 1

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.1 Exacerbations leading to emergency department visits	6		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1.1 ED visits between baseline and 6 months	4		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1.2 ED visits between 3 and 9 months from baseline	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1.3 ED visits between baseline and 2 years	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.2 Mean exacerbations resulting in emergency department visits	2		Mean Difference (IV, Fixed, 95% CI)	Subtotals only
1.2.1 Mean exacerbations between baseline and 6 months	2	430	Mean Difference (IV, Fixed, 95% CI)	-0.07 [-0.31, 0.16]
1.2.2 Mean exacerbations between 12 and 18 months from baseline	1	250	Mean Difference (IV, Fixed, 95% CI)	-0.72 [-1.51, 0.07]
1.3 Mean exacerbations requiring a course of oral corticosteroids	2		Mean Difference (IV, Fixed, 95% CI)	Subtotals only
1.3.1 Mean exacerbations between baseline and 6 months	1	250	Mean Difference (IV, Fixed, 95% CI)	-0.18 [-0.63, 0.26]
1.3.2 Mean exacerbations between 12 and 18 months from baseline	2	473	Mean Difference (IV, Fixed, 95% CI)	-0.08 [-0.20, 0.05]
1.4 Quality of life	2	682	Mean Difference (IV, Random, 95% CI)	0.37 [0.04, 0.71]
1.5 Mean symptom-free days	2	682	Mean Difference (IV, Random, 95% CI)	1.45 [-0.12, 3.01]
1.6 Days missed from school or work	1		Mean Difference (IV, Random, 95% CI)	Totals not selected

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.6.1 Mean days off school in 6 months	1		Mean Difference (IV, Random, 95% CI)	Totals not selected
1.7 Exacerbations leading to hospitalisation	4		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.7.1 Admission in 6 months from baseline	2		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.7.2 Hospitalisation between 3 and 9 months from baseline	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.7.3 Admissions between 6 and 18 months from baseline	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.7.4 Admissions between 12 and 18 months from baseline	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.7.5 Admissions between baseline and 2 years	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.8 Mean exacerbations leading to hospitalisation	2		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
1.8.1 Annual exacerbation rate	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
1.8.2 Mean admissions over 6 months since baseline	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
1.8.3 Mean exacerbations between 6 and 18 months	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Home-based education versus usual care, wait list or less intensive education programme delivered outside the home

Comparison 2

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.1 Exacerbations leading to emergency department visits	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
2.2 Mean exacerbations leading to emergency department visit	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.3 Mean exacerbations requiring a course of oral corticosteroids	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.4 Mean symptom-free days	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5 Exacerbations leading to hospitalisation	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
2.6 Mean exacerbations leading to hospital admission	2		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.6.1 Admissions between 6 and 12 months follow-up	2		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Home-based education versus less intensive home-based education

What's new

Date	Event	Description
8 September 2021	New citation required and conclusions have changed	Added 13 new studies. We updated the review with new background, methods, and summary of findings table
8 September 2021	New search has been performed	Updated search run on 13 September 2021.

History

Protocol first published: Issue 4, 2010
Review first published: Issue 10, 2011

Date	Event	Description
5 September 2014	Amended	PLS title amended. Reference to withdrawn protocol removed
11 April 2013	Amended	NIHR acknowledgement added

Contributions of authors

AOC: screening searches, extracted data, ran analyses, co-created summary of findings table, redrafted background and discussion.

MH: screening searches, extracted data, edited the review

ES: ran literature searches, organised S4M workflow, updated search results section and drafted PRISMA diagram.

KVCC: editing the review, supervision and guidance of AOC.

EJD: screening searches, extracted data, ran analyses, co-created summary of findings table, redrafted background and discussion.

Declarations of interest

AOC: none known.

MH: none known.

ES: none known.

KVCC: none known.

EJD: is the Deputy Co-ordinating Editor of Cochrane Airways. The review was signed off by a member of Cochrane Central Editorial Team.

Sources of support

Internal sources

- Emma Dennett, UK
  Supported by St George's University of London through employment.

External sources

- Emma Dennett, UK
  NIHR fund Emma Dennett's roles as Managing Editor/Coordingating Editor. See acknowledgments

Differences between protocol and review

The previously sparse methods section was updated to include the most up-to-date Cochrane methods as based on Cochrane Airways Group prepared protocol.

- Search methods updated to include trial registry platforms, reassessment of original search, and to use the screen4me and Cochrane Crowd workflows.
- Risk of bias methods expanded
- Measures of treatment effect added and specified
- ITT approach defined
- Categories of heterogeneity added from the Cochrane Handbook

The following additional outcomes are now included in the summary of findings table:

- Quality of life
- Mean symptom free days
- Days missed from school or work
- Exacerbations leading to one or more hospitalisations

The following PICO elements were updated

- Defined asthma diagnosis as based on GINA guidelines
- Defined that will exclude based on mixed-disease population
- Two new subgroups added (doctor-diagnosed asthma vs objectively defined asthma; Web and internet-based delivery versus face-to-face delivery)

Characteristics of studies

Characteristics of included studies [ordered by study ID]

Study characteristics	
Methods	Study design: Randomised controlled trial

	Recruitment setting: Child Allergy and Asthma outpatient clinic of Hacettepe University Hospital, and within the boundaries of the Ankara Metropolitan Municipality in Turkey Study duration and start date: Not reported
Participants	N (completed) = 80 (not reported completion) Mean age (± SD): Not reported. 67.5% of participants were between 12-14 years of age. 'The average age of the adolescents diagnosed with asthma was 8.12 years in the experimental group and 7.05 years in the control group'. Gender (%male): 72.5% Asthma severity: Not reported Diagnostic criteria: Not reported Concurrent treatment: Long-term control medication was used by 59% ('Long-term control medicine was used by 65% of the patients in the experimental group and 52.5% in the control group') Socioeconomic indicators: Not reported Ethnicity: Not reported Eligibility criteria: Patients diagnosed with asthma >12 months, using at least one long-term medicine and who had also been advised to carry their quick relief medicine with them, no chronic illness other than asthma, adolescent and parent consent to participate
Interventions	Educator: Study investigator with masters degree in nursing Audience: Adolescent's and their families ("Nursing interventions were carried out either in a separate room or together with their families according to adolescent's wishes") Where delivered: Home INTERVENTION GROUP: N (completed): n = 40 (completed not reported) N, duration and frequency of education sessions: 8 home visits over 5 months. "The study was explained to adolescents in the experimental group at the outpatient clinic. If they agreed to participate, they were first visited at their homes, then again 2 weeks later, weekly for 2 weeks, and monthly for 4 months..." "Home visits were made at times suitable for the adolescents and their families. The first home visit lasted 60–75 min on average and the others lasted 60 min." Educational/self-management strategy: Nursing care plans developed according to Orem's self-care model. "Dorothea Orem's self-care model consists of three main groups (nursing system model, self-care deficit model, and self-care model). This study is based on the self-care deficit theory and model. This model explains why and when individuals need nursing care. The self-care deficit model defines the difference between what can be done and what should be done with regard to health functions of individuals. Five different methods are available in Orem's theory to help patients: (a) behaving or acting on behalf of the individual, (b) guiding or orienting the individual, (c) providing physical and psychological support, (d) developing the environment in which the individual's needs are supported and helping this environment to exist, and (e) training the individual. This study benefited from the last four of the earlier-stated methods for nursing interventions to assure the self-care of adolescents with asthma (Orem, 2001)." The developed selfcare form contained the following subscales, the questions were yes/no format: • self-care related to use of medicines (16 questions) • self-care related to use of a PEF meter (12 questions) • self-care related to application of an asthma action plan (2 questions) • self-care related to keeping a daily follow-up schedule (2 questions) • self-care related to protecting themselves against factors that might trigger an asthma attack (42 questions). The contents of this form were reviewed for validity by four professors of paediatric nursing and one professor of paediatric allergy (physician). Nursing care plans were individualised and developed based on data collected and the diagnoses were based on deficiencies in the five subscales mentioned above. The nursing care plans were developed and put into action starting from the second visit. Where participants answered all questions in a subsection correctly, they were viewed as having adequate self-care in that area. Educational booklets given to the experimental group during home visits to further support the education. Booklet comprised two sections: basic information about asthma, and information related to self-care. Programme topics: Aimed at addressing deficiency on self-care related to the above five subscales.

	CONTROL GROUP: Two home visits. Demographic data form and self-care data form were administered at the first visit. Problems in self-care were identified at the end of the first visit. Second visit was made 5 months later and the self-care data form was administered again. No particular nursing interventions or home visits, only routine follow-up performed by nurses in the outpatient clinic. N (completed): n= 80 (not reported completion)
Outcomes	Outcomes measured: Treatment responsibility (adolescent vs. parent), self-care skills (using medicine with proper technique, using PEF with proper technique, keeping a daily follow-up schedule, applying the application of asthma action plan, protection from triggers) difference between first and last visits, nursing diagnoses identified Outcomes reported: As above Timepoints: First and last visit (baseline and 5 months later), also looked at each visit for nursing diagnoses identified during home visits
Notes	Funding: nil disclosed

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	No random sequence generation. "The groups were matched with respect to age and sex. The first patient to visit the outpatient clinic who fulfilled the research criteria was placed in the experimental group; the next patient with the same characteristics was placed in the control group, and so on."
Allocation concealment (selection bias)	High risk	Not concealed. "The groups were matched with respect to age and sex. The first patient to visit the outpatient clinic who fulfilled the research criteria was placed in the experimental group; the next patient with the same characteristics was placed in the control group, and so on."
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	High risk	Investigator made all home visits and administered questionnaires.
Incomplete outcome data (attrition bias) All outcomes	High risk	Not mentioned how many people completed the study
Selective reporting (reporting bias)	Unclear risk	No predefined protocol available
Other bias	Low risk	Nil identified

Altay 2013

Study characteristics

Methods	Study design: Quasi-experimental randomised controlled trial (cluster design) - schools randomised to intervention group and control group, then participants recruited from each school Recruitment setting: Schools in the Hidalgo County Independent School District (Texas, U.S.A.) Study duration and start date: May 2016 - June 2018
Participants	N (completed) = 313 (290) Mean age (± SD): 2.99 ± 2.7 - when diagnosed with asthma; age at recruitment not reported Gender (%male): 55.5% Asthma severity: At baseline for intervention group vs control group (mean ± SD) - Number of asthma attacks 0.77 ± 2.43 vs 0.24 ± 0.63; Hospitalizations 0.03 ± 0.28 vs 0.006 ± 0.08

	Diagnostic criteria: Diagnosed with asthma by a healthcare professional Concurrent treatment: 39.7% of children used inhaler steroids for more than two weeks Socioeconomic indicators: 54.4% had household income < $15,000 USD Ethnicity: 97.9% Hispanic, 2.1% Non-Hispanic Eligibility criteria: Families with children 1-17 years old, diagnosed with asthma by a healthcare professional and living in Hidalgo County, Texas
Interventions	Educator: Trained community health workers (CHW) Audience: children and their families Where delivered: Home INTERVENTION GROUP: N (completed): n = 139 (130) N, duration and frequency of education sessions: In-person session 60-90 minutes, once off educational session Educational/self-management strategy: Education session delivered in either English of Spanish. Home-based asthma educational intervention based on Asthma and Healthy Homes curriculum certified by the Texas Department of State Health Services. Intervention aimed to teach families how to more effectively manage their child's asthma, and create a healthier home environment. Also used content from the Seven Principles of Healthy Homes, a program developed by the National Healthy Homes Training Center and Network Programme topics: Included following components: asthma signs and symptoms, asthma management, identifying common asthma triggers, correct use of asthma medications, emergency actions in case of asthma attacks, fundamental components of asthma action plan. Also included information on how to reduce hazardous exposure in the household and learn how to keep the home dry, clean, ventilated, safe, pest-free and contaminant free. Incentives: not reported CONTROL GROUP: For the control group, CHWs only provided necessary educational materials related to asthma management without offering any direct education. N (completed): n= 174 (160) Other: CHWs provided participants in both the intervention and control groups with an allergen-proof mattress, pillow encasing, and non-chemical cleaner recipes, as well as instructions on how to use them.
Outcomes	Outcomes measured: Asthma exacerbations, hospitalisations, emergency room visits within last 4 weeks, physical health of child, activities of child, activities of family, emotional health of children, emotional health of families Outcomes reported: As stated Time points: Baseline, then at 3 months follow-up visit. As discussed with study author - plan was for data at baseline, 3, 6 and 12 months.
Notes	Funding: supported by Knapp Care Community Foundation and the Healthy South Texas

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomisation process unclear. 'The research team acquired a list of schools in the county's Independent School District (ISD) through the district's health director, and randomly and blindly assigned the 19 total schools in this list to either an intervention group or control group.'
Allocation concealment (selection bias)	Unclear risk	Allocation process unclear, '...and blindly assigned the 19 total schools in this list to either an intervention group or control group.'
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Unclear if outcome assessors were blinded

Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote 'Of the 313 enrolled participants, the intervention group included 139 participants and the control group had 174 participants, and 130 (93.5%) and 160 (92.0%) completed the study, respectively.'
Selective reporting (reporting bias)	Unclear risk	No published protocol found, assuming all measured outcomes reported
Other bias	High risk	Outcomes self-reported which could have been verified such as hospitalisations and ED visits Was a cluster RCT. Assessed unclear for recruitment bias - Allocation sequence not described, unclear whether allocation concealed prior to enrolling and assigning interventions. Unclear whether individual families were aware of the cluster allocation. "The research team acquired a list of schools in the county's Independent School District (ISD) through the district's health director, and randomly and blindly assigned the 19 total schools in this list to either an intervention group or control group. Children diagnosed with asthma attending any of the district's schools were invited to participate in the study, with informed consent obtained from each child's parent/guardian." "The schools of children were randomly and blindly assigned to each group and the completion rates of both groups were high (over 90%)." Assessed low risk for baseline characteristics - "Compared to the control group, the intervention group included fewer boys, family history of allergy, a household with a smoker, and households with a reported income of greater than or equal to $15,000. The control group had less public insurance holders and married parents/guardians than the intervention group. However, the characteristics between the two groups were not statistically different except for household income (p = 0.027), indicating that the two groups were comparable." Assessed unclear for adjustment for clustering in analysis as this was not mentioned.

Baek 2019

Study characteristics	
Methods	Study design: RCT Recruitment setting: Paediatric pulmonology outpatient clinic of a university hospital (Hospital das Clinicas of the UFMG, Belo Horizonte) in southeastern Brazil Study duration and start date: January 2016 - December 2016
Participants	N (completed) = 34 (29) Mean age (± SD): Intervention 10.7 ± 3.2 years; Control 10.3 ± 4.4 years Gender (%male): Intervention 43.7%; Control 53.8% Asthma severity: Severe or difficult to control asthma. ATS classification of severity reported to be used, but values not shown. ACT < 20 points was classified as uncontrolled Diagnostic criteria: Diagnosis and classification of asthma severity registered in medical records, based on criteria proposed by the ATS Concurrent treatment: Usual care Ethnicity: Not specifically reported though the study was undertaken in Brasil Eligibility criteria: Children and adolescents with severe or difficult to control asthma aged between three and 17 years living in Belo Horizonte or the metropolitan region.
Interventions	Educator: Nurses for home visits and usual care delivered by specialists from the Center for Patients with Difficult-to-Control Asthma (CEMAD) Audience: Parents and child Where delivered: Home INTERVENTION GROUP: N (completed): N = 17 (13) N, duration and frequency of education sessions: Three home visits with a 30 day interval after the first visit and 60 days after the second visit Educational/self-management strategy: Intervention group received usual outpatient care and nurse home visits - during home visits, the availability, expiry date, conservation and accessibility of medication, the medication adherence rate, as well as the appropriate use of

	the asthma spacer were evaluated. Issues related to environmental improvement, pathophysiology of asthma, medication's mechanism of action, questions about proposed treatment evaluated and addressed with family and patients. Educational materials used/provided: Checklists developed for the study and inhalational techniques observed and corrected in person. Programme topics: As above Incentives: Not reported Compliance: In the intervention group, one patient withdrew after the first home visit, two refused to participate in the study and one was discharged from the service before the first home visit was performed. In the control group one patient refused to participate. CONTROL GROUP: Received outpatient care from the outpatient team (CEMAD) with three consultants in the same periodicity as the intervention group N (completed): N = 17 (16)
Outcomes	Outcomes measured: Assessment of inhalation technique, clinical asthma control and adherence to corticosteroid use Outcomes reported: As stated Time points: Baseline, then at each outpatient or home visit (i.e. 30 days after the first visit and 60 days after the second visit). Study reported to be a 12-month study, but it appears this is the study duration, rather than follow up.
Notes	Funding: Universidad Federal de Minas Gerais primary sponsor

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomization was generated by computerized list'. Comment: sequence generation commented on
Allocation concealment (selection bias)	Unclear risk	Allocation process unclear. '17 patients were allocated in each group'.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Unclear who outcome assessors were. Evaluation of control group reported to be by a different professional than the one who evaluated the intervention group, but no other mention of blinding
Incomplete outcome data (attrition bias) All outcomes	Low risk	Attrition reported between groups with reasons provided
Selective reporting (reporting bias)	Low risk	Pre-specifiifed protocol available with outcomes matching those reported in the manuscript
Other bias	Low risk	Nil other biases identified

Bresolini 2020

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: clinics associated with a University School of Medicine or a children's hospital in Atlanta, Georgia, USA Study duration and start date: 12 months, September 1997 to June 1999
Participants	N (completed) = 101 (98)

	Mean age (range): 4.2 (1.1 to 7.0) Gender (% male): 63% Asthma severity: mild intermittent (19%), mild persistent (56%), moderate persistent (21%), severe persistent (4%) Diagnostic criteria: NAEPP Concurrent treatment: 85% had been previously prescribed one of more daily anti-inflammatories (cromolyn (43%), ICS (78%), antileukotriene modifier (6%), LABA (6%). In addition, some children had been prescribed theophylline (8%) and/or a brief course of OCS (26%) and all but one of the children had been prescribed SABA (98%, 16% were using SABA only) Socioeconomic indicators: parents received no high school (28%), high school qualification (50%), some college (22%) Ethnicity: 90% African American Eligibility criteria: children between 1 and 6.99 years of age at study entry and had made a healthcare visit for asthma in the preceding year and who were prescribed daily asthma medication. The primary caregiver had to speak English and have no know involvement with illegal drugs. Those who refused or could not be contacted were excluded.
Interventions	Educator: registered nurses trained in the Wee Wheezers at Home programme. Nurses attended supervisory sessions twice a month and focused on their cases and received ongoing training. The same nurse conducted all 8 sessions with a family. Audience: families (86% mothers) and their children. Others present in the household were also invited to participate Where delivered: home-based INTERVENTION GROUP N (completed): 55 (49) N, duration and frequency of education sessions: 8 weekly sessions of 90 minutes Educational/self-management strategy: Based on Wee Wheezers at Home programme. The teaching script of which was adapted for low-literacy levels (5th grade) and adapting for child audience and ensuring cultural appropriateness of materials. The material was delivered over 8 sessions rather than 4. Each 90-minute session consisted of the caregiver and nurse jointly completing a checklist of the child's symptoms for the previous week (5 minutes), a discussion of the previous week's homework (5 minutes), the session topics (60 minutes), a review of concepts learned during that session (5 minutes) and assigning homework (5 minutes). Example of caregiver/child activities include tracing the airflow on a picture of a child with the lungs drawn, identifying and colouring asthma cues and environmental triggers in a colouring book, practising belly breathing, keeping an asthma diary, watching videos about asthma management and practising the use of a peak flow meter. Educational materials used/provided: printed materials, homework and occasional videotapes Programme topics: session 1) basic concepts of asthma; 2) developmentally appropriate involvement of child in asthma self-management plan and asthma cues; 3) asthma medication and non-medication techniques for managing asthma symptoms as part of action plan and working together with child to administer medicines; 4) symptoms of asthma attacks, review of asthma action plan, children with chronic health problems; 5) symptom prevention including trigger identification, environmental control measures and use of preventative medication; 6) communication about asthma to teachers, physicians and family members; 7) review of asthma concepts; 8) review of communication about asthma. Incentives: at the baseline visit, parents gave consent and received USD 25 and were given USD 25 for each of 2 further data collection visits Compliance: 20% of the 49 families who completed the education received some or no lessons CONTROL GROUP: received no education but did receive the data collection visits. Families of control group were offered one educational home visit after completion of data collection. N (completed): 46 (46)
Outcomes	Outcomes measured: asthma morbidity: a rating of how much patents were bothered by symptoms, the number of symptom-free days since most recent asthma visit, the number of acute visits for asthma exacerbations. Caregivers quality of life: measured by questionnaire on how much caregiver was bothered or worried by their child's symptoms. Caregivers' rating of the level of child's participation in administering asthma medication and symptoms prevention and treatment. Outcomes reported: as stated

	Time points: baseline, 3 (actually about 19 weeks) and 12 months. The number of acute asthma visits were collected for the previous year at baseline and 12 months.
Notes	Funding: National Institute of Nursing Research grant R01NR04431

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	"Randomised". Groups balanced by medical site and season of enrolment. Comment: not described
Allocation concealment (selection bias)	Unclear risk	"Families were informed of their group assignment via a letter" Comment: unclear who assigned participants to their groups
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	A graduate student blind to group assignment abstracted asthma-related information from the child's medical records. Project social worker collected data from families was blinded, although may have become aware of group assignment in certain instances.
Incomplete outcome data (attrition bias) All outcomes	High risk	One control group family and 3 intervention families could not be contacted at 3 months and two control families could not be contacted at 12 months. Six families withdrew on assignment to treatment group and this can be assumed to be related to the treatment. Comment: only have outcome data for the 49/55 families who completed the intervention. Complete data for all the control patients.
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	Low risk	Observational used over self reports where possible

Brown 2002

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: community hospital Grand Rapids, USA Study duration and start date: 2004
Participants	N (completed) = 248 (239) adults and children; 137 (129) children Mean age (range): adults and children, but data were presented separately for those under 18 years Gender (% male): 46% Asthma severity: mild intermittent (23%), mild persistent (21%), moderate persistent (19), severe persistent (37%) Diagnostic criteria: NHLIB Expert Panel 2 Guidelines or had visited the ED at least once in the last year (71%) Concurrent treatment: 80% on inhaled corticosteroids Socioeconomic indicators: no high school diploma ~18%, high school qualification ~ 32%, some college ~50% Ethnicity: 30% African American, 59% white, 11% other Eligibility criteria: moderate to severe persistent asthma or had visited the ED at least once in the last year. Although moderate to severe asthma was an eligibility criterion, patients with mild intermittent of mild persistent were also included.
Interventions	Educator: trained asthma nurse educator Audience: parent and child

	Where delivered: primary care clinic/home INTERVENTION GROUP N (completed): 120 (117, 66 children) N, duration and frequency of education sessions: 1 session in primary care clinic within 3 weeks of initial ED visit, 1 session at home 6 weeks after first session. Educational/self-management strategy: 1) optimising medical therapy based on NHLBI guidelines; 2) optimising understanding of asthma management and control by stressing self evaluation and monitoring; 3) developing or refining individually tailored AMP; 4) conducting follow-up home visit to identify potential asthma triggers and reinforce recent changes in treatment and management Programme topics: before ED discharge patients received age-appropriate instruction from respiratory therapist on the use of inhaler/spacer/PEF meter from the asthma nurse educator who called to arrange a follow-up appointment with the primary care physician within 5 days. At the clinic appointment, patient, parent and asthma nurse educator worked with the primary care physician to review current treatment, develop written action plan and provide education about appropriate response to further asthma exacerbations. The home visit included review of current medication and inhaler, spacer and PEF meter techniques, asthma management plan and encouraged distribution of the plan to school, day-care etc. Basic education relating to triggers, early warning signs and prevention was also given, along with an in-home environmental evaluation. Incentives: 2 USD 10 grocery vouchers Compliance: 39% of the intervention group did not comply with any of the post ED activities CONTROL GROUP: standard management consistent with NHLBI 2 guidelines. Received instruction by respiratory therapist on proper use of inhaler and spacer, and if age appropriate, PEFM. Written discharge instructions including recommendation to contact PCP within 3 to 5 days to schedule follow-up appointment. If no regular PCP, referral made using hospital-affiliated paediatric clinic for children. ED physician dictation faxed to PCP. N (completed): 128 (122, 63 children)
Outcomes	Outcomes measured: primary outcome was time to first asthma relapse (asthma-related visit to ED or unscheduled urgent visit to physician office during 6-month follow-up period); secondary outcomes were total number of ED visits and hospitalisations during 6 months, self reported compliance with spacer and PEF, use of asthma management plan, self reported actions taken to reduce exposure to asthma triggers, missed work or school days Outcomes reported: as above Time points: follow-up data collected by telephone call at 2 and 6 months after enrolment
Notes	Funding: grant from the Centers for disease control and the Butterworth Foundation

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Patients were stratified by age and "randomised using computer-generated random numbers..." Patients were enrolled consecutively from selected ED shifts representing a broad range of time of day and day of week
Allocation concealment (selection bias)	Low risk	"... followed by the use of sealed opaque envelopes"
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition	High risk	Loss to follow-up was 21% in group and 6% in the control arm. Comment: the loss to follow-up was high and unbalanced, and there were more losses in the intervention arm which is related to the treatment and people's willingness to comply

bias) All outcomes		
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	High risk	ED visits and hospitalisations were self reported

Brown 2006

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: paediatric primary care (30%), pulmonary/allergy clinics (50%) and ED practices (20%) associated with the University of Maryland medical System and the Johns Hopkins Hospital, Baltimore, USA Study duration and start date: October 2001 to December 2003 (recruitment)
Participants	N (completed) = 221 (181) Mean age (range): 4.6 (2 to 9) Gender (% male): 65% Asthma severity: mild intermittent (5%), mild persistent (61%), moderate persistent (21%), severe persistent (14%) Diagnostic criteria: national guidelines Concurrent treatment: number of SABA prescriptions in the past 6 months from baseline from pharmacy data mean (SD) 1.8 (1.9), number of OCS prescriptions in the past 6 months from baseline from pharmacy data mean 0.6 (SD 0.9), number of ICS prescriptions in the past 6 months from baseline from pharmacy data mean 0.9 (SD 1.4) Baseline lung function: Socioeconomic indicators: no high school diploma (24%), high school qualification (39%), some college or trade school or college graduate (38%). Annual household income less than USD 20,000 48%, more than or equal to USD 20,000 40% (sic). Medicaid health insurance 80%. Ethnicity: African American 89%, other 11% Eligibility criteria: children resident in Baltimore aged 2 to 9 years with a previous medical diagnosis of asthma. Children should have experienced daytime asthma symptom at least 2 or more times a week within the past 30 days, nighttime asthma symptom at least 2 or more times a week within the past 30 days, use of a nebuliser to administer asthma medication within the past 30 days, 1 or more ED visits for asthma within the past 12 months or hospitalisation for asthma in the past 12 months. Exclusion criteria were low or no nebuliser use in the prior 30 days and children newly diagnosed as having asthma.
Interventions	Educator: 3 community health nurses with paediatric asthma training. Supervised monthly by a paediatric nurse asthma specialist. Audience: parents and child Where delivered: home NEBULISER INTERVENTION GROUP N (completed): 110 (95) N, duration and frequency of education sessions: 6 x 1-hour sessions over 6 months Educational/self-management strategy: The parent component of the educational intervention included teaching comparison of a child's normal breathing to breathing patterns noted during an acute asthma episode. Parents taught to recognise each asthma symptoms (cough, wheeze, inability to talk and signs including intercostal retractions and use of a PFM in children over 5 years of age, so that they could make accurate treatment decisions. Specific nebuliser-use education targeted accurate medication dispensing including measuring accurate amount of medication, pouring medication in nebuliser cup, the frequency of changing nebuliser mask and tubing, and the cleaning and maintenance of the nebuliser device. The programme was based on the Wee Wheezers Program and the A+ Asthma Club Program and teaching paediatric symptom identification in children with asthma, and recommendations for nebuliser therapy Educational materials used/provided: home visit checklist used by nurse (available in the public health nursing paper) Compliance: number of sessions attended mean: 5.6 (SD 1.2)

	STANDARD ASTHMA EDUCATION CONTROL GROUP: a less intensive intervention group. Received basic asthma education, comparable to education received during non-urgent care visits and 3 home visits. Facilitating access to acute asthma care, encouraging parents to obtain WAP from healthcare provider, addressed dose and frequency of current medication, teaching the use of a PFM to children over 5 years old. No symptom identification or nebuliser use was taught. 3 asthma education visits Completed home visits: mean 2.9 (SD 0.5) N (completed): 111 (86)
Outcomes	Outcomes measured: symptom frequency, appropriate nebulizer and asthma medication use, ED visits and hospitalisations (reported as events in the past 6 months) Outcomes reported: as above Time points: baseline, 12 months
Notes	Funding: grant NR05060 from the National Institute for Nursing Research Further information on education available from study authors: yes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomised "based on even or odd digits from a random digit list"
Allocation concealment (selection bias)	Low risk	Project co-ordinator and principal investigator did not know order of allocation (*email communication with author*)
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Project co-ordinator and co-investigators all blinded (*email communication with author*)
Incomplete outcome data (attrition bias) All outcomes	High risk	Nebuliser intervention: 14% excluded from follow-up (10% no pharmacy data, 2% died, 3% lost). SAE 23% excluded (18% no pharmacy data, 1% died, 4% lost.
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	High risk	Self reports were verified except for hospitalisations

Butz 2006

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: paediatric ED (72%), paediatric community practices (28%), Johns Hopkins Hospital, Baltimore, USA Study duration and start date: December 2004 to December 2006 (recruitment)
Participants	N (completed) = 231(193) Mean age (range): 8.02 (6 to 12) Gender (% male): 60.6% Asthma severity: mild intermittent (22.6%), mild persistent (48.3%), moderate persistent (16.1%), severe persistent (13.0%)

	Diagnostic criteria: NHLBI Concurrent treatment: controller medication use (68%), SABA canister equivalents in past 12 months (mean 2.61; SD 2.8), OCS fills past 12 months (mean 1.17; SD 1.5), ICS canisters past 12 months (mean 1.82; SD 2.6), LABA past 12 months (mean 0.44; SD 1.5), ratio controller to total asthma medications fills for 12 months (mean 0.41; SD 0.3) Baseline lung function: Socioeconomic indicators: income < USD 20,000 (57.1%); income ≥ USD 20,000 (42.9%); caregiver education < high school graduate (32.0%); high school graduate or more education (68.0%) Ethnicity: African American (92.6%), white (3.5%), other/missing (3.9%) Eligibility criteria: children 6 to 12 years old with physician-diagnosed asthma, currently used controller and/or SABA medication, with one or more asthma ED visits or hospitalisation in preceding year and no specialty care within past year.
Interventions	Educator: trained nurse/health educator Audience: parents and child Where delivered: home ASTHMA COMMUNICATION INTERVENTION N (completed): 121 (100). Mean 3.29 (SD 1.2) out of 4 visits. N, duration and frequency of education sessions: 4 home visits x 30 to 45 minutes each, over 8 weeks Educational/self-management strategy: communication skills education (role play, cue cards for enhanced communication with clinician), assistance in arranging clinician appointments, reinforcement of medication device technique. Also received control group education intervention (see below) Educational materials used/provided: written asthma educational materials (same as control) as well as one-page cue card to enhance caregiver to clinician communication Compliance: mean 3.29 (SD 1.2) out of 4 home visits; 60% had 1 clinic visit, 27% had 2 clinic visits CONTROL = STANDARD ASTHMA EDUCATION CONTROL GROUP: 3 x home asthma education visits, each 30 minutes over 8 weeks. Teaching topics: asthma triggers, medications, standard device training for PFM and inhaler/spacer technique, reducing barriers to regular follow-up asthma care. Families received written educational materials. No home environment assessment performed. N (completed): 110 (93). Mean 2.27 (SD 1.1) out of 3 visits.
Outcomes	Outcomes measured: morbidity measures (caregiver reported symptom days and nights over past 30 days, asthma severity using symptoms and rescue medication frequency algorithm from NHLBI, activity limitation from asthma, number of ED and clinician visits, number of hospitalisations), pharmacy-based medication use (appropriate controller and SABA medications based on pharmacy records over 12 months, oral corticosteroid prescription fills, appropriate controller med use (ratio of controller:total asthma medications)), caregiver rating of communication with PCP (4-item, 5-point Likert-type scale), and characteristics of home and clinician visits (checklists for completed home visits and psychosocial issues; for intervention group, checklists used to examine content of communication between clinician and caregiver) Outcomes reported: as above Time points: baseline, 12 months
Notes	Funding: grant NR008544 from the National Institute for Nursing Research

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Random digits generated by STATA (*email communication with Dr. Butz*)
Allocation concealment (selection bias)	Low risk	Sealed envelopes
Blinding of participants and personnel	Unclear risk	Not possible to blind patients or educators

(performance bias) All outcomes		
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Research staff remained blinded for all follow-up surveys
Incomplete outcome data (attrition bias) All outcomes	Low risk	Intention-to-treat analysis; fairly high, but balanced drop-out rates: intervention 17 % lost to follow-up and control 14 % lost to follow-up
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	Low risk	Although most health care utilisation outcome self reported, ED and clinician visits verified by child's clinician

Butz 2010

Study characteristics	
Methods	Study design: Randomised controlled trial Recruitment setting: Two urban paediatric hospital EDs in Baltimore, USA Study duration and start date: Dec 2008 - January 2010
Participants	N (completed) = 300 (274) Mean age (range): 166 (55%) aged 3-5; 134 (45%) aged 6-10 Gender (%male): 59.3% Asthma severity: mild intermittent: 15 (5%); mild persistent: 114 (38%); moderate persistent: 52 (17%); severe persistent: 117 (39%) Diagnostic criteria: NAEPP, physician diagnosed asthma Concurrent treatment: 76% used controller medication at baseline (self reported by caregivers) Socioeconomic indicators: 25 (9.6%) at poverty level; 213 (81.9%) below poverty level. 275 had Medicaid (92%) Ethnicity: African American (95.7%); white/Hispanic/other (13%) Eligibility criteria: Children 3-10 years, physician diagnosed asthma, persistent asthma (defined by national guidelines), controller medication use during the prior 6 months, and two or more ED visits or one hospitalisation during the prior 12 months of the index ED visit
Interventions	Educator: Trained Nurse/Health educator. Co-visits with nurses by senior nurse investigators Audience: Child and caregiver of child with asthma Where delivered: 2 sessions at home, one at the GP office with the nurse present INTERVENTION GROUP: Education plus review at PCP N (completed): 152 (138) N, duration and frequency of education sessions: 3 sessions, length not described Educational/self-management strategy: Information given at two sessions. 'For children in the intervention group, the caregiver received asthma education during two home visits including the same topics as the control group. Additionally, during the home visits, the intervention nurse reviewed the caregiver feedback letter that explained the number of the child's asthma medication fills over the past 12 months, the child's cotinine concentration, and tips for implementing a total home smoking ban. For the third intervention nurse visit, the nurse joined the caregiver and child at the PCP office for a preventive asthma care visit. During the PCP visit, the nurse delivered a separate clinician feedback letter to the PCP explaining the child's report of symptom days, inhaler technique, asthma medication fills and cotinine concentration. In addition, the nurse prompted the PCP to deliver a controller medication prescription, address SHS exposure for children with any exposure and sign a prepared AAP form. The PCP feedback letter included (1) a summary of the child's symptom frequency, inhaler technique, asthma control and pharmacy; fill report, (2) the child's cotinine level and (3) recommendations for preventive care based on national asthma guidelines [5]. All feedback letters were developed and signed by a paediatric allergist and a primary care paediatrician. After each PCP visit, the nurse completed an intervention clinic checklist

	recording (1) PCP review of feedback letter, (2) nurse discussion of controller and rescue medication fills, (3) nurse and parent discussion of cotinine level with PCP and home smoking ban counselling and (4) PCP review of the prepared AAP.' Programme topics: Education about asthma self-management targeting the use of preventer asthma medication, awareness of the child's exposures to asthma triggers, and importance of asthma preventive care visits. Also device training for peak flow meter and inhaler and spacer, completion of the written asthma action plan. Self-management was defined as "appropriate controller medication use or inhaler device technique in the context of the child's own environment and particularly for older children". Specific tips based on the monitoring were given "You may want to consider a step-up in inhaled steroid medication based on the frequency of daytime wheeze." Incentives: Caregivers received USD30.00 payment for completion of the baseline survey Compliance: 107 (71%) received all three nurse visits. 44 (29%) did not complete the scheduled PCP visits component of the intervention. Reasons for non-completion of the PCP visits included caregiver stressful life events such as hospitalisation or death of a family member, difficulty scheduling PCP visits due to conflicts with caregiver work schedule, child school priorities and lack of belief in preventive care by caregiver. CONTROL GROUP: "Children and caregivers assigned to the attention control group received asthma education only during three home visits, including the identification of asthma triggers, medication device training, environmental control education and the importance of controller medication use and preventive asthma care. Caregivers of children assigned to the control received their child's level of exposure to SHS (cotinine concentration) and tips for implementing a total home smoking ban, by mail at the end of the study" N (completed): 148 (136)
Outcomes	Outcomes measured: Primary outcome: the number of preventive asthma care vitis with a PCP (as reported by caregiver for past 6 months at ever 6 months data point). Secondary outcome: number of ED visits over 12 months (as reported by caregiver for past 6 months at every 6 months data point). Also looked at additional health outcomes - asthma severity and control. Asthma severity based on days and night time symptom frequency over the past 2 weeks using national asthma guidelines. Asthma control categories (well controlled, not well controlled or very poorly controlled) were based on the number of symptom days and nights, rescue medication use, activity limitation and number of ED visits and hospitalisations. Also looked at asthma medication use using pharmacy dispensation records (baseline and at 12 months) and SHS exposure. The use of an AAP in home assessed every 6 months. In a different analysis (Bellin 2015) - looked also at asthma management stress, life stress, social support and caregiver QOL (caregivers completed the Activity Limitations Scale of the Paediatric Asthma Caregiver's Quality of Life Questionnaire as a measure of QOL). Outcomes reported: Symptom free days past 14 days, change in symptom free days, symptom free nights past 14 days, asthma control, total ED visits, total hospitalisations, number of PCP visits, cotinine exposure (measure of second-hand smoke exposure), medication (controller) use, pharmacy fills at 12 months. Time points: Baseline, reported 12 month follow up.
Notes	Funding: All phases of this study were supported by a National Institute of Nursing Research, NIH grant NR010546.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'children were randomly assigned using random-number generation and stratified by child age (3–5 versus 6–10 years)'
Allocation concealment (selection bias)	Low risk	'the Project Coordinator assigned children to the intervention of control groups using a series of numbered opaque envelopes that had been pre-randomised in blocks of two by child's age'
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment	Low risk	"All study personnel, excluding the study coordinator and nurse interventionists, were blinded to group assignment." "All interviewers and research assistants were blinded to group assignment."

(detection bias) All outcomes		
Incomplete outcome data (attrition bias) All outcomes	Low risk	Less than 10% withdrew
Selective reporting (reporting bias)	Unclear risk	No published protocol found. Secondary outcomes in the NCT record differed from those reported in the primary publication (Primary outcome measures reported in NCT record : number of primary care appointments kept over 12 months [time frame: 12 months]; Secondary outcome measures reported in NCT record : Number of refills for anti-inflammatory medications prescribed over 12 months [time frame: 12 months])
Other bias	High risk	Outcomes were all care-giver self reported however could have been verified

Butz 2014

Study characteristics	
Methods	Study design: Parallel, randomised, controlled group design Recruitment setting: Recruitment from community in King County, USA - lists provided by Medicaid health plans (1378) or from provider referrals (184) Study duration and start date: May 2010 - October 2012
Participants	N (completed) = 373 (333) (373 enrolled; 182 in intervention group and 191 in control group of whom 154 and 179 respectively completed study) Mean age (range): 8.3 (range not provided, although eligibility criteria 3-17 years) Gender (%male): 59.2% Asthma severity: Severity not specifically discussed, asthma control - not well controlled or very poorly controlled asthma. Baseline: 4.8% well controlled, 47.2% not well controlled, 48% very poorly controlled Diagnostic criteria: Physician diagnosed, NAEPP definition of asthma control Concurrent treatment: Not reported Socioeconomic indicators: 81.5% families in study rents home vs owning home. Study undertaken in King County where 12.5% live in households with incomes less than 200% of the federal poverty level. Caregivers' education levels 42.3% completed less than high school, 25.1% some college, 23.5% high school graduate, 9.2% college graduate Ethnicity: 62.2% Hispanic, 15.3% Non-Hispanic Black, 8.8% Non-Hispanic White, 5.4% Non-Hispanic multiracial, 4.8% Non-Hispanic Asian/PI, 3.5% Non-Hispanic other Eligibility criteria: Children 3-17 years old who lived in King County with provider-diagnosed asthma that was either not well controlled or poorly controlled, were enrolled in 1 of 2 Medicaid plans, and had a caretaker conversant in either English or Spanish.
Interventions	Educator: CHW Audience: Caregiver and child Where delivered: Home, also allowing up to 2 telephone contacts in lieu of home visits INTERVENTION GROUP: N (completed): 182 (154) N, duration and frequency of education sessions: 4 home visits (allowing for up to 2 telephone contacts in lieu or home visits). Initial visit, then visits at 0.5, 1.5 and 3.5 months later. Also provided as-needed support via phone, email or additional home visits. Length not disclosed for session. Educational/self management strategy: A CHW provided education, support and service coordination for each household in the intervention. Initial visit to assess the participant's knowledge of asthma, asthma control level, challenges with controlling asthma, self-management practices and exposure to asthma triggers. Short home visits using motivational interviewing methods. CHWs included children in home visit activities and included them in asthma education, offered coaching on correct use of asthma devices. Educational materials used/provided: Programme topics: 'CHWs followed protocols that specified educational content' Incentives: Participants received a USD10 incentive for completing baseline data collection and USD35 for completing exit data collection

	Compliance: Intervention group 12 withdrawals and 16 lost to follow up; control group 4 withdrawals and 8 lost to follow up = 40 in total CONTROL GROUP: Usual care. Received asthma education and control resources AFTER exit interview. N (completed): 191 (179) Other: 'Participants received a low-emission vacuum cleaner, cleaning supplies, roach abatement supplies (if roaches present) and allergen-impermeable bedding covers' - 'both study arms received USD210 worth of asthma control supplies'
Outcomes	Outcomes measured: Asthma symptom-free days (self-reported number of 24hour periods during the prior 2 weeks without wheeze, tightness in chest, cough or SOB, a decrease in usual activities because of asthma, or nighttime awakening because of asthma), Paediatric Asthma Caregiver Quality of Life Scale Score, and self-reported asthma-related urgent health services use during the last 12 months (ED, hospitalisation or unscheduled clinic visits). Secondary outcomes: asthma attacks (defined as a time when asthma symptoms were worse, limiting activity more than usual or making you seek medical care for your child), days with rescue medication, nights with symptoms, and asthma control levels (as defined by NAEPP). Outcomes reported: As stated Time points: Baseline, then 'approximately 1 year after baseline'
Notes	Funding: Funded by the Centers for Disease Control and Prevention, National Centre for Environmental Health grant 5R1 8EH000537 Costs: Estimated cost for each home visit $205.20 and $210 for asthma control supplies per participant

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"we randomly assigned participants to groups using a permuted block design with varying block size. We stratified randomisation into 4 groups based on age (3---11 years and 12---17 years) and asthma-control level (not well controlled or very poorly controlled), respectively.'
Allocation concealment (selection bias)	Low risk	'sequence numbers and group allocation were concealed in sealed, opaque, numbered envelopes that were centrally prepared and sequentially provided to the CHWs who assigned participants to study groups'.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	'A CHW other than the one who provided the intervention collected exit data 1 year later upon study completion'. Unclear who collected data for those in the control group, and if outcome assessors were blinded to reviewing results
Incomplete outcome data (attrition bias) All outcomes	Low risk	Intervention group: Lost to follow-up (n=16) Discontinued participation (n=12) Analysed: n=154 in the complete case analysis, n=182 in the multiple imputation analysis. Control group: Lost to follow-up (n=8). Discontinued participation (n=4)
Selective reporting (reporting bias)	Unclear risk	No published protocol identified, but assume all measured outcomes reported
Other bias	High risk	All outcomes self reported

Campbell 2015

Study characteristics

Methods	Study design: Randomised controlled trial Recruitment setting: Two family group practices in Bristol (one suburban, one urban); Homes of 86 families with asthmatic children

	Study duration and start date: 1 October 1985 - 1 June 1986
Participants	N (completed) = 86 Mean age (range): 11.2 (5-15) Gender (%male): 69% Asthma severity: Not reported Diagnostic criteria: Not reported Socioeconomic indicators: Not reported. 'One practice population was apparently in a higher socioeconomic group than the other' Ethnicity: Not reported Eligibility criteria: Families with children 5-15 years old with asthma
Interventions	Educator: District Health Authority Nurse who had been trained for 1 week (full time) to have particular skills in the management of asthma. Audience: Child and families Where delivered: Home INTERVENTION GROUP: N (completed): 43 N, duration and frequency of education sessions: Not reported how many visits over a period of 6 months. Visiting nurse 'exercised their professional judgement as to the number of home visits required by each family'. Mean time spent in the home was 29 minutes Educational/self-management strategy: 'Nurse visited home and discussed asthma, its risk, treatment and factors likely to provoke attacks. Discussion centred on the affected child's treatment and the nurse indicated appropriate methods of preventing or curtailing attacks.' Educational materials used/provided: Discussion with patient Programme topics: As above Incentives: Not reported CONTROL GROUP: Routine care N (completed): 43
Outcomes	Outcomes measured: Peak Expiratory Flow Rate, Symptoms, Familles ability to use objective signs of asthma severity via a structured questionnaire to produce a 'Theoretical Knowledge Score' Outcomes reported: As above Time points: Baseline, and 3 other time points for both the PEF, symptoms and knowledge - not reported when these were
Notes	Funding: Allan and Hanbury (British Pharmaceutical company) assisted in purchase of peak flow meters Costs: Direct cost of nurse calculated from information recorded prospectively by the nurse - each visit cost 4.30 pounds. Also calculated to cost 15 pounds/patient/6 months.

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Randomisation performed by statistician, specific methods not described.
Allocation concealment (selection bias)	Unclear risk	Allocation process not clear or mentioned
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	"The treatment groups identity was hidden from the nurse investigator who collected the data from all 86 families and was not involved in the provision of their care"

Incomplete outcome data (attrition bias) All outcomes	Unclear risk	"51 our of 86 in the fourth assessment of peak expiratory flow had a complete data set" attrition not clearly reported for other aspects of the study.
Selective reporting (reporting bias)	Unclear risk	No protocol available to determine selective reporting
Other bias	Unclear risk	No protocol available to determine potential for other bias Was a cluster RCT. Assessed unclear for recruitment bias - as not clearly reported. Assessed low risk for baseline characteristics - mean peak expiratory flow was similar between intervention and control at baseline Assessed unclear for adjustment for clustering in analysis as there was no mention of adjustments for clustering in the analysis.

Carswell 1989

Study characteristics	
Methods	Study design: Randomised controlled trial Recruitment setting: 1 Urban children's hospital and 1 residential camp Study duration and start date: Start date April 2007, total duration not reported
Participants	N (completed) = 43 families (38) Mean age (range): 10.3 (8-13) Gender (%male): 63% Asthma severity: Severity not specifically reported. "Poorly controlled" (number of symptom days in the last 2 weeks intervention 4.2, control 3.5; and number of children with one or more days off school in the last 4 weeks Intervention 48%, control 35%). 93% of all participants had a verified ED visit for asthma over the 12 month period preceding baseline. The number of caregiver reported ED visits for asthma for the same period ranged from 0-12, with a mean of 3.6 (SD 2.7). 35% reported a hospitalisation for asthma during the past 12 months, with 20% reporting more than one admission Socioeconomic indicators: Over a third (36%) did not finish high school, 23% had a high school diploma only, and 33% reported some college Ethnicity: 98% African-American Eligibility criteria: Initial eligibility criteria were: (a) residence in one of two urban counties, (b) child age 8 to 13, (c) Medicaid or State Children's Health Insurance Program, (d) current prescription of a daily controller agent, and (e) poorly controlled asthma, defined as one or more ED visits or hospitalizations for asthma or prescription of more than one oral corticosteroid burst within the past year. Medical criteria were ascertained by medical record review. People meeting those categories were then screened for whether the parent was stressed or overwhelmed by the child's asthma and the other things they need to do to survive their life. Parents who had high levels of psychosocial stress and whose child agreed to take part in the study were enrolled.
Interventions	Educator: Two trained asthma counsellors - a postdoctoral fellow in psychology and a respiratory therapist Audience: Child and family Where delivered: Home INTERVENTION GROUP: HOME BASED FAMILY INTERVENTION (HBFI) - a home based, tailored, family intervention. N (completed): 23 families (21) N, duration and frequency of education sessions: 4 - 6 meetings over a period of 4 months. Average length of visit was 78 minutes (SD 11.0) with a range of 64-96 minutes. Educational/self-management strategy: Addressed family-selected goals targeting asthma management and stressors. During first visit, the asthma counsellors discussed the specific asthma management challenged identified from the baseline assessment and asked the family to choose 3-4 goals corresponding to the prepared modules, with at least two devoted to asthma management, and one to two related to psychosocial issues. Asthma counsellors implemented the prepared modules matching the family's goals. "All modules aimed to reframe problems in positive and/or relational terms, strengthen family bonds, identify and promote family strengths, and use problem-solving to cope with stress or barriers to effective asthma management."

	Educational materials used/provided: provided feedback on the child's lung functioning (using a portable spirometer) and MDI/spacer technique at all visits. Programme topics: Tailoring of intervention content was a collaborative process. "Curriculum content was guided by staff expertise in asthma education and family interventions, findings from our focus groups (Laster, Holsey, Shendell, McCarty, & Celano, 2009), and criteria developed by the CAB. Content on asthma management was adapted from the National Cooperative Inner City Asthma Study intervention (Evans et al., 1999). All modules aimed to reframe problems in positive and/or relational terms, strengthen family bonds, identify and promote family strengths, and use problem-solving to cope with stress or barriers to effective asthma management. The curriculum was piloted with one family, refined for the trial, and reviewed by two CAB members for adherence to content criteria. The HBFI manual consists of an introduction, eight modules on asthma management, and eight modules on psychosocial issues." "During the first visit, the asthma counsellors discussed the specific asthma management challenges identified from the baseline assessment, and asked the family to choose three to four goals corresponding to the prepared modules, with at least two devoted to asthma management, and one to two related to psychosocial issues. Specific family processes addressed in the psychosocial modules were family rules and discipline, family communication, and caregiver stress or depression. In subsequent sessions, ACs implemented the prepared modules matching the family's goals. If the child did not have a written asthma action plan, Developing a Written Asthma Action Plan was implemented first. All of the modules were designed to be implemented with the target child and his or her family members" Incentives: Not reported Compliance: 21 families received at least one home visit. Mean visits received 4.6 (SD 1.2) with 18 (86%) receiving 4-6 visits. CONTROL GROUP: Enhanced Treatment as Usual (ETAU) - one home visit to design a written asthma action plan. Trigger control resources were provided, ACs provided feedback on child's lung function and MDI/spacer technique, and implemented the 'Developing a Written Asthma Action Plan' module. N (completed): 20 families (19) All families in both control and intervention group received an asthma action plan and dust mite covers
Outcomes	Outcomes measured: Asthma management (assessed with the Family Asthma Management System Scale - FAMSS), MDI/Spacer technique (assessed with the metered dose inhaler checklist (MDIC), asthma morbidity (operationalised as number of school days missed - caregiver reported, asthma symptom days - caregiver reported and urgent health days for asthma - ED and admissions using medical records), family functioning, caregiver stress (three measures - the PSI-SF, the BSI and the CRISYS-R). Outcomes reported: Family asthma management, asthma morbidity - number of symptom days, number of school days missed in last 4 weeks (dichotomised to either 0 or more than 1 school day due to significant skew), MDI/spacer technique, PSI, BSI and CRISYS-R (at screening only), Brief Symptom Inventory. ED visit in 1 year interval following post (An ED visit was considered asthma-related if the diagnosis was asthma exacerbation or status asthmaticus, or if asthma treatment was given. ED visits occurring on consecutive days were counted as one visit, and the visit with the most severe episode was recorded). Hospitalization between baseline and 1 year after postintervention Timepoints: Asthma management, morbidity, family functioning, caregiver stress assessed at baseline, postintervention (4 months following the first home visit), 6 months after the intervention. ED visits and hospitalisations ascertained by medical record review for a year after the intervention.
Notes	Funding: supported by a grant from the National Heart Lung & Blood Institute

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'families were then randomly assigned to the Home-Base Family Intervention or the control group, enhanced treatment as usual, by block randomisation within age group (8 to 10 vs. 11 to 13)'
Allocation concealment (selection bias)	Unclear risk	Unclear if allocation concealed
Blinding of participants and personnel	Unclear risk	Not possible to blind patients or educators

(performance bias) All outcomes		
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'During these evaluation visits, trained assistants blind to group assignment re-administered the measures obtained at baseline'. 'Participants' videotaped demonstrations of their MDI/spacer technique were rated by a trained team blind to group assignment including a certified asthma educator and/or a paediatric allergist, with discrepancies reconciled by consensus.'
Incomplete outcome data (attrition bias) All outcomes	Low risk	Most families completed study, minimal withdrawals and all accounted for
Selective reporting (reporting bias)	Unclear risk	No prespecified protocol
Other bias	Low risk	No other biases identified

Celano 2012

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: paediatric outpatient office in Sudbury, Ontario, Canada Study duration and start date:
Participants	N (completed) = 40 families with 56 children. Intervention delivered to parents. (35) Mean age (range): 5 years (1 to 10) Gender (% male): 43% Asthma severity: collected, but not reported Socioeconomic indicators: well-supported financially and most families had 2 parents. 67% earned over CAD 40,000 Ethnicity: Eligibility criteria: Parents with at least 1 child, 10 years old or younger with a diagnosis of asthma for greater than 6 months. Parents must have responsibility for the management of the child's asthma, no previous participation in asthma health education programme, avoid any other education programme, and be able to read, write and communicate in English
Interventions	Educator: principal investigator of the project Audience: parents Where delivered: home-based INTERVENTION GROUP N (completed): 20 (18) families N, duration and frequency of education sessions: a single, 2-hour session Educational/self-management strategy: education session based on the Air Force Asthma Program Educational materials used/provided: childhood asthma education booklet representing conventional care Programme topics: provides information on asthma and decreases concerns related to the care of a child with asthma. Reinforcement of rational for therapy, compliance and follow-up. Assist the parent in the day-to-day management of their child's asthma and smoking cessation and alternative coping strategies to enhance respiratory health. CONTROL GROUP: received childhood asthma education booklet representing conventional care. The content of the education was the same for both groups, but the mode of delivery varied. N (completed): 20 (17) families
Outcomes	Outcomes measured: parental coping measured by PPI, quality of life measured by the PACQLQ and change in asthma measured by the CPC survey Outcomes reported: final values not reported apart from for caregiver perception of change Time points: 3-month follow-up
Notes	

	Cost: no detailed costing done, but asthma educator costs CAD 30 to 34 per hour inclusive of transport costs Funding: Ontario Lung Association awarded a fellowship to fund project

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"Families were randomly assigned to one of the treatment arms using the Moses-Oakford method, and were assigned in blocks to assure equal numbers in each group"
Allocation concealment (selection bias)	Unclear risk	"Consecutive asthmatic patients and their families were recruited by the office staff and referred to the researcher, unaware of the allocation schedule." Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	High risk	Not described, but study described as "non-blinded" so assumed not done
Incomplete outcome data (attrition bias) All outcomes	Low risk	5 families lost to follow-up; 2 from experimental, 3 from control
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	Low risk	Only self reports possible

Dolinar 2000

Study characteristics

Methods	Study design: Parallel, randomised, controlled trial Recruitment setting: 14 HeadStart preschool programs across 78 sites in Baltimore, Maryland, US (HeadStart - federally funded national program providing preventative health services and screening to low-income preschool students by engaging and empowering parents) Study duration and start date: 1 April 2011 to 31 Dec 2017 for data collection. Data analysed from 18 March 2018 to 30 August 2018
Participants	N (completed) = 398 children and their caregivers (341 at 3 months follow up, 328 at 6 months follow up, 325 at 9 months follow up, 310 at 12 months follow up) Mean age (range): 4.2, SD 0.7 (2-6) Gender (%male): 62.1% Asthma severity: Not reported. Used asthma control - Baseline with 'uncontrolled asthma' 236/398 (59.3%). Used TRACK score for asthma control. Diagnostic criteria: Physician diagnosed asthma (verified by primary care practitioner) Concurrent treatment: not reported Socioeconomic indicators: 185 participants (46.7%) unemployed with 92 (46.5%) in intervention; 93 (47%) in control. 154 participants (39.8%) annual household income < USD 10,000 with 42.5% in intervention, 37.1% in control. Ethnicity: 379 of all participants 'Black' (95.2%); 189 (95%) in intervention, 190 (95.5%) in control Eligibility criteria: 2-6 year old children, with a physician diagnosis of asthma with a caregiver with the ability to speak English, enrolled in Head Start and resides in Baltimore City or Baltimore County

Interventions	Educator: Head Start staff or Johns Hopkins School of Medicine asthma educators who were trained to deliver asthma education to increased applicability to a real world setting Audience: Caregivers Where delivered: Home for ABC intervention and telephone 'booster' calls INTERVENTION GROUP: Asthma Basic Care (ABC) family education combined with Head Start asthma education. N (completed): 199 (160 at 3 month follow up, 153 at 6 month follow up, 159 at 9 month follow up, 147 at 12 month follow up) N, duration and frequency of education sessions: The ABC family intervention consisted of four 30- to 45- minute in-person, at-home asthma management educational sessions and 3 booster calls tailored to the needs of preschool children in urban home environments Educational/self-management strategy: Asthma management sessions and booster phone calls. Content delivered via iPads and included images and video content for low health literacy levels. Interventionists encouraged participants to write or circle information on the iPads. During the first home visit, the research assistant obtained written consent from the caregiver, completed a structured survey with the caregiver, reviewed medication availability, and completed an environmental home screening. Educational information was tailored to the child's asthma treatment regimen and specific triggers and caregiver concerns. The delivery of the information using technology that is tailored to the specific child's treatment plan was a novel method to provide education on guideline-based asthma management. Families participated in problem-solving and goal setting with the interventionists at the end of each session to address barriers to asthma management. The intervention was designed such that most asthma education was provided within the initial visit. Intervention families also received 3 follow-up booster telephone calls after each assessment visit (3, 6, and 9 months) to check in on treatment goals and provide guidance if needed. Booster telephone calls included a review of current asthma symptoms and the current asthma treatment plan. Programme topics: Content was based on NAEPP guidelines addressed core areas of asthma management, including sx management, medication use, asthma action plans, acute care for exacerbations, environmental triggers, and working with HCPs. Incentives: Caregivers were offered compensation for completing assessments ($50 for home visits and $30 for telephone visits) but not for completion of intervention activities to reflect a real-world implementation. When 80% of a class was screened, Head Start staff were compensated $50 for their effort; payment was provided regardless of study eligibility or enrolment. Compliance: 144 (72.4%) out of 199 randomised, completed at least 1 home intervention session, with 69 (34.7%) completing all 4 home visits. 71 families (35.8%) completed all the booster telephone calls after the 3-, 6-, and 9-month follow-up surveys. 147 (73.9%) completed 12 month follow up CONTROL GROUP: 'School-based Head Start asthma education alone'. 'The Head Start asthma educational program was implemented at all participating Head Start programs. Asthma educators at Johns Hopkins School of Medicine served as expert facilitators for each Head Start program to provide guidance about asthma and increase awareness. Each program was encouraged to develop and implement program activities that would meet their families' needs. These activities included parent workshops, annual health fairs, distribution of written materials, and attendance at quarterly Health Advisory Committee meetings.' N (completed): 199 (181 at 3 month follow up, 175 at 6 month follow up, 166 at 9 month follow up, 163 at 12 month follow up)
Outcomes	Outcomes measured: Primary outcome- Asthma control as measured by the TRACK score. Secondary outcomes included use of health care services, courses of OCS, and asthma-related caretaker quality of life. Outcomes reported: As stated Time points: Assessment visits were completed at baseline and 3, 6, 9, and 12months
Notes	Funding: research was supported by grants R18 HL107723, T32HL007534-36, and F32HL149195-01 from the NHLBI.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomisation scheme was developed by a statistician using a random number generator'
Allocation concealment	Low risk	'Randomisation assignments were placed into sealed envelopes that were opened after families completed baseline surveys'

(selection bias)		
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'Research assistants who completed assessments were blinded and were different from intervention staff'
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Intervention group: 74% completed 1 home visit, 84% completed 3 mo vs. Control group 91% completed 3 mo. Unclear withdrawal definition & reasons for withdrawal ?related to intervention. "Initial intention-to-treat analyses compared the ABC plus Head Start group with the Head Start alone group at each point for outcome measures." Intention-to-treat analyses only reported.
Selective reporting (reporting bias)	Low risk	All outcomes reported as per protocol
Other bias	High risk	ED visits and hospitalisations self reported and not verified using hospital records

Eakin 2020

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: St Louis Children's hospital (SLCH; hospitalised children), Missouri, USA Study duration and start date: April 1997 to March 2001
Participants	N (completed) = 191 (189); intervention delivered to parents Mean age (range): 4.9 (2 to 8) Gender (% male): 59% Asthma severity: mean hospitalisations in the previous year; treatment 0.47 (SD 0.86) usual care 0.49 (SD 0.79). Mean ED visits in the previous year treatment 1.07 (SD 1.81) usual care 0.94 (SD 1.39). Parents rating of symptoms in the previous week of randomisation (1 = very often to 3 = never) treatment 2.28 (SD 0.52) usual care 2.35 (SD 0.50) Diagnostic criteria: not specified Concurrent treatment: not specified Baseline lung function: not specified Socioeconomic indicators (parents' education): no high school diploma 33%, high school qualification 40%, some college 23%, college graduate 4% Ethnicity: predominantly African American Eligibility criteria: parents of children 2 to 8 years old who had been hospitalised for asthma at SLCH, received Medicaid, diagnosis of asthma made by admitting physician, resident of predominantly African American population defined by zip codes in St Louis City and county, phone number on record. Excluded if the phone was disconnected, 10 phone calls went unanswered or refusal to participate.
Interventions	Educator: 3 trained asthma educators, African American women from the same neighbourhood as the participants who were high school educated and full-time university employees Educators received 3 months initial training in: asthma disease process, asthma action plans, communication techniques, social support, behaviour change strategies (including Transtheoretical Model). Weekly training thereafter with supervision meetings with nurse, psychologist and expert in Transtheoretical Model. Audience: parents of children with asthma Where delivered: in the home or a ‘neutral site, i.e. local fast food restaurant’ INTERVENTION GROUP

	N (completed): 97 (96) N, duration and frequency of education sessions: 2 home visits and telephone calls biweekly for 3 months, then monthly for duration of 2-year intervention Educational/self-management strategy: 1st and 2nd visit was a review of 7 key asthma management behaviours (see below) with parent and assessment of their readiness to adopt them (using Transtheoretical Model). Subsequent visits consisted of problem-solving and adoption of 7 key behaviours. Emphasis on use of asthma action plan. If child was re-hospitalised during the study, coaches reinitiate biweekly contact with parents. Coaches also discussed general stressors such as moving residence, social service resources, housing, illness of parent and new jobs. Coaches categorised parent's readiness to adopt management behaviours using the Transtheoretical Method, according to stage pre-contemplation, contemplation, preparation, action or maintenance. Use of asthma action plan emphasised at all stages. Other 6 behaviours discussed in order of parent's readiness to adopt them and individually tailored. The intervention was "implemented in a flexible manner that followed a nondirective supportive style" tailored to individual. The style was co-operative and accepting of feelings and choices, i.e. coaches said they would call back in a few weeks to "check in with you" not "check up on you". Coaches' approach was reliable and persistent, but non-demanding. Educational materials used/provided: not specified Programme topics: 1) use of an Asthma Action Plan; 2) administration of asthma controller medications; 3) administration of asthma-reliever medications at first symptoms; 4) attendance at asthma monitoring visits with a primary care provider every 3 to 4 months; 5) development of a collaborative partnership with the primary care provider; 6) minimisation of exposure to second-hand tobacco smoke; 7) minimisation of exposure to cockroach allergen Incentives: USD 10 for completing baseline survey, USD 10 for completing evaluations surveys by telephone each at 6, 12 and 18 months. USD 50 given on completion of final survey and home visit at 24 months. Compliance: 4% of patients did not participate in any education or phone calls, 86% had contacts through more than 4 of 8 quarters, and the mean number of contacts was 21 over the 2 years CONTROL GROUP: standard inpatient care pathway including asthma education and discharge planning, asthma action plan and suggested to attend a follow-up appointment with the primary care provider within 1 week of discharge N (completed): 94 (93)
Outcomes	Outcomes measured: hospitalisations, coaches records, telephone surveys (details not described) Outcomes reported: as above and ED visits not followed by hospitalisations Time points: hospitalisations were monitored from the hospital admissions register monthly and reported at 24 months. Telephone surveys: 0, 6, 12, 18, 24 months.
Notes	Cost: not specified Funding: NHLBI, NIEHS, peers for progress of the American Physicians Foundation and Eli Lily grants

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"On the basis of random numbers, under supervision by the project statistician" "Those randomised to the asthma coach group were assigned to a coach based on openings in their case load"
Allocation concealment (selection bias)	Unclear risk	Unclear
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment	Low risk	"Those abstracting hospitalisation data from charts were blind to condition and to the nature of the comparison between coaching and usual care" "...survey workers who were blinded to condition conducted computer-assisted

(detection bias) All outcomes		surveys with parents by telephone." All emergency care and hospitalisations due to asthma were scanned electronically using case numbers, addresses, names of guardians/children and child's date of birth
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Two withdrawals due to transfer of child custody "St Louis has a second paediatric hospital, Cardinal Glennon Children's Hospital but its records were not reviewed" "it is assumed that in the study cohort more than 95% of readmissions would be to SLCH, providing nearly complete ascertainment of all readmissions among study participants" Comment: there might have been hospitalisations in the other hospital that have gone unrecorded. The authors discuss the possibility that the true figure may be lower.
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	Unclear risk	Same rational as above regarding incomplete capture of hospitalisations with SLCH records only

Fisher 2009

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial. STAMP trial Recruitment setting: 7 centres in Texas, USA Study duration and start date: August 2003 to May 2006
Participants	N (completed) = 473 (301) Mean age (range): ~9.5 (5 to 17). Adults and children were enrolled in this study, but data were presented separately Gender (% male): 59% Asthma severity: mild intermittent 6.7%; mild persistent 28.8%; moderate persistent 33.6%; severe persistent 30.9% Diagnostic criteria: NAEPP and GINA 2002 Concurrent treatment: patents on SABA (95%); LABA (38%); OCS (5%); theophylline (< 1%); LTRA (41%); ICS alone (32%) Baseline lung function: FEV1 %predicted control group 97.4 (15.9); AM group 97 (19.5); ADM 100.3 (21.5) Socioeconomic indicators: Medicaid or SCHIP (56%); enrolled in indigent programme (2%); private insurance (36%); uninsured (6%) Ethnicity: black/other 17%; Caucasian 15%; Hispanic 68% Eligibility criteria: age 5 to 64 years with a physician diagnosis of asthma and access to telephone, access to a primary care provider (those without were provided telephone numbers for suitable clinics) AND one or more of the following: One hospitalisation, emergency department visit with a diagnosis of asthma within the previous 12 months or 4 or more office visits with a diagnosis of asthma within the previous 12 months or 6 or more canisters of inhaled beta2-agonist in the preceding 12 months or physician diagnosis of moderate to severe persistent asthma based on symptoms and/or pulmonary function testing. Exclusion criteria Other lung diseases with a possible reactive component, any disease other than asthma requiring long-term systemic corticosteroids, enrolment in any other asthma disease management programme, plan to move out of local area within the next 18 months.
Interventions	Educator: trained programme nurse Audience: There were 2 intervention groups of different intensity Intervention group: augmented disease management. Telephone disease management plus home visits. N (completed): 157 (94) Where delivered: telephone calls to child's home and home visits N, duration and frequency of education sessions: 6 or 7 telephone calls focusing on disease management and 4 home visits at 1, 2, 3 and 6 months Educational/self-management strategy: telephone call 1. Evaluate existing self-management strategy, health status and educational needs. Provide individual advice and training and

	developed written action plan. Subsequent calls reviewed written action plan and provided more advice and training. 24-hour hotline available which patients were encouraged to call if they experienced symptoms. Programme nurses faxed reports/recommendations to primary care provider who ultimately directed care. Patients also received 4 home visits from a pulmonary therapist. A locally developed programme structure around a national guideline based list of education topics. Provided hands-on instruction in use of equipment, reviewed an encouraged individualised asthma action plan and conducted a home environmental evaluation. Educational materials used/provided: an asthma action plan was provided if the child did not already have one Compliance: 70% completed at least 80% of the programme - although these data were for adults and children CONTROL GROUP: routine care. Spacers and peak flow meters were made available to control group on request. N (completed): 159 (2)
Outcomes	Outcomes measured: primary outcomes: time to first asthma-related emergency department visit or inpatient hospitalisation, AQLQ/PAQLQ overall score, and rates of asthma-related utilisation (inpatient admissions, ED visits and urgent office visits for asthma), respectively. Secondary outcomes: rate of initiation of controller medications, number of oral corticosteroid bursts prescribed during office visits, asthma symptom scores, and number of school days missed Symptoms measured on the Lara Asthma Symptom Scale and quality of life measure on PAQLQ and PACQLQ Outcomes reported: although "asthma symptom diaries" was in the initial protocol, authors decided not to use these pre-enrolment due to concerns over feasibility, reliability and validity Time points: 6 and 12 months. HCU outcomes collected through medical record review and telephone calls at 2-monthly intervals.
Notes	Cost: the telephone-only programme cost USD 531 per patient, and the augmented programme that included home visits cost USD 737 per patient Funding: Grant from US department of health and human services and the CDC There was also an adult arm of the trial where the same education was conducted in patents of 18 to 64 years of age

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"Individuals who met inclusion criteria and signed a consent form were randomly assigned to 1 of the 3 study groups, using a sequence of randomly permuted blocks generated with the statistical package Stata."
Allocation concealment (selection bias)	Low risk	"The randomisation sequence was transferred to a series of consecutively numbered, sealed cardboard randomisation boxes that contained a printed sheet in English and Spanish describing the participant's study group assignment as well as a holding chamber (spacer) for those randomly assigned to either of the intervention groups." "Boxes were packaged so that blinded research staff could not identify the group assignment from the sound or weight of the box. Non blinded study coordinators were available to answer participant questions about the study".
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Data collected by trained research staff blinded to intervention group. Medical record abstraction was performed by trained study staff who were blinded to study group
Incomplete outcome data (attrition	Low risk	"All participants were telephonically polled regarding healthcare utilization every 2 months throughout the trial. Study staff requested medical records for both inpatient and outpatient encounters from all identified providers and healthcare facilities for the entire duration of a participant's enrolment in the trial."

bias) All outcomes		"comprehensive healthcare utilization data were obtained for 99% of participants"
Selective reporting (reporting bias)	Unclear risk	"Our initial protocol used symptom-free days as 1 of the primary outcomes. However, before enrolment of study patients, we made a decision not to use asthma symptom diaries, based on concerns about feasibility, reliability, and validity." Comment: assumed done
Other bias	Low risk	Comprehensive healthcare utilisation data collected through the use of medical record review

Galbreath 2008

Study characteristics	
Methods	Study design: 3-arm parallel, randomised, controlled trial Recruitment setting: Children's Hospital of Wisconsin ED Study duration and start date: February 2003 to May 2004
Participants	N (completed) = 234 (180) Mean age (range): 6.8 years (study criteria 2 to 17 years) Gender (male): 66% Asthma severity: mild intermittent 30%; mild persistent 28%; moderate persistent 28%; severe persistent 14% Diagnostic criteria: NAEPP (1997) Concurrent treatment (uses controller medications): 60% Socioeconomic indicators: 60% public insurance Ethnicity: black 69%; white 21%; Latino 8% Eligibility criteria: residents of Wisconsin, aged 2 to 18 years of age, treated at the ED for acute asthma (defined as wheezing or respiratory distress treated with at least 1 inhaled bronchodilator treatment in a patient with physician-diagnosed asthma or history of wheezing treated with beta-agonists). Exclusions: Non-English speaking caregivers and participants with other chronic diseases (e.g. CF, bronchopulmonary dysplasia), tracheostomy, who had previously been enrolled in the study, enrolled in ED Allies tracking system (web-based computer database of ED visits for asthma or wheezing illnesses), or previously received care co-ordination or case management.
Interventions	Educator: case manager (nurse or social worker) Audience: families Where delivered: home (and telephone calls) INTERVENTION GROUP (intensive primary care linkage and care co-ordination/case management - CC/CM) N (completed): 118 (81) N, duration and frequency of education sessions: 6 home sessions (average 4/patient; 1st visit 60 minutes and subsequent 30 minutes), several phone calls (average 2.3 calls/patient) Educational/self-management strategy: Patients received standard education and discharge planning in ED same as control group. Intensive primary care linkage: copy of ED chart and letter recommending asthma care plan faxed to PCP office. Research co-ordinator called PCP office to notify of ED visit and enquire if follow-up scheduled. Subjects called day after ED visit and asked if follow-up arranged; could get assistance in making appointment (also called on days 3, 5, 7 until appointment reported); day 14 contacted again to see if follow-up visit made; if no PCP, given list or instructed to call insurance carrier for list. CC/CM: patients then enrolled in Flight Asthma Milwaukee (FAM) Allies coalition. This programme helped co-ordinate health and social services across different agencies and clinicians for children with asthma and their families. Patients were assigned to a nurse or social worker case manager (depending on patients' health insurance cover) who then: a) performed standardised asthma needs assessment and environmental and smoking assessments; b) identified and addressed family asthma goals by using a personalised care plan; c) provided asthma education by using the FAM Allies asthma toolkit and additional materials; and d) made referrals to community and other services as appropriate. Educational materials used/provided: FAM Allies asthma toolkit Programme topics: FAM Toolkit covers the following topics: trigger management, medications and delivery devices, self-management tools (written action plan and asthma diaries, peak flow meters) Incentives: none Compliance: 72% (85/118) had at least 1 home visit; average of 4 successful visits per patient and 2 missed per patient. 69% (81/118) completed all telephone follow-up at 1, 3 and 6 months

	CONTROL GROUP: Standard education and discharge planning in ED, including: Mastering Asthma (videotape) shown during ED visit, assessment and teaching of proper use of peak-flow meter and metered-dose inhaler with spacer device, acute asthma medications for current exacerbation, instructions to follow-up with primary caregiver within 7 days, written asthma care plan based on chronic symptoms N (completed): 116 (99)
Outcomes	Outcome measured: ED visits for asthma (self reported and through web-based tracking system), number of hospitalisations for asthma, use of controller medications, Integrated Therapeutics Group Child Asthma Short Form (ITG-CASF) quality of life score, smoking status of family and caregivers Outcome reported: ED visits for asthma (self reported and tracking system), use of controller medications, ITG-CASF quality of life score, smoking status of family and caregivers
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated list
Allocation concealment (selection bias)	Low risk	Sealed, opaque envelope, sequentially numbered study packet
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Single-blind (person collecting data through telephone interviews was blinded)
Incomplete outcome data (attrition bias) All outcomes	High risk	69% completed in CC/CM; 85% completed in control. The 77 patients lost to follow-up or excluded from analysis (including 2nd intervention arm of intensive primary linkage only) were similar to those completing the study with respect to age, chronic asthma severity, ED visits in previous 12 months. However, lost to follow-up were more likely to have public insurance and be non-white. Although the authors attempted to describe the baseline characteristics of all those lost to follow-up or with incomplete data, there was an imbalance in the control group (15%) versus the intervention group (31%).
Selective reporting (reporting bias)	High risk	Hospital admissions in previous 6 months not reported although measured
Other bias	Low risk	Provide self reported ED visits as well as those obtained through web-based tracking system

Gorelick 2006

Study characteristics

Methods	Study design: Randomised controlled trial Recruitment setting: 2 paediatric outpatient healthcare centres, 1 children's hospital emergency department Study duration and start date: July 2009 - December 2013
Participants	N (completed) = 151 (Follow up at 3 months = 131, follow up at 6 months =114, follow up at 9 months = 113, follow up at 12 months = 112) Mean age (range): 5.7 (2-9) Gender (%male): 64% Asthma severity: Not reported. At baseline 90% had either poorly or very poorly controlled asthma, and 63% had been hospitalised for asthma

	Diagnostic criteria: NAEPP for diagnosis Concurrent treatment: Not specifically reported, based on inclusion criteria had to have a prescription for an inhaled corticosteroid as an MDI Socioeconomic indicators: 42% had a caregiver that was employed. 27% of caregivers had less than a high school education. Ethnicity: 76% Spanish/Hispanic/Latino; 22% black/African American Eligibility criteria: Had to live in the Bronx, be between 2-9 years old with a diagnosis of persistent asthma based on national guidelines, and have a prescription for an inhaled corticosteroid as a MDI. If they were 2 years old at recruitment they must have had at least two prior episodes of wheezing that were reversible with beta-agonists. Otherwise, participants needed to have at least one asthma exacerbation in the past year requiring an acute or same-day clinic visit, ED visit, or hospitalisation. Primary caregivers also needed to speak English or Spanish and have a phone.
Interventions	Educator: CHW who shared their racial and ethnic backgrounds Audience: Caregiver and child Where delivered: Home INTERVENTION GROUP: N (completed): 75 (Receieved allocated intervention = 66, follow up at 3 months = 63, follow up at 6 months =55, follow up at 9 months = 54, follow up at 12 months = 53) N, duration and frequency of education sessions: 6 bi-weekly one hour sessions Educational/self-management strategy: Asthma education sessions delivered at home, geared towards the caregiver and the child. CHWs followed a script with developmentally appropriate materials. Families were also asked to complete assignments between sessions. Materials were written at a 5th grade reading level and were available in English and Spanish. Educational materials used/provided: Content for the sessions was adapted from the evidence-based Wee Wheezers and Wee Wheezers at Home curricula to maximize relevance to low-income minority families in the Bronx Programme topics: Following topics covered: (1) Overview of asthma including signs and symptoms; (2) Asthma medications, including management practices, MDIspacer administration and addressing barriers to adherence; (3) Symptom prevention, including home environmental assessments and information on eliminating triggers; (4) Review of asthma action plans; and (5) Techniques for communicating asthma-related needs to teachers, family members and physicians. Incentives: Caregivers received USD5 after completion of the baseline assessment, USD5 after completion of the 3-month survey, USD10 after completion of the 6-month survey and USD15 after completion of the 12-month survey. Children received a small toy or book at each visit as well as a hypoallergenic pillow or mattress cover. Compliance: 66 received allocated intervention. 57 (76%) - completed at least 5 of the 6 lessons. (9 completed 1-4 lessons (12%); and 9 did not complete any (12%)). Lost to follow up at 3 months = 12, lost to follow up at 6 months =8, lost to follow up at 9 months = 1, lost to follow up at 12 months = 1 CONTROL GROUP: Usual care please one visit from CHW after completion of the study N (completed): 76 (Follow up at 3 months = 68, follow up at 6 months =59, follow up at 9 months = 59, follow up at 12 months = 59)
Outcomes	Outcomes measured: Primary outcome: caregiver reported asthma symptom days (mean number of asthma symptom days in the past 14 days. Asthma symptom days was defined as the maximum of the following outcomes: number of days when the child experienced daytime symptoms such as wheezing, chest tightness or cough; number of days the child had to slow down or stop activities because of asthma; and number of nights the child woke up due to asthma). Secondary outcomes: asthma-related healthcare utilization, defined as the number of asthma-related hospitalizations, ED visits, or urgent clinic visits; caregivers' asthma knowledge, illness representation, management behaviours and MDI-spacer administration technique, medication adherence, and home environmental triggers. Outcomes reported: As above Timepoints: Baseline, 3, 6, 9, 12 months
Notes	Funding" 'The study was funded by the American Lung Association Clinical Patient Care Grant (CG-1,20 837-N, Reznik – PI), the New York Community Trust Foundation (Reznik – PI), Stony Wold-Herbert Fund (Reznik – PI), Monaghan Medical Corporation (Reznik – PI) and Department of Pediatrics, the Children's Hospital at Montefiore.'

Risk of bias

Bias	Authors' judgement	Support for judgement

Random sequence generation (selection bias)	High risk	Open label randomisation
Allocation concealment (selection bias)	High risk	Open label randomisation
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Unclear if outcome assessors blinded
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	up to 16 % participants lost to follow up at each follow-up point
Selective reporting (reporting bias)	High risk	Means reported without a measure of variance (e.g. SD), so they are not suitable for meta-analysis.
Other bias	High risk	Self-reported outcome measures with unblinded participants including healthcare utilisation which was not verified with medical records. Data based on recall, so subject to recall bias

Jonas 2020

Study characteristics	
Methods	Study design: parallel, randomised, 3-arm controlled trial Recruitment setting: 1 university asthma allergy clinic in an urban medical centre and 1 private practice asthma allergy clinic in a suburban area in New Orleans, USA Study duration and start date:
Participants	N (completed) = 15 Withdrawals: from 20 eligible randomised children, 2 were run as pilot participants and 3 participants dropped out during treatment, so 5 were excluded from analysis Mean age (range): 9 years (7 to 12) Gender (% male): intervention 57%; control 75% Asthma severity: moderate to severe persistent Diagnostic criteria: National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program criteria Concurrent treatment: inhaled corticosteroids (beclomethasone or fluticasone) Baseline lung function FEF 25%-75%, mean (± SD): intervention 76.4 (17.8); control 54.2 (37.5) Socioeconomic indicators: intervention: no high school diploma % mother (father) 0 (0)%, high school qualification 0 (14)%, some college 100 (86)%; control: no high school diploma 50 (57)%, high school qualification 25 (14)%, some college 25 (29)%. Household income intervention < USD 30,000 29%, USD 30,000 to 50,000 14%, > USD 50,000 57%; control < USD 30,000 62%, USD 30,000 to 50,000 13%, > USD 50,000 25% Ethnicity: 20% African American, 53% European American, 27% Hispanic American Eligibility criteria: moderate-severe persistent asthma as determined by their physician according to NHLBI guidelines and had been prescribed an inhaled corticosteroid (beclomethasone or fluticasone). Participants should have been less than 70% adherent to medication during run-in. Participants who were adherent to medication regimen by electronic monitoring during 2 weeks run-in period were excluded.

Interventions	Educator: 2 licensed psychologists and 2 masters-level graduate students in psychology. There was a manual for each session and educators completed a checklist of tasks and treatment met regularly to discuss implementation. Adherence data reviewed and discussed with children/parents at each session Audience: children and parents Where delivered: home-based INTERVENTION GROUP N (completed): 7 (7) N, duration and frequency of education sessions: 6 weekly sessions, approximately 60 minutes in length Educational/self-management strategy: standard care plus a comprehensive asthma education programme. Targeted adherence improvement strategies such as focused education, monitoring, contingency management and discipline techniques. Aimed at improving adherence to ICS. Adherence to inhaled corticosteroids was measured by MDILog (records date, time of activation of a MDI) Pulmonary function tests taken by spirometer Educational materials used/provided: 'The Clubhouse Kids Learn About Asthma' computer program Programme topics: session 1) taught about treatment through interactive computer program The Clubhouse Kids Learn About Asthma and written material covering normal lung function, physiology of asthma, medications, trigger reduction strategy; session 2) monitoring skills and adherence improvement strategies such as taking medication with regularly scheduled activities; session 3) behavioural management techniques to promote adherence; session 4) barriers to adherence for individual families and written solutions provided; session 5) adherence-related cognitive restructuring component – children's thought related to taking their asthma medication were examined; session 6) review of adherence improvement strategies. Incentives: none Compliance: the majority of families did not attend all follow-up sessions CONTROL GROUP: standard care plus a comprehensive asthma education programme delivered in the home, on topic from Air Wise Program. Six sessions of approximately 60 minutes including lung anatomy, identification of asthma triggers and prevention of asthma attacks, treatment and monitoring of symptoms. Also watched The Clubhouse kids Learn About Asthma. Parents and children learned about the importance of communication with service providers and were taught relaxation techniques and coping strategies for stress/asthma management. No targeted adherence strategies. N (completed): 8 (8)
Outcomes	Outcomes measured: adherence, pulmonary lung function Outcomes reported: reported only FEF 25%-75% as it is the most sensitive measure Time points: adherence: measured continually by electronic device at baseline, at each of the 6 visits, 2 weeks after the intervention (called 2 month) and then each month for the following 10 months Pulmonary lung function: each week of baseline and then once a month for 12 months paediatric QoL: once during baseline and the each month for 12 months healthcare cost data collected each month for 12 months
Notes	Cost: expenses related to asthma management incurred by families over the full 12 months; intervention USD 111.63; control USD 214.43, although there was a large standard deviation for the particularly high month in the control group which may reflect a particularly high cost and skew the cost for this treatment Funding: National Institute of Child Health and Human Development Grant number HD34784 Based on the thesis of Jodie L Kamps; we did not look at the thesis in the process of writing this review

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Stratified by age < 9/6 and > 9.7 year prior to randomisation. "A randomisation table was developed by a statistics consultant prior to participant recruitment to assign children to a group…"

Allocation concealment (selection bias)	Unclear risk	"… and we assigned children to groups based on this table."
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Very small study with poor follow-up. However, the losses to follow-up were balanced between arms.
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	Low risk	Only self reports possible

Kamps 2008

Study characteristics	
Methods	Study design: Randomised, controlled, parallel group study Recruitment setting: Community and public health clinics (94%), hospitals and EDs (5%) and community referrals (1%) in King County, Washington Study duration and start date: November 2002 - October 2004
Participants	N (completed) = 309 (271) Mean age (range): 8 years (3-13) Gender (%male): 63.8% Asthma severity: Mild, intermittent: 20.1%, Mild, persistent: 41.1%, Moderate, persistent: 29.8%, Severe, persistent: 9.1% Diagnostic criteria: Provider-diagnosed asthma. Asthma was considered persistent or poorly controlled if the caretaker reported that his or her child had symptoms or used β-agonist medications more than twice per week; the child was using daily controller medication; or the child had a hospitalisation, emergency department visit, or unscheduled clinic visit for asthma in the past 6 months. Used a modified version of the NAEPP for asthma severity Socioeconomic indicators: 50.5% household income <100% of 2001 federal poverty level, 49.5% 100-200% of 2001 federal poverty level; 43% caregivers did not complete high school Ethnicity: 11.3% white, 20.1% Caucasian, 11.0% Vietnamese, 5.8% other Asian, 47.9% Hispanic, 3.9% other Eligibility criteria: Household eligibility criteria were the presence of a child aged 3 to 13 years with clinician-diagnosed asthma that was persistent or poorly controlled; income below 200% of the 2001 federal poverty threshold or the child enrolled in Medicaid; caretaker primary language of English, Spanish, or Vietnamese; and location in King County, Washington.
Interventions	Educator: Community Health Workers (CHWs). CHWs shared ethnic backgrounds with participants and had personal or family experience with asthma. Audience: Children and caregiver Where delivered: Home and clinic INTERVENTION GROUP: 'Nurse + CHW group' - asthma education and support in both clinics and also in participants' homes from community health workers N (completed): 156 (135) N, duration and frequency of education sessions: Participants received 1 intake, and an average of 4.5 follow-up visits during the course of a year as well as interim phone

	communications. Educational/self-management strategy: Used social cognitive theory and the transtheoretical stages of the change model to guide development of the intervention. At the initial visit, CHWs reviewed the participants' asthma control, self-management practices, and access to medical care. Based on this assessment, results from a home environmental checklist and allergy testing, and use of motivational interviewing methods, CHWs developed a set of protocol-driven client and CHW actions. At follow-up visits, CHWs assessed progress and reviewed a core set of educational topics. Also provided social support and advocacy for clients (e.g. housing issues, insurance coverage) Educational materials used/provided: CHWs also fit allergen-impermeable bedding encasements on the children's beds and gave participants a low-emission vacuum with a power head and embedded dirt finder, 2-layer microfiltration vacuum bags, a high quality doormat, a cleaning kit and plastic medication boxes Programme topics: Medication use, action plans, effective use of the medical system, medication adherence, and trigger reduction. Incentives: Grocery gift card incentives ($75) for completing data collection Compliance: 153 received at least 1 CHW follow-up visit after initial intake visit. 'CHWs made a mean of 3.1 follow-up visits to each participant (median, 3.0). The mean and median intervals between first and last intervention visits were 52.6 weeks and 51.9 weeks respectively.' CONTROL GROUP: 'Nurse only group' - Asthma education and support only in clinics from nurses 'nurse-only' group. All nurses employed by the project had same training. Nurses conducted a structured intake that they used in conjunction with allergy test results to develop a client-specific asthma-management plan. They also prepared an asthma action plan which was reviewed by the patient's medical provider. Education began at the initial visit and the nurses offered clients 3 follow-up clinic visits at 3 month intervals. Also referred patients to other resources like social workers and school nurses, and assisted clients in accessing their medical providers (i.e. in making appointments). If a child failed to keep an appointment the nurse would try to call the child's home. After completing exit data collection, members of the nurse-only group received a CHW home visit and the full package of environmental resources. All study participants received spacers and allergen impermeable bedding encasements, and children 7 years or older received a PFM. N (completed): 153 (136) Other: Community health workers completed standardized home inspections and questionnaires using a home environmental checklist for participants both in the nurse-only and nurse + CHW groups. The checklist included items on exposure to allergens and tobacco smoke and home conditions contributing to exposures (e.g., carpeting, food debris and storage, moisture problems). Research nurses at a general clinical research centre collected clinical data and performed skin-prick testing for allergies to dust mite mix, regional mould mix, cats, dogs, cockroaches, and rodents.
Outcomes	Outcomes measured: Primary prespecified outcomes: Asthma symptom-free days (self-reported number of 24 hour periods during the prior 2 weeks without wheeze, tightness in chest, cough, SOB, slowing down activities because of asthma or nighttime awakening because of asthma), paediatric asthma caretaker quality of life scale score (range 1-7, with higher scores indicating better quality of life), and use of urgent health services (self-reported during the last 3 months - i.e. ED, hospital or unscheduled clinic visit). Secondary prespecified outcomes: asthma attack frequency ('a time when asthma symptoms were worse, limiting activity more than usual or making you seek medical care'), rescue medication use, days with activity limited by asthma, and missed work and school days due to asthma. Intermediate outcomes: participants' report of asthma self-management behaviours, controller and medication use, exposure to triggers in the home, asthma self-regulation and social support and self-efficacy specific to asthma. Outcomes reported: As stated Time points: Baseline prior to randomisation. Exit data aimed to be collected exactly 1 year after baseline data collection. Difficulties in scheduling appointments led to delays for some participants. Half had data collected less than 13 months after baseline and 70.5% less than 15 months (range, 247–737 days).
Notes	Funding: This study was primarily funded by grant 1R01-ES11378 from the National Institutes of Environmental Health Sciences (Dr Krieger). Additional support was provided by the Allies Against Asthma Program of the Robert Wood Johnson Foundation; grant U50/CCU011820-02 from the Centers of Disease Control and Prevention Urban Research Centers Cooperative Agreement; and grant MO1-RR-00037 from the National Institutes of Health to the University of Washington General Clinical Research Center.

Risk of bias

Bias	Authors' judgement	Support for judgement

Random sequence generation (selection bias)	Low risk	'We randomly assigned participants to groups using a permuted block design with varying block design. We stratified randomisation into 2 asthma-severity levels (mild and moderate/severe persistent).'
Allocation concealment (selection bias)	Low risk	'Sequence numbers and group allocation were concealed in sealed, opaque, numbered envelopes that were centrally prepared and sequentially provided to the research nurse, who assigned participants to study groups'
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Unclear if nurse collecting exit data were blind to participant allocation. Quote: 'research nurses collected clinical exit data, and a CHW who did not work with the participant collected environmental data'
Incomplete outcome data (attrition bias) All outcomes	Low risk	"We report the results of an as-randomized analysis that used the baseline value of the outcome variable of interest as the exit value for participants who did not complete the study. We examined baseline differences between groups with the t or χ 2 tests and paired t, signed-rank, or McNemar tests for within-group baseline-to-exit changes." "The study was completed by 271 of the participants (88%): 136 in the nurse-only group (89%) and 135 in the nurse + CHW group (87%), including 3 children who were randomly assigned but did not receive the intervention. Among participants completing the study, members of the 2 groups were similar at baseline except for the aforementioned differences in race and housing tenure. " "Of those enrolled, 135 in the nurse-only group and 133 in the nurse + CHW group received the intervention as allocated."
Selective reporting (reporting bias)	Unclear risk	No prespecified protocol
Other bias	High risk	Self-reported outcome measures such as health care utilisation not verified using medical records

Krieger 2009

Study characteristics	
Methods	Study design: Randomised controlled trial Recruitment setting: USA, Chicago - in two specific community areas with historically high Puerto Rican populations. Community Partners (a local health coalition, a parent-led service organisation and a church, school principals, parent organisers, housing organisations, youth programs, neighbourhood associations), school-based and community clinics. Recruitment based on physician referral and community partner referral. Study duration and start date: October 2009 - March 2012
Participants	N (completed) = 101; n=51 in elementary school cohort and n=50 in high school cohort; n=50 were in control and n=51 in intervention arms (89) Mean age (range): Mean age not available. In elementary school cohort - Median age in 'CHW' (intervention) arm 9, median age in 'MAIL' (control) arm 9. In high school cohort - Median age in 'CHW' (intervention) arm 15, median age in 'MAIL' (control) arm 16. Age range 5-18 years. Gender (%male): Elementary school cohort: 61% female; High school cohort: 42%. Asthma severity: Elementary school cohort: CHW arm - 3 low (12%), 9 mild (35%), 7 moderate (27%), 7 severe (27%) (using 12 month severity score). MAIL arm - 5 low (20%), 6 mild (24%), 11 moderate (44%), 3 severe (12%). HIgh school cohort: CHW arm - 4 low (16%), 4 mild (16%), 10 moderate (40%), 4 severe (16%) (using 12 month severity score). MAIL arm - 3 low (12%), 3 mild (12%), 15 moderate (60%), 2 severe (8%) Diagnostic criteria: Asthma control assessed using Asthma Functional Severity Score. A score1 on the Asthma Therapy Assessment Questionnaire was used at screening to determine uncontrolled asthma. Persistent asthma was determined by self-report of having been prescribed an ICS in the last year OR any of

	the following: In the past four weeks, had asthma symptoms (cough, wheezing, shortness of breath and chest tightness)>2 days/week, nighttime symptoms > 3–4 times/week, short-acting b2-agonist use for symptom control > 2 days/week, some interference with normal activity; or 2 exacerbations requiring OCS in the past year. Concurrent treatment: Elementary school cohort: CHW arm 11 participants (42%) had ICS and MAIL arm 12 participants (48%) had ICS at baseline; High school cohort: CHW arm 2 participants (8%) had ICS and MAIL arm 4 participants (16%) had ICS at baseline. Socioeconomic indicators: Caregivers' education - Elementary school cohort: CHW arm <high school - 8 (31%); high school - 5 (19%), >high school - 13 (50%); MAIL arm < high school - 3 (12%), high school 9 (36%), > high school 13(52%). High school cohort: CHW arm < high school - 9 (36%); high school - 7 (28%), > high school - 9 (36%); MAIL arm < high school - 5 (20%), high school 7 (28%), > high school 13(52%). Ethnicity: Elementary school cohort: CHW arm Puerto Rican - 20 (77%); other Latino/Hispanic 3 (12%), other - 3 (12%); MAIL arm Puerto Rican - 2 (8%), other Latino/Hispanic 5 (20%), other 2(8%). High school cohort: CHW arm Puerto Rican - 17 (68%); other Latino/Hispanic 7 (28%), other - 0; MAIL arm Puerto Rican - 20 (83%), other Latino/Hispanic 4 (17%), other 0 Eligibility criteria: Self described Puerto Rican heritage, child between ages of 5-18 years, child lives in the same household as caregiver at least five days out of the week, child has persistent asthma and/or uncontrolled asthma.
Interventions	Educator: Community Health Workers (CHWs), recruited through community advertisements. CHWs trained by certified asthma educator. Audience: Child/adolescent and their family Where delivered: Home visits for intervention arm. INTERVENTION GROUP: Offered four CHW visits over four months in the home. Used lung models and demonstration metered dose inhalers to lead discussions with families, emphasising exploratory learning. N (completed): 51; 26 in the elementary school cohort; 25 in the high school cohort (n=49 at 5-months and n=47 at 12-months) N, duration and frequency of education sessions: Four home visits over four months, duration of visits and frequency unknown Educational/self-management strategy: Face-to-face delivery of education via community health worker using lung models and demonstration of metered dose inhalers etc. Discussed environmental rearrangement, problem-solving, enlisting social support and self monitoring (e.g. when discussing asthma symptoms, participants were encouraged to track their symptoms on a piece of paper for a week.) At end of each visit, families filled out a behaviour change plan on which they wrote one small change they wanted to make in the upcoming month and plan required them to specify the time and manner in which they were going to implement the change, to brainstorm challenges and strategies to assess their confidence Educational materials used/provided: Families given written information on places they could receive medical care, insurance, housing assistance and home remediation services. Families were NOT given supplies such as vacuums or cleaning materials and their physicians were not directly contacted regarding the study because the goal was to empower families to seek out and use existing resources. Programme topics: Both arms covered general asthma facts, controller and quick-relief medications, inhalers and spacers, symptom recognition, asthma triggers and access to care as recommended in the Expert Panel Report 3 Guidelines. Incentives: Participants offered travel assistance to come to the research office for skin allergy testing. Upon completion of data collection, each caregiver (and high school participant) received USD 25. Compliance: In elementary school group: 16 received full four visits (62%) and 19 received CHW at some stage (although 7 participants had not had contact attempted with CHW falsification reports found); in high school cohort 18 received full four visits (72%) and 22 received CHW at some point (although 2 participants had not had contact attempted with CHW falsification reports found). CONTROL GROUP: 'MAIL' group. Received four single-page bilingual colour mailed newsletters that covered the same core asthma topics and self-management skills on the same schedule as the intervention group. No home visits. N (completed): 50; 25 in elementary school group, 25 in high school cohort (n=48 at 5-months and n=46 at 12-months)
Outcomes	Outcomes measured: Primary outcome measure: asthma medication adherence (defined as the objectively measured number of doses of ICS taken compared to ICS-recommended doses). Secondary outcome measure: asthma trigger reduction (obtained by self-report and trigger behaviour summary score, a visual home assessment and objective measurement

	e.g. took some saliva to test for cotinine for smoking). Also asthma control over prior 12 months (using asthma functional severity scale) Outcomes reported: As above Timepoints: Baseline, 5 months and 12 months
Notes	Funding: Funded by the National Heart Lung and Blood Institute of the National Institues of Health: IR21HL087769-01A1 and 1R21HL093346-)1A1

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"Participants were randomised by the data management team using a standard computerized four-block randomisation scheme"
Allocation concealment (selection bias)	Unclear risk	Allocation process not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators. 'Families were told they would receive either four mailed newsletters with information about asthma or four community health worker visits for asthma education'
Blinding of outcome assessment (detection bias) All outcomes	Low risk	"Outcomes were assessed by research assistants blinded to study arm at pre-randomization, five months (immediately after intervention completion) and 12 months post-randomization to determine sustainability" "To ensure no differential ascertainment, bilingual Puerto Rican research assistants blind to study arm collected data in the home"
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Falsified data mentioned in report - Unclear where missing data went and how analysed.
Selective reporting (reporting bias)	Low risk	All outcome measures reported.
Other bias	Unclear risk	Falsification of data from CHW group described

Martin 2015

Study characteristics	
Methods	Study design: Randomised comparative effectiveness trial Recruitment setting: 6 Erie Family Health Centres in Chicago and Evanston, Illinois. Erie mailed introductory letters to potentially eligible families identified through their EMR. Families were then screened for eligibility by telephone. If eligible and interested, a home data collection visit was scheduled. Erie Family Health Centres is a group of community health centres serving mainly low income Hispanic and African American families in the Chicago area. Study duration and start date: March 2016 - 2019
Participants	N (completed) = 223 (210 completed follow up at 6 months, 215 completed follow up at 12 months, 212 completed follow up at 18 months, 209 completed follow up at 24 months) Mean age (range): 9.4 (5-16) Gender (%male): 56% Asthma severity: Low (10%), mild (28%), moderate (43%), severe (19%). Diagnostic criteria: Uncontrolled asthma defined in multiple ways including ACQ score alone, ACT score alone, cACT score alone, oral steroid burst alone or in multiple ways. Concurrent treatment: 44% at baseline had an ICS controlled medication observed in the home, 82% reliever

	Socioeconomic indicators: Low income (62.3% with household income of USD 59,000 or less): < USD 20,000 46 participants, (20.9%); USD 20,000-59,000 91 participants (41.4%). Caregivers' education < high school 64 participants (28.7%), high school or GED 84 (37.7%) Ethnicity: 85.2% Hispanic (of which 83.7% of these claimed Mexican Heritage), 18% Black, 28% White, 54% Other Eligibility criteria: A patient at Erie (Erie Family Health Center), 5-16 years old, living with the caregiver at least 5 days out of the week, and have uncontrolled asthma.
Interventions	Educator: CHW fluent in English and Spanish Audience: Caregiver and child Where delivered: Intended for in the home, although CHWs had the flexibility to meet at other locations. INTERVENTION GROUP: 10 home visits over 12 months for asthma education N (completed): 108 (99 completed follow up at 6 months, 105 completed follow up at 12 months, 105 completed follow up at 18 months, 103 completed follow up at 24 months) N, duration and frequency of education sessions: 10 visits over 12 months offered. Home visits lasted 1-2 hours. Median of 7 visits (interquartile range = 4) received Educational/self-management strategy: CHWs education them on 'core curriculum' which 'consisted of standard topics for asthma educators and intended to reduce impairment (prevent chronic symptoms, reduce use of quick-relief medications, maintain healthy activity level(s) and reduce risk (prevent exacerbations, minimise emergency care, prevent reduced lung growth and minimised adverse therapy effects)'. 'CHWs approached each visit with the intention to teach one or two of the core curriculum topics. Behavior change plans from the previous visit, which are small goals leading to a specific change over a several-week period, were also reviewed and discussed. The main portion of the visit involved an education session around a core curriculum topic and when a CHW noted a barrier in the delivery of the education, she then incorporated a relevant self-management skill. After each visit, the CHWs filled out a report of the topics covered, behavior change plans, and potentially relevant issues.' CHW visits ended with families completing a written behavioural change plan detailing short-term goals. The Asthma Action at Erie Trial employs a modified community-based participatory research (CBPR) approach. CBPR is characterised by a reciprocal transfer of expertise, shared decision-making power, and mutual ownership of research products and processes. Programme topics: Sessions covered asthma symptoms, control, triggers, action plans, medication technique, adherence and caregiver or child concerns. Protocol was flexible, allowing for prioritisation of specific family needs. Incentives: Families reimbursed $50 for the main assessments and $25 for the 18 month call. Compliance: 102 received 'some intervention'. 6% received no intervention (n=6). CONTROL GROUP: AE-C group. 2 in clinic sessions with a certified asthma educator. Families offered a 1 hour session at an Erie clinic within a month of randomisation and again at 6 months. Sessions were followed with a phone call form the AE-C 2 weeks alter to answer any questions. Sessions covered asthma symptoms, control, triggers, action plans, medication technique, adherence and caregiver or child concerns. AE-C visit frequency and topics were chosen to align with national guidelines for asthma-self management education N (completed): 115 (111 completed follow up at 6 months, 110 completed follow up at 12 months, 107 completed follow up at 18 months, 106 completed follow up at 24 months). 56 received no intervention, 59 received some intervention: 'In the AE-C group 49% received no intervention, 29% received 1 session, and 22% received 2.'
Outcomes	Outcomes measured: Primary outcome - asthma control (captured through ACT for those 12 years or older, or cACT for 5-11 year olds) and self reported asthma-related activity limitation over the past 14 days. Additional measures included the ACQ (short term i.e. past 7 days, asthma control), health care utilisation for asthma (verified by EMR at 12 and 24 months for urgent care visits, emergency department visits and hospitalisations for asthma), oral corticosteroid bursts, and asthma symptoms over the past year (using the Asthma Functional Severity Scale) asthma medication (type, technique and adherence) and home triggers. Covariates included child and caregiver depression and PTSD, as well as family social support and functioning. Outcomes reported: Asthma control, ACQ, health care utilisation, steroid bursts at 6 months post baseline for ACT and activity limitation and 12 months post baseline and at 1 year post intervention completion. Time points: Baseline and 6 months, and post intervention at 12, 18 and 24 months.
Notes	Funding: This study was funded by the National Institutes of Health, National Heart, Lung, and Blood Institute (R01HL123797).

	Costs: To deliver 84 AE-C sessions cost $11373 ($135 per session) and to deliver 722 CHW visits cost $53390 ($74 per visit)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomisation was conducted in a 1:1 ratio using randomly mixed permuted blocks of size four and six to ensure reasonably equal allocation while reducing predictability of the assignment sequence.'
Allocation concealment (selection bias)	Unclear risk	'Upon completion of the randomisation assignment, the data management team generated a letter to the participant that informed him/her of their study status and also notified the Erie AE-C who assigned the patient to a CHW if randomised to that arm.'
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators. 'Intervention investigators and staff were un-blinded to treatment arm because they needed to work with the CHWs and monitor intervention fidelity and data accuracy. However, study staff and investigators did not have access to interim outcomes data.'
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'Although double blinding in a behavioral controlled trial is impossible, blinding was maximized by the following four strategies: 1) incomplete disclosure of study goals for participants during consent, 2) blinding outcomes assessors; 3) incomplete disclosure of research hypotheses for non-investigators staff, and 4) training co-investigators and staff in the concept of equipoise" “To preserve data integrity, the data collection team was completely separate from the intervention team; they did not communicate regarding participants, and interventionists did not have access to baseline or follow-up data.'
Incomplete outcome data (attrition bias) All outcomes	Low risk	"In the AE-C group, 49% received no intervention, 29% received 1 session, and 22% received 2. In the CHW group, 6% received no intervention, with a median of 7 visits (IQR= 4) received" Comment: Good fidelity to the intervention, with poor fidelity to the control. This would tend to overestimate the treatment effect, but be closer to real life where people are not getting so much education and support.
Selective reporting (reporting bias)	Unclear risk	Secondary outcome of 'asthma medication (type, technique and adherence) not reported on but data able to be provided from the authors. .
Other bias	Low risk	Nil other biases identified

Martin 2021

Study characteristics	
Methods	Study design: parallel, randomised, controlled trial Recruitment setting: patients discharged from paediatric medical ward of Auckland Hospital for asthma Study duration and start date: April 1983 to April 1984
Participants	N (completed) = 200 (164), European children and 168 (95) Polynesian children Mean age (range): (2 to 14) Gender (% male): Same age and sex ratio across European and Polynesian children Asthma severity: "In this study the children were having frequent attacks of asthma (an average of 13 each year, lasting on average two days), were missing an average of three and a half weeks of school because of asthma, and by the completion of the study had had an average of 5-3 admissions to hospital for asthma." Concurrent treatment: "European children were taking a larger number of medications for asthma than Polynesians (1-8 (1-2) v 1-4 (1-3), respectively, P<0-001), and were significantly more likely to be taking cromoglycate, inhaled steroids, and sympathomimetics." Baseline lung function: Socioeconomic indicators: European children significantly more advantaged than Polynesian children Ethnicity: either European or Polynesian

	Eligibility criteria: excluded if child was less than 2 years old, they lived outside the hospital catchment area, had had a previous life-threatening attack or they were not either Polynesian of European
Interventions	Educator: community child health nurse Audience: children and their families Where delivered: home INTERVENTION GROUP N (completed): European 83; Polynesian 50 N, duration and frequency of education sessions: 6 monthly sessions Educational/self-management strategy: basic asthma management with emphasis on reducing environmental triggers and encouraging patient to visit GP rather than ED. No attempt made to influence type of treatment or follow-up that the patient received. Educational materials used/provided: Programme topics: 1) Explanation of anatomy, pulmonary physiology, pathophysiology of lung and factors that can provoke asthma 2) description of drugs used in asthma 3) emphasis of importance of avoiding stimuli that may provoke asthma and controlling patient's environment 4) check on drug compliance and correct use of aerosols 5) encouraged to attend follow-up clinic visit to either paediatrician at outpatient clinic or GP and to consult GP rather than ED. Incentives: Compliance: "Of the returns, eight (6%) had no visits as the families could not be located, 35 (26%) had some but not all six of the monthly visits, and 92 (68%) had all six of the monthly visits." CONTROL GROUP: not described, assume no intervention N (completed): European 81; Polynesian 45 Net treatment:
Outcomes	Outcomes measured: self administered postal questionnaire (6 months after discharge from hospital), school absenteeism. Days off school, exacerbations leading to hospitalisation, GP and other treatment outside the home. Outcomes reported: as above Time points: number of readmissions, duration of readmission at 6 and 18 months
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	"randomised"
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Blinding of those extracting data from hospital charts was not described. Self reported outcomes, except hospitalisations.
Incomplete outcome data (attrition bias) All outcomes	High risk	Not stated
Selective	Unclear risk	No protocol published, but assume all of the measured outcomes reported

reporting (reporting bias)		
Other bias	Unclear risk	Used hospital records to confirm readmissions and length of hospital stay

Mitchell 1986

Study characteristics	
Methods	Study design: Randomised controlled trial Recruitment setting: Unclear how many centres or location - 'Medical record review and direct contact with clinical staff identified 399 patients who were hospitalised or admitted to the ED twice in 1 year for asthma.' "Participants initially approached in person by medical staff at the time of a regularly scheduled visit to a university affiliated paediatric asthma clinic or during an inpatient hospitalisation or were informed of the study by letters sent to their homes'. *Associated with Michigan US Study duration and start date: September 2008 - June 2013
Participants	N (completed) = 170 (156) - 2 families in control group removed from study due to safety concerns which developed during treatment, and 1 family removed as didn't meet study criteria Mean age (range): All participants mean not reported. Intervention mean - 13.32; Control mean - 13.64. Range 12-16 Gender (%male): Intervention group 61%; Control group 62% Asthma severity: Moderate to severe persistent asthma (as part of inclusion criteria) Diagnostic criteria: Physician diagnosis Concurrent treatment: 'Expected to be prescribed a daily asthma controller medication based on national standards of care' (as having moderate to severe persistent asthma part of inclusion criteria) Baseline lung function: FEV1, 2.05 in MST, 2.21 in control Socioeconomic indicators: Annual family income mean in both groups $13000 - $15999; 50% single-parent household in intervention group, 67% single parent household in control group Ethnicity: African American (by inclusion criteria) Eligibility criteria: Self reported African American ethnicity, ages 12-16, moderate to severe asthma and an inpatient hospitalisation or at least 2 emergency department visits for asthma in the last 12 months. Also had to be residing in a home setting with a caregiver who was willing to participate in treatment. Having moderate to severe persistent asthma ensured that enrolled participants would be expected to be prescribed a daily asthma controlled medication based on national standards of care.
Interventions	Educator: Intervention delivered to patients by four master's level therapists with varied backgrounds (one psychologist, three social workers) Audience: Adolescent with asthma and their family members Where delivered: Home and community INTERVENTION GROUP: Multisystemic therapy adapted for health care settings (MST-HC) - a home and community-based family therapy grounded in the social-ecological model. Targets severe problems with chronic illness medical conditions. N (completed): 84 (82) N, duration and frequency of education sessions: Number of sessions dependent on clinical need - could take place several times per week (or day) initially, and then only weekly once the adolescent's asthma management had improved. Occurred over 6 months. Mean length of treatment, excluding drop-outs - 5.14months and mean number of sessions was 27.09 (SD 12.03; range 4-62). Educational/self-management strategy: MST has several key features: 1. A comprehensive set of identified RFs associated with the problem behaviour is targeted through interventions that are individualised for each adolescent. 2. These interventions integrate empirically based clinical treatments (e.g. CBT) into a broad-based ecological framework that addresses relevant RFs across family, school and community contexts. 3. Interventions focus on promoting behaviour changes in the adolescent's natural ecology by empowering caregivers with skills and resources to address difficulties inherent in raising adolescents and empowering adolescents to cope with medical, family, school and neighbourhood problems. 4. Services are delivered via a home-based model, which facilitates high engagement and low dropout rate, and are delivered in home, school, and/or neighbourhood settings at times convenient to the family. 5. MST includes an intensive quality assurance system that aims to optimise youth outcomes by supporting therapist fidelity to MST

	treatment principles. MST-HC therapists began with an initial multisystemic assessment designed to identify the strengths and weaknesses of the adolescent, the family, and their transactions with extrafamilial systems (e.g., peers, school, community, medical treatment team). A functional assessment of nonadherent behavior through interviews and in-vivo observations was used to identify setting events and the antecedents and consequences of inadequate asthma management across the family, peer, school and community settings. Based upon this assessment, the MST-HC therapist chose from a menu of evidence-based interventions that best treat the identified problem behaviours (e.g., under use of preventive medications, poor identification of asthma triggers, not carrying rescue medications at all times) and their particular causes in each family. The MST-HC therapist provided treatment to families and their related contacts (extended family members, school personnel, medical team contacts), with the number of sessions per week dependent upon clinical need.MST-HC treatment goals identified conjointly by family members and the MST-HC therapist during the assessment phase were explicitly targeted for change during the treatment phase. For the proposed study, treatment goals were typically related to illness management (e.g. takes 90% of controlled medications based on medication counts). MST-HC interventions targeted asthma management problems within the family system, peer network and the broader community systems within which the family was embedded. MST-HC therapists drew upon evidence-based intervention techniques that included CBT, behaviour therapy, parent training, and behavioural family systems therapy. Programme topics: Individual interventions with adolescents included addressing asthma knowledge deficits or skills deficits such as improper use of inhalers. Family interventions in MST-HC include introducing systematic monitoring, reward and discipline systems in order to decrease caregiver disengagement from the asthma regimen; developing family organisational routines such as regular controller medication administration times, and helping caregivers to communicate effectively with each other about asthma care and avoidance of triggers. School interventions included helping caregivers improve communication strategies with school personnel such as teachers, counsellors and school nurses regarding their child's asthma care needs and increasing the accessibility of medications to youth whilst in school. Interventions within the health care system included helping family resolve barriers to keeping medical appointments and promoting positive family-physician communication and relationships. Incentives: Families provided USD 50 to compensate them for participating in each data collection Compliance: 'In MST, 85% of families received the allocated intervention (at least 3 sessions)' (n=71) CONTROL GROUP: In home support. Weekly, home-based, client-centred, nondirective supportive family counselling. Home-based delivery of services chosen to avoid inequity of treatment dose due to ease of access to services (e.g. home vs office). Weekly visit had three goals: 1. To provide empathic support to the youth and caregivers regarding the adolescent's asthma and related care needs, 2. to provide the family with opportunities to discuss barriers they identified to the completion of asthma care, and 3. to discuss the availability of supports to help the family with asthma management. Non-asthma related problems such as family relationship problems could also be discussed during the visits of requested by the family. FS intervention was 6 months in length and was matched to MST-HC for length of treatment. Since MST session dose is flexible, matching the control condition for dose was not possible but an approximate dose of weekly 45 minute sessions consistent with traditional outpatient therapy approaches was chosen. Mean length of treatment, excluding dropouts was 4.20 months and mean number of sessions was 11.03. FS provided by six master's level clinicians and one bachelor's level clinician. N (completed): 83 (74) (86 allocated to comparison intervention, 3 moved from study) '71% received the allocated intervention' (59 of 83)
Outcomes	Outcomes measured: Asthma management (using Family Asthma Management System Scale), Lung functioning (FEV1), medication adherence phone diary. Also looked at hospital and emergency department utilisation for asthma exacerbation, symptom severity Outcomes reported: As above Time points: Reported on baseline and posttreatment (7 months). 7- and 12-months post-baseline assessments done. Inpatient hospitalizations, and ED visits from 12 months before enrolment to 12 months after enrolment.
Notes	Funding: Supported by National Institutes of Health research grant 1R01HL087272-01A1.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Unclear randomisation process. 'Randomisation was stratified based on 1.severity of asthma complications as indicated by the number of recent hospitalizations or ED visits (three or more hospitalizations/ED visits in the previous 12 months vs. zero to two hospitalizations/ED visits) and (2) receipt of asthma specialty care (visit to

		hospital-based multidisciplinary asthma specialty clinic in the last 13 months or not).
Allocation concealment (selection bias)	Unclear risk	Allocation process not disclosed
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'All data collectors were blind to the participant's study condition'
Incomplete outcome data (attrition bias) All outcomes	Low risk	'Participants who completed the follow-up assessment did not differ from non completers on baseline demographics, asthma management measures or FEV1)'. 'Primary outcomes at the follow up were analysed for both the intent-to-treat sample (all randomised participants), and per-protocol sample (participants who received a predefined minimum dose of treatment).' 'At the 12-month follow-up, 89% of families remained in the study. There were no differences in retention between the MST-HC and FS groups at the 12-month assessment (x2 = 0.001; P = .98; Fig 2). In the MST-HC group, 85% of families received a minimum dose (3 sessions41) of the allocated intervention. In the FS group, 71% received the allocated intervention. MST-HC and FS participants differed in single-parent household (x2 = 4.655; P = .031) and income (x2 = 14.507; P = .043); thus, both were included as covariates in subsequent models. There were no significant differences on any outcome measures between MST-HC and FS participants at baseline.'
Selective reporting (reporting bias)	High risk	Hospitalization data at 7 months postbaseline not reported (even though it is in clinicaltrials.gov as a primary outcome). However th e 12 months postbaseline was reported. All other outcomes specified were reported. In clinicaltrials.gov , Hospitalizations and ED visits were reported as primary outcomes, but in study reported it as secondary outcome. Also missing ED data for 7 months and 12 months post baseline, and hospitalizations 7 months post baseline.
Other bias	Low risk	Objective measure (FEV1) used and asthma-related ED visits and inpatient hospitalizations was obtained from medical records. When a hospitalisation or ED visit outside the local institution was reported via any of these sources, the research team obtained a release and collected medical records. Only reports that were corroborated by medical records were included in the analysis.

Naar-King 2014

Study characteristics	
Methods	Study design: 3-arm, parallel, randomised, controlled trial Recruitment setting: Johns Hopkins Paediatric ED, Baltimore, USA Study duration and start date:
Participants	N (completed) = 250 (204) Mean age (range): 7.0 (2 to 12) Gender (% male): 62% Asthma severity: physician diagnosed asthma, 2 x ED visits or 1 x hospitalisations in the preceding year and on asthma controller medications Diagnostic criteria: physician diagnosed asthma Concurrent treatment: LTRA24%; ICS 72% Socioeconomic indicators: Medicaid (86%); caregiver completed high school (69%); household income < USD 10,000 per year (38%) Ethnicity: 98% Black Eligibility criteria: physician diagnosed asthma, 2 ED visits or one hospitalisation for asthma in the previous year, resident in Baltimore City and prescribed asthma controller medication
Interventions	Educator: trained asthma educators

	Audience: parent and child Where delivered: home INTERVENTION GROUP: Asthma Basic Care Group (ABC) N (completed): n = 84, 92% completed 6 month and 96% completed 18-month surveys N, duration and frequency of education sessions: 5 x 30 to 45 minutes sessions at weeks 1, 2, 3, 4 and 8 weeks after randomisation Educational/self-management strategy: 5 core components 1) review of prescribed asthma regimen and training in medication, spacer and peak flow technique; 2) development of an asthma action plan; 3) identification of barriers to accessing health care and problem-solving to remove them; 4) discussion of beliefs and concerns about asthma and medications; 5) provision of written asthma education materials. Educational materials used/provided: written asthma education materials and asthma action plan. INTERVENTION GROUP: Adherence Monitoring with Feedback Group (AMF) N (completed): n = 83, 87% completed 6-month and 80% completed 18-month surveys N, duration and frequency of education sessions: Educational/self-management strategy: received the ABC programme as described above plus the following: 1) objective feedback of medication adherence from an electronic adherence monitor and the asthma educator was trained to provide support in a non-threatening way; 2) families were encouraged to set asthma control goals (e.g. no coughing at night); 3) the importance of positive reinforcement such as verbal praise and low-cost rewards was emphasised. The educator worked with families to identify barriers when goals were not achieved; 4) families were taught strategies to monitor adherence and asthma symptoms by using behavioural charts and symptom diaries, the educator highlighted relationships between improvements in symptoms and adherence where possible. Educational materials used/provided: written asthma education materials and asthma action plan Incentives: none but parents were encouraged to provide low-cost rewards and verbal praise as incentives for adherence CONTROL GROUP: usual care N (completed): n = 83, 92% completed 6-month and 93% completed 18-month surveys Compliance: 67% completed all 5 visits. Completed 4.0 and 3.8 visits on average for the ABC and AMF intervention groups respectively
Outcomes	Outcomes measured: caregiver-reported frequency of asthma symptoms, ED visits, hospitalisation, courses of OCS, adherence to ICS and number of ICS refills Outcomes reported: as above Time points: baseline, 6, 12 and 18 months Patients were encouraged to seek care from their primary care provider
Notes	Funding: NHLBI grant

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	"randomised" via blocked randomisation schema
Allocation concealment (selection bias)	Low risk	Assignment place in sealed envelopes which were opened after completion of baseline surveys
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection	Low risk	Research staff who conducted telephone surveys were blinded

bias) All outcomes		
Incomplete outcome data (attrition bias) All outcomes	Low risk	The numbers lost to follow-up at each survey were balanced between treatment arms and consistently around 10% which is to be expected
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	High risk	Although adherence was monitored both by self reports and through pharmacy records, hospitalisations and ED visits were only recorded via self reports

Otsuki 2009

Study characteristics	
Methods	Study design: 3-arm, parallel, randomised, controlled trial Recruitment setting: San Diego, California. Families recruited from Federally Qualified Health Centers, commercial HMO, school/daycare, local asthma initiatives, or self referred Study duration and start date:11 June 2004 to 16 October 2007
Participants	N (completed) = 252 (211 completed at least 1 follow-up) Mean age (range): 7.37 (2 to 14) Gender (% male): 61.1% Asthma severity: mild 27.0%, moderate 40.5%, severe 32.5% Diagnostic criteria: persistent asthma (mild, moderate, severe) as per NHLBI criteria using symptoms, activity level, exacerbations Concurrent treatment: Baseline lung function: Socioeconomic indicators: 84% recruited from Federally Qualified Health Centres (subsidised community clinics treating generally un/underinsured on sliding scale fee); most patients low income; mother's education < 6th grade 26%, 7th to 9th grade 23%, 10th to 12th grade 24%, high school graduate 8%, some college 13%, college graduate 5%, graduate/professional degree 0.4%; father's education < 6th grade 28%, 7th to 9th grade 25%, 10th to 12th grade 21%, high school graduate 8%, some college 11%, college graduate 7%, graduation/professional degree 0.5% Ethnicity: Hispanic 83% (Spanish only 56%), non-Hispanic white 4%, non-Hispanic black 8%, other 4% Eligibility criteria: 2 to 14 years with physician-diagnosed persistent asthma, whose parents spoke English or Spanish
Interventions	Educator: CC = 2 bilingual, bicultural bachelor's level asthma home visitors; PST = bilingual, bicultural, master's level health educator Audience: PST = primary caregiver, although children encouraged to participate Where delivered: INTERVENTION GROUP: care co-ordination (CC); care co-ordination + problem-solving skill training (CC + PST) N (completed): CC = 81 (71); PST = 84 (60) N, duration and frequency of education sessions: CC = 5, 45 to 60 minutes sessions, weekly; PST = 6, 45 to 60 minutes sessions, weekly Educational/self-management strategy: CC = structured set of educational interventions with written material, based on NHLBI guidelines, Robert Wood Johnson Foundation's Allies Against Asthma community health worker model; PST = based on D'Zurilla's conceptualisation and adapted from comprehensive protocol used in previous trial of PST in mothers and children with cancer Educational materials used/provided: CC = written materials on programme topics (described below); PST = treatment manual, worksheets for each step, cartoon handouts to reinforce main ideas Programme topics: CC = what is asthma, asthma medications and devices, asthma action plan, how to recognise and respond to symptom onset, how to reduce irritants and allergens in home. Referred families when needed to existing health insurance enrolment assistance, smoking cessation, other community support services; provided PCP with summaries of

	interventions, updates on progress, and noting family difficulties and needs; PST = session 1 rapport building, understanding medical and social situation, presenting overview of PST curriculum, assigning first homework; session 2 review homework, introduced idea of developing alternative solutions, assigned homework (defining and evaluating options); session 3 review homework, developed action plan, assigned homework (implementing action plan); session 4 to 6 depended on outcome of actions, focusing on alternative plans if results of action plan not satisfactory to client or on additional problems if results satisfactory Compliance: treatment fidelity (percent of prescribed intervention behaviours performed) 98.4% CC, 97.5% CC + PST; intervention fidelity (percent of sessions delivered) 91.6% CC, 71.8% CC + PST; in PST group, 23.8% received no PST sessions, 52.4% received all PST sessions CONTROL GROUP: received ongoing asthma care from their place of care; after T3 follow-up, offered CC + PST intervention N (completed): 87 (73)
Outcomes	Outcomes measured: parent-reported child generic HRQOL using PedsQL total, asthma symptoms using PedsQL asthma, utilisation (recall of ED, inpatient, urgent doctor's appointments for asthma over past 6 months at T1, 3 months at T2, 6 months at T3) Outcomes reported: PedsQL total parent, child; PedQL asthma parent, child; daytime symptoms, night-time symptoms, ED visits, visits to hospital, unscheduled office visits Time points: baseline (T1), post-intervention (about 3 months after baseline, T2), 6 month follow-up (about 9 months after baseline, T3)
Notes	Cost: Funding: grant from Maternal and Child Health Bureau of the Health Resource and Services Administration; 2nd author holds copyright and trademark of PedsQL

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Blocked randomisation, stratified by site of care and disease severity; prepared randomisation lists created by statistician
Allocation concealment (selection bias)	Low risk	Randomisation lists concealed until intervention assignment
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not possible to blind patients or educators
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Research staff blinded to intervention group administered surveys
Incomplete outcome data (attrition bias) All outcomes	High risk	CC intervention: 20% lost (7% refused), PST intervention 32% lost (19% refused) These are unbalanced and assumed to be due to the nature of the intervention
Selective reporting (reporting bias)	Unclear risk	No protocol published, but assume all of the measured outcomes reported
Other bias	High risk	Parent-reported healthcare utilisation

Seid 2010

ABC: Asthma Basic Care; AM: Asthma management; ADM: Augmented disease management (in Galbreath, DM plus in-home visits by a respiratory therapist); AMF: Adherence Monitoring with Feedback; AMP: asthma management plan; AQLQ: Asthma Quality of Life Questionnaire; ATS: American Thoracic Society; CC: care co-ordination; CDC: Centers for Disease Control and

Prevention; CF: cystic fibrosis; CHW: community health worker; CM: case management; CPC: Caregiver perception of change survey; ED: emergency department; EMR: electronic medical record; FEV1: forced expiratory volume in one second; GCSE: General Certificate of Secondary Education, academic qualification, generally taken in a number of subjects by students aged 14 to 16 in secondary education in England, Wales, and Northern Ireland; GINA: Global Initiative for Asthma; GP: general practitioner; HCU: healthcare utilisation; High School Diploma - a diploma awarded for the completion of high school. In the United States a high school is an upper secondary school which educates children from grade nine (14 years old) or 10 (15) through grade 12 (17 or 18); HRQOL: health-related quality of life; ICS: inhaled corticosteroid; ITT: intention-to-treat analysis; LABA: long-acting $beta_2$-agonist; LTRA: leukotriene receptor antagonists; NAEPP: National Asthma Education and Prevention Program; NHLBI: National Heart, Lung, and Blood Institute guidelines; NIEHS: National Institute of Environmental Health Sciences; NS: not stated; OCS: oral corticosteroids; PACQLQ: Paediatric Asthma Caregiver's Quality of Life Questionnaire; PAQLQ: Paediatric Quality of Life Questionnaire; PCP: primary care provider; PEF: peak expiratory flow; PFM: peak flow meter; PPI: Hymovich's Parent Perception Inventory; PST: problem-solving skill training; QoL: quality of life; SABA: short-acting $beta_2$ agonist; SAE: serious adverse event; SCHIP: State Children's Health Insurance Program administered by the United States Department of Health and Human Services that matches funds to states for health insurance to families with children. Designed to cover uninsured children in families with incomes that are modest but too high to qualify for Medicaid; SD: standard deviation; STAMP: South Texas Asthma Management Project; TRACK: Test for Respiratory and Asthma Control in Kids; WAP: written action plan.

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
ACTRN12621000673842	No home-based intervention.
Adams 2004	Not delivered in the home
Adgate 2008	Focus on removing allergen through cleaning procedures
Agertoft 1998	The education component was provided in the clinic and the training was using the turbuhaler at home
Agrawal 2005	Patients in the intervention group were given an individualised written home-management plan, but the standard education administered to both intervention and control groups was not delivered at home
Akkaya 1997	Education delivered in an outpatient clinic
Aleman Mendez 1992	No data available to extract, unsure of where education was delivered, randomisation not described and could not contact author.
Alexander 1972	Education delivered in groups in treatment rooms in care homes.
Alexander 1988	Appointments held in the allergy division in a medical centre.
Andersen 2007	Published as abstract only. Appears to be education delivered by the internet. Author did not confirm that there was no face to face education delivered in the home.
Arbes 2003	Provided insect bait and professional cleaning.
Arbes 2004	Provided insect bait and professional cleaning.
Barnes 2008	Provided home-cleaning.
Bateman 2000	Education mainly in adults. Full text not published.
Becker 2003	Education delivered to small groups, i.e. outside home.
Bender 1997	Observational study, not an RCT.
Bender 2003	Delivered in patient education centres.
Bird 2012	Not an RCT.
Bonner 2002	Although this intervention included a baseline interview delivered at home and home visits and telephone calls to check compliance, the education component of this study was delivered in group sessions outside of the home.
Bonsignore 2008	Delivered exercise training and monitoring in a gym centre.
Boone 2002	Intervention was a computer game. No face-to-face component delivered.
Borba 2013	Prospective uncontrolled study.
Bramson 1996	Commentary piece, not an RCT.
Brewin 1995	Education delivered in the hospital.
Brosco 2005	This is an ongoing observational study designed to document prevalence of asthma in preschool children, identify barriers to optimal asthma care, assess clinics and improve asthma outcomes.
Bryant 2001	Removal of common indoor asthma triggers.

Study	Reason for exclusion
Bryant-Stephens 2004	The active group received education plus environmental remediation whereas the control group received observational home visits only.
Bryant-Stephens 2008a	The comparison group was the same home-based education plus environmental remediation - i.e. a higher intensity intervention.
Burkhart 2001	Education component delivered outside the home. Weekly telephone calls encourage adherence to peak flow monitoring.
Burkhart 2007	Sessions conducted in child-friendly interview rooms at the university.
Butz 2005a	Education delivered in workshops.
Butz 2007	Not delivered in the home.
Bynum 2001	Education delivered by video teleconference calls at local clinics.
Callahan 2003	Provided mattress encasings and HEPA filters.
Callahan 2004	Not an RCT.
CAMP	Describes recruitment into education programme, not an RCT.
Catov 2005	Not an RCT.
Chan 2003	Web-based education.
Chan 2007	Clinic and web-based education.
Chiang 2004	Group parent education sessions delivered on an outpatient basis.
Clark 1986	Education delivered in hospital clinics.
Claus 2004	Education delivered to small groups.
Cohen 1979	Single asthma discussion group.
Colland 2004	Study aimed at encouraging parents and children to recognise prodromal signs and to double the amount of medication at the first prodromal sign. Visits conducted at an outpatient clinic.
Cote 1997	Adults.
Dahl 1990	Web-based education delivered at school/home.
Deaves 1993	Not an RCT.
Delaronde 2005	Quasi-randomised - some of the patients had a choice about which group they were allocated. Results data included adult data.
Donaghy 1995	Education delivered in the clinic. Also patients in the range 13 to 50 years old.
Eggleston 2004	Provided HEPA filter.
Eggleston 2005	Provided cockroach/rodent extermination, mattress/pillow encasings etc.
Evans 1999	Education component delivered to groups.
Everhart 2020	Both arms of study involve home education and environmental modification. Intervention coordination of asthma care over multiple settings.
Finkelstein 2002	No education component delivered other than environmental awareness.
Flores 2009	Group work.
Gardida 2002	Education delivered in schools.
Greineder 1995	Education delivered outside the home.
Greineder 1999	Education delivered outside the home.
Griffiths 2004	Education delivered outside the home.
Guendelman 2002	Education delivered in the clinic, game played at home.
Holley 2018	Published as abstract only. Unclear what intervention is and no mention of home-based education. Author unable to be contacted.
Holzheimer 1998	Education delivered outside the home. Children were given a book to take home at the end of the intervention.
Homer 2000	Computer game played in the hospital clinic.
Homer 2005	Education delivered to multidisciplinary teams from practices (physician, nurse and front office staff person) rather than children or parents of children with asthma.
Horner 2004	Education delivered in school.
Horner 2006	Education delivered in school.
Horner 2008	Education delivered in school.
Horwitz 2021	Not an RCT.
Hovell 1994	Compared groups randomised to receive counselling to reduce a child's exposure to environmental tobacco smoke.
Hovell 2002	Both groups received same asthma education, but the more intense group also received counselling of the parent in reducing the child to environmental tobacco smoke. Although one could argue that this is simply a more intense form of education, we felt that the trial was asking a different clinical question than intended by our review.
Hughes 1991	Study aimed at improving the home environment and reducing exposure to tobacco smoke. Mainly delivered outside the home.

Study	Reason for exclusion
Huss 2003	Web-based education.
Indinnimeo 2009	Not delivered in the home.
Jain 1991	Yoga training given during a hospital stay.
Jan 2007	Web-based education.
Jenkinson 1988	Study old and not aimed at behaviour change, no separate paediatric data or outcomes useful to our review.
Jerant 2009	Adults.
Jones 2001	Aimed at reduce a child's exposure to environmental tobacco smoke.
Joseph 2000	Education delivered in a hospital meeting room.
Joseph 2005	Education delivered in school.
Kamps 2004	A commentary article.
Karnick 2007	Delivered at the clinic.
Kay Bartholomew 2006	Education delivered in school.
Kercsmar 2006	Received environmental remediation including a water filter and mould/damp ventilation.
Khan 2004	Single phone call delivered education.
Klinnert 2005	Trial is in infants younger than 2 years old and main focus was environmental remediation.
Kokubu 1999	Adults.
Kotses 1996	Adults.
Krishna 2003	Education via computer package available in consultation and waiting rooms.
Kuijer 2007	Adults.
La Roche 2006	Delivered to groups of patients at outpatient clinic.
LeBaron 1985	Education delivered in the office.
Lecheler 1988	Intervention comparing interval and continuous running training with not educational component.
Lee 2010	Adults.
Letz 2004	Education delivered in the clinic.
Lewis 1987	Sessions that started out as individual families and then moved into group sessions, therefore delivered outside the home.
Lewis 1994	Education given in lectures.
Li 2006	Patients not allocated randomly.
Lieberman 2001	Review of video games for different diseases, some of which were asthma. Not an RCT.
Linicome 2001	Part of PAC-PORT II trial delivering education to healthcare providers.
Liu 2001	Patients randomised to 3 intervention groups, however the control group was not randomised, but selected from a neighbouring hospital.
Liu 2007	Adults.
Mandhane	Education delivered in school.
Marabini 2002	Adults.
Margolis 2021	Wrong intervention. Aimed at environmental remediation.
McCarthy 2002	Education component delivered in groups.
McConnell 2005	Provided mattress encasings and trained families in cleaning.
McGhan 2010	Education delivered in school.
McNabb 1985	Education delivered in a clinic.
McPherson 2006	Game played at home.
Mendes 2010	An aerobic exercise intervention.
Meszaros 2003	Adults.
Mildenhall 1997	Adults.
Morgan 2004	Provided environmental remediation including mattress encasings and HEPA filters.
Mosnaim 2008	Education/positive messages delivered by MP3 players rather than face-to-face.
Moudgil 1998	Observational study.
NCT00217906	Delivered in school.
NCT04995692	Wrong intervention.
Nelson 2011	No mention of home delivery of intervention.
Ng 2021	Wrong intervention - web-based.
Nishioka 2006	Not an RCT.
Nokela 2010	Adults.
Page 1999	Not an RCT.

Study	Reason for exclusion
Parker 2008	Environmental remediation given.
Perrin 1992	Delivered in a clinic.
Persky 1999	Emphasis on environmental remediation.
Petro 2005	Adults.
Put 2003	Adults and delivered outside the home.
Rakos 1985	Education was in the form of a self-help kit.
Rhee 2008	This study aimed to help decision-making and reduce risk by reducing substance misuse among participants.
Ronchetti 1997	Delivered in groups in a clinic.
Rubin 1986	Computer game used in the clinic.
Rylance 2021	No home-based intervention.
Schatz 2006	Adults.
Schmidt 1993	Not randomised.
Shames 2004	Video game plus a telephone hotline.
Shegog 2001	Education delivered on a university campus.
Shields 1990	Telephone calls were reinforcement rather than education - which was delivered in the ED.
Shields 2004	Education delivered at school.
Slader 2006	Adults.
Smith 2004	The telephone call to the parents home did not deliver education (which was administered previously in the ED), just encouraged and helped the parents to make a follow-up appointment.
Sommaruga 1995	Adults.
Steurer-Stey 2010	Adults and delivered in outpatients.
Stevens 2002	Education delivered in an outpatient clinic.
Stukus 2018	Intervention not involving any face-to-face component delivered in real-time at home.
Sublett 2000	Adults.
Sun 2010	Adults.
Szczepanski 2010	Delivered in groups.
Tagaya 2005	No education delivered in the home. There was a booklet to take home.
Takaro 2004	Emphasis on providing environmental remediation.
Takaro 2004a	Provided environmental remediation such as mattress encasements.
Talabere 1990	We could not obtain separate data for the children educated at home from this thesis.
Thoonen 2002	Adults.
Tong 2002	Patients not allocated randomly.
Tony 2021	No home-based intervention.
Tsoukleris 2007	An observational study.
Urek 2005	Adults.
Vagedes 2021	Wrong intervention.
Valery 2007	Much of the education was delivered outside the home.
Valery 2010	Education delivered in a primary health care setting.
van Es 2001	Education delivered by doctors in group/individual sessions at the clinic and additional education provided by an asthma nurse at the same visit.
Vazquez 1993	Delivered in the clinic.
Venkat 2020	Not RCT. Not home-based.
Volerman 2020	No face to face component.
Walders 2006	Education delivered in the clinic. Patients in the experimental group were granted access to an hotline where they could ask an asthma nurse for advice; this was not deemed to be an education intervention.
Warschburger 2003	Education delivered to groups of parents at the clinic.
Weiss 2003	Education provided to physician.
Wensley 2001	Self-management education delivered outside the home, although the participants were randomised to either symptom-based or PFM-based monitoring at home.
Willems 2004	Education component was minimal/absent.
Williams 2006	Environmental remediation the main focus, supplied mattress casings etc.
Wilson 1996a	Small group sessions therefore not in the child's home.
Wise 2007	Internet telehealth care intervention.
Yang 2005	Not an RCT.

Study	Reason for exclusion
Yoon 1989	Adults.
Zhao 2005	Patients not allocated randomly.
Zorc 2005	Emergency department based.

Abbreviations: CAMP: Childhood Asthma Management Program; ED: Emergency Department; HEPA: high-efficiency particulate air (filter); NEJM: New England Journal of Medicine; PFM: peak flow meter; RCT: randomised controlled trial.

Characteristics of studies awaiting classification [ordered by study ID]

Methods	Booklet explained by a nurse in 4 sessions and the showing of a videotaped dramatisation of the same information
Participants	Intervention group N = 16 parents Control group N = 15 parents
Interventions	
Outcomes	Six-month follow-up
Notes	"Preliminary report shows that the parents of both groups had similar levels of knowledge of asthma at the initial test. On retesting at the six-month follow-up, the parents in both groups did significantly better than on the initial test. However, the experimental group's improvement was statistically better than that of the controls (P = 0.003). More important are the changes in attitude and behaviour implied by the higher rate of casualty visits, and the higher rate of attacks identified in cases as compared with controls. The fall in admissions among cases, while controls had a steady rate of admissions in both the year of the study and in the preceding year, has positive economic implications that are especially exciting in a developing country such as ours (AU)."

Cameron 1989

Methods	RCT
Participants	Inclusion criteria: 1. Meeting the diagnostic criteria of paediatric asthma developed by Chinese Pediatric Society, Chinese Medical Association in 2008; 2. Aged 4 to 14 years; 3. Consenting the follow-up including home visit and phone by nurses; 4. Having symptoms within 3 months. Exclusion criteria: 1. Having neurological disorders, cognitive impairment, chronic diseases of heart, liver, kidney etc. 2. The participant of other intervention studies. 3. Do not consent. China.
Interventions	Control group: Guidance of the use of bronchiectasis and use inhalation steroids; Education of asthma knowledge. Intervention group: Addition to control approach, home visit and follow-up by telephone.
Outcomes	Asthma control; frequency of attack; quality of life; times visiting emergency room; times of hospitalisation; absent school days.
Notes	

ChiCTR1800014551

Methods	RCT
Participants	USA
Interventions	Intervention: 2 asthma nurse home visits. Based on EZ Breathers (an asthma education program in Head Start) Control: standard educational literature
Outcomes	Medication availability, parent's sleepless nights, parent limiting child's physical activity, GP visits, ED visits.
Notes	

Kelly 2005

Methods	
Participants	

Interventions	
Outcomes	
Notes	

Mishra 2005

Methods	This appears to be an intervention about a mobile asthma education unit called a 'breathmobile'
Participants	
Interventions	
Outcomes	
Notes	

NCT00094276

Methods	Randomized wait-list control trial
Participants	11 chronically absent students aged 5 to 11, with co-morbid asthma. USA.
Interventions	Home visit vs standard care. Home visits: 2 visits by team (paediatric medical provider and school staff member). Visits will consist of a home environment evaluation, medication adherence and knowledge assessment, distribution of home environmental allergen reduction items such as mattress and pillow encasements, as well as review and reinforcement of any asthma action plans or care plans provided by patient's primary care physicians or medical home. Control group: standard interventions carried out by the school system for students at risk for chronic absenteeism.
Outcomes	Primary outcome: Missed School Days. Secondary Outcomes: 1) HCU (number of ED or urgent care visits for asthma), 2) asthma symptom report (patient and family self-report of number of days when asthma symptoms were experienced, collected monthly), 3) ACT. Time frame: One academic year.
Notes	

NCT03335046

Methods	RCT. Parallel, open-label trial
Participants	Estimated enrolment 226 10 to 15 years
Interventions	Participants will be randomly assigned to 1) Self management or 2) Motivational interviewing plus self-management training. The duration of the intervention condition will be 5 home visits over 2 months. Follow-up measures will be collected from families at 3 and 6 months post-randomisation.
Outcomes	Primary outcome measure: adherence to asthma controller therapy as measured by electronic medication monitoring. Secondary outcome measures: number of symptom-free days, emergency department utilisation and hospitalisation, caregiver/adolescent quality of life.
Notes	

Rand 2006

Methods	Controlled trial of an asthma education intervention
Participants	Children with asthma. Program is part of the Allies Against Asthma initiative. USA.
Interventions	Intervention (n=114): received a minimum of 4 structured home visits. Control (n=114): standard care.
Outcomes	ED visits, paediatrician visits, symptom free days, nights with symptoms, number of ICS prescriptions, number of children with PAAP, use of pillow and mattress covers.
Notes	

Taylor-Fishwick 2005

Methods	RCT
Participants	"70 patients with asthma were randomised into individual education (n=35) and group education (n=35)."
Interventions	"Each patients in individual education group received a 40 minutes one to one education. Group education was performed with groups consisting of 6-10 patients. Education lessons was 40 minutes in this group. Each group received asthma education about asthma, triggering factors, symptoms, treatment, peak flow meter and inhalation techniques. Every patient had also physiotherapy education consisting of respiration and relaxation exercises. The patients were evaluated before, 1 week and 7 weeks after the educational programs."
Outcomes	Disease symptoms, pulmonary function tests, quality of life and knowledge levels
Notes	

Yildiz 2002

Abbreviations: ACT: asthma control test; ED: emergency department; GP: general practitioner; HCU: healthcare utilisation; PAAP: personalised asthma action plan; RCT: randomised controlled trial.

Appendices

Appendix 1. Database search strategies

Database/search platform/date of last search	Search strategy	Results
Airways Register (via Cochrane Register of Studies) Date of most recent search: 13 September 2021	1 MESH DESCRIPTOR Asthma EXPLODE ALL AND INREGISTER 2 (asthma* or wheez*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 3 AST:MISC1 AND INREGISTER 4 #1 OR #2 OR #3 5 MESH DESCRIPTOR Pediatrics EXPLODE ALL AND INREGISTER 6 MESH DESCRIPTOR Infant EXPLODE ALL AND INREGISTER 7 MESH DESCRIPTOR Child EXPLODE ALL AND INREGISTER 8 MESH DESCRIPTOR Adolescent EXPLODE ALL AND INREGISTER 9 (paediatric* or paediatric* or child* or infant* or young* or preschool* or pre-school* or school* or adolescen* or teen* or youth* or juvenile*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 10 MESH DESCRIPTOR Child Health Services EXPLODE ALL AND INREGISTER 11 #5 OR #6 OR #7 OR #8 OR #9 OR #10 12 MESH DESCRIPTOR Self-Management AND INREGISTER 13 MESH DESCRIPTOR Self Care AND INREGISTER 14 (self-manag* or self manag*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 15 (self-car* or self car*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 16 (self-monitor* or self monitor*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 17 MESH DESCRIPTOR Patient Education as Topic AND INREGISTER 18 MESH DESCRIPTOR Health Education AND INREGISTER 19 (educat* or train* or instruct* or teach* or taught or coach* or learn* or behav*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 20 MESH DESCRIPTOR Patient-Centered Care EXPLODE ALL AND INREGISTER 21 MESH DESCRIPTOR Patient Care Planning AND INREGISTER 22 (patient-cent* or patient cent*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 23 (patient-focus* or patient focus*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER	• June 2020=675 • September 2021=44

	24 MESH DESCRIPTOR disease management AND INREGISTER 25 ((management*) NEAR1 (plan* or program*)):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 26 ((case* or disease*) NEAR1 management*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 27 #26 OR #25 OR #24 OR #23 OR #22 OR #20 OR #21 OR #19 OR #18 OR #17 OR #16 OR #15 OR #14 OR #12 OR #13 28 MESH DESCRIPTOR Home Care Services EXPLODE ALL AND INREGISTER 29 MESH DESCRIPTOR House Calls AND INREGISTER 30 MESH DESCRIPTOR Ambulatory Care AND INREGISTER 31 MESH DESCRIPTOR Community Health Nursing EXPLODE ALL AND INREGISTER 32 MESH DESCRIPTOR Community Health Workers AND INREGISTER 33 (home* or house* or visit* or communit*):ti,ab,kw,mh,emt,eh,ky,mc AND INREGISTER 34 #28 OR #29 OR #30 OR #32 OR #31 OR #33 35 #4 AND #11 AND #27 AND #34	
CENTRAL (via Cochrane Register of Studies) Date of most recent search: 13 September 2021	1 MESH DESCRIPTOR Asthma EXPLODE ALL AND CENTRAL:TARGET 2 (asthma* or wheez*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 3 AST:MISC1 AND CENTRAL:TARGET 4 #1 OR #2 OR #3 AND CENTRAL:TARGET 5 MESH DESCRIPTOR Pediatrics EXPLODE ALL AND CENTRAL:TARGET 6 MESH DESCRIPTOR Infant EXPLODE ALL AND CENTRAL:TARGET 7 MESH DESCRIPTOR Child EXPLODE ALL AND CENTRAL:TARGET 8 MESH DESCRIPTOR Adolescent EXPLODE ALL AND CENTRAL:TARGET 9 (paediatric* or paediatric* or child* or infant* or young* or preschool* or pre-school* or school* or adolescen* or teen* or youth* or juvenile*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 10 MESH DESCRIPTOR Child Health Services EXPLODE ALL AND CENTRAL:TARGET 11 #5 OR #6 OR #7 OR #8 OR #9 OR #10 AND CENTRAL:TARGET 12 MESH DESCRIPTOR Self-Management AND CENTRAL:TARGET 13 MESH DESCRIPTOR Self Care AND CENTRAL:TARGET 14 (self-manag* or self manag*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 15 (self-car* or self car*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 16 (self-monitor* or self monitor*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 17 MESH DESCRIPTOR Patient Education as Topic AND CENTRAL:TARGET 18 MESH DESCRIPTOR Health Education AND CENTRAL:TARGET 19 (educat* or train* or instruct* or teach* or taught or coach* or learn* or behav*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 20 MESH DESCRIPTOR Patient-Centered Care EXPLODE ALL AND CENTRAL:TARGET 21 MESH DESCRIPTOR Patient Care Planning AND CENTRAL:TARGET 22 (patient-cent* or patient cent*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 23 (patient-focus* or patient focus*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 24 MESH DESCRIPTOR disease management AND CENTRAL:TARGET 25 ((management*) NEAR1 (plan* or program*)):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 26 ((case* or disease*) NEAR1 management*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 27 #26 OR #25 OR #24 OR #23 OR #22 OR #20 OR #21 OR #19	• June 2020=1111 • September 2021=86

	OR #18 OR #17 OR #16 OR #15 OR #14 OR #12 OR #13 AND CENTRAL:TARGET 28 MESH DESCRIPTOR Home Care Services EXPLODE ALL AND CENTRAL:TARGET 29 MESH DESCRIPTOR House Calls AND CENTRAL:TARGET 30 MESH DESCRIPTOR Ambulatory Care AND CENTRAL:TARGET 31 MESH DESCRIPTOR Community Health Nursing EXPLODE ALL AND CENTRAL:TARGET 32 MESH DESCRIPTOR Community Health Workers AND CENTRAL:TARGET 33 (home* or house* or visit* or communit*):ti,ab,kw,mh,emt,eh,ky,mc AND CENTRAL:TARGET 34 #28 OR #29 OR #30 OR #32 OR #31 OR #33 AND CENTRAL:TARGET 35 #4 AND #11 AND #27 AND #34 AND CENTRAL:TARGET	
MEDLINE (Ovid) ALL Date of most recent search: 13 September 2021	1 exp asthma/ 2 (asthma* or wheez*).ti,ab. 3 1 or 2 4 exp Pediatrics/ 5 exp Infant/ 6 exp Child/ 7 exp adolescent/ 8 (paediatric$ or paediatric$ or child$ or infant$ or young$ or preschool$ or pre-school$ or school$ or adolescen$ or teen$ or youth$ or juvenile$).tw. 9 exp Child Health Services/ 10 or/4-9 11 Self-Management/ 12 Self Care/ 13 (self-manag$ or self manag$).ti,ab. 14 (self-car$ or self car$).ti,ab. 15 (self-monitor$ or self monitor$).ti,ab. 16 Patient Education as Topic/ 17 Health Education/ 18 (educat$ or train$ or instruct$ or teach$ or taught or coach$ or learn$ or behav$).ti,ab. 19 exp Patient-Centered Care/ 20 Patient Care Planning/ 21 ed.fs. 22 (patient-cent$ or patient cent$).ti,ab. 23 (patient-focus$ or patient focus$).ti,ab. 24 disease management/ 25 (management$ adj (plan$ or program$)).ti,ab. 26 ((case$ or disease$) adj1 management$).ti,ab. 27 or/11-26 28 exp Home Care Services/ 29 House Calls/ 30 Ambulatory Care/ 31 exp Community Health Nursing/ 32 Community Health Workers/ 33 (home$ or house$ or visit$ or communit$).ti,ab. 34 or/28-33 35 (controlled clinical trial or randomised controlled trial).pt. 36 (randomised or randomised).ab,ti. 37 placebo.ab,ti. 38 dt.fs. 39 randomly.ab,ti. 40 trial.ab,ti. 41 groups.ab,ti. 42 or/35-41 43 Animals/ 44 Humans/ 45 43 not (43 and 44) 46 42 not 45 47 3 and 10 and 27 and 34 and 46	• June 2020=1491 • September 2021=90
Embase (Ovid) Date of most recent search: 13 September 2021	1 exp asthma/ 2 (asthma* or wheez*).ti,ab. 3 1 or 2 4 exp pediatrics/ 5 exp infant/	• June 2020=1407 • September 2021=114

	6 exp child/ 7 exp adolescent/ 8 juvenile/ 9 (paediatric$ or paediatric$ or child$ or infant$ or young$ or preschool$ or pre-school$ or school$ or adolescen$ or teen$ or youth$ or juvenile$).tw. 10 exp child health care/ 11 or/4-10 12 exp self care/ 13 (self-manag$ or self manag$).ti,ab. 14 (self-car$ or self car$).ti,ab. 15 (self-monitor$ or self monitor$).ti,ab. 16 patient education/ 17 health education/ 18 (educat$ or train$ or instruct$ or teach$ or taught or coach$ or learn$ or behav$).ti,ab. 19 patient care/ 20 patient care planning/ 21 (patient-cent$ or patient cent$).ti,ab. 22 (patient-focus$ or patient focus$).ti,ab. 23 case management/ 24 disease management/ 25 (management$ adj (plan$ or program$)).ti,ab. 26 ((case$ or disease$) adj1 management$).ti,ab. 27 or/12-26 28 home care/ 29 home visit/ 30 visiting nursing service/ 31 exp ambulatory care/ 32 community health nursing/ 33 (home$ or house$ or visit$ or communit$).ti,ab. 34 or/28-33 35 Randomized Controlled Trial/ 36 randomisation/ 37 controlled clinical trial/ 38 Double Blind Procedure/ 39 Single Blind Procedure/ 40 Crossover Procedure/ 41 (clinica$ adj3 trial$).tw. 42 ((singl$ or doubl$ or trebl$ or tripl$) adj3 (mask$ or blind$ or method$)).tw. 43 exp Placebo/ 44 placebo$.ti,ab. 45 random$.ti,ab. 46 ((control$ or prospectiv$) adj3 (trial$ or method$ or stud$)).tw. 47 (crossover$ or cross-over$).ti,ab. 48 or/35-47 49 exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/ 50 human/ or normal human/ or human cell/ 51 49 and 50 52 49 not 51 53 48 not 52 54 3 and 11 and 27 and 34 and 53	
ERIC Date of most recent search: 13 September 2021	asthma AND home	• June 2020=16 • September 2021=0
ClinicalTrials.gov Date of most recent search: 13 September 2021	Study type: Interventional Condition: asthma Intervention: self-management OR education OR disease management OR case management Other terms: home Age: Child	• June 2020=92 • September 2021=15
WHO trials portal Date of most recent search: 13 September 2021	Condition: asthma Intervention: self-management OR education OR disease management OR case management	• September 2021=2

Appendix 2. Calculation of number of ED visits for Mitchell 1986

Intervention group

Europeans: 83 (total) x 48% (asthma attack not responding to Tx at home) x 34% Tx @ hospital = 14
Polynesians: 50 (total) x 49% (asthma attack not responding to Tx at home) x 47% Tx @ hospital = 12

Control group

Europeans: 81 (total) x 46% (asthma attack not responding to Tx at home) x 11% Tx @ hospital = 4
Polynesians: 45 (total) x 44% (asthma attack not responding to Tx at home) x 30% Tx @ hospital = 6

References

References to studies included in this review

Altay 2013 {published data only}

20588821

* Altay N, Çavuşoğlu H. Using Orem's self-care model for asthmatic adolescents. Journal for Specialists in Pediatric Nursing 2013;18(3):233-42. 20588822

Baek 2019 {published data only}

20588823

* Baek J, Huang K, Conner L, Tapangan N, Xu X, Carrillo G. Effects of the home-based educational intervention on health outcomes among primarily Hispanic children with asthma: a quasi-experimental study. BMC Public Health 2019;19(1):912. 20588824

Bresolini 2020 {published data only}

20588825

* Bresolini DSR, Queiroz MVNP, Gaspar GR, Reis LD, Araujo A, Lasmar LMLBF. Use of home visits in pediatric severe asthma: randomized controlled trial. Revista da Escola de EnfermageM da USP 2020;54:e003538. 20588826

Brown 2002 {published data only}

20588827

* Brown JV, Bakeman R, Celano MP, Demi AS, Kobrynski L, Wilson SR. Home-based asthma education of young low-income children and their families. Journal of Pediatric Psychology 2002;27(8):677-88. 20588828

Brown JV, Demi AD, Wilson SR, Lee SY, Bakeman R, Celano M, et al. A home-based asthma education program for low-income families and their young asthmatic children. American Journal of Respiratory and Critical Care Medicine 2000;161(Suppl 3):A902. 20588829

Brown JV, Demi AS, Celano MP, Bakeman R, Kobrynski L, Wilson SR. A home visiting asthma education program: challenges to program implementation. Health Education and Behavior 2005;32(1):42-56. 20588830

Brown 2006 {published data only}

20588831

* Brown MD, Reeves MJ, Meyerson K, Korzeniewski SJ. Randomized trial of a comprehensive asthma education program after an emergency department visit. Annals of Allergy, Asthma, and Immunology 2006;97(1):44-51. 20588832

Reeves MJ, Brown MD, Meyerson K, Korzeniewski S. A randomized controlled trial of an asthma education program following an emergency department (ED) visit for asthma in children and adults. In: Annals of Allergy, Asthma, and Immunology. Vol. C47. 2005:A22. 20588833

Butz 2006 {published data only}

20588834

Butz AM, Syron L, Johnson B, Spaulding J, Walker M, Bollinger ME. Home-based asthma self-management education for inner city children. Public Health Nursing 2005;22(3):189-99. 20588835

* Butz AM, Tsoukleris MG, Donithan M, Hsu VD, Zuckerman I, Mudd KE, et al. Effectiveness of nebulizer use-targeted asthma education on underserved children with asthma. Archives of Pediatrics and Adolescent Medicine 2006;160(6):662-8. 20588836

Butz 2010 {published data only}

20588837

Butz A, Kub J, Donithan M, James NT, Thompson RE, Bellin M, et al. Influence of caregivers and provider communication on symptom days and medication use for inner-city children with asthma. Journal of Asthma 2010;47:478-85. 20588838

Butz 2014 {published data only}

20588839

Bellin MH, Osteen P, Kub J, Bollinger ME, Tsoukleris M, Chaikind L, et al. Stress and quality of life in urban caregivers of children with poorly controlled asthma: a longitudinal analysis. Journal of Pediatric Health Care 2015;29(6):536-46. 20588840

* Butz AM, Halterman J, Bellin M, Kub J, Tsoukleris M, Frick KD, et al. Improving preventive care in high risk children with asthma: lessons learned. Journal of Asthma 2014;51(5):498-507. 20588841

Butz AM, Halterman JS, Bellin M, Kub J, Frick KD, Lewis-Land C, et al. Factors associated with completion of a behavioral intervention for caregivers of urban children with asthma. Journal of Asthma 2012;49(9):977-88. 20588842

NCT00860418. Pediatric asthma alert intervention for minority children with asthma (PAAL). https://clinicaltrials.gov/ct2/show/NCT00860418 (first received 12 March 2009). 20588843

Campbell 2015 {published data only}

20588844

Campbell J D, Brooks M, Hosokawa P, Robinson J, Song L, Krieger J. Community Health Worker Home Visits for Medicaid-Enrolled Children With Asthma: Effects on Asthma Outcomes and Costs. American Journal of Public Health 2015;105(11):2366-72. 20588845

Carswell 1989 {published data only}

20588846

Carswell F, Robinson EJ, Hek G, Shenton T. A Bristol experience: benefits and cost of an 'asthma nurse' visiting the homes of asthmatic children. Bristol Medico-

Chirurgical Journal 1989;104(1):11-2. 20588847

Celano 2012 {published data only}

20588848

* Celano MP, Holsey CN, Kobrynski LJ. Home-based family intervention for low-income children with asthma: a randomized controlled pilot study. Journal of Family Psychology 2012;26(2):171-8. 20588849

Dolinar 2000 {published data only}

20588850

Dolinar RE. Influence of a home-based asthma health education program on quality of life and coping in parents of children with asthma [Thesis]. Ottawa: University of Ottawa, 1997. 20588851

* Dolinar RM, Kumar V, Coutu-Wakulczyk G, Rowe BH. Pilot study of a home-based asthma health education program. Patient Education and Counseling 2000;40(1):93-102. 20588852

Eakin 2020 {published data only}

20588853

Eakin MN, Zaeh S, Eckmann T, Ruvalcaba E, Rand CS, Hilliard ME, et al. Effectiveness of a home- and school-based asthma educational program for head start children with asthma: a randomized clinical trial. JAMA Pediatrics 2020;174(12):1191-8. 20588854

Fisher 2009 {published data only}

20588855

Fisher EB, Strunk RC, Highstein GR, Kelley-Sykes R, Tarr KL, Trinkaus K, et al. A randomized controlled evaluation of the effect of community health workers on hospitalization for asthma: the asthma coach. Archives of Pediatrics and Adolescent Medicine 2009;163(3):225-32. 20588856

Galbreath 2008 {published data only}

20588857

* Galbreath AD, Smith B, Wood PR, Inscore S, Forkner E, Vazquez M, et al. Assessing the value of disease management: impact of 2 disease management strategies in an underserved asthma population. Annals of Allergy, Asthma and Immunology 2008;101(6):599-607. 20588858

NCT00124085. Asthma in a decentralized patient population: is traditional disease management enough? clinicaltrials.gov/ct/show/NCT00124085 (first received 9 August 2012). 20588859

Gorelick 2006 {published data only}

20588860

* Gorelick MH, Meurer JR, Walsh-Kelly CM, Brousseau DC, Grabowski L, Cohn J, et al. Emergency department allies: a controlled trial of two emergency department-based follow-up interventions to improve asthma outcomes in children. Pediatrics 2006;117(4 Pt 2):S127-34. 20588861

Jonas 2020 {published data only}

20588862

* Jonas JA, Leu CS, Reznik M. A randomized controlled trial of a community health worker delivered home-based asthma intervention to improve pediatric asthma

outcomes. Journal of Asthma 2020:1-12. 20588863 [DOI: 10.1080/02770903.2020.1846746]
NCT01003340. A community health worker home intervention to improve pediatric asthma outcomes. https://clinicaltrials.gov/ct2/show/NCT01003340 (first received 15 February 2018). 20588864
Reznik M, Jaramillo Y, Wylie-Rosett J. Demonstrating and assessing metered-dose inhaler–spacer technique: pediatric care providers' self-reported practices and perceived barriers. Clinical Periatrics 2014;53(3):270-6. 20588865
Reznik M, Johnson Silver E, Cao Y. Evaluation of MDI-spacer utilization and technique in caregivers of urban minority children with persistent asthma. Journal of Asthma 2014;51(2):149-55. 20588866
Reznik M, Ozuah PO. Measurement of inhaled corticosteroid adherence in inner-city, minority children with persistent asthma by parental report and integrated dose counter. Journal of Allergy (Cairo) 2012;2012:570850. 20588867 [DOI: 10.1155/2012/570850]

Kamps 2008 {published data only}

20588868

* Kamps JL, Rapoff MA, Roberts MC, Varela RE, Barnard M, Olson N. Improving adherence to inhaled corticosteroids in children with asthma: a pilot of a randomized clinical trial. Children's Health Care 2008;37(4):261-77. 20588869
Kamps JL. Improving adherence to inhaled corticosteroids in children with asthma [Thesis]. Kansas: University of Kansas, 2002. 20588870

Krieger 2009 {published data only}

20588871

Krieger J, Takaro T K, Song L, Beaudet N, Edwards K. A randomized controlled trial of asthma self-management support comparing clinic-based nurses and in-home community health workers: the Seattle-King County Healthy Homes II Project. Archives of Pediatric and Adolescent Medicine 2009;163(2):141-9. 20588872

Martin 2015 {published data only}

20588873

* Martin MA, Mosnaim GS, Olson D, Swider S, Karavolos K, Rothschild S. Results from a community-based trial testing a community health worker asthma intervention in Puerto Rican youth in Chicago. Journal of Asthma 2015;52(1):59-70. 20588874
Martin MA, Thomas AM, Mosnaim GS, Greve M, Swider SM, Rothschild SK. Home asthma triggers: barriers to asthma control in Chicago Puerto Rican children. Journal of Health Care for the Poor and Underserved 2013;24(2):813-27. 20588875
Martin MAMD, Olson DBA, Mosnaim GMD, Ortega DBA, Rothschild SKMD. Recruitment, asthma characteristics, and medication behaviors in Midwestern Puerto Rican youth: data from Project CURA. Annals of Allergy, Asthma, and Immunology 2012;109(2):121-7. 20588876
Pappalardo AAMD, Karavolos KMA, Martin MAMD. What really happens in the home: the medication environment of urban, minority youth. The Journal of Allergy and Clinical Immunology in Practice 2016;5(3):764-70. 20588877

Martin 2021 {published data only}

20588878

Martin MA, Bisarini R, Roy A, Mosnaim G, Rosales G, Weinstein S, et al. Implementation lessons from a randomized trial integrating community asthma education for children. Journal of Ambulatory Care Management 2020;43(2):125-35. 20588879

* Martin MA, Pugach O, Mosnaim G, Weinstein S, Rosales G, Roy A, et al. Community health worker asthma interventions for children: results from a clinically integrated randomized comparative effectiveness trial (2016–2019). American Journal of Public Health 2021;111(7):1328-37. 20588880 [PMID: 34111359]
Martin MA, Pugach O, Rosales G, Songthangtham N, Weinstein S, Roy A, et al. Results from a randomized controlled trial comparing integrated asthma community health worker intervention to certified asthma educator services. American Journal of Respiratory and Critical Care Medicine 2020;201:A4480. 20588881
Mosnaim GS, Weinstein SM, Pugach O, Rosales G, Roy A, Walton S, et al. Design and baseline characteristics of a low-income urban cohort of children with asthma: The Asthma Action at Erie Trial. Contemporary Clinical Trials 2019;79:55-65. 20588882
NCT02481986. Asthma Action at Erie Trial. clinicaltrials.gov/ct2/show/NCT02481986 (first received 25 June 2015). 20588883
Pappalardo AA, Mosnaim G, Pugach O, Rosales G, Martin MA. Medication and environmental trigger changes in children receiving community asthma intervention: results from a randomized controlled trial. American Journal of Respiratory and Critical Care Medicine 2021;203(9):A007. 20588884
Weinstein SM, Orozco K, Pugach O, Rosales G, Songthangtham N, Martin MA. Parent nativity and child asthma control in families of Mexican heritage: the effects of parent depression and social support. Academic Pediatrics 2020;20(7):967-74. 20588885
Weinstein SM, Pugach O, Rosales G, Mosnaim GS, Orozco K, Pappalardo AA, et al. Psychosocial moderators and outcomes of a randomized effectiveness trial for child asthma. Journal of Pediatric Psychology 2021;46(6):673-87. 20588886
Weinstein SM, Pugach O, Rosales G, Mosnaim GS, Walton SM, Martin MA. Family chaos and asthma control. Pediatrics 2019;144(2):e20182758. 20588887

Mitchell 1986 {published data only}

20588888

* Mitchell EA, Ferguson V, Norwood M. Asthma education by community child health nurses. Archives of Disease in Childhood 1986;61(12):1184-9. 20588889

Naar-King 2014 {published data only}

20588890

Ellis DA, King P, Naar-King S, Lam P, Cunningham PB, Secord E. Effects of family treatment on parenting beliefs among caregivers of youth with poorly controlled asthma. Journal of Developmental and Behavioral Pediatrics 2014;35(8):486-93. 20588891
Ellis DA, King P, Naar-King S. Mediators of treatment effects in a randomized clinical trial of multisystemic therapy-health care in adolescents with poorly controlled asthma: Disease knowledge and device use skills. Journal of Pediatric Psychology 2016;41(5):522-30. 20588892
Naar-King S, Ellis D, Cunningham P, Pennar AL, Lam P, Brownstein NC, et al. Comprehensive community-based intervention and asthma outcomes in African American adolescents. Pediatrics 2018;142(4):e20173737. 20588893
Naar-King S, Ellis D, King PS, Lam P, Cunningham P, Secord E, et al. Multisystemic therapy for high-risk African American adolescents with asthma: a randomized clinical trial. Journal of Consulting and Clinical Psychology 2014;82(3):536-45. 20588894

Otsuki 2009 {published data only}

20588895

NCT00233181. Adherence intervention for minority children with asthma. clinicaltrials.gov/ct2/show/NCT00233181 (first recieved 5 October 2005). 20588896

* Otsuki M, Eakin MN, Rand CS, Butz AM, Hsu VD, Zuckerman IH, et al. Adherence feedback to improve asthma outcomes among inner-city children: a randomized trial. Pediatrics 2009;124(6):1513-21. 20588897

Otsuki M, Kalesan B, Butz A, Rand C, Riekert K. Longitudinal evaluation of a randomized controlled trail of an adherence promoting intervention for inner-city children. In: American Thoracic Society International Conference, May 18-23, 2007, San Francisco, California, USA. 2007:A18. 20588898

Seid 2010 {published data only}

20588899

NCT00250588. Problem-solving skills training to improve care for children with asthma. clinicaltrials.gov/ct/show/NCT00250588 (first received 3 June 2013). 20588900

Seid M, Varni JW, Gidwani P, Gelhard LR, Slymen DJ. Problem-solving skills training for vulnerable families of children with persistent asthma: report of a randomized trial on health-related quality of life outcomes. Journal of Pediatric Psychology 2010;35(10):1133-43. 20588901

References to studies excluded from this review

ACTRN12621000673842 {published data only}

20588902

ACTRN12621000673842. Care from Home program: a comprehensive community-based care coordination for management of paediatric asthma (CoMPAs) project. http://www.who.int/trialsearch/Trial2.aspx?TrialID=ACTRN12621000673842 (first received 3 June 2021). 20588903

Adams 2004 {published data only}

20588904

Adams CD, Joseph KE, MacLaren JE, DeMore M, Koven L, Detweiler MF, et al. Parent-youth teamwork in pediatric asthma management. Journal of Allergy and Clinical Immunology 2004;113(Suppl 2):S159. 20588905

NCT00166582. Parent-youth teamwork in pediatric asthma management. clinicaltrials.gov/ct2/show/NCT00166582 (first received 14 September 2005). 20588906

Adgate 2008 {published data only}

20588907

Adgate JL, Ramachandran G, Cho SJ, Ryan AD, Grengs J. Allergen levels in inner city homes: baseline concentrations and evaluation of intervention effectiveness. Journal of Exposure Science and Environmental Epidemiology 2008;18(4):430-40. 20588908

Agertoft 1998 {published data only}

20588909

Agertoft L, Pedersen S. Importance of training for correct Turbuhaler use in preschool children. Acta Paediatrica 1998;87(8):842-7. 20588910

Agrawal 2005 {published data only}

20588911

Agrawal SK, Singh M, Mathew JL, Malhi P. Efficacy of an individualized written home-management plan in the control of moderate persistent asthma: a randomized, controlled trial. Acta Paediatrica 2005;94(12):1742-6. 20588912

Akkaya 1997 {published data only}

20588913

Akkaya E, Yilmaz A, Ece F, Bayramguler B, Baran A, Akakca A. Effects of patient education to the life quality in asthma patients: 3 years experience. European Respiratory Journal 1997;10(Suppl 25):194S. 20588914

Aleman Mendez 1992 {published data only}

20588915

Aleman Mendez S, Sanchez Palacios A. An integrated approach to the psychological features of the asthmatic child. Allergologia et Immunopathologia 1992;20(6):240-5. 20588916

Alexander 1972 {published data only}

20588917

Alexander AB, Miklich DR, Hershkoff H. The immediate effects of systematic relaxation training on peak expiratory flow rates in asthmatic children. Psychosomatic Medicine 1972;34(5):388-94. 20588918

Alexander 1988 {published data only}

20588919

Alexander JS, Younger RE, Cohen RM, Crawford LV. Effectiveness of a nurse-managed program for children with chronic asthma. Journal of Pediatric Nursing 1988;3(5):312-7. 20588920

Andersen 2007 {published data only}

20588921

Andersen UM. Does a www-based interactive computer program change asthma outcomes, quality of life and asthma knowledge. Journal of Allergy and Clinical Immunology 2007;119(Suppl 1):S9. 20588922

Arbes 2003 {published data only}

20588923

Arbes SJ Jr, Sever M, Archer J, Long EH, Gore JC, et al. Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: a randomized controlled trial. Journal of Allergy and Clinical Immunology 2003;112(2):339-45. 20588924

Arbes 2004 {published data only}

20588925

Arbes SJ Jr, Sever M, Mehta J, Gore JC, Schal C, et al. Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: month 12 continuation results. Journal of Allergy and Clinical Immunology 2004;113(1):109-14. 20588926

Barnes 2008 {published data only}

20588927

Barnes CS, Kennedy K, Gard L, Forrest E, Johnson L, Pacheco F, et al. The impact of home cleaning on quality of life for homes with asthmatic children. Allergy and Asthma Proceedings 2008;29(2):197-204. 20588928

Bateman 2000 {published data only}

20588929

Bateman ED, Kruger MJ. A computer-based home-monitoring disease management programme, Pulmassist Plus® (PAP), achieves significant improvement in quality of life, and healthcare costs in moderate and severe asthma. American Journal of Respiratory and Critical Care Medicine 2000;161(Suppl 3):A457. 20588930

Bateman ED, Kruger MJ. Improvements in prescriptions and health care utilisation in patients with moderate or severe asthma enrolled in a 12 month study with the Pulmassist Plus® (PAP) disease management programme. In: American Thoracic Society 2000 International Conference; May 5-10; Toronto, Canada. Vol. 161 (Suppl 3). 2000:A787. 20588931

Becker 2003 {published data only}

20588932

Becker AB, Whitters D, Gillespie CA, Filuk SE, McColm JE, Thomas NJ, et al. Impact of a randomized asthma education program on asthma control in children. Journal of Allergy and Clinical Immunology 2003;111(Suppl 2):S212. 20588933

Bender 1997 {published data only}

20588934

Bender BG, Ikle DN, DuHamel T, Tinkelman D. Retention of asthmatic patients in a longitudinal clinical trial. Journal of Allergy and Clinical Immunology 1997;99(2):197-203. 20588935

Bender 2003 {published data only}

20588936

Bender BG, Ellison MC, Gleason M, Murphy JR, Sundstrom DA, Szefler SJ. Minimizing attrition in a long-term clinical trial of pediatric asthma. Annals of Allergy, Asthma, and Immunology 2003;91(2):168-76. 20588937

Bird 2012 {published data only}

20588938

Bird SR, Noronha M, Kurowski W, Orkin C, Sinnott H. Integrated care facilitation model reduces use of hospital resources by patients with pediatric asthma. Journal for Healthcare Quality 2012;34(3):25-33. 20588939

Bonner 2002 {published data only}

20588940

Bonner S, Zimmerman BJ, Evans D, Irigoyen M, Resnick D, Mellins RB. An individualized intervention to improve asthma management among urban Latino and African-American families. Journal of Asthma 2002;39(2):167-79. 20588941

Bonsignore 2008 {published data only}

20588942

Bonsignore MR, La Grutta S, Cibella F, Cuttitta G, Messineo B, Veca M, et al. Effects of 12 week aerobic training in children with mild intermittent asthma. In: Proceedings of the American Thoracic Society. 2006:A162 [Poster C72]. 20588943

Bonsignore MR, La Grutta S, Cibella F, Scichilone N, Cuttitta G, Interrante A, et al. Effects of exercise training and montelukast in children with mild asthma. Medicine and Science in Sports and Exercise 2008;40(3):405-12. 20588944

Boone 2002 {published data only}

20588945

Boone D, Counsell P, Dobson C, Baker EH. Effect of computer-assisted education on inhaler technique and knowledge in children with asthma. In: European Respiratory Society Annual Congress. 2002:P2062. 20588946

Borba 2013 {published data only}

20588947

Borba Rodrigues CD, Pereira RP, Roth DPdT. Effects of an outpatient education program in patients with uncontrolled asthma. Jornal Brasileiro de Pneumologia 2013;39(3):272-9. 20588948

Bramson 1996 {published data only}

20588949

Bramson R. Self-management of asthma. Journal of Family Practice 1996;43(1):21-2. 20588950

Brewin 1995 {published data only}

20588951

Brewin AM, Hughes JA. Effect of patient education on asthma management. British Journal of Nursing 1995;4(2):81-2, 99-101. 20588952

Brosco 2005 {published data only}

20588953

NCT00304304. HealthSpark 2: improving asthma care for preschool children. clinicaltrials.gov/ct2/show/NCT00304304 (first received 17 March 2006). 20588954 [URL: http://www.clinicaltrials.gov/ct/show/NCT00304304]

Bryant 2001 {published data only}

20588955

Bryant-Stevens T. Reducing asthma triggers in the asthmatic child's bedroom: a randomized, controlled study using lay home visitors. In: Annual Meeting of the American Public Health Association, Philadelphia, October 22, 2001. 2001:30067. 20588956

Bryant-Stephens 2004 {published data only}

20588957

Bryant-Stephens T. Asthma and environmental control: the results of a randomized, controlled study to remove asthma triggers from the bedrooms of children with persistent asthma. Chest 2004;126(Suppl 4):761S. 20588958

Bryant-Stephens 2008a {published data only}

20588959

Bryant-Stephens T, Li Y. Outcomes of a home-based environmental remediation for urban children with asthma. Journal of the National Medical Association 2008;100(3):306-16. 20588960

Burkhart 2001 {published data only}

20588961

Burkhart PV, Dunbar-Jacob JM, Fireman P, Rohay J. Children's adherence to recommended asthma self-management. Pediatric Nursing 2002;28(4):409-14. 20588962

Burkhart PV, Dunbar-Jacob JM, Rohay JM. Accuracy of children's self-reported adherence to treatment. Journal of Nursing Scholarship 2001;33(1):27-32. 20588963
Burkhart PV, Rayens MK. Self-concept and health locus of control: factors related to children's adherence to recommended asthma regimen. Pediatric Nursing 2005;31(5):404-9. 20588964
Burkhart PV, Ward HJ. Children's self-reports of characteristics of their asthma episodes. Journal of Asthma 2003;40(8):909-16. 20588965
Burkhart PV. Effect of contingency management on adherence to peak flow monitoring in school-age children with asthma [Phd Thesis]. University of Pittsburgh, 1996. 20588966

Burkhart 2007 {published data only}

20588967

Burkhart PV, Rayens MK, Oakley MG, Abshire DA, Zhang M. Testing an intervention to promote children's adherence to asthma self-management. Journal of Nursing Scholarship 2007;39(2):133-40. 20588968
Burkhart PV, Rayens MK, Revelette WR, Ohlmann A. Improved health outcomes with peak flow monitoring for children with asthma. Journal of Asthma 2007;44(2):137-42. 20588969

Butz 2005a {published data only}

20588970

Butz A, Pham L, Lewis L, Lewis C, Hill K, Walker J, et al. Rural children with asthma: impact of a parent and child asthma education program. Journal of Asthma 2005;42(10):813-21. 20588971
NCT00218803. Teaching children with asthma and who live in a rural setting how to self-manage their asthma. clinicaltrials.gov/ct/show/NCT00218803 (first received 22 September 2005). 20588972

Butz 2007 {published data only}

20588973

Butz A, Land C, Walker J, Bollinger M E. Improving asthma communication with inner city parents, does it work? Journal of Allergy and Clinical Immunology 2007;119(1 Suppl):S66 [257]. 20588974
NCT00133666. Improving asthma communication in minority families. clinicaltrials.gov/ct/show/NCT00133666 (first received 23 August 2005). 20588975

Bynum 2001 {published data only}

20588976

Bynum A, Hopkins D, Thomas A, Copeland N, Irwin C. The effect of telepharmacy counseling on metered-dose inhaler technique among adolescents with asthma in rural Arkansas. Telemedicine Journal and E-Health 2001;7(3):207-17. 20588977

Callahan 2003 {published data only}

20588978

Callahan KA, Eggleston PA, Rand CS, Kanchanaraksa S, Swartz LJ, Wood RA. Knowledge and practice of dust mite control by specialty care. Annals of Allergy, Asthma and Immunology 2003;90(3):302-7. 20588979

Callahan 2004 {published data only}

20588980

Callahan KA, Rand CS, Grant CS, Curtin-Brosnan JM, Swartz LJ, Diette GB, et al.

Providing an in-home allergen control intervention; a comparison of behavioural changes in inner-city homes of children with asthma. Journal of Allergy and Clinical Immunology 2004;113(2 Suppl):S102. 20588981

CAMP {published data only}

20588982

Childhood Asthma Management Program Research Group. Recruitment of participants in the childhood Asthma Management Program CAMP. I. Description of methods. Journal of Asthma 1999;36(3):217-37. 20588983

Catov 2005 {published data only}

20588984

Catov JM, Marsh GM, Youk AO, Huffman VY. Asthma home teaching: two evaluation approaches. Disease Management 2005;8(3):178-87. 20588985

Chan 2003 {published data only}

20588986

Chan DS, Callahan CW, Sheets SJ, Moreno CN, Malone FJ. An Internet-based store-and-forward video home telehealth system for improving asthma outcomes in children. American Journal of Health-System Pharmacy 2003;60(19):1976-81. 20588987

Chan 2007 {published data only}

20588988

Chan DS, Callahan CW, Hatch-Pigott VB, Lawless A, Proffitt HL, Manning NE, et al. Internet-based home monitoring and education of children with asthma is comparable to ideal office-based care: results of a 1-year asthma in-home monitoring trial. Pediatrics 2007;119(3):569-78. 20588989

NCT00282516. Asthma in-home monitoring (AIM) trial. clinicaltrials.gov/ct/show/NCT00282516 (first received 26 January 2006). 20588990

Chiang 2004 {published data only}

20588991

Chiang LC, Huang JL, Yeh KW, Lu CM. Effects of a self-management asthma educational program in Taiwan based on PRECEDE-PROCEED model for parents with asthmatic children. Journal of Asthma 2004;41(2):205-15. 20588992

Clark 1986 {published data only}

20588993

Clark NM, Feldman CH, Evans D, Duzey O, Levison MJ, Wasilewski Y, et al. Managing better: children, parents, and asthma. Patient Education and Counseling 1986;8(1):27-38. 20588994

Clark NM, Feldman CH, Evans D, Levison MJ, Wasilewski Y, Mellins RB. The impact of health education on frequency and cost of health care use by low income children with asthma. Journal of Allergy and Clinical Immunology 1986;78(1 Pt 1):108-15. 20588995

Claus 2004 {published data only}

20588996

Claus R, Michael H, Josef L, Jan-Torsten T, Marion S. Internet based patient education evaluation of a new tool for young asthmatics. European Respiratory Journal

2004;24(Suppl 48):383s. 20588997

Cohen 1979 {published data only}

20588998

Cohen HI, Harris C, Green HW, Goodriend-Resnik S. Cost-benefit analysis of asthma self-management educational program in children. Journal of Allergy and Clinical Immunology 1979;63(3):155-6. 20588999

Colland 2004 {published data only}

20589000

Colland VT, Essen-Zandvliet LE, Lans C, Denteneer A, Westers P, Brackel HJL. Poor adherence to self-medication instructions in children with asthma and their parents. Patient Education and Counseling 2004;55(3):416-21. 20589001

Cote 1997 {published data only}

20589002

Cote J, Cartier A, Robichaud P, Boutin H, Malo JL, Rouleau M, et al. Influence on asthma morbidity of asthma education programs based on self-management plans following treatment optimization. American Journal of Respiratory and Critical Care Medicine 1997;155(5):1509-14. 20589003

Dahl 1990 {published data only}

20589004

Dahl J, Gustafsson D, Melin L. Effects of a behavioral treatment program on children with asthma. Journal of Asthma 1990;27(1):41-6. 20589005

Deaves 1993 {published data only}

20589006

Deaves D. An assessment of the value of health eduction in the prevention of childhood asthma. Journal Advanced Nursing 1993;18:354-63. 20589007

Delaronde 2005 {published data only}

20589008

Delaronde S, Peruccio DL, Bauer BJ. Improving asthma treatment in a managed care population. American Journal of Managed Care 2005;11(6):361-8. 20589009

Peruccio D, Bauer B, Delaronde S. Improving asthma treatment and quality of life in a managed care population. Journal of Allergy and Clinical Immunology 2005;115(Suppl 2):S63. 20589010

Donaghy 1995 {published data only}

20589011

Donaghy D. The asthma specialist and patient education. Professional Nurse 1995;11(3):160-2. 20589012

Eggleston 2004 {published data only}

20589013

Eggleston PA, Butz A, Rand A, Swartz L, Callahan K, Curtin-Brosnan J, et al. Home environmental treatment improves asthma in inner city children. Journal of Allergy and Clinical Immunology 2004;113(Suppl 2):S179. 20589014

Eggleston 2005 {published data only}

20589015

Eggleston PA, Butz A, Rand C, Curtin-Brosnan J, Kanchanaraksa S, Swartz L, et al. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. Annals of Allergy, Asthma, and Immunology 2005;95(6):518-24. 20589016

Evans 1999 {published data only}

20589017

Evans R 3rd, Gergen PJ, Mitchell H, Kattan M, Kercsmar C, Crain E, et al. A randomized clinical trial to reduce asthma morbidity among inner-city children: results of the National Cooperative Inner-City Asthma Study. Journal of Pediatrics 1999;135(3):332-8. 20589018

Sullivan SD, Weiss KB, Lynn H, Mitchell H, Kattan M, Gergen PJ, et al. The cost-effectiveness of an inner-city asthma intervention for children. Journal of Allergy and Clinical Immunology 2002;110(4):579-81. 20589019

Everhart 2020 {published data only}

20589020

Everhart RS, Mazzeo SE, Corona R, Holder RL, Thacker LR, Schechter MS. A community-based asthma program: study design and methods of RVA Breathes. Contemporary Clinical Trials 2020;97:106121. 20589021

Finkelstein 2002 {published data only}

20589022

Finkelstein JA, Fuhlbrigge A, Lozano P, Grant EN, Shulruff R, Arduino KE, et al. Parent-reported environmental exposures and environmental control measures for children with asthma. Archives of Pediatrics and Adolescent Medicine 2002;156(3):258-64. 20589023

Flores 2009 {published data only}

20589024

Flores G, Bridon C, Torres S, Perez R, Walter T, Brotanek J, et al. Improving asthma outcomes in minority children: a randomized, controlled trial of parent mentors. Pediatrics 2009;124:1522-32. 20589025

Gardida 2002 {published data only}

20589026

Gardida A, Rojas M, Tavera C, Catalan M. Evaluation of an educational program to control asthma in school age children in the Morelos state, Mexico. Revista del Instituto Nacional de Enfermedades Respiratorias 2002;15(1):27-30. 20589027

Greineder 1995 {published data only}

20589028

Greineder DK, Loane KC, Parks P. Reduction in resource utilization by an asthma outreach program. Archives of Pediatric and Adolescent Medicine 1995;149(4):415-20. 20589029

Greineder 1999 {published data only}

20589030

Greineder DK, Loane KC, Parks P. A randomized controlled trial of a pediatric asthma outreach program. Journal of Allergy and Clinical Immunology 1999;103(3 Pt 1):436-40. 20589031

Griffiths 2004 {published data only}

20589032

Griffiths C, Foster G, Barnes N, Eldridge S, Tate H, Begum S, et al. Specialist nurse intervention to reduce unscheduled asthma care in a deprived multiethnic area: the east London randomised controlled trial for high risk asthma (ELECTRA). BMJ 2004;328(7432):144. 20589033

Guendelman 2002 {published data only}

20589034

Guendelman S, Meade K, Benson M, Chen YQ, Samuels S. Improving asthma outcomes and self-management behaviors of inner-city children: a randomized trial of the Health Buddy interactive device and an asthma diary. Archives of Pediatrics and Adolescent Medicine 2002;156(2):114-20. 20589035

Guendelman S, Meade K, Chen YQ, Benson M. Asthma control and hospitalizations among inner-city children: results of a randomized trial. Telemedicine Journal and E-Health 2004;10(Suppl 2):114-20. 20589036

Guendelman S, Meade K, Chen YQ, Benson M. Asthma control and hospitalizations among inner-city children: results of a randomized trial. Telemedicine Journal and E-Health 2004;10(Suppl 2):s6-s14. 20589037

Holley 2018 {published data only}

20589038

Holley S, Knibb R, Latter S, Liossi C, Mitchell F, Snape C, et al. Self-efficacy, asthma control and quality of life in adolescents with asthma taking part in an intervention study. Clinical and Translational Allergy 2018;8(Suppl 2):P8. 20589039

Holzheimer 1998 {published data only}

20589040

Holzheimer L, Mohay H, Masters B. Evaluation of asthma self management materials for young children. Australian and New Zealand Journal of Medicine 1995;25:451. 20589041

Holzheimer L, Mohay H, Masters IB. Educating young children about asthma: comparing the effectiveness of a developmentally appropriate asthma education video tape and picture book. Child: Care, Health & Development 1998;24(1):85-99. 20589042

Homer 2000 {published data only}

20589043

Homer C, Susskind O, Alpert HR, Owusu MS, Schneider L, Rappaport LA, et al. An evaluation of an innovative multimedia educational software program for asthma management: report of a randomized, controlled trial. Pediatrics 2000;106(1 Pt 2):210-5. 20589044

Homer 2005 {published data only}

20589045

Homer CJ, Forbes P, Horvitz L, Peterson LE, Wypij D, Heinrich P. Impact of a quality improvement program on care and outcomes for children with asthma. Archives of Pediatric and Adolescent Medicine 2005;159(5):464-9. 20589046

Horner 2004 {published data only}

20589047

Horner SD. Effect of education on school-age children's and parents' asthma

management. Journal for Specialists in Pediatric Nursing 2004;9(3):95-102. 20589048

Horner 2006 {published data only}

20589049

Horner SD, Rew DL, Brown SA, Fouladi RT. Promoting asthma self-management among rural families and children. Proceedings of the American Thoracic Society 2006:A52 [Poster 108]. 20589050

Horner 2008 {published data only}

20589051

Horner SD, Fouladi RT. Improvement of rural children's asthma self-management by lay health educators. Journal of School Health 2008;78(9):506-13. 20589052

Horner SD, Rew DL, Brown SA. Enhancing asthma management among rural Mexican American, white and African American school-aged children and their parents. In: American Thoracic Society International Conference, May 18-23, 2007, San Francisco, California, USA. 2007:Poster #714. 20589053

Horwitz 2021 {published data only}

20589054

Horwitz D, Kestenbom I, Goldbart A, Chechik T, Dizitzer Y, Golan-Tripto I. The effect of a coaching program on asthma control and health care utilization in children with asthma. The Journal of Asthma 2021;58(2):240-7. 20589055

Hovell 1994 {published data only}

20589056

Hovell MF, Meltzer SB, Zakarian JM, Wahlgren DR, Emerson JA, Hofstetter CR, et al. Reduction of environmental tobacco smoke exposure among asthmatic children: a controlled trial. [erratum appears in Chest 1995 May;107(5):1480]. Chest 1994;106(2):440-6. 20589057

Hovell 2002 {published data only}

20589058

Hovell MF, Meltzer SB, Wahlgren DR, Matt GE, Hofstetter CR, Jones JA, et al. Asthma management and environmental tobacco smoke exposure reduction in Latino children: a controlled trial. Pediatrics 2002;110(5):946-56. 20589059

Hughes 1991 {published data only}

20589060

Hughes DM, McLeod M, Garner B, Goldbloom RB. Controlled trial of a home and ambulatory program for asthmatic children. Pediatrics 1991;87(1):54-61. 20589061

Huss 2003 {published data only}

20589062

Huss K, Winkelstein M, Nanda J, Naumann PL, Sloand ED, Huss RW. Computer game for inner-city children does not improve asthma outcomes. Journal of Pediatric Health Care 2003;17(2):72-8. 20589063

Indinnimeo 2009 {published data only}

20589064

Indinnimeo L, Bonci E, Capra L, La Grutta S, Monaco F, Paravati F, et al. Clinical effects of a long-term educational program for children with asthma - Aironet. A 1-yr randomized controlled trial. Pediatric Allergy and Immunology 2009;20:654-9. 20589065

Jain 1991 {published data only}

20589066

Jain SC, Rai L, Valecha A, Jha UK, Bhatnagar SO, Ram K. Effect of yoga training on exercise tolerance in adolescents with childhood asthma. Journal of Asthma 1991;28(6):437-42. 20589067

Jan 2007 {published data only}

20589068

Jan RL, Wang JY, Huang MC, Tseng SM, Su HJ, Liu LF. An internet-based interactive telemonitoring system for improving childhood asthma outcomes in Taiwan. Telemedicine Journal and e-Health 2007;13(3):257-68. 20589069

Jenkinson 1988 {published data only}

20589070

Jenkinson D, Davison J, Jones S, Hawtin P. Comparison of effects of a self management booklet and audiocassette for patients with asthma. BMJ 1988;297(6643):267-70. 20589071

Jerant 2009 {published data only}

20589072

Jerant A, Moore-Hill M, Franks P. Home-based, peer-led chronic illness self-management training: findings from a 1-year randomized controlled trial. Annals of Family Medicine 2009;7(4):319-27. 20589073

Jones 2001 {published data only}

20589074

Jones JA, Wahlgren DR, Meltzer SB, Meltzer Eli O, Clark NM, Hovell MF. Increasing asthma knowledge and changing home environments for Latino families with asthmatic children. Patient Education and Counseling 2001;42(1):67-79. 20589075

Joseph 2000 {published data only}

20589076

Joseph CLM, Havstad S, Ownby DR, Johnson CC, Tilley BC. "What's the 411 on asthma?" Asthma education for African American teenagers. American Journal of Respiratory and Critical Care Medicine 2000;161(Suppl 3):A621. 20589077

Joseph 2005 {published data only}

20589078

Joseph CL, Havstad S, Anderson EW, Brown R, Johnson CC, Clark NM. Effect of asthma intervention on children with undiagnosed asthma. Journal of Pediatrics 2005;146(1):96-104. 20589079

Kamps 2004 {published data only}

20589080

Kamps AWA. Unscheduled care for people with asthma in a multi-ethnic area is

reduced following educational outreach programme by specialist nurses. Evidence Based Healthcare 2004;8(4):190-1. 20589081

Karnick 2007 {published data only}

20589082

Johnson RD, Karnick P, Seals G, Margellos H, Silva A, Whitman S, et al. Randomized study of the impact of intensive asthma education (IAE), with/without case management (CM), on the health of inner city asthmatic children: preliminary results of the Chicago Asthma Initiative (IAE). Pediatric Research 2002;51(4):212A #1234. 20589083

Karnick P, Margellos-Anast H, Seals G, Whitman S, Aljadeff G, Johnson D. The pediatric asthma intervention: a comprehensive cost-effective approach to asthma management in a disadvantaged inner-city community. Journal of Asthma 2007;44(1):39-44. 20589084

Kay Bartholomew 2006 {published data only}

20589085

Kay Bartholomew L, Sockrider M, Abramson S L, Swank PR, Czyzewski DI, Tortolero SR, et al. Partners in school asthma management: evaluation of a self-management program for children with asthma. Journal of School Health 2006;76(6):283-90. 20589086

Kercsmar 2006 {published data only}

20589087

Kercsmar CM, Dearborn DG, Schluchter M, Xue L, Kirchner HL, Sobolewski J, et al. Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. Environmental Health Perspectives 2006;114(10):1574-80. 20589088

Khan 2004 {published data only}

20589089

Khan MSR, O'Meara M, Henry RL. Background severity of asthma in children discharged from the emergency department. Journal of Paediatrics and Child Health 2003;39(6):432-5. 20589090

Khan MSR, O'Meara M, Stevermuer TL, Henry RL. Randomized controlled trial of asthma education after discharge from an emergency department. Journal of Paediatrics and Child Health 2004;40(12):674-7. 20589091

Khan S, O'Meara M, Hurst T, Henry RL. Randomised controlled trial of asthma education by telephone after discharge from an emergency department. European Respiratory Journal 2003;22(Suppl 45):P2294. 20589092

Klinnert 2005 {published data only}

20589093

Klinnert MD, Liu AH, Pearson MR, Ellison MC, Budhiraja N, Robinson JL. Short-term impact of a randomized multifaceted intervention for wheezing infants in low-income families. Archives of Pediatrics and Adolescent Medicine 2005;159(1):75-82. 20589094

Klinnert MD, Liu AH, Pearson MR, Tong S, Strand M, Luckow A, et al. Outcome of a randomized multifaceted intervention with low-income families of wheezing infants. Archives of Pediatrics and Adolescent Medicine 2007;161(8):783-90. 20589095

Klinnert MD, Liu AH, Price M, Ellison MC, Budhiraja N. Short-term impact of a multi-faceted intervention for wheezy infants at risk for asthma. Journal of Allergy and Clinical Immunology 2004;113(Suppl 2):S302. 20589096

Kokubu 1999 {published data only}

20589097

Kokubu F, Nakajima S, Ito K, Makino S, Kitamura S, Fukuchi Y, et al. Hospitalization reduction by an asthma tele-medicine system. Arerugi - Japanese Journal of Allergology 2000;49(1):19. 20589098

Kokubu F, Suzuki H, Sano Y, Kihara N, Adachi M. Tele-medicine system for high-risk asthmatic patients. Arerugi - Japanese Journal of Allergology 1999;48(7):700-12. 20589099

Kotses 1996 {published data only}

20589100

Kotses H, Stout C, McConnaughy K, Winder J A, Creer TL. Evaluation of individualized asthma self-management programs. Journal of Asthma 1996;33(2):113-8. 20589101

Krishna 2003 {published data only}

20589102

Krishna S, Francisco BD, Andrew Balas E, Konig P, Graff GR, Madsen RW. Internet-enabled interactive multimedia asthma education program: a randomized trial. Pediatrics 2003;111(3):503-10. 20589103

Kuijer 2007 {published data only}

20589104

Kuijer RG, De Ridder DTD, Colland VT, Schreurs KMG, Sprangers MAG. Effects of a short self-management intervention for patients with asthma and diabetes: evaluating health-related quality of life using then-test methodology. Psychology and Health 2007;22(4):387-411. 20589105

La Roche 2006 {published data only}

20589106

La Roche MJ, Koinis-Mitchell D, Gualdron L. A culturally competent asthma management intervention: a randomized controlled pilot study. Annals of Allergy, Asthma and Immunology 2006;96(1):80-5. 20589107

LeBaron 1985 {published data only}

20589108

LeBaron S, Zeltzer LK, Ratner P, Kniker WT. A controlled study of education for improving compliance with cromolyn sodium ®: the importance of physician-patient communication. Annals of Allergy 1985;55(6):811-8. 20589109

Lecheler 1988 {published data only}

20589110

Lecheler J, Biberger A, Seligmann C, Dorsch U, Hasse-Dorsch I. Sports therapy in the treatment of pediatric bronchial asthma. Comparison of interval and continuous training. Praxis und Klinik der Pneumologie 1988;42(7):475-8. 20589111

Lee 2010 {published data only}

20589112

Lee JK, Yang YH. Evaluation of an education program for patients with asthma who use inhalers. Journal of Korean Academy of Nursing 2010;40(2):202-12. 20589113

Letz 2004 {published data only}

20589114

Letz K, Smits W. A randomized trial comparing peak expiratory flow versus symptom self-management plans for children with persistent asthma. Journal of Allergy and Clinical Immunology 2004;113(Suppl 2):S286. 20589115

Letz KL, Schlie AR, Smits WL. A randomized trial comparing peak expiratory flow versus symptom self-management plans for children with persistent asthma. Pediatric Asthma Allergy and Immunology 2004;17(3):177-90. 20589116

Lewis 1987 {published data only}

20589117

Lewis MA, de la Sota A, Rachelefsky G, Lewis CE, Quinones H, Richards W. ACT-asthma control y tratamiento para ninos: a progress report. Health Education Quarterly 1987;14(3):281-90. 20589118

Lewis 1994 {published data only}

20589119

Lewis MA, Rachelefsky G, Lewis CE, Leake B, Richards W. The termination of a randomized clinical trial for poor Hispanic children. Archives of Pediatric and Adolescent Medicine 1994;148:364-7. 20589120

Li 2006 {published data only}

20589121

Li S, Zhang Z. Influence of self-care education on self-care ability and quality of living of asthma patients. Chinese Nursing Research 2006;20(4A):885-7. 20589122

Lieberman 2001 {published data only}

20589123

Lieberman D A. Management of chronic pediatric diseases with interactive health games: theory and research findings. Journal of Ambulatory Care Management 2001;24(1):26-38. 20589124

Linicome 2001 {published data only}

20589125

Linicome V, Lozano P, Jones C, Bryant J E, Finkelstein J, Shulruff R, et al. The nurse-patient collaboration: experiences with a self-management support intervention for asthma. Journal of Allergy and Clinical Immunology 2001;107(2):S73. 20589126

Liu 2001 {published data only}

20589127

Liu C Y, Feekery C. Can asthma education improve clinical outcomes? an evaluation of a pediatric asthma education program. Journal of Asthma 2001;38(3):269-78. 20589128

Liu 2007 {published data only}

20589129

Liu WT, Wang CH, Huang CD, Kuo H P. A novel mobile phone-based self-care system improves asthma control [Abstract]. In: American Thoracic Society International Conference, May 18-23, 2007, San Francisco, California, USA. 2007:A93. 20589130

Mandhane {published data only}

20589131

Mandhane PJ, McGhan SL, Sharpe HM, Wong E, Hessel PA, Befus AD, et al. A child's asthma quality of life rating does not significantly influence management of their asthma. Pediatric Pulmonology 2010;45:141-8. 20589132

Marabini 2002 {published data only}

20589133

Marabini A, Brugnami G, Curradi F, Anulli R, Casciola G, Pettinari L, et al. Short-term effectiveness of an asthma patient education program. American Journal of Respiratory and Critical Care Medicine 1998;157(Suppl 3):A737. 20589134

Marabini A, Brugnami G, Curradi F, Casciola G, Stopponi R, Pettinari L, et al. Short-term effectiveness of an asthma educational program: results of a randomized controlled trial. Respiratory Medicine 2002;96(12):993-8. 20589135

Marabini A, Brugnami G, Curradi F, Siracusa A. Does an asthma education program improve quality of life? A two-year randomized trial. Journal of Asthma 2005;42(7):577-81. 20589136

Siracusa A, Anulli R, Brugnami G, Casciola G, Curradi F, Marabini A, et al. Effectiveness of an asthma education programme: a one year follow-up study. European Respiratory Journal 1998;12(Suppl 29):P193. 20589137

Margolis 2021 {published data only}

20589138

Margolis RHF, Dababnah S, Sacco P, Jones-Harden B, Bollinger ME, Butz A, et al. The effects of caregiver social support and depressive symptoms on child medication adherence and asthma control. Journal of Racial and Ethnic Health Disparities 2021:1-9. 20589139 [DOI: 10.1007/s40615-021-01065-w]

McCarthy 2002 {published data only}

20589140

McCarthy MJ, Herbert R, Brimacombe M, Hansen J, Wong D, Zelman M. Empowering parents through asthma education. Pediatric Nursing 2002;28(5):465-73. 20589141

McConnell 2005 {published data only}

20589142

McConnell R, Milam J, Richardson J, Galvan J, Jones C, Thorne PS, et al. Educational intervention to control cockroach allergen exposure in the homes of Hispanic children in Los Angeles: results of the La Casa study. Clinical and Experimental Allergy 2005;35(4):426-33. 20589143

McGhan 2010 {published data only}

20589144

McGhan SL, Wong E, Sharpe HM, Hessel PA, Mandhane P, Boechler VL, et al. A children's asthma education program: Roaring Adventures of Puff (RAP), improves quality of life. Canadian Respiratory Journal 2010;17(2):67-73. 20589145

McNabb 1985 {published data only}

20589146

McNabb WL, Wilson-Pessano SR, Hughes GW, Scamagas P. Self-management education of children with asthma: AIR WISE. American Journal of Public Health

1985;75(10):1219-20. 20589147

McPherson 2006 {published data only}

20589148

Glazebrook C, McPherson A, Forster D, James C, Crook I, Smyth A. The asthma files: randomised controlled trial of interactive multimedia program to promote self-management skills in children. In: American Thoracic Society 100th International Conference, May 21-26, 2004, Orlando. Vol. D29. 2004:P506. 20589149

McPherson A, Glazebrook C, Smyth S. Effectiveness of a multimedia education program for children with asthma. European Respiratory Journal 2003;22(Suppl 45):P2299. 20589150

McPherson AC, Glazebrook C, Forster D, James C, Smyth A. A randomized, controlled trial of an interactive educational computer package for children with asthma. Pediatrics 2006;117(4):1046-54. 20589151

Mendes 2010 {published data only}

20589152

Mendes F, Cukier A, Stelmach R, Martins M, Carvalho C. Effect of aerobic training on autonomic modulation in asthmatic patients. In: European Respiratory Society Annual Congress, Barcelona, Spain. 2010:E2161. 20589153

Meszaros 2003 {published data only}

20589154

Meszaros A, Orosz M, Magyar P, Mesko A, Vincze Z. Evaluation of asthma knowledge and quality of life in Hungarian asthmatics. Allergy 2003;58(7):624-8. 20589155

Mildenhall 1997 {published data only}

20589156

Mildenhall S, McLean M, Pearce S, Noble M, Harrison BDW. Evaluation of a home based coping skills training programme for high risk asthma sufferers. Thorax 1997;52(Suppl 6):A46 P62. 20589157

Morgan 2004 {published data only}

20589158

Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, Evans R, et al. Results of a home-based environmental intervention among urban children with asthma. New England Journal of Medicine 2004;351(11):1068-80. 20589159

Mosnaim 2008 {published data only}

20589160

Mosnaim GS, Cohen MS, Rhoads CH, Rittner SS, Powell LH. Use of MP3 players to increase asthma knowledge in inner-city African-American adolescents. International Journal of Behavioral Medicine 2008;15(4):341-6. 20589161

Mosnaim GS, Rhoads C, Cohen M. Adolescents disease empowerment and persistency technology (ADEPT) increases asthma knowledge among inner city African American teenagers using MP3 players. Journal of Allergy and Clinical Immunology 2007;119(Suppl 1):S285. 20589162

Moudgil 1998 {published data only}

20589163

Moudgil H, Honeybourne D. Differences in asthma management between white European and Indian subcontinent ethnic groups living in socioeconomically

deprived areas in the Birmingham (UK) conurbation. Thorax 1998;53(6):490-4. 20589164

Moudgil H, Honeybourne D. Evaluating the asthma education of white European and Indian subcontinent asthmatics. Thorax 1997;52(Suppl 6):A47 P64. 20589165

Moudgil H, Honeybourne D. Reducing the need for urgent health care: impact of asthma education in white European and Indian subcontinent groups. American Journal of Respiratory and Critical Care Medicine 1998;157(Suppl 3):A632. 20589166

NCT00217906 {published data only}

20589167

NCT00217906. A+ asthma early intervention in asthma management. clinicaltrials.gov/ct2/show/NCT00217906 (first received 22 September 2005). 20589168 [URL: http://www.clinicaltrials.gov/ct/show/NCT00217906]

NCT04995692 {published data only}

20589169

NCT04995692. Telehealth Education for Asthma Connecting Hospital and Home (TEACHH). https://clinicaltrials.gov/ct2/show/NCT04995692 (first received 9 August 2021). 20589170

Nelson 2011 {published data only}

20589171

NCT00149500. Social support and education in asthma follow-up (SSEA). clinicaltrials.gov/ct2/show/NCT00149500 (first received 8 September 2005). 20589172

* Nelson KA, Highstein G, Garbutt J, Trinkaus K, Fisher EB, Smith SR, et al. A randomized controlled trial of parental asthma coaching to improve outcomes in urban minority children. Archives or Pediatric Adolescent Medicine 2011;165(6):520-6. 20589173

Ng 2021 {published data only}

20589174

Ng JSK, Chau JPC, Chan AWK, Lui JKC, Cheng JWCH. A nurse-led web-based home asthma education program for children and their families: a randomized controlled trial. Journal of Pediatric Nursing 2021;59:158-63. 20589175

Nishioka 2006 {published data only}

20589176

Nishioka K, Saito A, Akiyama K, Yasueda H. Effect of home environment control on children with atopic or non-atopic asthma. Allergology International 2006;55(2):141-8. 20589177

Nokela 2010 {published data only}

20589178

Nokela M, Heibert Arnlind M, Ehrs PO, Krakau I, Forslund L, Wikstrom Jonsson E. The influence of structured information and monitoring on the outcome of asthma treatment in primary care: a cluster randomized study. Respiration 2010;79(5):388-94. 20589179

Page 1999 {published data only}

20589180

Page P, Lengacher C, Holsonback C, Himmelgreen D, Pappalardo LJ, Lipana MJ, et al. Quality of care-risk adjustment outcomes model: testing the effects of a community-based educational self-management program for children with asthma. Nursing Connections 1999;12(3):47-58. 20589181

Parker 2008 {published data only}

20589182

Parker EA, Israel BA, Robins TG, Mentz G, Xihong L, Brakefield-Caldwell W, et al. Evaluation of community action against asthma: a community health worker intervention to improve children's asthma-related health by reducing household environmental triggers for asthma. Health Education and Behavior 2008;35(3):376-95. 20589183

Perrin 1992 {published data only}

20589184

Perrin JM, MacLean WE Jr, Gortmaker SL, Asher KN. Improving the psychological status of children with asthma: a randomized controlled trial. Developmental and Behavioural Pediatrics 1992;13(4):241-7. 20589185

Persky 1999 {published data only}

20589186

Persky V, Coover L, Hernandez E, Contreras A, Slezak J, Piorkowski J, et al. Chicago community-based asthma intervention trial: feasibility of delivering peer education in an inner-city population. Chest 1999;116(4 (Suppl 1)):216S-23S. 20589187

Petro 2005 {published data only}

20589188

Petro W, Schulenburg JMVD, Greiner W, Weithase J, Schulke A, Metzdorf N. Efficacy of a disease management programme in asthma [Effizienz eines Disease Managment Programmes bei Asthma]. Pneumologie 2005;59(2):101-7. 20589189

Put 2003 {published data only}

20589190

Put C, van den Bergh O, Lemaigre V, Demedts M, Verleden G. Evaluation of an individualised asthma programme directed at behavioural change. European Respiratory Journal 2003;21(1):109-15. 20589191

Put CL, Verleden G, Van Den Bergh O, Demedts M. Evaluation of an individualized asthma program aiming at behavioral change. In: Annual Thoracic Society 97th International Conference; San Francisco CA ,May 18-23. 2001. 20589192

Rakos 1985 {published data only}

20589193

Rakos RF, Grodek MV, Mack KK. The impact of a self-administered behavioral intervention program on pediatric asthma. Journal of Psychosomatic Research 1985;29(1):101-8. 20589194

Rhee 2008 {published data only}

20589195

Rhee H, Hollen PJ, Belyea MJ, Sutherland MA. Decision-making program for rural adolescents with asthma: a pilot study. Journal of Pediatric Nursing 2008;23(6):439-50. 20589196

Ronchetti 1997 {published data only}

20589197

Ronchetti R, Indinnimeo L, Bonci E, Corrias A, Evans D, Hindi-Alexander M, et al. Asthma self-management programmes in a population of Italian children: a multicentric study. Italian Study Group on Asthma Self-Management Programmes. European Respiratory Journal 1997;10(6):1248-53. 20589198

Rubin 1986 {published data only}

20589199

Rubin DH, Leventhal JM, Sadock RT, Letovsky E, Schottland P, Clemente I, et al. Educational intervention by computer in childhood asthma: a randomized clinical trial testing the use of a new teaching intervention in childhood asthma. Pediatrics 1986;77(1):1-10. 20589200

Rylance 2021 {published data only}

20589201

Rylance S, Chinoko B, Mnesa B, Jewell C, Grigg J, Mortimer K. An enhanced care package to improve asthma management in Malawian children: a randomised controlled trial. Thorax 2021;76(5):434-40. 20589202

Schatz 2006 {published data only}

20589203

Schatz M, Gibbons C, Nelle C, Harden K, Zeiger RS. Impact of a care manager on the outcomes of higher risk asthmatic patients: a randomized controlled trial. Journal of Asthma 2006;43(3):225-9. 20589204

Schmidt 1993 {published data only}

20589205

Schmidt S, Konning J, Szczepanski R, Gebert N, Hummelink R, Wahn U. Asthma training in practice. Evaluation of an integrated care concept including the involvement of a paediatrician in practice. Padiatrische Praxis 1993;45:635-41. 20589206

Shames 2004 {published data only}

20589207

Bergman DA, Mayer ML, Sharek PJ, Robinson T, Shames R. An asthma disease management program: results from a randomized clinical trial. Pediatric Research 2001;4(4):457A. 20589208

Shames RS, Sharek P, Mayer M, Robinson TN, Hoyte EG, Gonzalez-Hensley F, et al. Effectiveness of a multicomponent self-management program in at-risk, school-aged children with asthma. Annals of Allergy, Asthma, and Immunology 2004;92(6):611-8. 20589209

Shegog 2001 {published data only}

20589210

Shegog R, Bartholomew LK, Parcel GS, Sockrider MM, Masse L, Abramson SL. Impact of a computer assisted education program on factors related to asthma self-management behavior. Journal of the American Medical Informatics Association 2001;8(1):49-61. 20589211

Shields 1990 {published data only}

20589212

Shields MC, Griffin KW, McNabb WL. The effect of a patient education program on emergency room use for inner-city children with asthma. American Journal of Public Health 1990;80(1):36-8. 20589213

Shields 2004 {published data only}

20589214

Shields M D, Patterson E E, Brennan M P, Linskey K, Webb D, Patterson C C. A cluster randomised intervention trial of asthma clubs to improve quality of life in primary school children - the school care and asthma management project (SCAMP). Thorax 2004;59(Suppl II):ii21. 20589215

Slader 2006 {published data only}

20589216

Slader CA, Reddel HK, Spencer LM, Belousova EG, Armour CL, Bosnic-Anticevich SZ, et al. Double blind randomised controlled trial of two different breathing techniques in the management of asthma. Thorax 2006;61(8):651-6. 20589217

Smith 2004 {published data only}

20589218

Smith SR, Jaffe DM, Fisher EB Jr, Trinkaus KM, Highstein G, Strunk RC. Improving follow-up for children with asthma after an acute Emergency Department visit. Journal of Pediatrics 2004;145(6):772-7. 20589219

Sommaruga 1995 {published data only}

20589220

Sommaruga M, Spanevello A, Migliori GB, Neri M, Callegari S, Majani G. The effects of a cognitive behavioural intervention in asthmatic patients. Thorax 1995;50(5):398-402. 20589221

Steurer-Stey 2010 {published data only}

20589222

Steurer-Stey C, Storch M, Steffen-Bürgi B, Steurer J, Puhan M. A general self-management program improves self-efficacy but not short-term adherence with asthma self-management behavior: a randomized controlled trial. In: European Respiratory Society Annual Congress, Barcelona, Spain. 2010:P3989. 20589223

Stevens 2002 {published data only}

20589224

Stevens CA, Wesseldine LJ, Couriel JM, Dyer AJ, Osman LM, Silverman M. Parental education and guided self-management of asthma and wheezing in the pre-school child: a randomised controlled trial. Thorax 2002;57(1):39-44. 20589225

Stukus 2018 {published data only}

20589226

Stukus DR, Farooqui N, Strothman K, Ryan K, Zhao S, Stevens JH, et al. Real-world evaluation of a mobile health application in children with asthma. Annals of Allergy, Asthma, and Immunology 2018;120(4):395-400.e1. 20589227

Sublett 2000 {published data only}

20589228

Sublett JL, Basile F, Wighton T, Wald JA, Vivra. The impact of expert allergy care and

a nurse telephonic asthma disease management program on outcomes in asthmatics. American Journal of Respiratory and Critical Care Medicine 2000;161(Suppl 3):A904. 20589229

Sun 2010 {published data only}

20589230

Sun HW, Wang JP, Wang SZ, Wang YY, Song YP, Yang ZH, et al. Effect of educational and psychological intervention on the quality of life of asthmatic patients. Respiratory Care 2010;55:725-8. 20589231

Szczepanski 2010 {published data only}

20589232

Szczepanski R, Jaeschke R, Spindler T, Ihorst G, Forster J, ASEV Study Group. Preschoolers' and parents' asthma education trial (P2AET) - a randomized controlled study. European Journal of Pediatrics 2010;169:1051-60. 20589233

Tagaya 2005 {published data only}

20589234

Tagaya E, Tamaoki J, Konodo M, Taira M, Nagai A, Amo M, et al. Effect of self-management program in patients with mild to moderate asthma: a randomised controlled study. Respirology 2006;11(Suppl 5):PS-1-10. 20589235

Tagaya E, Tamaoki J, Nagai A, Murasugi H, Igi H. The role of a self-management program in the control of mild to moderate asthma: a randomized controlled study. Allergology International 2005;54(4):527-31. 20589236

Tagaya E, Tamoki J, Nagal A, Igi H. Role of self management program alone in asthma control in mild to moderate asthmatics, randomized controlled study. In: American Thoracic Society 2005 International Conference; May 20-25; San Diego, California. Vol. A40. 2005:G18. 20589237

Takaro 2004 {published data only}

20589238

Takaro TK, Krieger JW, Song L. Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle. Journal of Exposure Analysis and Environmental Epidemiology 2004;14(Suppl 1):S133-43. 20589239

Takaro 2004a {published data only}

20589240

Takaro TK, Krieger JW, Song L. Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle. Journal of Exposure Analysis and Environmental Epidemiology 2004;14(Suppl 1):S133-43. 20589241

Talabere 1990 {published data only}

20589242

Talabere LR. The effects of an asthma education program on selected health behaviors of school-age children who have recently experienced an acute asthma episode [Thesis]. Ohio State University, 1990. 20589243

Thoonen 2002 {published data only}

20589244

Thoonen BPA, Schermer TRJ, Jansen M, Smeele I, Jacobs AJE, Grol R, et al. Asthma

education tailored to individual patient needs can optimise partnerships in asthma self-management. Patient Education and Counseling 2002;47(4):355-60. 20589245

Tong 2002 {published data only}

20589246

Tong R, Pan J, Tao M. The effect of psychological intervention on childhood asthma. Chinese Mental Health Journal 2002;16(8):555-7. 20589247

Tony 2021 {published data only}

20589248

Tony SM, Abdelrahman MA, Osama H, Abdelrahim MEA. Advanced counselling using training device and smartphone application on inhalation technique from metered? dose inhaler with spacer equipped with different interfaces in asthmatic children. International Journal of Clinical Practice 2021;75(9):e14413-n/a. 20589249

Tsoukleris 2007 {published data only}

20589250

Tsoukleris M, Hsu V, Vibbert CL, Bollinger ME, Butz AM. Asthma controller awareness, knowledge, health beliefs and behaviours. Journal of Allergy and Clinical Immunology 2007;119(Suppl 1):S285. 20589251

Urek 2005 {published data only}

20589252

Urek MC, Markoviu AS, TuDman Z, Urek R, Uvorisec B, Tudoric N, et al. The influence of patient education on asthma treatment. European Respiratory Journal 2003;2(Suppl 45):P1612. 20589253

Urek MC, Tudoric N, Plavec D, Urek R, Koprivc-Milenovic T, Stojic M. Effect of educational programs on asthma control and quality of life in adult asthma patients. Patient Education and Counseling 2005;58(1):47-54. 20589254

Vagedes 2021 {published data only}

20589255

Vagedes J, Helmert E, Kuderer S, Vagedes K, Wildhaber J, Andrasik F. The Buteyko breathing technique in children with asthma: a randomized controlled pilot study. Complementary Therapies in Medicine 2021;56:102582. 20589256

Valery 2007 {published data only}

20589257

Valery PC, Masters IB, Clements V, Taylor B, Laifoo Y, Chang AB. A randomised controlled study on education intervention for childhood asthma by the Aboriginal and Torres Strait Islander health workers in Torres Strait region. Respirology 2007;12(Suppl 4):A193. 20589258

Valery PC, Masters IB, Taylor B, O'Rourke, Laifoo Y, Chang AB. Education intervention for childhood asthma by indigenous health workers in the Torres Strait, Australia. Respirology 2009;14(Suppl 1):A41. 20589259

Valery PC, Masters IB, Taylor B, O'Rourke P, Laifoo Y, Chang AB. A randomised controlled study on education intervention for childhood asthma by indigenous health workers in the Torres Strait. Respirology 2008;13(Suppl 2):A67. 20589260

Valery 2010 {published data only}

20589261

Valery PC, Masters IB, Taylor B, Laifoo Y, O'Rourke PK, Chang AB. An education intervention for childhood asthma by Aboriginal and Torres Strait Islander health workers: a randomised controlled trial. Medical Journal of Australia 2010;192(10):574-9. 20589262

van Es 2001 {published data only}

20589263

van Es SM, Nagelkerke AF, Colland VT, Scholten RJ, Bouter LM. An intervention programme using the ASE-model aimed at enhancing adherence in adolescents with asthma. Patient Education and Counseling 2001;44(3):193-203. 20589264

Vazquez 1993 {published data only}

20589265

Vazquez MI, Buceta JM. Effectiveness of self-management programmes and relaxation training in the treatment of bronchial asthma: relationships with trait anxiety and emotional attack triggers. Journal of Psychosomatic Research 1993;37(1):71-91. 20589266

Vazquez MI, Buceta JM. Psychological treatment of asthma: effectiveness of a self-management program with and without relaxation training. Journal of Asthma 1993;30(3):171-83. 20589267

Venkat 2020 {published data only}

20589268

Venkat PK, Chinnasami B, Sundar S, Sadasivam K, Ramraj B. Effect of health education on wheeze related knowledge, attitude and practice (KAP) among parents of wheezing children. Annals of Tropical Medicine and Public Health 2020;23(19). 20589269 [DOI: 10.36295/ASRO.2020.232140]

Volerman 2020 {published data only}

20589270

Volerman A, Luna V, Siros M, Hull A, Wei H, Movva P, et al. A randomized clinical trial evaluating the effectiveness of virtual teach-to-goal education vs brief intervention for hospitalized children with asthma. Chest 2020;158(4):A1791-2. 20589271

Walders 2006 {published data only}

20589272

Walders N, Kercsmar C, Schluchter M, Redline S, Kirchner HL, Drotar D. An interdisciplinary intervention for undertreated pediatric asthma. Chest 2006;129(2):292-9. 20589273

Walders N. A randomized controlled trial of a problem-solving intervention for pediatric asthma [Thesis]. Cleveland: Case Western Reserve University, 2003. 20589274

Warschburger 2003 {published data only}

20589275

Warschburger P, Von Schwerin AD, Buchholz HT, Petermann F. An educational program for parents of asthmatic preschool children: short- and medium-term effects. Patient Education and Counseling 2003;51(1):83-91. 20589276

Weiss 2003 {published data only}

20589277

Weiss KB, Lozano P, Finkelstein JA, Carey V, Sullivan S, Fuhlbrigge A, et al. A randomized controlled clinical trial to improve asthma care for children through

provider education and health systems change: a description of the pediatric asthma care patient outcome research team (PAC-PORT II) study design. Health Services and Outcomes Research Methodology 2003;4(4):265-82. 20589278

Wensley 2001 {published data only}

20589279

Wensley D, Silverman M. Peak flow monitoring for guided self-management in childhood asthma: a randomized controlled trial. American Journal of Respiratory and Critical Care Medicine 2004;170(6):606-12. 20589280

Wensley DC Silverman M. The quality of home spirometry in school children with asthma. Thorax 2001;56(3):183-5. 20589281

Willems 2004 {published data only}

20589282

Willems DCM, Joore MA, Hendricks JJE, van Duurling RAH, Wesseling GJ, Severns JL, et al. The cost effectiveness of an information communication technology supporting self management program in asthmatics. In: Proceedings of the American Thoracic Society. 2006:A597 [Poster D3]. 20589283

Willems DCM, Joore MA, Hendriks HJE, van Duurling AH, Wesseling GJ, Wouters EFM. The cost effectiveness of an ICT supporting self-management program in children with asthma. European Respiratory Journal 2005;26(Suppl 49):Abstract No. 1189. 20589284

Willems DCM, Joore MA, Hendriks HJE, van Duurling AJ, Wesseling GJ, Wouters EFM. The feasibility of ICT supporting self management program in asthma. European Respiratory Journal 2004;24(Suppl 48):256s. 20589285

Willems DCM, Joore MA, Nieman FHM, Hendriks JJE, Severns JL, Wouters EFM. The effects of an information communication technology supporting self management intervention on quality of life symptoms and medical consumption of asthmatics. In: Proceedings of the American Thoracic Society. 2006:A90 [Poster E5]. 20589286

Williams 2006 {published data only}

20589287

Williams SG, Brown CM, Falter KH, Alverson CJ, Gotway-Crawford C, Homa D, et al. Does a multifaceted environmental intervention alter the impact of asthma on inner-city children? Journal of the National Medical Association 2006;98(2):249-60. 20589288

Wilson 1996a {published data only}

20589289

Wilson SR, Latini D, Starr NJ, Fish L, Loes LM, Page A, et al. Education of parents of infants and very young children with asthma: a developmental evaluation of the Wee Wheezers program. Journal of Asthma 1996;33(4):239-54. 20589290

Wise 2007 {published data only}

20589291

Shanovich KK, Pulvermacher AD, Hollman SJ, Richardson PA, Wise ME, Lee SH, et al. Nurse case management services provided to supplement a web-based asthma education program. Journal of Allergy and Clinical Immunology 2008;121(4 Suppl 1):S40. 20589292

Wise M, Gustafson DH, Sorkness CA, Molfenter T, Staresinic A, Meis T, et al. Internet telehealth for pediatric asthma case management: integrating computerized and case manager features for tailoring a web-based asthma education program. Health Promotion Practice 2007;8(3):282-91. 20589293

Wise M, Pulvermacher A, Shanovich KK, Gustafson DH, Sorkness C, Bhattacharya A. Using action research to implement an integrated pediatric asthma case management and ehealth intervention for low-income families. Health Promotion Practice 2009;11(6):798. 20589294

Yang 2005 {published data only}

20589295

Yang BH, Chen YC, Chiang BL, Chang YC. Effects of nursing instruction on asthma knowledge and quality of life in schoolchildren with asthma. Journal of Nursing Research 2005;13(3):174-83. 20589296

Yoon 1989 {published data only}

20589297

Yoon R, McKenzie DK, Bauman A. Randomised controlled trial evaluation of an asthma education program. Australian Journal of Hospital Pharmacy 1989;19(1):51. 20589298

Zhao 2005 {published data only}

20589299

Zhao X, Gao G. Influence of health education on quality of life of asthma patients [Chinese]. Chinese Nursing Research 2005;19(9B):1809-10. 20589300

Zorc 2005 {published data only}

20589301

NCT00113633. Educational video for improving follow-up after emergency department visit for asthma. clinicaltrials.gov/ct2/show/NCT00113633 (first received 10 June 2005). 20589302

Zorc JJ, Chew A, Allen JL, Shaw K. Beliefs and barriers to follow-up after an emergency department asthma visit: a randomized trial. Pediatrics 2009;124(4):1135-42. 20589303

References to studies awaiting assessment

Cameron 1989 {published data only}

20589304

Cameron ES, Remy L, Dillon Remy MT, Bratt DE. Childhood asthma education project. West Indian Medical Journal 1989;38(Suppl 1):20. 20589305

ChiCTR1800014551 {published data only}

20589306

ChiCTR1800014551. Developing a nursing clinical pathway from outpatient-center to home care for the asthmatic children and making the assessment for it: a randomized controlled trial. https://trialsearch.who.int/Trial2.aspx?TrialID=ChiCTR1800014551 (first received 20 January 2018). 20589307

Kelly 2005 {published data only}

20589308

Kelly CS, Taylor-Fishwick JC, Harrison L, Collins-Odoms C, Hixson J. EZ breathers: a partnership to improve asthma management using a combination of staff education and home visits in a Head Start population. Journal of Allergy and Clinical Immunology 2005;115(Suppl 2):S63. 20589309

Mishra 2005 {published data only}

20589310

Mishra N, Rao KVR, Padhi SK. Asthma education for better compliance in disease management. Indian Journal of Allergy Asthma and Immunology 2005;19(1):25-8. 20589311

NCT00094276 {published data only}

20589312

NCT00094276. Improving asthma care for minority children in Head Start. clinicaltrials.gov/ct2/show/NCT00094276 (first received 15 October 2004). 20589313

NCT03335046 {published data only}

20589314

NCT03335046. Home Visits to Optimize Medical and Educational Success Among Sacramento Schoolchildren With Asthma. clinicaltrials.gov/ct2/show/NCT03335046 (first received 7 November 2017). 20589315

Rand 2006 {published data only}

20589316

NCT00269282. Motivating asthma adherence in urban teens. clinicaltrials.gov/ct2/show/NCT00269282 (first received 23 December 2006). 20589317

Taylor-Fishwick 2005 {published data only}

20589318

Taylor-Fishwick JC, Kelly CS, Butterfoss FD, Harrison L, Hixson J, Smith L. Asthma ambassadors - a home visiting program in public housing programs in Southeastern Virginia. Journal of Allergy and Clinical Immunology 2005;115(Suppl 2):S67. 20589319

Yildiz 2002 {published data only}

20589320

Yildiz A, Ongen G, Gemicioglu B, Oncel A, Erturan S, Musellim B. The effect of individual and group education on disease symptoms, pulmonary functions and quality of life in asthma patients. European Respiratory Journal 2002;20(Suppl 38):454s. 20589321

Additional references

Akinbami 2020

Akinbami LJ, Salo PM, Cloutier MM, Wilkerson JC, Elward KS, Mazurek JM, et al. Primary care clinician adherence with asthma guidelines: the National Asthma Survey of Physicians. The Journal of Asthma 2020;57(5):543-55.

Altman 2003

Altman DG, Bland JM. Statistics notes: interaction revisited: the difference between two estimates. BMJ 2003;326(7382):219. [DOI: 10.1136/bmj.326.7382.219]

Asher 2019

Asher Innes, Bissell Karen, Chiang Chen-Yuan, El Sony Asma, Ellwood Philippa, García-Marcos Luis, Marks Guy B, Mortimer Kevin, Pearce Neil, Strachan David. Calling time on asthma deaths in tropical regions—how much longer must people wait for essential medicines? The lancet respiratory medicine 2019;7(1):13-15.

Asher 2021

Innes AM, Rutter CE, Bissell K, Chiang CY, El Sony A, Ellwood E, et al. Worldwide trends in the burden of asthma symptoms in school-aged children: Global Asthma Network Phase I cross-sectional study. The Lancet (British edition) 2021;398(10311):1569-80.

Bodenheimer 2002

Bodenheimer T, Wagner EH, Grumbach K. Improving primary care for patients with chronic illness: the chronic care model, Part 2. JAMA 2002;288:1909-14.

Boulet 2015

Boulet Louis-Philippe. Asthma education: An essential component in asthma management. The European respiratory journal 2015;46(5):1262-1264.

Chan 2021

Chan M, Gray M, Burns C, Owens L, Woolfenden S, Lingam R, et al. Community-based interventions for childhood asthma using comprehensive approaches: a systematic review and meta-analysis. Journal of Allergy, Asthma, and Clinical Immunology 2021;17(1):19-6.

Cochrane Airways 2022

Cochrane Airways Trials Register. https://airways.cochrane.org/trials-register (accessed 1 April 2022).

D'Zurilla 1971

D'Zurilla TJ, Goldfried M. Problem-solving and behavior modification. Journal of Abnormal Psychology 1971;78:107-26.

D'Zurilla 1986

D'Zurilla TJ. Problem-Solving Therapy: A Social Competence Approach to Clinical Intervention. New York: Springer, 1986.

Fernandes 2019

Fernandes JC, Biskupiak WW, Brokaw SM, Carpenedo D, Loveland KM, Tysk S, et al. Outcomes of the Montana asthma home visiting program: a home-based asthma education program. Journal of Asthma 2019;56(1):104-10.

Friedman 2006

Friedman AR, Butterfoss FD, Krieger JW, Peterson JW, Dwyer M, Wicklund K, et al. Allies community health workers: bridging the gap. Health Promotion Practice 2006;7(Suppl 2):96S-107S.

Gaffney 2021

Gaffney AW, Himmelstein DU, Christiani DC, Woolhandler S. Socioeconomic inequality in respiratory health in the US from 1959 to 2018. JAMA Internal Medicine 2021;181(7):968-976.

GINA 2021

Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention, updated 2021. available from www.ginasthma.org/gina-reports/.

Gorelick 2004

Gorelick MH, Brousseau DC, Stevens MW. Validity and responsiveness of a brief, asthma-specific quality-of-life instrument in children with acute asthma. Annals of Allergy, Asthma, and Immunology 2004;92:47-51.

GRADEpro GDT 2015 [Computer program]

GRADEpro GDT: GRADEpro Guideline Development Tool. McMaster University, 2015 (developed by Evidence Prime, Inc). Available from gradepro.org, 2015.

Guastaferro 2018

Guastaferro K, Self-Brown S, Shanley JR, Whitaker DJ, Lutzker JR. Engagement in home visiting: an overview of the problem and how a coalition of researchers worked to address this cross-model concern. Journal of Child and Family Studies 2018;29(1):4-10.

Halterman 2001

Halterman JS, Yoos L, Sidora K, Kitzman H, McMullen A. Medication use and health care contacts among symptomatic children with asthma. Ambulatory Pediatrics 2001;1:275-9.

Harris 2019

Harris K, Kneale D, Lasserson TJ, McDonald VM, Grigg J, Thomas J. School-based self-management interventions for asthma in children and adolescents: a mixed methods systematic review. Cochrane Database of Systematic Reviews 2019, Issue 1. Art. No: CD011651. [DOI: 10.1002/14651858.CD011651.pub2]

Head Start 2021

Administration for Children and Families, US Department of Health and Human Services, Office of Head Start. The Head Start parent, family, and community engagement framework: promoting family engagement and school readiness, from prenatal to age 8. https://eclkc.ohs.acf.hhs.gov/school-readiness/article/head-start-parent-family-community-engagement-framework Updated March 14 2021. Accessed Nov 2 2021..

Henggeler 2009

Henggeler SW, Schoenwald SK, Borduin CM, Rowland MD, Cunningham PB. Multisystemic therapy for antisocial behavior in children and adolescents, 2nd ed. New York, NY, US: Guilford Press, 2009.

Higgins 2019

Higgins JPT, Thomas J (editors). Cochrane Handbook for Systematic Reviews of Interventions. Chichester: John Wiley & Sons, 2019.

Isik 2017

Isik Elif, Isik Ismet S. Students With Asthma and Its Impacts. NASN school nurse 2017;32(4):212-216.

Isik 2019

Isik E, Fredland NM, Freysteinson WM. School and community-based nurse-led asthma interventions for school-aged children and their parents: a systematic

literature review. Journal of Pediatric Nursing 2019;44:107-14.

Juniper 1996a

Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in the parents of children with asthma. Quality of Life Research 1996;5(1):27-34.

Juniper 1996b

Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in children with asthma. Quality of Life Research 1996;5(1):35-46.

Krieger 2005

Krieger JW, Takaro TK, Song L, Weaver M. The Seattle-King County Healthy Homes Project: a randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. American Journal of Public Health 2005;95:652-9.

Lee 2022

Lee GN, Koo HYR, Han K, Lee YB. Analysis of quality of life and mental health in patients with atopic dermatitis, asthma and allergic rhinitis using a nation-wide database, KNHANES VII. Allergy, Asthma & Immunology Research 2022;14(2):273-83.

Liu 2022

Liu WY, Jiesisibieke ZL, Tung TH. Effect of asthma education on health outcomes in children: a systematic review. Archives of Disease in Childhood 2022.

Marshall 2018

Marshall IJ, Noel-Storr AH, Kuiper J, Thomas J, Wallace BC. Machine Learning for Identifying Randomised Controlled Trials: an evaluation and practitioner's guide. Research Synthesis Methods 2018;9(4):602-614.

McDonald 2017

McDonald S, Noel-Storr AH, Thomas J. Harnessing the efficiencies of machine learning and Cochrane Crowd to identify randomised trials for individual Cochrane reviews. In: Global Evidence Summit. Cape Town, South Africa, 13th-16th September 2017.

Mitchell 1981

Mitchell EA, Elliott RB. Hospital admissions for asthma in children: a prospective study. New Zealand Medical Journal 1981;93:331-3.

Mitchell 1984

Mitchell EA, Cutler DR. Paediatric admission to Auckland Hospital for asthma from 1970-1980. New Zealand Medical Journal 1984;97:67-70.

Nannini 2020

Nannini Luis J. Treat to target approach for asthma. The Journal of asthma 2020;57(6):687-690.

Neltner 2010

Neltner T. National healthy homes training center and network: building capacity for healthy homes. Journal of Public Health Management and Practice

2010;16(5):S75-78.

Noel-Storr 2018

Noel-Storr AH and the Project Transform team. Cochrane Crowd: new ways of working together to produce health evidence. In: Evidence Live 2018. Oxford, UK, 18th-20th June 2018.

Oh 2019

Oh H, Stickley A, Singh F, Koyanagi A. Self-reported asthma diagnosis and mental health: findings from the collaborative psychiatric epidemiology surveys. Psychiatry Research 2019;271:721-5.

Papadopoulos 2020

Papadopoulos NG, Custovic A, Deschildre A, Mathioudakis AG, Phipatanakul W, Wong G, et al. Impact of COVID-19 on pediatric asthma: practice adjustments and disease burden. The Journal of Allergy and Clinical Immunology in Practice 2020;8(8):2592-2599.e3.

Pinnock 2017

Pinnock H, Parke HL, Panagioti M, Daines L, Pearce G, Epiphaniou E, et al. Systematic meta-review of supported self-management for asthma: a healthcare perspective. BMC medicine 2017;15(1):64-64.

Portnoy 2016

Portnoy J, Waller M, De Lurgio S, Dinakar C. Telemedicine is as effective as in-person visits for patients with asthma. Annals of allergy, asthma, & immunology 2016;117(3):241-5.

Ramdzan 2021

Ramdzan SN, Suhaimi J, Harris KM, Khoo EM, Liew SM, Cunningham S, et al. School-based self-management interventions for asthma among primary school children: a systematic review. NPJ primary care respiratory medicine 2021;31(1):18.

Rapoff 1999

Rapoff MA. Adherence to Pediatric Medical Regimens. New York: Kluwer Academic/Plenum, 1999.

Reddel 2019

Reddel HK, FitzGerald JM, Bateman ED, Bacharier LB, Becker A, Brusselle G, et al. GINA 2019: a fundamental change in asthma management. Treatment of asthma with short-acting bronchodilators alone is no longer recommended for adults and adolescents 2019;53(6):1901046.

Redmond 2021

Redmond C, Akinoso-Imran AQ, Heaney LG, Sheikh A, Kee F, Busby J. Socioeconomic disparities in asthma health care utilization, exacerbations, and mortality: A systematic review and meta-analysis. Journal of allergy and clinical immunology 2021.

Review Manager 5.3 [Computer program]

Review Manager (RevMan). Version 5.3. Copenhagen: Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014, 2014.

Safiri 2022

Safiri S, Carson-Chahhoud KV, Karamzad N, Sullman MJM, Nejadghaderi SA, Taghizadieh A, et al. Prevalence, deaths and disability-adjusted life-years due to asthma and its attributable risk factors in 204 countries and territories, 1990-2019. Chest 2022;161(2):318-29. [DOI: 10.1016/j.chest.2021.09.042]

Schneider 1997

Schneider SL, Richard M, Huss K, Huss RW, Thompson LC, Butz AM et al. Moving health care education into the community. Nursing Management 1997;28(9):40-3.

Scott 2018

Scott Kerry, Beckham S W, Gross Margaret, Pariyo George, Rao Krishna D, Cometto Giorgio, Perry Henry B. What do we know about community-based health worker programs? A systematic review of existing reviews on community health workers. Human resources for health 2018;16(1):39-39.

Shaak 2022

Shaak S, Brown K, Reichart C, Zimmerman D. Community health workers providing asthma education. Journal of Asthma 2022;59(3):572-9.

Sharrad 2021

Sharrad K J, Kopsaftis ZA, Carson-Chahhoud KV, Stallman HM. The modifiable biopsychosocial drivers of psychological distress for adolescents with asthma: Implications for Clinical Care. Paediatric Respiratory Reviews 2021.

SIGN158 2019

SIGN Guideline Development Group. British Guideline on the Management of Asthma. Scottish Intercollegiate Gruidelines Network 2019;(Revised edition July 2019):1-214. [ISSN: 978-1-909103-70-2]

Sinharoy 2018

Sinharoy A, Mitra S, Mondal P. Socioeconomic and environmental predictors of asthma-related mortality. Journal of Environmental and Public Health 2018;2018:9389570-7.

Stempel 2019

Stempel H, Federico MJ, Szefler SJ. Applying a biopsychosocial model to inner city asthma: Recent approaches to address pediatric asthma health disparities. Paediatric Respiratory Reviews 2019;32:10-5.

Tates 2001

Tates K, Meeuwesen L. Doctor-parent-child communication: a (re) view of the literature. Social Sciences Medicine 2001;52:839-51.

Thomas 2017

Thomas J, Noel-Storr AH, Marshall I, Wallace B, McDonald S, Mavergames C, et al. Living systematic reviews: 2. combining human and machine effort. Journal of Clinical Epidemiology 2017;91:31-37. [DOI: 10.1016/j.jclinepi.2017.08.011]

Tran 2020

Tran P, Tran L. Comparisons between 2015 US asthma prevalence and two measures of asthma burden by racial/ethnic group. Journal of Asthma 2020;57(2):217-227.

Uchima 2019

Uchima O, Sentell T, Dela Cruz MR, Braun KL. Community health workers in pediatric asthma education programs in the United States: A systematic literature review. Children's health care 2019;48(2):215-243.

Varni 1999

Varni JW, Sahler OJ, Katz ER, Mulhern RK, Copeland DR, Noll RB, et al. Maternal problem-solving therapy in pediatric cancer. Journal of Psychosocial Oncology 1999;16(3 & 4):41-71.

Wagner 2001

Wagner EH, Augstin BT, Davis CI, Hindmarsh M, Schaefer J, Bonomi A. Improving chronic illness care: translating evidence into action. Health Affairs 2001;20:64-78.

Wilson 1996b

Wilson SR, Fish L, Page A, Starr-Schneidkraut N. Wee Wheezers: an educational program for parents of children with asthma under the age of seven. Palo Alto, CA: American Institutes for Research.

Wolf 2002

Wolf FM, Guevara JP, Grum CM, Clark NM, Cates CJ. Educational interventions for asthma in children. Cochrane Database of Systematic Reviews 2002, Issue 4. Art. No: CD000326. [DOI: 10.1002/14651858.CD000326]

Yaghoubi 2019

Yaghoubi M, Adibi A, Safari A, FitzGerald JM, Sadatsafavi M. The projected economic and health burden of uncontrolled asthma in the United States. American Journal of Respiratory and Critical Care Medicine 2019;200(9):1102-12.

References to other published versions of this review

Welsh 2010

Welsh EJ, Cates CJ. Home-based educational interventions for children with asthma.. Cochrane Database of Systematic Reviews 2010, Issue 4. Art. No: CD008469. [DOI: 10.1002/14651858.CD008469]

Welsh 2011

Welsh EJ, Hasan M, Li P. Home-based educational interventions for children with asthma. Cochrane Database of Systematic Reviews 2011, Issue 10. Art. No: CD008469. [DOI: 10.1002/14651858.CD008469.pub2]

Figures and tables

Additional tables

Table 1

Study	% severe (how identified)	Inclusion criteria relating to HCU/meds	Mean age (range)	Social indicators (education status refers to caregiver)
Altay 2013 N = 80	Not reported	Inclusion criteria included having used 'at least one long-term medicine and advised to carry their quick relief medicine with them'	Mean not reported (12 to 18)	Not specified
Baek 2019	Not reported	No inclusion criteria relating to HCU/meds	2.99 (1 to 17)	54.4% had household income < USD 15,000

N = 313				
Bresolini 2020 N = 34	Not reported. Severe or difficult to control asthma classified as per the ATS Classification of severity and using the ACT.		Intervention: 10.7 (3 to 17) Control: 10.3 (3 to 17)	Not specified
Brown 2002 N = 101	4 (as per medication regimen)	Healthcare visit for asthma in past year and on daily asthma medication	4.2 (1 to 7)	Low-income families < high school 28%, high school qualification 50%, > high school 22% 90% African-American
Brown 2006 N = 137	37 (NHLBI).	Moderate to severe asthma or had visited the ED in the past year	< 18	< high school 18%, high school qualification 32%, > high school 50% 30% African-American, 59% white
Butz 2006 N = 221	14 (NAEPP)	Regular nebuliser use and ED visit/hospitalisation in past year	4.5 (2 to 9)	Low-income families < high school 24%, high school qualification 28%, > high school 38% on MedicAid 80% African-American 89%
Butz 2010 n = 213	13 (NHLBI)	≥ 1 asthma ED visits or hospitalisation in preceding year	8.0 (6 to 12)	Caregiver education < high school graduate 32%; high school graduate or more education 68% Income < USD 20,000: 57.1%; ≥ USD 20,000: 43%
Butz 2014 N = 300	39 (NAEPP)	Controller medication use during the prior 6 months, and two or more ED visits or one hospitalisation during the prior 12 months of the index ED visit.	166 (55%) aged 3 to 5 and 134 (45%) aged 6 to 10 (3 to 10)	Low-income families Below the poverty level in USA 81.9% on Medicaid 92% African-American 95.7%
Campbell 2015 N = 373	Not reported. However, at baseline 48% very poorly controlled, 47.2% not well controlled (NAEPP)		8.3 (3 to 17)	Rent home (vs. owning home) 81.5% Completed less than high school 42.3%, high school 23.5% , some college 25.1% Hispanic 62.2%
Carswell 1989 N = 86	Not reported	No inclusion criteria relating to HCU/meds	11.2 (5 to 15)	Not specified
Celano 2012 N = 43	Not reported	Current prescription of a daily controller agent, poorly controlled asthma defined as one or more of following: ED visits or hospitalisations for asthma, or prescription of more than one OCS burst within the past year.	10.3 (8 to 13)	Over a third (36%) did not finish high school, 23% had a high school diploma only African American 98%
Dolinar 2000 N = 56	'Stable asthma' with a diagnosis for over 6 months. Those presenting with an acute exacerbation were excluded.		5 (1 to 10)	High school 38%, college/university 63% Family income < CAD 20,000 13%
Eakin 2020	Not reported. 59.3% had uncontrolled		4.2 (2 to 6)	Unemployed 46.7%

N = 398	asthma (TRACK score)			Annual household income < USD 10,000 39.8%
Fisher 2009	Not specified but recruited after hospitalisation		4.9 (2 to 8)	No high school diploma 33%, high school qualification 40%, some college 23%, college graduate 4%
Galbreath 2008 N = 473	31 (NAEPP) 48 (GINA 2002)	ED visit or hospitalisation or 4 x GP visits or 6+ canisters of beta-agonist or diagnosis of moderate-severe asthma in past year.	9.5 (5 to 17)	Medicaid or SCHIP 56%, Black/other 18%, white 15%, Hispanic 68%
Gorelick 2006 N = 352	14 (NAEPP)	Current ED visit for asthma, treated with 1 inhaled bronchodilator, and history of physician diagnosed asthma or wheezing treated with beta-agonists	6.8 (2 to 18)	60% public insurance Black 69%, white 21%, Latino 8%
Jonas 2020 N = 151	Not reported. 90% had either poorly or very poorly controlled asthma at baseline (NAEPP)	Prescription for ICS, have at least one asthma exacerbation in the past year requiring an acute or same-day clinic visit, ED visit or hospitalisation	5.7 (2 to 9)	Unemployed 52% Less than high school education 27% Spanish/Hispanic/Latino 76% Black/African American 22%
Kamps 2008 N = 15	Moderate to severe persistent (NHLBI)	Prescribed ICS	9 (7 to 12)	Half of participants recruited from urban and half from suburban areas Intervention: high school qualification mothers 0% fathers 14%, some college mothers100% fathers 86%; control: no high school diploma mothers 50% fathers 57%, high school qualification mothers 25 fathers 14%, some college mothers 25 fathers 29%. 20% African-American, 53% European American, 27% Hispanic American
Krieger 2009 N = 309	9.1 (NAEPP)		8 (3 to 13)	50.5% household income < 100% of 2001 US federal poverty level 49.5% 100 to 200% of 2001 US federal poverty level 43% did not complete high school
Martin 2015 N = 101	Elementary school cohort intervention 27 Elementary school cohort control 12 High school cohort intervention 16 High school cohort control 8 (Asthma Functional Severity Score)		Mean not reported (5 to 18)	Elementary school cohort intervention 50% > high school Elementary school cohort control 52% > high school High school cohort intervention 36% > high school High school cohort control 52% > high school

Martin 2021 N = 223	19		9.4 (5 to 16)	Low income families Low caregiver educational level with 66.4% < high school/GED Hispanic 85.2%
Mitchell 1986 N = 368		Children who had been admitted to hospital for asthma. Patients who had been discharged from hospital in the past year	5.8 (2 to 14)	European children significantly more advantaged than Polynesian children
Naar-King 2014 N = 170		Moderate to severe asthma and an inpatient hospitalisation or at least 2 ED visits for asthma in the last 12 months for inclusion. Expected to be prescribed daily controller	Intervention 13.32 (12 to 16) Control 13.64 (12 to 16)	Low income Single-parent household 50% in intervention group and 67% in control group 100% African-American
Otsuki 2009 ABCa N = 250 (total)	Physician diagnosed asthma	2 x ED visits or 1 x hospitalisations in the preceding year and on asthma controller medications	ABCa group: 7.14 (2 to 12) AMFa group: 6.83 (2 to 12)	Medicaid 89%, caregiver completed high school 69% 98% African-American
Seid 2010 N = 252	66		7.37 (2 to 14)	85% from subsidised community clinics (most low-income) No diploma 73%, high school graduate 8%, > college 19% Hispanic 83%, white 4%, Black, 8%

Abbreviations.

ABC: Asthma Basic Care; ACT: asthma control test; AMF: Adherence Monitoring with Feedback; ATS: American Thoracic Society; ED: emergency department; GED: general educational development; GINA: Global Initiative for Asthma; HCU: health care utilisation; ICS: inhaled corticosteroids; NAEPP: National Asthma Education and Prevention Program; NHLBI: National Heart, Lung, and Blood Institute; OCS: oral corticosteroids; TRACK: Test for Respiratory and Asthma Control in Kids.

Baseline characteristics

Table 2

Study	No./length sessions, where	Educator	Programme length (follow-up time)	Basic education[1], printed materials and homework	Medication/ inhaler technique	Self-management	Monitori or telec
Altay 2013 N = 80	8 x sessions in the home over 5 months, with first visit lasting 60-75 mins on average, and the others lasted 60 mins, Turkey.	Study investigator with masters' degree in nursing	5 months (5 months)	√	√	√	
Baek 2019 N = 313	1 x 60-90 minute session, at home, USA	Trained CHW	One off education (3 months)	√	√	√	
Bresolini 2020 N = 34	3 x home visits, Brazil	Nurse	90 days (30 days after first visit, 60 days after second visit)	√	√	√	
		Nurse		√√	√	√	

Brown 2002 N = 101	8 x 90-minute home weekly, USA		< 6 months (12 months)				
Brown 2006 N = 137	1 x clinic, 1 x home, USA	Nurse	< 6 months (6 months)	√	√	√	
Butz 2006 N = 221	6 x 1-hour, home, USA	Nurse	6 months (12 months)	√	√	√	
Butz 2010 n = 231	4 x 30 to 45 minutes home, accompanied to primary care clinic visits x 6 months, USA	Nurse/health educator	8 weeks (12 months)	√√	√	√	
Butz 2014 N = 300	3 sessions (2 x at home, 1 x at GP office), USA	Nurse	4 months (12 months)	√√	√	√	√

Campbell 2015 N = 373	4 x home visits (allowing up to 2 telephone contacts in lieu), USA	CHW	3.5 months (12 months)	√	√	√	
Carswell 1989 N = 86	No. of sessions not disclosed (at visiting nurse discretion), home visits, UK	Nurse	6 months (Not disclosed follow up time points)	√		√	
Celano 2012 N = 43	4 to 6 x home visits, average visit length 78 minutes, USA	Trained asthma counsellors	4 months (12 months)	√	√	√	
Dolinar 2000 N = 56	1 x 2-hour, home, Canada	PI (nurse)	< 6 months (3 months)	√√	√	√	√
Eakin 2020 N = 398	4 x 30-45 minute sessions at home, and 3 x telephone calls, USA	Asthma educators	9 months (12 months)	√	√	√	
Fisher 2009	2 x home, biweekly telephone calls x 3 months, then monthly, USA	3 African American women from same neighbourhoods as participants	2 years (2 years)	√	√	√	√
Galbreath 2008 N = 473	4 x home at 1, 2, 3 and 6 months, 6 to 7 telephone sessions, USA	Registered nurses for education over the phone and 24 hour hotlines. Pulmonary therapist	6 (12 months)	√	√	√	√
Gorelick 2006 N = 352	1 x 60 minutes home then 5 x 30 minutes home, plus several telephone calls	Case manager (nurse or social worker)	6 months (6 months)	√√	√	√	√

	over 6 months, USA						
Jonas 2020 N = 151	6 x biweekly one hour sessions, home, USA	CHW who shared racial and ethnic background	< 6 months (12 months)	√√√	√	√	
Kamps 2008 N = 15	6 x 1 hour, weekly, home, USA	Licensed psychologists or masters-level psychology graduate students	< 6 months (12 months)	√√	√	√	
Krieger 2009 N = 309	1 intake home visit + average of 4.5 follow up visits at home, also received interim phone communication, USA	CHW who shared ethnic backgrounds with participants and had personal or family experience with asthma	12 months (12 months)	√	√	√	
Martin 2015 N = 101	Offered 4 visits over 4 months, home, USA	CHW	4 months (12 months)	√√√	√	√	
Martin 2021 N = 223	Offered 10 visits of 1 to 2 hours over 12 months, home (flexibility to meet at other locations), USA	CHW	12 months (24 months)	√	√	√	

Mitchell 1986 N = 368	6 x 1 hour, monthly, home, New Zealand	Community child health nurse	6 months (18 months)	√	√	√	
Naar-King 2014 N = 170	Session duration and frequency dependent on clinical need, delivered via a home-based model, delivered at home, school and or/neighbourhood settings USA	Either a psychologist or social worker	6 months (7 months)	√	√	√	
Otsuki 2009 ABCa N = 250 (total)	5 x 30 to 40 minutes, home, USA	Trained asthma educators	< 6 months (18 months)	√√	√	√ discussed strategies	
Otsuki 2009 AMFa	5 x 30 to 40 minutes, home, USA	Trained asthma educators	< 6 months (18 months)	√√	√	√	√ electron medicatic feedback monitors
Seid 2010 N = 252 (total)	5 x 45 to 60 minutes, weekly, USA	Bilingual, bicultural bachelors educated asthma home visitors	< 6 months (9 months)	√√	√	√	
Seid 2010 problem-solving	6 x 45 to 60 minutes, weekly, USA	Bilingual, bicultural masters educated asthma home visitors	< 6 months (9 months)	√√	√	√	

Abbreviations: CHW: Community Health Worker; PFM: peak flow meter; WAP: written asthma action plan.

Intervention characteristics

Table 3

Study	Control group risk ED visits	Control group risk hospitalisations (period reported, from baseline)
Altay 2013	NR	NR
Baek 2019	NR	NR
Bresolini 2020	NR	NR
Brown 2002	*	*
Brown 2006	38% (0 to 6 months)	-
Butz 2006	47% (0 to 6 months)	13% (0 to 6 months)
Butz 2010	NR	NR
Butz 2014	mean 2.24 (SD 2.7)	mean 0.45 (SD 0.9)
Campbell 2015	$	$
Carswell 1989	NR	NR
Dolinar 2000	10% (0 to 6 months)	-
Eakin 2020	23% (0 to 3 months)	12% (0 to 12 months)
Fisher 2009	54% (0 to 2 years)	59% (0 to 2 years)
Galbreath 2008		
Gorelick 2006	38% (0 to 6 months)	-
Jonas 2020	NR	NR
Kamps 2008	NR	NR
Krieger 2009		
Martin 2015	NR	NR
Martin 2021	NR	NR
Mitchell 1986 Europeans	5% (0 to 6 months)	21% (6 months) 16% (6 to 18 months)
Mitchell 1986 Polynesians	13% (0 to 6 months)	27% (6 months) 33% (6 to 18 months)
Naar-King 2014	NR	NR
Otsuki 2009	-	17% (6 months) 12% (12 to 18 months)
Seid 2010	15% (3 to 9 months)	8% (3 to 9 months)

Abbreviations: NR: not reported;

* acute asthma visits at 12 months usual care: mean 2.80

$ combined hospitalisation, ED and urgent care visits: mean 3.07

Control group event rates

Table 4

Study	% completed full education programme	Partial completion	Completed no sessions	Lost to follow-up	Withdrawals
Altay 2013	Not reported	Not reported	0	0	0
Baek 2019	93.5%				
Bresolini 2020	76.5%		11.8%		Intervention group: 1 after first home visit, 2 refused to participate Control group: 1 refused to participate
Brown 2002	71%	11%	7%		11%
Brown 2006	38%*	9% received only clinic visit* 15% received	39%*	Intervention group 21% Control group 6% (reported for children)	Not reported * these data are from both adults and children

		only home visit*			
Butz 2006	Most completed			Nebuliser: 14% excluded from follow-up (10% no pharmacy data, 2% died, 3% lost). SAE 23% excluded (18% no pharmacy data, 1% died, 4% lost)	Not reported
Butz 2010		More intense group received mean 3.29 out of 4 visits Control received mean 2.27 out of 3 visits		More intense group 17% Control group 14%	Not reported
Butz 2014	71%	29%		Intervention group: 13 Control group: 12	Intervention group 1 (caregiver death)
Campbell 2015	6.6%	91.7%	1.6%	Intervention group: 16 Control group: 8	Intervention group: 12 Control group: 4
Carswell 1989	100% (only needed one home visit)				
Celano 2012	86% received 4 to 6 visits	91% received at least one visit	9%	Intervention group: 1 Control group: 2	Intervention group: 2 from after baseline assessment and randomisation, before any intervention
Dolinar 2000	100%			5%	0
Eakin 2020	34.7% completed all 4 visits; 35.8% completed all the booster telephone calls	72.4%		Intervention group: 12 month follow up complete 73.9% Control group: 12 month follow up complete 81.9%	
Fisher 2009			4% (no substantive contact)	Control group: 12 month follow up complete 81.9%	Not reported
Galbreath 2008	70% completed at least 80% of the intervention - although this was for adults and children			35%	2
Gorelick 2006	Average of 4 (out of 6) home visits per patient (average of 2 missed visits per patient); average 2.3 calls per patient	72% had at least 1 home visit		22%	
Jonas 2020		76% completed at least 5 of the 6 lessons 12% completed 1-4 lessons	12%	73.9% completed 12 month follow up Intervention group lost to follow up: 12 at 3 months, 8 at 6 months, 1 at 9 months, 1 at 12 months Control group lost to follow up: 8 at 3 months, 9 at 6 months, 0 at 9 months, 0 at 12 months	
	100%	-	-	2 months 33%	3

Kamps 2008				6 months 60% 12 months 67%	
Krieger 2009	133 of those allocated (156) 'completed the intervention as allocated' 85%		23/156 no sessions (15%)	Intervention group: 17 Control group: 13	Intervention group: 4 Control group: 4
Martin 2015	Elementary school cohort: 62% High school cohort: 72%		Elementary school cohort: 27% High school cohort: 12%	Elementary school cohort intervention: 1 at 5 months, 1 at 12 months Elementary school cohort control: 1 at 5 months, 1 at 12 months High school cohort intervention: 1 at 5 months, 3 at 12 months High school cohort control: 1 at 5 months, 3 at 12 months	0
Martin 2021		94% received 'some intervention'	6%	Intervention group completion of follow up: 99 at 6 months, 105 at 12 months, 105 at 18 months, 103 at 24 months (n=108) Control group completion of follow up: 111 at 6 months, 110 at 12 months, 107 at 18 months, 106 at 24 months (n=115)	2
Mitchell 1986	68%	26%	6%	Not reported	Not reported
Naar-King 2014	85% 'received the allocated intervention'; at least 3 sessions		15%	Intervention: 2 Control: 9	
Otsuki 2009	ABC 71%; AMF 63%			~10%	1 person deceased in each group
Seid 2010	67% completed all 5 visits	Completed 4.0 (CC) and 3.8 (CC + PST) visits on average		CC intervention: 20% lost (7% refused), PST intervention 32% lost (19% refused)	PST 19% and CC 6% "refused"

Abbreviations. ABC: asthma basic care; AMF: adherence monitoring with feedback; CC: care co-ordination; SAE: serious adverse event; PST: problem-solving skill training.

Completers/withdrawals

Table 5

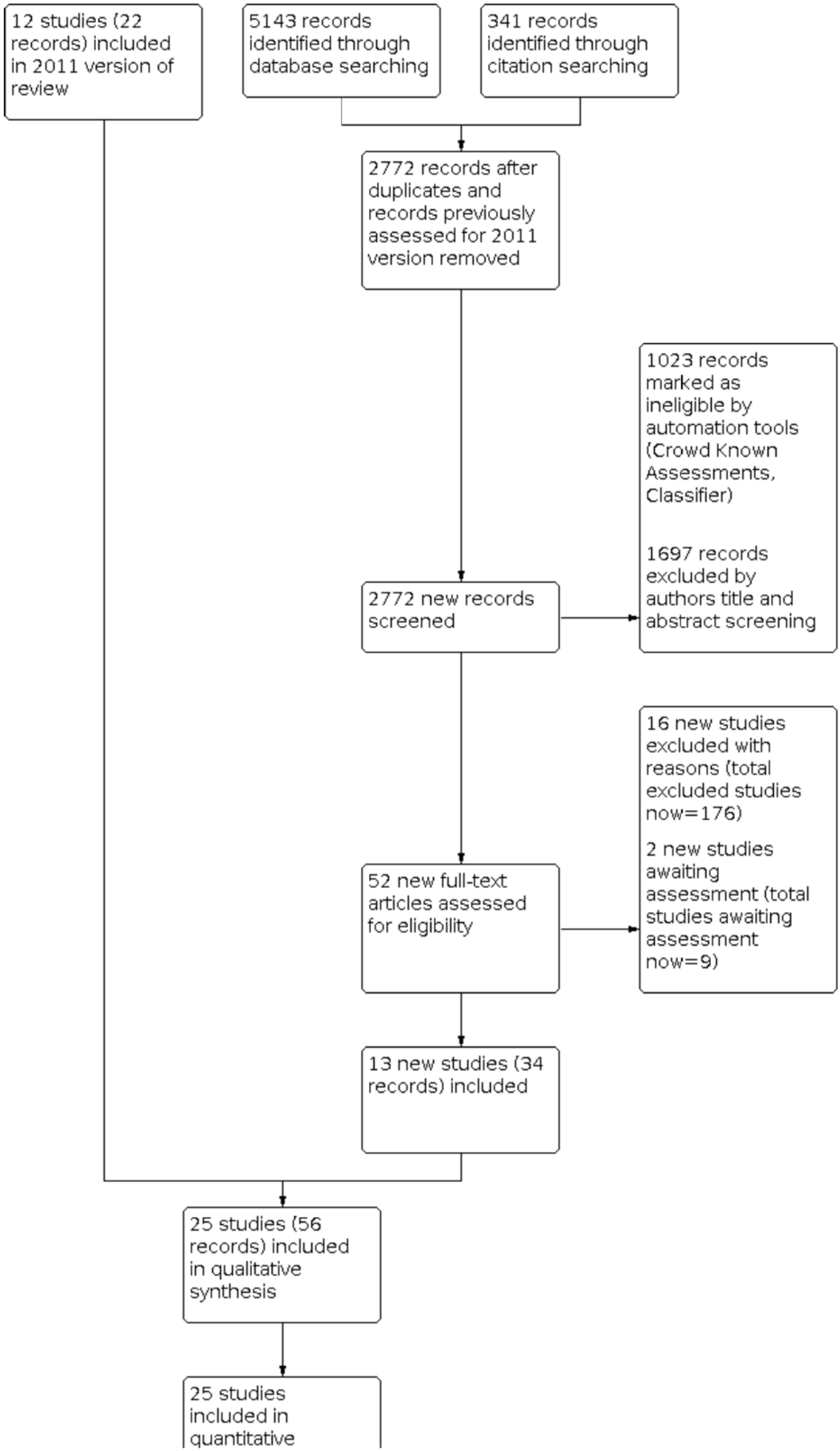
Study	Aims
Altay 2013	"This study was performed to determine the effect of nursing interventions based on Orem's self-care model on the development of self-care activities of adolescents with asthma. The hypothesis was that nursing interventions performed according to Orem's self-care model would increase an adolescent's self-care skills in illness management."
Baek 2019	To examine the impact of a home-based educational intervention on asthma-related health outcomes among primarily Hispanic children in Hidalgo County, located along the Texas-Mexico border, by comparing outcome changes from baseline assessments to follow-up
Bresolini 2020	To evaluate the impact of home visits on inhalation technique and drug treatment adherence rates in children and adolescents with severe asthma
Brown 2002	"A home-based program may be the most developmentally appropriate and ecologically valid methods of delivering asthma education to low income inner city families". T o evaluate efficacy in terms of parental participation and effectiveness in terms of decreasing morbidity and increasing the caregiver's quality of life and asthma management skills.
Brown 2006	A "structured comprehensive asthma education program delivered by an experienced asthma nurse educator within a local asthma coalition would be an effective method of reducing asthma relapse in patients who had moderate-sever persistent asthma."

Butz 2006	"Low-income minority children have disproportionately high morbidity and mortality rates" and "tend to rely on hospital emergency rooms as primary source of asthma care". Therefore aimed to decrease ED visits/hospital admissions by helping parents understand when the child's asthma was worsening and train them specifically in home nebuliser use.
Butz 2010	Hypothesised that a programme designed to improve clinician-caregiver communication would be associated with reduced symptom days and nights and increased compliance with appropriate controller medication in inner-city children.
Butz 2014	To test the efficacy of a clinician and caregiver feedback intervention on improving preventive asthma care following an asthma ED visit compared to an attention control group.
Campbell 2015	To test the hypotheses that a simplified and streamlined version of the 'Healthy Homes' program (evidence-based community health worker asthma home visit program) previously developed, would reduce urgent medical care, improve asthma-related quality of life and symptom-free days, generate a positive return on investment relative to usual care, and be cost-effective.
Carswell 1989	Measure the effectiveness and cost of District Health Authority nurses as providers of support to families with asthmatic children
Celano 2012	Aim to assess efficacy of family intervention as compared to 'enhanced treatment as usual' in improving asthma management and morbidity for children with poorly controlled asthma living with caregivers with high levels of psychological stress.
Dolinar 2000	Does home-based education resource influence parental coping, perception of asthma change and quality of life?
Eakin 2020	To determine if a multilevel home and preschool asthma educational program is more effective in improving asthma control compared with a pre-school based program alone.
Fisher 2009	Hypothesised that "CHWs may help reduce disproportionate asthma health burden among children from low-income families". Used a non-professional asthma coach to try and reduce rehospitalisation.
Galbreath 2008	A telephonic and home-visiting asthma education delivered by a respiratory therapist designed to decrease healthcare utilisation and generate cost savings.
Gorelick 2006	Evaluated the impact of educating children in the ED and then following up with home-based education interventions compared to standard care alone.
Jonas 2020	To evaluate the effects of using CHWs to deliver the home-based asthma education program (Wee Weezers) on asthma symptoms among children with persistent asthma
Kamps 2008	Designed to increase adherence to asthma treatment regimens.
Krieger 2009	To compare the marginal benefit of in-home asthma self-management support provided by CHWs with standard asthma education from clinic-based nurses. Tested the hypothesis that adding in-home visits by CHWs to traditional clinic-based education by nurses would improve self-management practices, reduce asthma-trigger exposure, and decrease asthma morbidity beyond that seen with nurse education alone.
Martin 2015	Test efficacy of a CHW intervention to improve use of inhaled corticosteroids and reduce home asthma triggers in Puerto Rican youth in Chicago
Martin 2021	Aim 1: to assess the efficacy of the integrated CHW home asthma intervention relative to the certified asthma educator (AE-C) intervention at 12-months post-randomization as demonstrated by asthma control. Aim 2: assesses maintenance of intervention efficacy, as demonstrated by asthma control at 18 and 24 months after randomisation. Aim 3: compares the costs and cost-effectiveness of the two interventions. Aim 4: to assess the efficacy of the CHW intervention relative to AE-C education, as demonstrated by asthma control, among those experiencing depression, stress, and/or PTSD.
Mitchell 1986	In New Zealand readmission rates are higher in Polynesian children than in European children. The study was designed to find out if community child health nurses in the patients home could reduce school absenteeism, encourage visits to the GP and reduce the number of readmissions to hospital and teach parents when and how to seek medical help for an attack not responding to usual treatment.
Naar-King 2014	The purpose of this study was to test whether Multisystemic Therapy, a home- and community-based family therapy grounded in the social-ecological model, adapted for health care settings, could improve asthma management (particularly adherence to daily controller medications and responding to asthma exacerbations) and lung functioning in high-risk urban adolescents with moderate to severe persistent asthma.
Otsuki 2009	To evaluate feedback of electronically monitored adherence and education programme in reducing ED visits and asthma mediation adherence, symptoms, hospitalisations and courses of oral steroids.
Seid 2010	Problem-solving may be useful in helping families, especially lower socioeconomic status families improve their asthma management behaviours to improve quality of life.

Abbreviations: ED: Emergency Department; CHW: Community Health Worker

Aims of studies

Figure 1


12 studies (22 records) included in 2011 version of review
5143 records identified through database searching
341 records identified through citation searching
2772 records after duplicates and records previously assessed for 2011 version removed
1023 records marked as ineligible by automation tools (Crowd Known Assessments, Classifier)
1697 records excluded by authors title and abstract screening
2772 new records screened
16 new studies excluded with reasons (total excluded studies now=176)
2 new studies awaiting assessment (total studies awaiting assessment now=9)
52 new full-text articles assessed for eligibility
13 new studies (34 records) included
25 studies (56 records) included in qualitative synthesis
25 studies included in quantitative

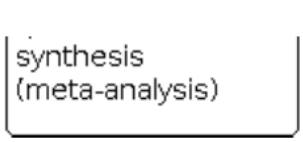
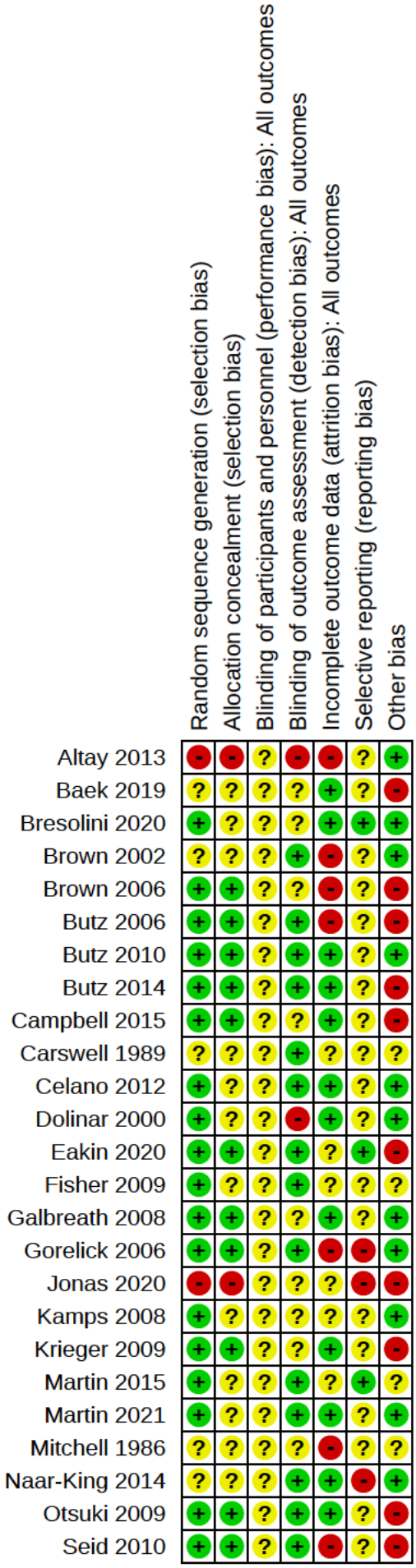
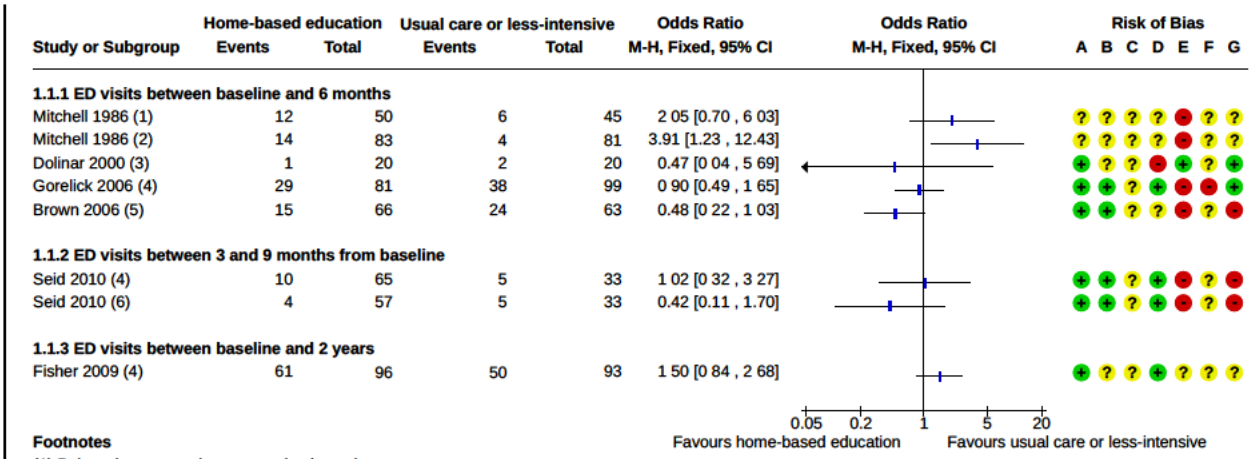


Figure 2



'Risk of bias' summary: review authors' judgements about each risk of bias item for each included study.

Analysis 1.1



Footnotes

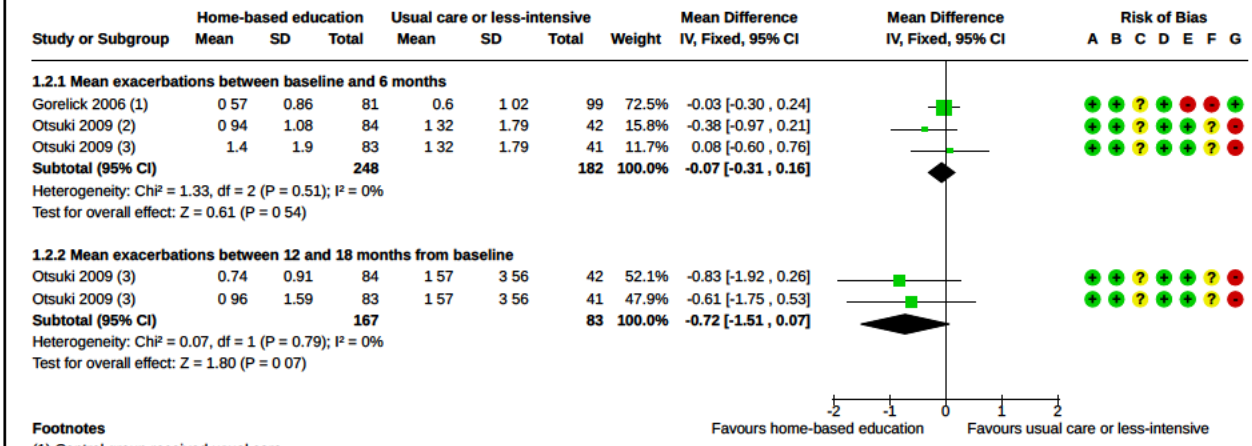
(1) Polynesians, control group received usual care
(2) Europeans, control group received usual care
(3) Control group received usual care + educational booklet
(4) Control group received usual care
(5) Control group received sual care + instruction in inhaler/PFM technique
(6) Problem-solving, control group received usual care

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 1: Exacerbations leading to emergency department visits

Analysis 1.2



Footnotes

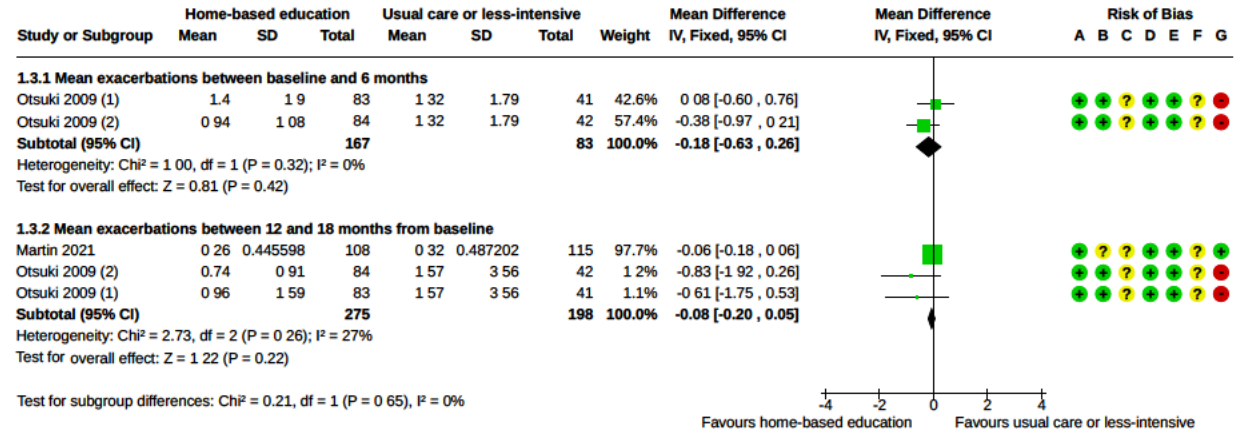
(1) Control group received usual care
(2) ABC, control group received usual care
(3) AMF, control group received usual care

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 2: Mean exacerbations resulting in emergency department visits

Analysis 1.3

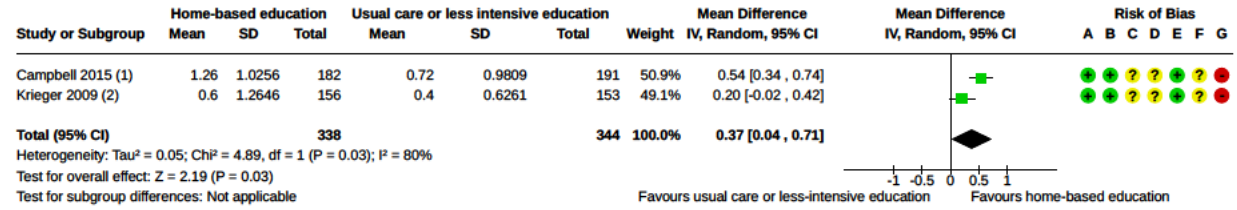


Footnotes
(1) AMF, control group received usual care
(2) ABC, control group received usual care

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 3: Mean exacerbations requiring a course of oral corticosteroids

Analysis 1.4

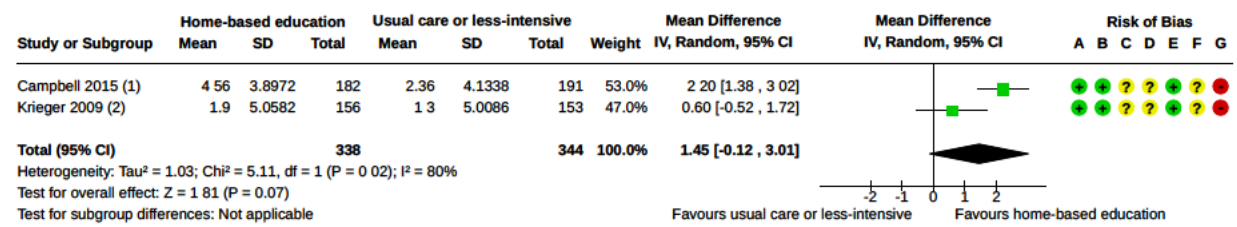


Footnotes
(1) Control group received usual care
(2) Control group received asthma education + spacers + bedding encasements

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 4: Quality of life

Analysis 1.5



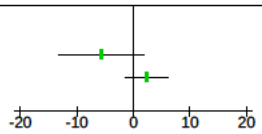
Footnotes
(1) Control group received usual care
(2) Control group received asthma education + spacers + bedding encasements

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 5: Mean symptom-free days

Analysis 1.6

Study or Subgroup	Home-based education Mean	SD	Total	Usual care or less-intensive Mean	SD	Total	Mean Difference IV, Random, 95% CI	Mean Difference IV, Random, 95% CI	Risk of Bias A B C D E F G
1.6.1 Mean days off school in 6 months									
Mitchell 1986 (1)	6.8	6.6	50	12.4	25 2	45	-5.60 [-13.19 , 1.99]		? ? ? ? - ? ?
Mitchell 1986 (2)	8.6	15.1	83	6.3	8 8	81	2 30 [-1.47 , 6.07]		? ? ? ? - ? ?



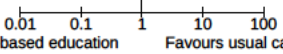
Footnotes
(1) Europeans, control group received usual care
(2) Polynesians, control group received usual care

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 6: Days missed from school or work

Analysis 1.7

Study or Subgroup	Home-based education Events	Total	Usual care or less-intensive Events	Total	Odds Ratio M-H, Fixed, 95% CI	Odds Ratio M-H, Fixed, 95% CI	Risk of Bias A B C D E F G
1.7.1 Admission in 6 months from baseline							
Mitchell 1986 (1)	28	94	22	106	1.62 [0 85 , 3 09]		? ? ? ? - ? ?
Mitchell 1986 (2)	27	84	23	84	1.26 [0 65 , 2.44]		? ? ? ? - ? ?
Otsuki 2009 (3)	13	84	7	42	0.92 [0 34 , 2 50]		+ + ? + + ? -
Otsuki 2009 (4)	19	83	7	41	1.44 [0 55 , 3.77]		+ + ? + + ? -
1.7.2 Hospitalisation between 3 and 9 months from baseline							
Seid 2010 (5)	4	65	2	33	1.02 [0.18 , 5 86]		+ + ? + - ? -
Seid 2010 (6)	1	57	3	33	0.18 [0 02 , 1.79]		+ + ? + - ? -
1.7.3 Admissions between 6 and 18 months from baseline							
Mitchell 1986 (2)	27	84	28	84	0.95 [0 50 , 1 80]		? ? ? ? - ? ?
Mitchell 1986 (1)	30	94	17	106	2.45 [1 25 , 4 83]		? ? ? ? - ? ?
1.7.4 Admissions between 12 and 18 months from baseline							
Otsuki 2009 (3)	12	84	5	42	1.23 [0.40 , 3.77]		+ + ? + + ? -
Otsuki 2009 (4)	12	83	5	41	1.22 [0.40 , 3.72]		+ + ? + + ? -
1.7.5 Admissions between baseline and 2 years							
Fisher 2009 (5)	35	96	55	93	0.40 [0 22 , 0.71]		+ ? ? + ? ? ?

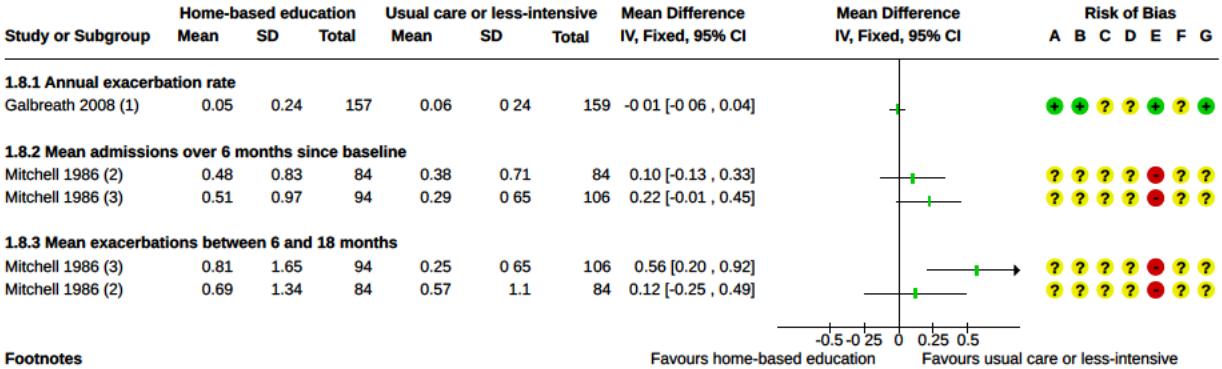


Footnotes
(1) Europeans, control group received usual care
(2) Polynesians, control group received usual care
(3) ABC, control group received usual care
(4) AMF, control group received usual care
(5) Control group received usual care
(6) Problem solving, control group received usual care

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 7: Exacerbations leading to hospitalisation

Analysis 1.8



Footnotes

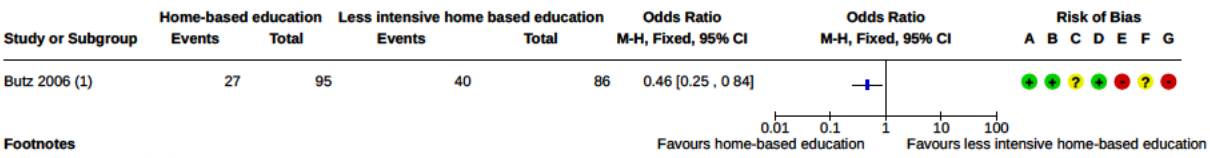
(1) Control group received usual care
(2) Polynesians, control group received usual care
(3) Europeans, control group received usual care

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 1: Home-based education versus usual care, wait list or less intensive education programme delivered outside the home, Outcome 8: Mean exacerbations leading to hospitalisation

Analysis 2.1



Footnotes

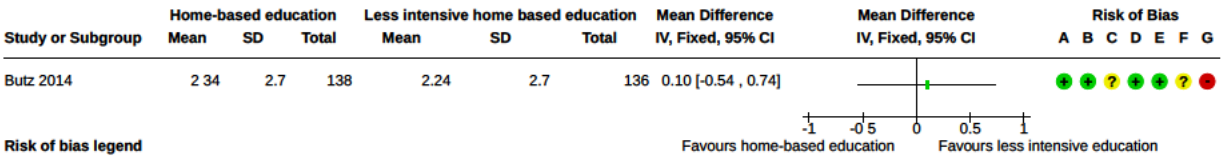
(1) Control group received basic asthma education

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 1: Exacerbations leading to emergency department visits

Analysis 2.2



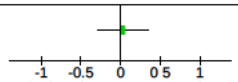
Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 2: Mean exacerbations leading to emergency department visit

Analysis 2.3

Study or Subgroup	Home-based education Mean	SD	Total	Less intensive home based education Mean	SD	Total	Mean Difference IV, Fixed, 95% CI	Mean Difference IV, Fixed, 95% CI	Risk of Bias A B C D E F G
Butz 2010 (1)	0.65	1.2	100	0.62	1.1	93	0.03 [-0.29 , 0.35]		



Favours home-based education | Favours less intensive home-based education

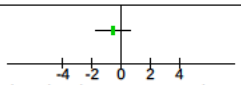
Footnotes
(1) Control group received asthma education visits + educational materials

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 3: Mean exacerbations requiring a course of oral corticosteroids

Analysis 2.4

Study or Subgroup	Home-based education Mean	SD	Total	Less intensive home based education Mean	SD	Total	Mean Difference IV, Fixed, 95% CI	Mean Difference IV, Fixed, 95% CI	Risk of Bias A B C D E F G
Butz 2014 (1)	9.15	5.2	138	9.74	4 8	136	-0.59 [-1.77 , 0.59]		



Favours less intensive education | Favours home-based education

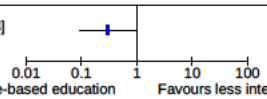
Footnotes
(1) Symptom free days in the past 14 days

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 4: Mean symptom-free days

Analysis 2.5

Study or Subgroup	Home-based education Events	Total	Less intensive home based education Events	Total	Odds Ratio M-H, Fixed, 95% CI	Odds Ratio M-H, Fixed, 95% CI	Risk of Bias A B C D E F G
Butz 2006 (1)	4	95	11	86	0.30 [0.09 , 0 98]		



Favours home-based education | Favours less intensive home-based education

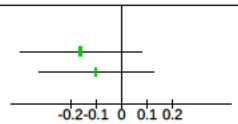
Footnotes
(1) Control group received basic asthma education

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 5: Exacerbations leading to hospitalisation

Analysis 2.6

Study or Subgroup	Home-based education Mean	SD	Total	Less intensive home based education Mean	SD	Total	Mean Difference IV, Fixed, 95% CI	Mean Difference IV, Fixed, 95% CI	Risk of Bias A B C D E F G
2.6.1 Admissions between 6 and 12 months follow-up									
Butz 2010 (1)	0.11	0.4	100	0.27	1.1	93	-0.16 [-0.40 , 0.08]		
Butz 2014	0.35	1	138	0.45	0.9	136	-0.10 [-0.33 , 0.13]		



Favours home-based education | Favours less intensive home-based education

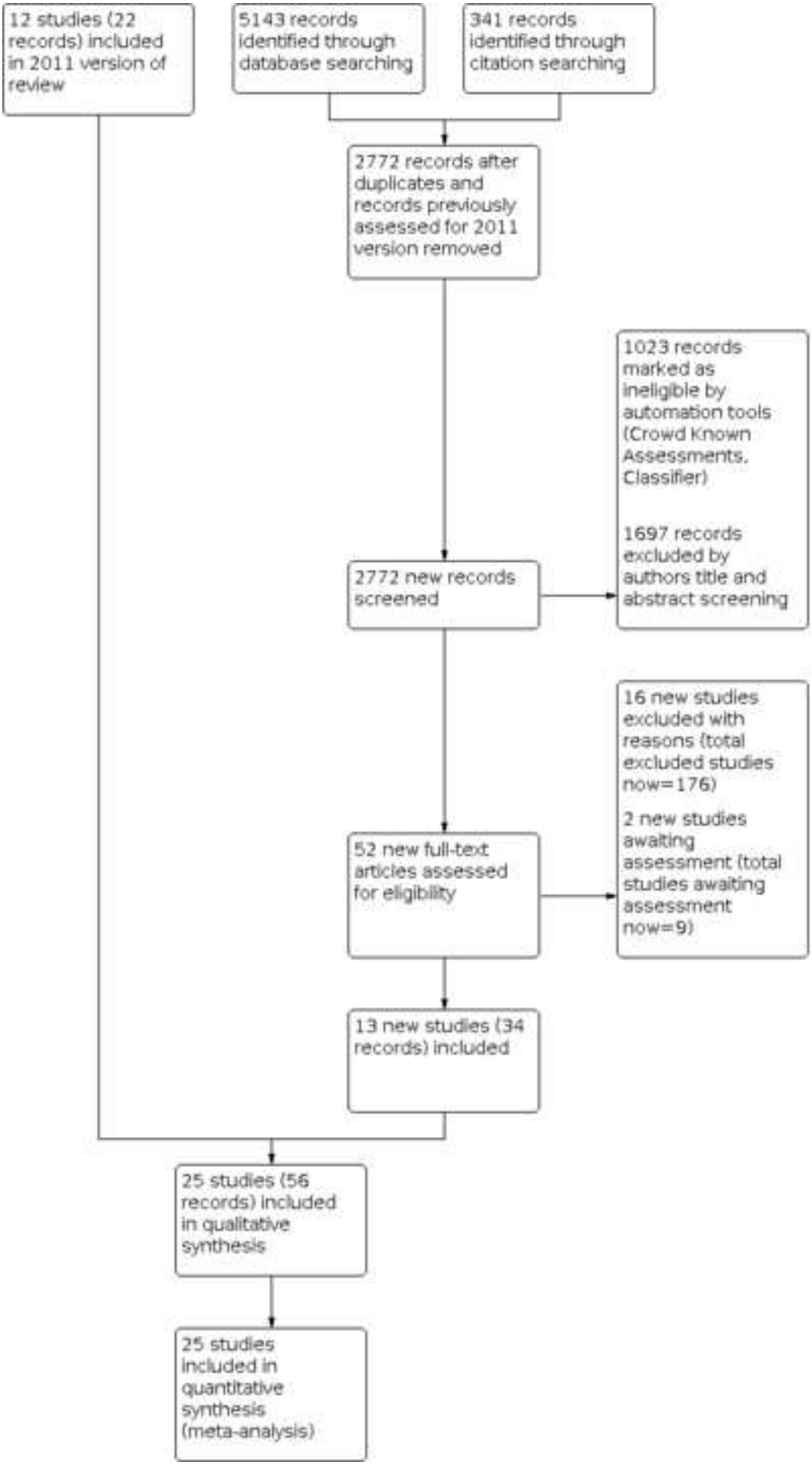
Footnotes
(1) Control group received asthma education visits + educational materials

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Comparison 2: Home-based education versus less intensive home-based education, Outcome 6: Mean exacerbations leading to hospital admission

Figure Flow diagram

Click here to access/download;Figure;CD008469-FIG-01.png



Chapter 7.

Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework

---

Antonia O'Connor[1,2], Andrew Tai[1,2,3], Malcolm Brinn[4,5], Amy Hoang[6], Daniele Cataldi[6], Kristin V Carson-Chahhoud[2,4,5]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2] School of Medicine, University of Adelaide, Adelaide, South Australia, [3]Robinson Research Institute, The University of Adelaide, [4]Translational Medicine and Technology Research Group, University of South Australia, [5]Australian Centre for Precision Health, South Australian Health and Medical Research Institute, [6]Paediatric Medicine Division, Women's and Children's Hospital, South Australia

Submitted to Pediatric Pulmonology 2022

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework

---

Publication status: Submitted for publication

Publication details: O'Connor A, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework. Pediatric Pulmonology

Principal Author:

Name of principal author (candidate)	Antonia O'Connor
Contribution to the paper	Gap in knowledge identified and conceived the study to answer clinical question. Planned and designed the method of study to address gap, obtained ethics approval (including governance and SSA), designed semi-structured interviews, participant recruitment and consent, led qualitative interviews, uploaded transcripts into transcription software with corrections of auto-transcripts in accordance with the protocol, collected and analysed data in accordance with pre-specified methodology, synthesis and interpretation of data, wrote manuscript and developed structure and arguments, revisions of manuscript and approved final version. Prepared manuscript in format for journal and submitted for publication. Acted as corresponding author.
Overall percentage (%)	70%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.

Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Andrew Tai		
Contribution to the paper	Contributed to design of study and methodology to answer clinical question, contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Malcolm Brinn		
Contribution to the paper	Contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Amy Hoang		
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.		
Signature		Date	21/06/2022

Name of co-author	Daniele Cataldi
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.

Signature		Date	23/06/2022

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Identified gap in knowledge and contributed to design of study and methodology to answer clinical question whilst acting in supervisory role for principal author. Contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process (primary supervisor)		
Signature		Date	21/06/2022

Results from Chapter 6 did not identify the home as the optimal place for educational interventions to be delivered in. In fact, they did not identify any difference in asthma related health outcomes when asthma educational interventions were delivered in the home versus standard care, education delivered outside the home or a less intensive educational intervention delivered at home. Based on these results, asthma education delivered to children within a hospital setting was explored for investigation of the designed augmented reality-enhanced intervention. In addition, it was thought more appropriate to continue the work and progress already made from Chapter 5 which occurred in an adult hospital setting. Lastly, as a paediatric respiratory advanced trainee, I am based in a hospital setting and therefore investigation in this environment was more relevant to my expertise.

Chapter 5 identified augmented reality technology as favourable to delivering asthma inhaler technique education in adults. Participants held a strong belief that this technology could aid in improvement of inhaler technique. For children and adolescents with asthma, technology-enhanced interventions have been highlighted as a generation appropriate, accessible educational intervention and production of evidence of augmented reality as a suitable educational delivery mechanism for education (specifically inhaler technique) is required.

Qualitative investigation and research in health design is crucial when there is scant evidence published about a subject. It enables an understanding of how individuals or groups interpret different phenomena within their natural environment. By allowing healthcare environments to be explored through qualitative research, it is possible to generate new knowledge and develop evidence-based interventions to influence implementation. The TDF in particular, is a validated framework used for investigation of health behaviour change interventions (104). In the case of the study in Chapter 7, the TDF formed the basis to identify the current perceived barriers and facilitators for delivery and receivership of asthma education within a clinical setting. Understanding the determinants of behaviour is pertinent to guide any behaviour change intervention. The use of technology-based innovations for asthma education was also explored specifically with the goal to guide and inform development of an augmented reality technology-based intervention for asthma inhaler education for children.

A total of sixteen participants were interviewed and completed questionnaires which was within our goal sample size identified for meaningful analysis in qualitative research. Healthcare professionals reported more barriers for asthma inhaler education delivery than children with asthma and their caregivers identified in receiving education. Barriers

identified included time pressures within a hospital setting, uncertainty of whose role it was to deliver asthma inhaler education and a lack of confidence in delivery of education for inhalers prescribed less frequently. Facilitators identified included all participant groups viewing the use of technology-based innovations positively in improving asthma education, indicating a possible solution for the barriers identified with the use of an augmented reality-enabled educational intervention.

Examining barriers and facilitators in technology-enhanced asthma inhaler technique education in children: A mixed methods evaluation using the Theoretical Domains Framework

O'Connor A (MBBS)[1,2], Tai A (MBBS, FRACP, PhD) [1,2,3], Brinn M (PhD) [4,5], Hoang A (MBBS)[6], Cataldi D (MBBS)[6], Carson-Chahhoud KV (PhD) [2,4,5]

[1]*Respiratory and Sleep Department, Women's and Children's Hospital, South Australia, Australia*

[2]*School of Medicine, The University of Adelaide, South Australia, Australia*

[3]*Robinson Research Institute, The University of Adelaide, South Australia, Australia*

[4]*Translational Medicine and Technology Research Group, University of South Australia, South Australia, Australia*

[5]*Australian Centre for Precision Health, South Australian Health and Medical Research Institute, South Australia, Australia*

[6]*Paediatric Medicine, Women's and Children's Hospital, South Australia, Australia*

Corresponding author: Dr. A O'Connor

Email: antonia.chan@sa.gov.au

CO-AUTHOR EMAILS:

1. andrew.tai@sa.gov.au

2. malcolm.brinn@unisa.edu.au

3. amy.hoang@sa.gov.au

4. daniele.cataldi@sa.gov.au

5. kristin.carson-chahhoud@unisa.gov.au

Keywords: asthma, inhaler technique, asthma education, behaviour change, technology-based interventions

ETHICAL STATEMENT: Ethics approval was obtained by the committee of the study site (Women's and Children's Hospital Human Research Ethics Committee) in August 2020 (HREC/20/WCHN/74).

CONFLICT OF INTEREST STATEMENT: There are no conflicts of interest to disclose.

ABBREVIATED TITLE (MAX 50 CHARACTERS) Barriers and facilitators of inhaler technique education

AUTHOR CONTRIBUTION STATEMENT:

A. O'Connor conceived and designed the study, collected and analysed the data, wrote the manuscript draft and performed critical revisions prior to submission; A. Tai reviewed manuscript, provided critical revisions, approved the final version to be published;
M. Brinn reviewed manuscript, provided critical revisions, approved the final version to be published; A. Hoang assisted with qualitative data entry and coding, approved the final version to be published; D. Cataldi assisted with qualitative data entry and coding, approved the final version to be published; K. Carson-Chahoud conceived and designed study, provided critical revisions to the manuscript, approved the final version to be published, supervised study.

WORD COUNT: 3447 (not including abstract or references)

Abstract

Introduction

Educational interventions for asthma inhaler technique have been identified as successful in improving technique in children, yet inhaler technique has not improved over time. New approaches should be considered, including the use of technology-based interventions such as smartphone and tablet applications. Adoption and implementation of such technology in healthcare has been historically slow. This mixed-methods study aimed to identify the barriers and facilitators of delivering and receiving asthma inhaler education for children in a hospital setting, including technology-based interventions.

Methods

Children with asthma, their caregivers, and healthcare professionals who regularly provide asthma education, were invited to participate in a qualitative interview and brief questionnaire to describe their experiences, knowledge, beliefs and recommendations about asthma education delivery. The Theoretical Domains Framework was used to develop questions for the semi-structured moderator guide, questionnaire, and provide the rigorous evaluation framework for deductive thematic analysis.

Results

Sixteen interviews and questionnaires were conducted with participants. Overall, healthcare professionals perceived more barriers in asthma inhaler education delivery than asthmatic children and their caregivers to receiving the education. Healthcare professionals and caregivers identified time-pressures within a hospital setting as a barrier for providing sufficient education. However, all participants felt they had adequate knowledge in their asthma management skills and inhaler technique. Technology-based innovations were viewed positively by all participant groups to improve asthma education.

Conclusions

Several barriers and facilitators to current hospital-based asthma education delivery were reported by target end-users. Future programs should consider these findings when developing asthma inhaler educational interventions, particularly those using technology-enhanced information delivery.

1. Introduction

Asthma control is defined as 'the extent to which the manifestations of asthma can be observed, or have been reduced or removed by treatment' (1). Despite well-controlled asthma being a primary goal in asthma management, only half of children and adolescents currently achieve this (1, 2). Inhaled therapy is the foundation of pharmacological management in achieving asthma control. Successful use requires correct inhaler device technique, as the ability of the medication to be delivered and deposited into the respiratory tract for pharmacological action is crucial. Poor technique correlates with suboptimal control (3-5).

Educational interventions can significantly improve inhaler technique, as identified in a systematic review from 2017 by Klijin et. al (6). Normansell et al. also identified benefits of inhaler technique interventions on asthma control and quality of life in a separate 2017 systematic review (however results were not statistically significant) (7). In both reviews, studies with interventions targeting children were smaller in number and size compared to adults (6, 7). Educational interventions designed for children and their caregivers are important, given the inherent challenges facing the paediatric population. This includes coordination between dose actuation and inhalation, the ability to perform fast inhalation, and nasal breathing in younger children (8). A systematic review from 2016 reviewed the effect of 17 educational interventions on the ability of children to perform the correct technique with their inhaler device (9). Educating children on the correct steps of their inhaler, regardless of who this was taught by, did improve device technique, which was reported as the number of steps performed correctly in most of the included studies (9).

Despite knowing educational interventions can be successful in improving patients' inhaler technique, correct administration of inhaler devices has not improved over time. A recent study found 86% of 150 paediatric patients were not using their metered dose inhaler correctly (10). This prompted new approaches for educational interventions on asthma inhaler technique to be considered (11). Technology-based interventions, such as telemedicine, websites, and the use of smartphone and tablet devices, have been explored as potential options for delivering asthma education and self-management skills (12). Adoption and implementation of these technologies by healthcare professionals (HCPs), however, has been historically slow, with little exploration of their attitudes toward novel technologies as an education support tool (13, 14).

Exploration into possible barriers and facilitators perceived by HCPs and members of the asthma community to asthma educational interventions, including those which are technology-based, is pertinent. The understanding of the determinants of behaviour can guide the design of behaviour change interventions, and improve the likelihood of their successful adoption, implementation and maintenance.

Therefore, the aim of this study was to identify the barriers and facilitators in delivering and receiving asthma inhaler education for children in a hospital setting (either inpatient or outpatient), to guide the design and implementation of a technology-based inhaler technique educational intervention for the paediatric asthmatic population.

2. Methods

2.1 Overview and theoretical framework

This study was guided by the Theoretical Domains Framework (TDF) to inform semi-structured interviews, questionnaires and provide a framework for deductive thematic analysis. The exploration of barriers and facilitators of asthma inhaler technique education is part of a larger study, in which a technology-based inhaler technique educational intervention designed for children is being examined. The designed intervention uses smartphone or tablet devices for education delivery, and the acceptability and usability of this intervention is also being reviewed. The pre-defined protocol for this study has been published elsewhere and the iterative co-design process for the intervention will be described in a future paper (15).

The TDF is a widely accepted, validated framework in research which is designed to understand determinants of behavioural changes to investigate for potential implementation problems for application in the real world (16, 17). It has commonly been used in identifying the influences on implementation of evidence-based recommendations in HCPs, and now extends to other areas which involve behaviour change in patients at individual and general population levels (16). Multiple behaviour and behaviour change theories have been grouped into domains. The 18 domains included in this study are: knowledge, skills, social/professional role and identity, beliefs about capabilities, optimism, belief about consequences, intentions, goals, innovation, socio-political context, organisation, patient, innovation strategy, social influences, positive emotions, negative emotions, behavioural regulation and nature of the behaviours (18).

2.2 Setting and recruitment

Recruitment occurred at a tertiary paediatric hospital in Australia. To enable information rich cases, purposive sampling was intended from three key groups – HCPs with experience in delivering asthma education, children with asthma and their caregivers.

HCPs included paediatric respiratory doctors, general paediatricians, general practitioners, nursing staff, pharmacists, and asthma educators. Inclusion criteria comprised of having worked in their profession and treated patients with asthma for at least 12 months in the previous five years, and age >18 years.

Inclusion criteria for children included a clinical diagnosis of asthma and being aged 8-17 years. Caregivers were parents/guardians of asthmatic children and adolescents aged 8-17 years.

Halfway through recruitment, inclusion criteria changed to children 8-12 years due to difficulties recruiting the older cohort. The reduced available sample pool of children >12 years was thought secondary to restrictions on patients attending the hospital unless medically necessary, and reduced patients being hospitalised for asthma during the SARS-CoV-2 pandemic.

Exclusion criteria included inability to give informed consent or being non-English speaking.

There is no current criteria for determining sample size for qualitative research (19). A sample size of approximately 15-20 participants was identified to be able to ensure enough

breadth and depth of data collected by participants and achieve data saturation, but also small enough to be able to achieve meaningful analysis (20).

2.3 Instruments, data collection and analysis

Qualitative and quantitative data was obtained from questionnaires and one-on-one semi-structured interviews to allow for triangulation of data to optimise the accuracy and support for themes identified. Triangulation ensures rigour and is gold standard in qualitative studies. It is defined as 'the practice of using multiple sources of data or multiple approaches to analysing data to enhance the credibility of a research study' (21).

Questionnaires were formed based on the TDF domains for the purpose of triangulation. Participants were asked to indicate their level of agreeance to statements on a 7-point Likert scale (with one being strongly disagree, to seven being strongly agree) which were related to asthma education (see supporting material Tables 1.1, 1.2 and 1.3).

Interviews utilised moderator guides framed by the TDF and were conducted by a qualitative interview trained researcher. Each interview was approximately 20-40 minutes in duration. Participants' previous experiences and knowledge surrounding asthma education, specifically inhaler technique education and technology-based asthma educational resources were explored. Interviews were audio-recorded, de-identified, auto-transcribed then checked back to ensure accuracy.

Deductive thematic analysis into the domains of the TDF was used for coding of interview responses (22). NVivo 12 software was used for data entry, coding and analysis (23). Two researchers coded interviews jointly (AO and either AH or DC) to ensure inter-rater reliability and minimise bias. Disagreements were resolved with discussion. Major subthemes within domains were identified.

Responses from questionnaires were collated and mean, median and modes were calculated for the Likert-scale responses for statements. The sample size appropriate for qualitative investigation is too small for formal statistical analysis with either parametric or non-parametric testing.

2.4 Ethics

Prior to interviews being conducted, informed consent was obtained. Ethics approval was obtained in August 2020 (HREC/20/WCHN/74).

3. Results

3.1 Participant characteristics

Sixteen participants were consented for the study (Table 1). HCPs were 66% female. There was equal representation of doctors and nurses. Experience in their profession ranged from five to 20 years. All nurses had previously undertaken a nursing educator role, including two who had asthma specific educator roles.

Table 1. Participant age and gender

	Health care professionals (n=6)	Asthmatic children (n=5)	Caregivers of children with asthma (n=5)
Mean age (SD)	34.33 (4.32)	9.8 (1.10)	41.8 (2.79)
Gender (n=female)	4	2	5

3.2 Barriers and facilitators for asthma inhaler technique education

All domains were coded within the 16 interviews. Various subthemes of the barriers and facilitators of asthma inhaler technique education within the hospital setting, including technology-based educational interventions were identified. Results from interviews will be presented in a narrative synthesis format with representative quotes which demonstrated the participants' beliefs incorporated. Table 2 will include further supporting quotes for the identified subthemes within the relevant domain. Table 3 shows the mean, median and mode of the statements in the questionnaire per participant group.

Subthemes identified were predominantly in the domains of skills, knowledge, social/professional role, beliefs about capabilities, beliefs about consequences, innovation and innovation strategy, patient and organisation. The TDF domains of socio-political context, nature of the behaviours, behavioural regulation, emotions (positive and negative), social influences, intentions and goals did not generate consistent subthemes and beliefs from participants.

3.2.1 Barriers: health care professionals

3.2.1.1 Difficulties with educating on inhalers not prescribed frequently

Delivering education on inhalers not prescribed frequently was a described barrier – *"So the actual practical use of, um, some of the inhalers and spacers and the different types…um, turbo-inhaler versus rapihaler…I don't think I have the, um, practical skills. I often defer that to somebody else"* (HCP, 6). This differed to HCPs' suggested high agreeance levels within the questionnaire in which a mean and median of six was answered to the statement 'I feel confident I give adequate education about how a child should use their asthma medications/inhalers'.

3.2.1.2 Time pressures

HCPs described time pressures as a barrier to delivering education. With time pressures both in outpatient clinics and inpatient wards, the possibility of insufficient provision of education was raised - *"With the high volume of patients that we are seeing, sometimes we are getting caught out by not doing the counselling part very well, or we are just doing the bare minimum"* (HCP, 5). Time pressures were coded into the 'beliefs about consequences' and 'organisation' domains.

3.2.1.3 Use of telehealth during SARS-CoV-19 pandemic

The difficulties in the practicalities of education delivery with telehealth, especially during the SARS-CoV-19 pandemic was also raised as a barrier - *"Recently I suppose one of the barriers is that a lot of it has been telehealth. ..So you aren't in person, it's not as easy to just hand over something that you've printed out and give them straight face to face….I do find sometimes it is a little bit more difficult…to try and educate over the telephone"* (HCP,6).

3.2.1.4 Uncertainty of which HCP has the primary role in asthma and inhaler technique education

Another barrier identified in asthma and inhaler technique education delivery was incongruency in differing HCPs' opinions on who's role it was to ensure asthmatic patients used their inhalers correctly. This varied from opinions it should be the person prescribing (i.e. the doctor), to the nursing staff caring for patients on wards, and to pharmacists. *"I would say that that is a combination of probably nursing and pharmacy'* (HCP, 3); *'If you're prescribing your medication, you should definitely be ensuring that the inhaler is used appropriately, and explain how that occurs… I think there are other people that can help with that role if it's delegated such as pharmacists or… educators such as asthma nurses"* (HCP, 1).

3.2.1.5 Lack of access to devices for technology-based educational interventions

HCPs voiced concerns about the use of technology-based resources in instances where there was unavailability of devices required. This was either in a hospital setting or at home within families who were of lower socioeconomic status – *'It relies on, um, the family having*

a device that you can use….I know that other places I've worked…lots of families don't have smartphones or tablets' (HCP, 5). This was coded under the domains of 'patient' but also 'organisation' due to the lack of resources able to be provided – '*If it was required to be done in hospital, the downside would be the need for screens. We don't have iPads on the ward that they can use…We wouldn't because we get stuff stolen too frequently as it is, and we don't have the budget to replace it'* (HCP, 5).

3.2.2 Barriers: asthmatic patients and their caregivers

Overall, asthmatic patients and their caregivers reported fewer perceived barriers during interviews compared with HCPs.

3.2.2.1 Consequences of time pressures within the hospital

Parents also described time pressures within a hospital setting as a barrier for not receiving the education they thought was required - *"I can't blame anyone because I thought that…everybody's busy, nobody can stop and explain to me things*" (Caregiver, 4).

3.2.2.2. Minimal knowledge on technology-based educational interventions

In regards to barriers of new educational intervention strategies involving smartphones and tablet devices, children and caregivers reported minimal knowledge and awareness of health-related applications, including asthma related applications when specifically asked.

3.2.2.3 Knowledge of where to locate asthma resources

Despite not reporting this in interviews, asthmatic patients reported low confidence in knowledge of where to locate asthma information on the questionnaire, with a mean of 2.2

and median of one. Caregivers were more confident with this with a mean of 4.8 and median of six.

3.2.3 Facilitators: health care professionals

3.2.3.1 Awareness and knowledge of asthma resources for education including inhaler technique educational resources and technology-based interventions

Despite asthmatic patients reporting low confidence on where to locate asthma resources, HCPs frequently reported their awareness and knowledge of online resources, smartphone applications for health and/or asthma education - *"You can refer them to… the asthma council websites…there's an asthma kids app.. that you can have on your phone, which can kind of help them to track their symptoms and how their control is…as far as puffer and spacer technique, there's definitely things on the asthma website about how to correctly do it, there are videos*" (HCP, 2). This was consistently reflected on the questionnaire with a mean of 5.67 and median of six for the statement 'I know where to look for resources about asthma, including management to provide children and adolescents with asthma'.

3.2.3.2 Confidence of asthma inhaler technique education and asthma knowledge

HCPs reported self-confidence in their knowledge of asthma and their capabilities of delivering education to patients and their caregivers, including inhaler device technique - *'I feel confident with, um, most preventers…puffer and spacer technique, and I feel confident in educating patients regarding the appropriate use of these' (HCP, 1).* This was also reflected on their questionnaire with a mean and median of six on the for the statement 'I am happy with my own knowledge of asthma'.

3.2.3.2. Optimism in the use of technology-based education

Optimism in technology-based interventions was a major facilitator for providing asthma education. HCPs were overall positive about the use of smartphones/tablet devices and applications for delivery of education - *'I think in the age of increasing… technology, awareness, it's much easier to get guidelines and access to services, um, with anyone that's got the internet. So I think it should be easier and easier to link in with those services and link in with good education'* (HCP, 6).

3.2.4 Facilitators: asthmatic patients and their caregivers

Overall, children and their caregivers believed they received most of their asthma education within a healthcare setting and had received adequate training on how to use their prescribed inhalers. They were also confident about their own knowledge of asthma.

3.2.4.1 Usefulness of technology-based resources for asthma and inhaler technique education

Caregivers and asthmatic patients acknowledged that using a smartphone/tablet application for education and management of their asthma would be useful. This was coded into the domain of 'innovation' and 'innovation strategy' - *"It's easy, accessible, um, and you always have it with you…and you could get your, um, relatives, or whoever they stay at the house to download it, to make sure they've got content to go to and to be able to access if you're not around"* (Caregiver, 5). Caregivers and asthmatic patients also believed the use of smartphones and tablet applications would be useful for children specifically. This was

coded under the ‘Patient” domain - “*He's more interested in… seeing and learning. So if I tell something he will not understand, but if he see something, he will learn more faster, you understand more faster… I feel those apps will be like, um, very useful for the kids.’*

(Caregiver, 4).

Table 2. Additional illustrative quotes from relevant domains and subthemes identified

TDF Domain	**Subtheme identified**	**Illustrative Quotes (participant ID)**
Knowledge	HCP awareness of asthma educational resources including technology-based resources – facilitator	"Um, in terms of where to direct them, if patients have questions regarding asthma, I will often, uh, direct them to sort of, um, the parent information or a patient information on asthma Australia" (HCP, 1) "'Um, and if I think they need resources for the puffers, I'll usually print some stuff off for them" (HCP, 2)
	Minimal awareness of asthma educational resources by asthmatic community and smartphone or tablet applications - barrier	Q: "Have you ever been given like, actual resources about asthma?" (interviewer) A: "No" (Caregiver, 5)

Skills	Confidence in ability to manage own asthma including describing asthma inhaler technique - facilitator	"'One puff and four breath, then keep doing that until you get to twelve puffs" (Asthmatic child, 2)
Role/identity	Differing beliefs in ensuring inhalers taken properly - barrier	"It's got to start at the physician first and then be reiterated and backed up by...like we have here, nursing staff." (HCP, 3) "I would say that that is a combination of probably nursing and pharmacy." (HCP, 4) "I was under, under the understanding that generally some of the inhaler technique stuff is done by the nursing staff on the ward." (HCP, 5) "I would usually, I guess hope that the pharmacist goes through that with them." (HCP, 6)
Beliefs about capabilities	HCPs confidence in own capabilities in delivering education - facilitator	"Yep, I feel pretty confident in my knowledge of asthma." (HCP, 1)

	HCPs beliefs in other HCPs capabilities in delivering education – barrier	"My experience would be that there is a variable, um, knowledge and education from the community when I see these patients in the hospital" (HCP, 6) "We've noticed that a lot of our new staff maybe don't have the knowledge to provide the education" (HCP, 4)
Beliefs about consequences	Time pressures – barrier	"I think the time factor comes into it, we're a lot busier than we ever used to be, with the acuity." (HCP, 4)
	Effect of telehealth implementation due to COVID - barrier	"At the moment.. clinic's been, um, sort of changed to telehealth a lot of the time that makes particularly given that our respiratory clinics are primarily via phone, um, it makes it difficult to, um, demonstrate in-person appropriate puffer and space technique, and also limits our ability to bring patients in for one-on-one asthma education with our nursing staff as well" (HCP,1)

	Being in an acute setting whilst receiving education - barrier	“The families are in, they've just had this acute episode, they're tired, you've got a sick child hospitalized. So there's only so much do you know, you're information overloading them I think a lot of times. So they're only taking away so much information” (HCP, 3)
Optimism	Use of technology for education useful - facilitator	“Yeah, I think there's definitely potential with the increased use of smartphones to open that up to a wider audience” (HCP, 4) “Yes. It'll be useful.” (when asked about whether applications will be useful for health and asthma education) (Caregiver, 4)
Organisation	Limitations of being able to educate staff and patients due to time pressures - barrier	“I think my overbooked clinics will certainly put that pressure on me...the pressure of trying to see a number of patients in a limited time” (HCP, 6). “Time is a factor, also just the nature of the ward. Like we don't get ever close, we can't all ever go to an education session” (HCP, 3) “I remember I used to give education and you would spend an hour in that room with the family to make sure they understood. You'd be like, 'I'm just going to do some education. If you need me, I'll be in that room.'….Whereas now, I don't know that staff on the floor have that time” (HCP, 4)

Innovation/innovation strategy	Use of technology including smartphone and tablet education for inhaler technique delivery- facilitator	“I have always, um, like for years talked about developing an app, um, where, you know, if you still, if you want to send them home with the book, that's fine. But in the increasing use of QR codes and things like that, whether it's a QR code that links into a video or something that is a bit more like audio based in case they can't read. Um, you know, just as they can't read, particularly in these days of COVID, most people know what that QR code means that they, even if they don't can't read what it's opening, they could figure out to try it.” (HCP, 3) “if there are specific resources like apps or, um, websites that are smartphone friendly, they could be an easy way for parents and patients to have education in their own home. Um, and, uh, sort of provide ease of access towards those educational resources without them having to go sort of hunting on the internet for those, um, resources.” (HCP, 1)
Patient	Use of technology including smartphone and tablet education for	“Kids love to watch phones or a iPad device of any means. So it'd engage them.” (HCP 3) “I think it'd be really good to be able to kind of offer that as an app or something like that. That's easily accessible on, you know, everyone's smartphones. Yeah. Um, and then would

	inhaler technique delivery in children and families – facilitator	be exciting enough that a kid would want to be involved in it rather than just having to be sat down and forced to watch a video maybe." (HCP, 6) "Because if some kids can't read, it could be on a voice message that they can listen to it" (asthmatic child, 3) "People who are suffering from such problem, even like a new, a mother whose child is newly diagnosed asthma, they can show this app to them and see, see how it is, how we, it be very easy for them as well." (Caregiver, 4)

Table 3. Mean, median and modes for 7 Likert-scale responses for statements

Statement	Mean	Median	Mode
HCPs			
I feel confident delivering adequate training and/or education to children and adolescents with asthma, and their caregivers.	5.83	6	6
I feel confident I give adequate education about how a child should use their asthma medications/inhalers.	6	6	5
I know where to look for resources about asthma, including management to provide children and adolescents with asthma.	5.67	6	6

I provide children and adolescents with asthma, and their families, educational resources.	5.17	5	5
I am happy with my own knowledge of asthma.	6	6	6
Children with asthma			
I understand what asthma is.	5.4	6	4
I have received enough training and/or education from relevant doctors and nurses as to how to keep my asthma in control.	4.8	6	6
I am confident I know how to use my asthma medications (including puffers).	6.4	7	7
I get enough education about how to use my asthma medications/puffers properly.	6	6	6
In my experience, I know where to look for information about asthma, including management.	2.2	1	1
I receive most of my education about asthma in a healthcare setting.	6.2	6	6
Caregivers of children with asthma			
I have received adequate training and/or education from relevant health professionals as to how to care for my asthmatic child.	4.6	6	6
I am confident I know how to give or instruct my child on their use of their asthma medications/inhalers.	5.4	6	7
I get adequate education about how my child should use asthma medications/inhalers.	4.8	6	6
In my experience, I know where to look for information about asthma, including management.	4.8	6	7

I receive most of my education about my child's asthma in a healthcare setting.	4.8	6	6
I am happy with my own knowledge of asthma.	4.6	5	NA
I am happy with my child's level of understanding of asthma and management.	5	6	6

4. Discussion

Barriers and facilitators to hospital-based asthma education delivery, specifically inhaler technique education, were explored in this study. This included exploration of technology-based educational resources. This insight gained from HCPs, children with asthma and their caregivers is useful to the design of future asthma educational interventions. Results from this study will inform the ongoing design process of a technology-based inhaler educational intervention created for children with asthma.

Principal findings showed that whilst all study participants felt they had adequate knowledge and confidence in their skills of asthma management and inhaler technique, there were still perceived barriers by HCPS and caregivers to the delivery of optimal asthma education in the hospital setting.

Barriers of education delivery included the consequences of hospital-based time pressures and were compounded by the uncertainty of individuals' HCP educational roles with mixed opinions on who should ensure adequate asthma inhaler technique training was delivered to patients. Educational interventions that can be delivered within settings that are not limited by time pressures and those where there is a clear identifiable educator may increase the success of the intervention.

Major facilitators identified by HCPs to asthma education included the awareness of resources including those which are technology-based such as smartphone applications.

Optimism of improvement of education with technology-based innovations was also identified. This was shared by asthmatic children and their caregivers.

A paucity of published evidence examining similar education barriers and facilitators for hospitalised children of asthma limited effective comparison with previous work. Our 2019 systematic review examined more broadly the perceived barriers of asthma caregivers in managing their child with asthma (24). This systematic review identified that caregivers felt a lack of asthma education was provided at the time of diagnosis and during subsequent medical visits. These findings were similar to an earlier qualitative study by Mowrer et. al reviewing asthmatic patients and HCPs' perceptions on asthma care (25). More asthma education was thought required, especially around inhaler medication and technique from this study. This differs from our findings showing caregivers felt they had been given adequate training about managing their child with asthma. It is possible that our findings differ due to the participants who were enrolled in our study. Children managed in a tertiary paediatric hospital may represent a more severe or poorly controlled cohort, and hence may receive more appointments or greater amounts of education.

Existing evidence on the barriers and facilitators of technology-based interventions for asthma education including inhaler technique in children and their caregivers is also limited. In 2014, Schneider et. al reported on the perceived barriers and benefits from HCPs of the use of mobile technology for an adolescent asthma cohort for care and self-management (26). Benefits included increasing interaction with patients, the use of a different mode for consultation and communication and the opportunity to increase engagement with this demographic. Barriers such as concerns of security, additional services needing to be

provided outside of their routine responsibilities and the feasibility of the use of mobile technology were identified. Interestingly, none of these barriers were highlighted by HCP participants for the current study however is worthwhile considering for technology-based intervention design. More recently, Iio et al. in 2020 reported on beneficial features of a prototype asthma mobile application education intervention developed for children and caregivers however the barriers to its use were not explored. (27). In our study, we found that through the identification of barriers, the opportunity was provided to take an iterative co-design approach for a technological-based asthma education intervention to remove potential factors precluding end-user uptake. This process will be described in a future paper.

Limitations of this study include its limited generalisability with participants recruited from a single hospital site. Asthmatic children and their caregivers who do not utilise a tertiary paediatric hospital and HCPs who work outside of the hospital may have identified additional barriers and facilitators for asthma inhaler technique education delivery and technology-based resources. Asthmatics and their families recruited may have also been of similar demographics limiting generalisability. With the change in inclusion criteria during the study, our study was also limited by not exploring the perceived barriers and facilitators of adolescents. This change was carefully considered by asthma clinical care and technological design experts, and the study team. A smaller age range for participants was thought more likely to lead to more in-depth analysis. There were also limitations to our findings in that multiple domains did not generate any consistent subthemes. As this is one study within one site, it is possible some subthemes have not been identified by this participant cohort. However, to ensure methodological rigour and minimise this risk, our

study was performed using gold standard qualitative procedures. Quantitative measures through the Likert-scale were used to confirm qualitative data allowing triangulation of data. A pre-specified protocol was published, qualitative interview training was undertaken, two coders were used for coding and a validated framework were also used.

5. Conclusion

This qualitative study identified the perceived barriers and facilitators from HCPs, children with asthma and their caregivers, of asthma education delivered within a hospital setting. Asthma inhaler technique education and use of technology-enabled resources were both specifically explored. This information can be used to inform the design of future asthma educational interventions and presents the opportunity to improve secondary care, especially with the use of technological innovations. More research is however needed to identify the best modalities to achieve this. Future research should explore the barriers and facilitators in children <8, adolescents, participants from multiple ethnic backgrounds, differing socioeconomic status, and a spectrum of asthma severity levels.

Recommendations for clinical practice cannot be made based on this evaluation alone due to the limitations described, however the subthemes for facilitators and barriers within the domains can be used for hypothesis generating purposes.

Acknowledgments

The authors would like to thank the children with asthma, their families and the health care professionals for their time in participation of this study.

References

1. Asthma. GIF. Global Strategy for Asthma Management and Prevention 2020 [Available from: www.ginasthma.org.
2. Tosca MA, Marseglia GL, Ciprandi G. The real-world "ControL'Asma" study: a nationwide taskforce on asthma control in children and adolescents. Allergologia et immunopathologia. 2021;49(1):32-9.
3. Al-Jahdali H, Ahmed A, Al-Harbi A, Khan M, Baharoon S, Bin Salih S, et al. Improper inhaler technique is associated with poor asthma control and frequent emergency department visits. Allergy, asthma, and clinical immunology. 2013;9(1):8-.
4. Capanoglu M, Dibek Misirlioglu E, Toyran M, Civelek E, Kocabas CN. Evaluation of inhaler technique, adherence to therapy and their effect on disease control among children with asthma using metered dose or dry powder inhalers. The Journal of asthma. 2015;52(8):838-45.
5. Padmanabhan M, Tamilarasu K, Rajaram M, Batmanabane G. Inadequate inhaler technique, an everlasting problem, is associated with poor disease control – A cross sectional study. Advances in respiratory medicine. 2019;87(4):217-25.
6. Klijn SL, Hiligsmann M, Evers SMAA, Román-Roíguez M, van der Molen T, van Boven JFM. Effectiveness and success factors of educational inhaler technique interventions in asthma & COPD patients: a systematic review. NPJ primary care respiratory medicine. 2017;27(1):24-10.
7. Normansell R, Kew KM, Mathioudakis AG, Normansell R. Interventions to improve inhaler technique for people with asthma. Cochrane database of systematic reviews. 2017;2017(3):CD012286-CD.
8. Price D, Bosnic-Anticevich S, Briggs A, Chrystyn H, Rand C, Scheuch G, et al. Inhaler competence in asthma: Common errors, barriers to use and recommended solutions. Respiratory medicine. 2012;107(1):37-46.
9. Gillette CP, Rockich-Winston NMSP, Kuhn JA, Flesher SMD, Shepherd MMD. Inhaler Technique in Children With Asthma: A Systematic Review. Academic pediatrics. 2016;16(7):605-15.
10. Almomani BA, Al-Qawasmeh BS, Al-Shatnawi SF, Awad S, Alzoubi SA. Predictors of proper inhaler technique and asthma control in pediatric patients with asthma. Pediatric pulmonology. 2021;56(5):866-74.
11. Sanchis J, Gich I, Pedersen S. Systematic Review of Errors in Inhaler Use: Has Patient Technique Improved Over Time? Chest. 2016;150(2):394-406.
12. Ferrante G, Licari A, Marseglia GL, La Grutta S. Digital health interventions in children with asthma. Clinical and experimental allergy. 2021;51(2):212-20.
13. Licari A, Ferrante G, Marseglia MDGL, Corsello MDG, La Grutta S. What Is the Impact of Innovative Electronic Health Interventions in Improving Treatment Adherence in Asthma? The Pediatric Perspective. The journal of allergy and clinical immunology in practice (Cambridge, MA). 2019;7(8):2574-9.
14. Zakerabasali S, Ayyoubzadeh SM, Baniasadi T, Yazdani A, Abhari S. Mobile Health Technology and Healthcare Providers: Systemic Barriers to Adoption. Healthcare informatics research. 2021;27(4):267-78.
15. O'Connor A, Tai A, Kopsaftis Z, Carson-Chahhoud K. Qualitative Study Protocol: Augmented Reality Technology to Deliver Asthma Inhaler Technique Training for Children and Adolescents With Asthma. International journal of qualitative methods. 2021;20:160940692110422.

16. Atkins L, Francis J, Islam R, O'Connor D, Patey A, Ivers N, et al. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implementation science : IS. 2017;12(1):77-.
17. Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. Implementation science : IS. 2012;7(1):37-.
18. Huijg JM, Gebhardt WA, Dusseldorp E, Verheijden MW, van der Zouwe N, Middelkoop BJC, et al. Measuring determinants of implementation behavior: psychometric properties of a questionnaire based on the theoretical domains framework. Implementation science : IS. 2014;9(1):33-.
19. Cleary M, Horsfall J, Hayter M. Data collection and sampling in qualitative research: does size matter? Journal of advanced nursing. 2014;70(3):473-5.
20. Guest G, Namey E, Chen M. A simple method to assess and report thematic saturation in qualitative research. PloS one. 2020;15(5):e0232076-e.
21. Salkind N. Encyclopedia of Research Design. 2010.
22. Vaismoradi M, Turunen H, Bondas T. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. Nursing & health sciences. 2013;15(3):398-405.
23. NVivo. QSR International Pty Ltd; 2020.
24. Fawcett R, Porritt K, Stern C, Carson-Chahhoud K. Experiences of parents and carers in managing asthma in children: a qualitative systematic review. JBI Evidence Synthesis. 2019;17(5):793-984.
25. Mowrer JL, Tapp H, Ludden T, Kuhn L, Taylor Y, Courtlandt C, et al. Patients' and providers' perceptions of asthma and asthma care: a qualitative study. Journal of Asthma. 2015;52(9):949-56.
26. Schneider T, Panzera AD, Martinasek M, McDermott R, Couluris M, Lindenberger J, et al. Physicians' perceptions of mobile technology for enhancing asthma care for youth. Journal of Child Health Care. 2014;20(2):153-63.
27. Iio M, Miyaji Y, Yamamoto-Hanada K, Narita M, Nagata M, Ohya Y. Beneficial Features of a mHealth Asthma App for Children and Caregivers: Qualitative Study. JMIR Mhealth Uhealth. 2020;8(8):e18506.

Supporting Material

Table 1.1 Asthma education questionnaire for health care professionals

Please circle the number that best represents how strongly you disagree (1) or agree (7) with the following statements:

I feel confident delivering adequate training and/or education to children and adolescents with asthma, and their caregivers.	1	2	3	4	5	6	7
I feel confident I give adequate education about how a child should use their asthma medications/inhalers.	1	2	3	4	5	6	7
I know where to look for resources about asthma, including management to provide children and adolescents with asthma.	1	2	3	4	5	6	7
I provide children and adolescents with asthma, and their families, educational resources.	1	2	3	4	5	6	7
I am happy with my own knowledge of asthma.	1	2	3	4	5	6	7

Table 1.2 Asthma education questionnaire for caregivers of children with asthma

Please circle the number that best represents how strongly you disagree (1) or agree (7) with the following statements:

I have received adequate training and/or education from relevant health professionals as to how to care for my asthmatic child.	1	2	3	4	5	6	7
I am confident I know how to give or instruct my child on their use of their asthma medications/inhalers.	1	2	3	4	5	6	7
I get adequate education about how my child should use asthma medications/inhalers.	1	2	3	4	5	6	7
In my experience, I know where to look for information about asthma, including management.	1	2	3	4	5	6	7
I receive most of my education about my child's asthma in a healthcare setting.	1	2	3	4	5	6	7
I am happy with my own knowledge of asthma.	1	2	3	4	5	6	7
I am happy with my child's level of understanding of asthma and management.	1	2	3	4	5	6	7

Table 1.3 Asthma education questionnaire for children with asthma

Please circle the number that best represents how strongly you disagree (1) or agree (7) with the following statements:

I understand what asthma is.	1	2	3	4	5	6	7
I have received enough training and/or education from relevant doctors and nurses as to how to keep my asthma in control.	1	2	3	4	5	6	7
I am confident I know how to use my asthma medications (including puffers).	1	2	3	4	5	6	7
I get enough education about how to use my asthma medications/puffers properly.	1	2	3	4	5	6	7
In my experience, I know where to look for information about asthma, including management.	1	2	3	4	5	6	7
I receive most of my education about asthma in a healthcare setting.	1	2	3	4	5	6	7

Chapter 8.

Co-design of an augmented reality asthma inhaler educational intervention for children: Development and usability study

---

Antonia O'Connor[1,2], Andrew Tai[1,2,3], Malcolm Brinn[4,5], Amy Hoang[6], Daniele Cataldi[6], Kristin V Carson-Chahhoud[2,4,5]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2] School of Medicine, University of Adelaide, Adelaide, South Australia, [3]Robinson Research Institute, The University of Adelaide, [4]Translational Medicine and Technology Research Group, University of South Australia, [5]Australian Centre for Precision Health, South Australian Health and Medical Research Institute, [6]Paediatric Medicine Division, Women's and Children's Hospital, South Australia

Submitted to JMIR Pediatrics and Parenting 2022

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

Co-design of an augmented reality asthma inhaler educational intervention for children: development and usability study

---

Publication status: Submitted for publication

Publication details: O'Connor A, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. Co-design of an augmented reality asthma inhaler educational intervention for children: Development and usability study. Journal of Medical Internet Research – Pediatrics and Parenting

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Gap in knowledge identified and conceived the study to answer clinical question. Planned and designed the method of study to address gap, obtained ethics approval (including governance and SSA), designed interviews, altered system usability scale for children, contributed to design of intervention, participant recruitment and consent, led interviews, collected and analysed data in accordance with pre-specified methodology, synthesis and interpretation of data, wrote manuscript and developed structure and arguments, revisions of manuscript and approved final version. Prepared manuscript in format for journal and submitted for publication. Acted as corresponding author.		
Overall percentage (%)	70%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Andrew Tai		
Contribution to the paper	Contributed to design of study and methodology to answer clinical question, contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/6/2022

Name of co-author	Malcolm Brinn		
Contribution to the paper	Development of intervention and delivery of the products used in this research, contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Amy Hoang		
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.		
Signature		Date	21/06/2022

Name of co-author	Daniele Cataldi		
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.		
Signature		Date	23/06/2022

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Identified gap in knowledge and contributed to design of study and methodology to answer clinical question whilst acting in supervisory role for principal author. Contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process (primary supervisor)		
Signature		Date	21/6/2022

The use of smartphone and tablet devices can be an effective way to improve patient knowledge and treatment adherence in healthcare. Results from Chapter 7 identified the use of technology-based interventions, such as mobile devices were viewed positively by healthcare professionals with experience in asthma education, asthmatic children and their caregivers. Results from Chapter 5 identified that augmented reality was perceived to be a possible useful tool for asthma inhaler technique education. These provide support for the development of an augmented reality enhanced educational intervention for children with asthma.

Digital health interventions which incorporate a co-design process in their development with targeted end users and key stakeholders have the highest likelihood of successful uptake and effectiveness on their intended outcomes. In young people in particular, a user-based perspective is essential to ensure the intervention is appealing and engaging. Despite the multitude of health-related smartphone and tablet applications available, almost half (47%) of teenagers who have a health-related application do not use it (105). This may be reflective of an intervention which is not suited to their needs or preferences. Co-design not only considers the end user requirements, it also allows for feedback from those who have the knowledge of the clinical care pathways and healthcare system they are within. This is advantageous due to the ability to develop an intervention which can complement standard care and ensure successful integration of the intervention within the relevant setting. The publication of specific details of the co-design process of interventions is important to enable reproducibility and scientific rigour.

The evaluation of usability of digital health interventions is also essential in the design process. Educational technology-based interventions which are perceived as having good usability improve the effectiveness of education and acceptance of the intervention. For Chapter 8, the widely used System Usability Scale (SUS) standardised questionnaire was applied as the measure of perceived usability (106).

Results from this study described the co-design process of an augmented reality asthma inhaler technique educational intervention. This incorporated the preferences of children with asthma, their caregivers and healthcare professionals who were experienced in asthma education delivery. Key suggestions included animation and increased augmented reality experiences which were able to be incorporated into later iterations. Removal of elements identified as burdensome was also able to be achieved. The usability of the intervention was overall perceived to be excellent.

Original Paper: Co-design of an augmented reality asthma inhaler educational intervention for children: Development and usability study

O'Connor A[1,2], Tai A[1,2,3], Brinn M[4,5], Hoang A[6], Cataldi D[6], Carson-Chahhoud KV[2,4,5]

[1]*Respiratory and Sleep Department, Women's and Children's Hospital, South Australia, Australia*

[2]*School of Medicine, The University of Adelaide, South Australia, Australia*

[3]*Robinson Research Institute, The University of Adelaide, South Australia, Australia*

[4]*Translational Medicine and Technology Research Group, University of South Australia, South Australia, Australia*

[5]*Australian Centre for Precision Health, South Australian Health and Medical Research Institute, South Australia, Australia*

[6]*Paediatric Medicine, Women's and Children's Hospital, South Australia, Australia*

Corresponding author: Dr. A O'Connor
Email: antonia.chan@sa.gov.au
Phone: (08) 8161 7234

WORD COUNT: 4855

Abstract

Background

The use of smartphone and tablet applications (apps) to deliver healthcare education is becoming increasingly common and has been identified as an effective way to improve patient knowledge and treatment adherence. This has also been demonstrated in the asthma population. Despite asthma being more prevalent in paediatrics, there are minimal apps which are targeted specifically for children. Only half of children have acceptable control of their asthma symptoms and over 90% do not use their asthma inhalers correctly. With children being increasingly connected to technology, there is an opportunity to improve asthma inhaler technique education by delivery via smartphone/tablet apps. Augmented reality (AR) delivered via a smartphone/tablet app was utilised in this study to capitalise on growing technological innovations.

Objectives

Our aims of this study are to describe a co-design process, development and design outcomes of a smartphone/tablet app which incorporates AR technology to deliver asthma inhaler technique education to children with asthma. This study also aims to provide usability evaluation using the System Usability Scale (SUS) of the designed intervention to inform our work and future research, and to be able to provide recommendations for others performing similar work.

Methods

The development of the AR asthma inhaler technique education app was based on an iterative co-design process with likely end-users (children with asthma, their caregivers and health care professionals) to maximise the likelihood of the successful uptake of the intervention within a clinical setting. The design process involved multiple stages: recruitment of end-users for qualitative interviews and usability testing on a previously designed educational intervention which utilised an AR-embedded smartphone/tablet app, ideation of content for a specific asthma inhaler technique education intervention with asthmatic children and health professionals, development of the asthma inhaler specific intervention, and two further rounds of qualitative interviews and usability testing with re-design of the initial prototype.

Results

Using a co-design process, the AR asthma inhaler technique education app was able to be designed with incorporation of the preferences of asthmatic children, their caregivers and health professionals who had experience in asthma education delivery. Using this process, ease of use of the application and the novel nature of the intervention was frequently described, with key suggestions of addition of animation and increased AR experiences able to be applied to later iterations. It was also possible to remove elements of the intervention which were identified as burdensome. Usability of the intervention overall was perceived to be excellent, and the mean SUS score of the intervention was found to be highest in the final round of evaluation.

Conclusions

Results from this co-design process and usability evaluation will be used to develop a final AR asthma inhaler technique educational intervention for children to be evaluated in the clinical setting.

Trial registration: ACTRN12621000306819

Keywords: asthma; asthma education; paediatric; paediatric asthma; co-design; usability; development; smartphone; tablet; augmented reality

Introduction

There are currently over six billion smartphone users worldwide, with a 50% increase in the number of users over the last five years (1). With the abundance of smartphone users, and over 50,000 healthcare or medical applications (apps) available, the ease of access and convenience became clear during the SARS-CoV-2 pandemic, where surveys found 40% trialled new healthcare apps for monitoring of their health in this time (2, 3). Systematic reviews of healthcare education delivered via smartphone or tablet apps have identified effectiveness for outcomes such as improved knowledge, adherence to medications or treatment and improved clinical care (4). For asthma self-management, healthcare apps have also shown positive effects with improvements in quality of life and asthma control (5, 6).

Despite asthma being more prevalent in the paediatric population and only 50% of this population having acceptable control of their asthma symptoms, only 5% of the almost 150 apps available related to asthma are targeted specifically towards children (7-9). This subgroup of asthma patients is increasingly connected to digital technology, with the age of introduction continually dropping, and research suggesting some children are more familiar with devices such as smartphone and tablets before books (10). It is clear that smartphone and tablet related apps should be designed, or more importantly co-designed, for this population

Although still described as a relatively new process (11), co-design of digital health interventions facilitates active collaboration between intended end-users, key stakeholders and software developers, to build a program with the highest likelihood of successful uptake and effectiveness on intended outcomes (12, 13). There is growing awareness about the importance of consumer co-design for tech-based health interventions among youth, and the need to publish specific details of the consumer engagement process, enabling reproducibility and scientific rigour (12-16). The risk of inadequate engagement is inferior and less appealing products can lead to low uptake and effectiveness (16). In 2016, Schneider et.al. highlighted the importance of app development in collaboration with a cohort of young people with asthma. However, to our knowledge, few studies since then have published on a user-centred design process in asthma (17-21).

In addition to co-design with potential end-users and stakeholders, the usability of an intervention should also be evaluated through the design process. The International Organisation of Standardisation defines usability as ‘the extent to which the intervention or product can achieve specified goals by specified users with effectiveness, efficiency and satisfaction’ (22). Perceived good usability has been shown to improve the effectiveness of the education from the intervention as well as improve productivity and end-user well-being in health-related apps (23, 24). Poor usability of technology-based systems, such as electronic health systems, perceived by clinicians is linked to increased physician burnout and workload and lower acceptance of the system, therefore good usability is vital for increasing the likelihood of successful uptake of the intervention within clinical settings (25-28).

With asthma inhaler technique in children well studied to be frequently performed incorrectly and 92% of children missing steps in their inhaler use, there is a clear ongoing need for alternative methods to deliver asthma inhaler technique education to this cohort (29, 30). Given the popularity of smartphones among young people and their increasing use, a smartphone/tablet app may be an effective way to address this. With the small number of

apps available for young people with asthma but the growing popularity of their usage, there is a need to co-design a smartphone/tablet app for this cohort. To maximise effectiveness, a co-design process that focuses on usability is necessary. The acceptability of the designed app as well as contextual analysis provided through the Theoretical Domains Framework (TDF) will be presented in a future paper.

Objectives

To capitalise on growing technological innovations in children with asthma and to address the paucity of co-designed apps, we undertake a co-design process for a smartphone/tablet app which utilises augmented reality (AR) technology to deliver asthma inhaler technique education. As AR is a novel technology for delivering asthma education, the co-design process of an intervention and evaluation of its usability is necessary. Our aims were to describe the process, development, design outcomes and perform usability evaluation to inform our work and future research, as well as to provide recommendations for others performing similar work.

Methods

Overview

We created an AR-enabled smartphone/tablet app to address the 92% of children who have incorrect asthma inhaler technique. Co-design needed to be a key approach as did usability evaluation. Qualitative evaluation based on the Theoretical Framework of Acceptability and TDF were obtained through interviews and questionnaires, however this manuscript will focus on the iterative co-design process and usability.

Development of the AR asthma inhaler technique education intervention was based on an iterative co-design process (31). This involved the below following steps:

1. Likely end-users of the intervention and asthma health care professionals (HCPs) recruited
2. Round one of semi-structured one-on-one interviews with likely end-users and asthma HCPs
    a. Previously designed AR educational intervention for physiotherapy devices in cystic fibrosis shown to participants during first round interviews (iteration 1)
    b. Qualitative evaluation and usability testing of the concept of AR itself and the use of smartphone/tablets for delivering education.
    c. Ideation of content for asthma inhaler technique education intervention with end-users and HCPs
3. Development of AR educational intervention for asthma inhaler technique specifically (iteration 2)
4. Round two of interviews with likely end-users and asthma HCPs
    a. Qualitative evaluation of intervention and usability testing
5. Third iteration developed based on feedback and user testing
6. Round three of interviews for qualitative evaluation of iteration 3, usability testing and obtainment of further feedback

Ethics

Ethics and governance was approved on the 21st of August 2020 after the study was reviewed by the Human Research Ethics Committee of the study site (approval number HREC/20/WCHN/74).

Participants were provided with participant information sheets prior to enrolment and informed consent was obtained by all participants prior to interviews being taken.

Recruitment and participants

An approximate total sample size of 15-20 participants was determined prior to recruitment to participate in three to four usability testing rounds. This sample size was based on previous usability studies and experts of usability testing advocating that five users be involved per round as 80% of usability problems can be found within these five users (32). Five users per round was not a strict rule however as Faulkner et. al suggested increasing numbers tested can improve data confidence (33).

Purposive sampling was planned for recruitment to ensure adequate diversity of likely-end users for maximal transferability of the intervention. Likely end-users were children with asthma, their caregivers and HCPs who had experience in the management of children with asthma. Purposive sampling was also used to ensure a broad range of experiences, backgrounds and opinions could be obtained from participants.

Inclusion criteria for likely end-users were children aged 8-17 years who had a clinical diagnosis of asthma, their caregivers, and were able to give consent. With purposive sampling intended to gain good representation of end-users, it was identified mid-recruitment that predominantly younger children were presenting to hospital during the SARS-CoV-2 pandemic when recruitment was occurring, and there were minimal face-to-face outpatient clinic appointments also affecting recruitment from the older cohort. The decision was made half-way through recruitment to change the inclusion criteria to children aged 8-12 years in consultation with experts in clinical care and technological innovation design.

Inclusion criteria for HCPs were nursing professionals, paediatric general medical doctors, respiratory doctors, pharmacists, asthma educators or general practitioners who had treated and/or managed children with asthma regularly for over 12 months in the previous five years.

Those who were non-English speaking were excluded.

Participants were recruited by the primary investigator from July 2021 at a tertiary paediatric hospital within Australia. Potential participants were approached and screened for inclusion and provided with patient information sheets. Potential participants were given time to review the information sheets and given the opportunity to decline participation.

Data collection and analysis

Co-design data was obtained through one-on-one interviews using semi-structured moderator guides by the primary investigator who had received interview training. Focus groups had

been initially planned for the co-design process however due to the SARS-CoV-2 pandemic, this changed to one-on-one interviews. Interviews took approximately 20 – 40 minutes per participant and involved four components:

1. Exploring the participants' previous experiences with asthma and asthma education (specifically inhaler technique education), experiences with smartphone and tablet apps in healthcare and experiences with AR;
2. Being shown the intervention by the interviewer;
3. Being able to use the intervention as a one-off;
4. Exploration of participants' views and experiences of the trialled intervention.

All interviews were audio-recorded, auto-transcribed and check backed by the primary investigator, to ensure all data was verbatim. Feedback from each iteration was consolidated by the primary investigator and discussed with the project team which resulted in an agreed set of changes over subsequent iterations. The evidence underpinning these recommendations have been presented in the results with supporting evidence from the quotes. We prioritised changes where there was some consensus by participants that a change was needed and that were within the scope of our budget and time.

Usability data was collected via the System Usability Scale (SUS) questionnaire. The SUS is a common, simple, standardised questionnaire for perceived usability which has been used since the 1980s (34, 35). It was chosen for this study due to its known suitability in evaluation of computer systems, medical systems and mobile devices, its relatively simple ease of administration, its ease of interpretation with known reference standards and suitability with small sample sizes (36). Participants were asked to complete the questionnaire once the interview had been completed.

The standard approach of scoring of the SUS was used, in which the ten questions were answered based on the five-point scale, odd-numbered items had 1 subtracted from the raw score and even numbered items had the raw score subtracted from 5, with the sum of the adjusted scores multiplied by 5 for the standard SUS score (34). If a participant did not score an item, it was given a raw score of 3 (34). The standard SUS scores were entered into Microsoft Excel to determine the mean, median and standard deviation for all participants. The higher the score, the better the usability with Bangor 2008 suggesting a system needs to score above 70 to be considered at least passable and better systems will score in the high 70s to high 80s, with scores over 90 indicating a truly superior system (37).

The SUS which was supplied for children had small wording modifications (see Table 1).

Table 1. SUS for children.

Item	SUS Statement	Modified statement for children
1	I think that I would like to use this system frequently.	I think that I would like to use this resource often.
2	I found the system unnecessarily complex.	I found the resource unnecessarily complicated.
3	I thought the system was easy to use.	I thought the resource was easy to use.
4	I think that I would need the support of a technical person to use this system.	I think that I would need the support of a technical person to be able to use this resource.

5	I found the various functions in this system were well integrated.	I found the various functions in this resource were put together well.
6	I thought were was too much inconsistency in this system.	I thought there was too many differences in this resource.
7	I would imagine that most people would learn to use this system very quickly.	I imagine that most people would learn to use this resource very quickly.
8	I found the system very cumbersome to use.	I found the resource very difficult to use.
9	I felt very confident using the system.	I feel very confident using the resource.
10	I needed to learn a lot of things before I could get going with this system.	I needed to learn a lot of things before I could get going with this resource.

Results

Participant characteristics

A total of 16 participants were recruited from 16 potential participants approached between July 2021 and April 2022. This included five children with asthma, their five caregivers and six HCPs who had experience in managing patients with asthma. There were three rounds ranging from four to six participants per round.

HCPs (n=6) included respiratory and general paediatrics doctors and nursing staff who also had backgrounds working within inpatient settings, emergency departments, intensive care units as well as in educator roles within the hospital.

Children (n=5) and their caregivers (n=5) with asthma had been predominantly diagnosed by a general paediatrician or respiratory specialist and were recruited whilst admitted into hospital for treatment of asthma exacerbations. All caregivers were female and there was a broad range of educational levels from not having completed Year 12, to completion of tertiary education.

Table 2. Number of participants per round of interviews

	First iteration (n=4)	**Second iteration (n=6)**	**Third iteration (n=6)**
Health care professionals, n	2	2	2
Children with asthma, n	1	2	2
Caregivers of children with asthma, n	1	2	2
Sex (males:females)	0:4	1:5	4:2

Co-design process and intervention feedback

Iteration 1: Interviews and feedback

Participants were initially shown an educational intervention which incorporated AR to deliver education via a smartphone/tablet app on physiotherapy in cystic fibrosis. This was undertaken to provide a basic demonstration as to how AR-enabled technology delivered via a smartphone/tablet app works. A paper pamphlet was triggered when the smartphone/tablet app was open and hovered over it to come to life, with activation of digital content on education of physiotherapy equipment (see figure 1). Participants were then given time to use the smartphone/tablet to trial the use of the intervention themselves, provide feedback on their experiences of the AR technology, and generate ideas of content specifically for an asthma inhaler technique educational intervention which utilised AR.

Figure 1. Iteration 1 demonstrated and used by participants in first round

During the first round of interviews (n=4), the use of AR technology was found to be novel, interesting, and easy to use – *'It was, it was new. It was good'* (caregiver, female); *'It's like really being in the future… Like I wouldn't have ever, if you look at this piece of paper, you wouldn't expect that to kind of come to life. So I think that will be like the surprise factor as well, make it interesting for them and yeah. Get their attention'* (health professional, female); '[it was] *pretty easy to use'* (child, female).

Suggestions and ideas for content were recommended through the interviews for provision of education on all asthma inhaler devices as well as education of the asthma disease process itself – '*It would good to have one, I guess, I mean, for each of the puffers or each of the puffer types like a metered dose inhaler and a spacer, and then like your, um, elliptas and kind of going through all of them with how to use them, that would be good'* (health professional, female); *'So particularly, um, use of inhalers, um, reliever and preventer, and sort of, um, a video representation to children of how they should use their preventer or their reliever'* (health professional, female); *'I guess that would be good to have a broad overview of asthma and what asthma is'* (health professional, female).

To create content that younger people were more likely to engage with, addition of animation and the need to improve relatability to children were suggestions provided to ensure it was more age appropriate – *'somehow you have to make it sound exciting rather than just so factual'* (health professional, female); *'So I don't know if younger ones potentially, um, like cartoony…'* (health professional, female)

The use of the paper pamphlet to trigger the AR and the digital educational content itself was also raised as a potential burden - '*I guess the paper based resource has limitations in terms of, if you need the paper to use the app and if patients lose the paper, then it makes, has some issues…'* (health professional, female).

Iteration 2: Interviews and feedback

A second iteration designed specifically for asthma inhaler technique education utilising the same AR technology as iteration 1 was created (see Figure 2 and Figure 3). Using the same mechanism of activation of educational digital content via a piece of paper, a poster of three children was created which triggered via a smartphone/tablet app for the children to come to life, to deliver educational information on asthma and asthma inhalers on the smartphone device. Due to time constraints, a purely app-based intervention was unable to be developed for iteration 2 (note: this was achieved by iteration 3) and hence the same paper-based trigger mechanism was used. Components of feedback from participants which were addressed in this iteration included education on multiple inhaler devices and a broad overview of asthma, the use of animation, and the use of peer role models to improve relatability to young children. Multiple videos were created to demonstrate the use of the different types of inhalers, with users prompted to click on the inhaler that they wished to learn about. Scripts were written based on Lung Foundation inhaler technique videos, reviewed by asthma educators within the paediatric hospital and had 'readability' scores generated via Grammarly to ensure they were age appropriate (38, 39).

Figure 2. Iteration 2 demonstrated and used by participants in second round

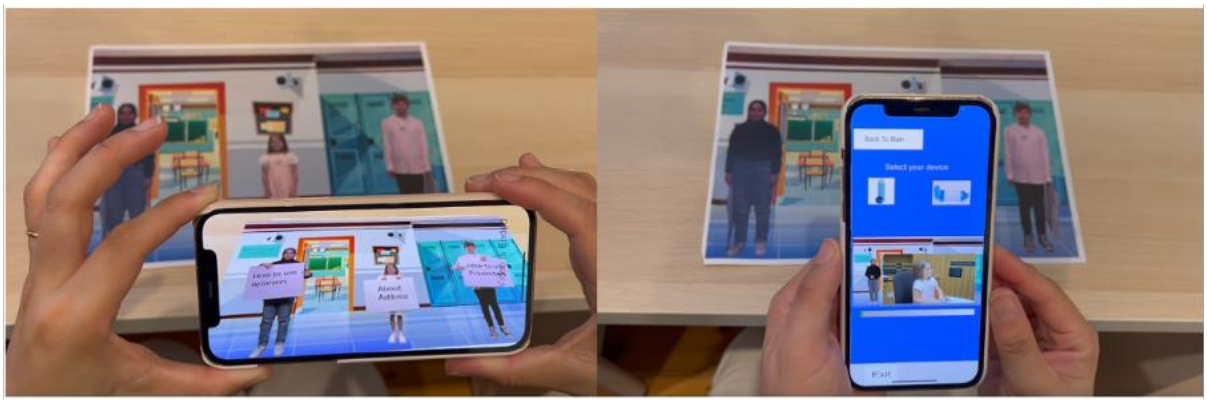


Figure 3. Iteration 2 demonstrated and used by participants in second round – digital educational content for multiple asthma inhaler devices

In the second round of interviews (n=6), participants received a demonstration of the AR asthma intervention and then were invited to use it themselves. After testing the intervention, feedback was again provided, and suggestions made for improvements.

The technical functional aspects of the app were commented on in regards to both the ease of use, as well as the burden of the paper-based requirement for triggering and launching the app. The ease of the launch of the app was commented on by most participants – *'Easy to do, Just click'* (caregiver, female). However technical issues related to functionality features of needing the paper-based resource was highlighted which created difficulty in its use at times – *'It would be, it would be good if once it started playing it, you didn't have to hold it there. Once you click out of the main menu'* (health professional, female); '*Maybe that once it's on, maybe it'll lock…because it's not comfy putting it over [the paper]'* (child, female).

Asthma education delivered by children actors was received positively and thought to be a relatable means to deliver information - '*my first thought is, oh, this is cool. It's actually kids doing it, which would really target kids. So I was like, oh, that's nice. It just makes it really relatable'* (health professional, female); '*as a kid with asthma, I think it makes it very relatable because you've got kids talking about it, kids demonstrating'* (health professional, female).

Feedback and suggestions were also provided to improve engagement and decrease boredom for children. This was predominantly reflected in suggestions of animation incorporation, increased AR use and gamification - *'I do think that you have to [include] a game… just to teach them.'* (caregiver, female); '*It'd be good if it was more interactive because some people might have trouble listening to things.'* (child, female); '*Maybe you could like, have, um,*

maybe cartoon people next to them.' (child, female); 'Just add a little bit more to the actual product... Come to life a little bit more then it grabs the kids' (health professional, female).

More components of asthma education were also requested in regards to content, such as expanding on asthma symptom triggers and the addition of asthma action plans - *'One of the things that I think you should put on it is triggers'* (caregiver, female); *'you could go through steps of even like your asthma action plan'* (health professional, female).

Iteration 3: Interviews and feedback

The third iteration of the AR asthma inhaler educational intervention was devoid of the paper-based trigger and modified, with additional major changes being expansion of animation and pivoting of the users' AR experience through the smartphone to increase interaction of the app with young people. With the removal of the piece of paper required to trigger the smartphone/tablet app, instead an area of flooring was used. Once the app was opened, the user scanned the floor which prompted the participant to place a 'portal' onto the ground which then allowed the participant to enter the 'portal' into a room which they could view on their smartphone/tablet. Asthma inhaler educational videos and an animation were available on the walls of the room for participants to watch (see Figure 3a and 3b). Additional educational content on triggers was also added however gamification was not yet incorporated into this iteration due to limitations on funding and time it would take to create appropriate gamification for this particular intervention.

Figure 4. Iteration 3 demonstrated and used by participants in the third round – images having entered a room through portal, and screens shown on the walls of the room with asthma inhaler educational video

Figure 5. Iteration 3 demonstrated and used by participants in the third round – images having entered a room through portal, and screens shown on the walls of the room with whiteboard animation

Figure 4.

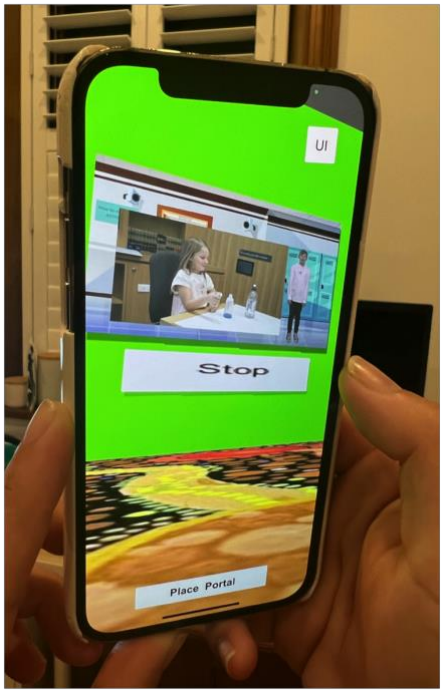
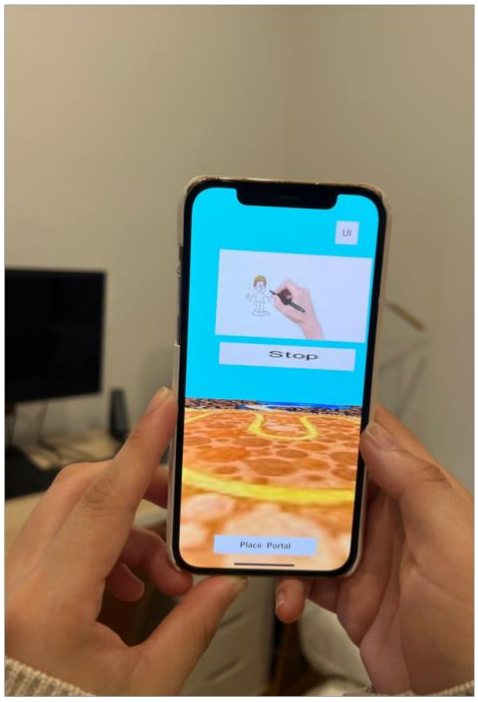


Figure 5.



Six participants provided feedback in the third round of interviews after testing of the AR smartphone/tablet intervention.

An animated introduction using whiteboard animation was well received by all participants as was the increased AR experience via the use of the portal and room - *'The introduction was kind of fun. The playground and that stuff'* (child, male); *'the use of the drawings in the intro video, uh, was a great idea'* (health professional, male); '*You kind of just go into the portal and then the videos come up, I kind of like that you have to move the phone'* (caregiver, female); *'I liked the drawings'* (caregiver, female).

Having children involved as the actors was once again highlighted as a positive to the intervention, as was the use of AR as a novelty technology and increasing the AR experience as suggested in iteration 2 to increase interactivity - '*I think, I think the, uh, use of augmented reality is a novelty that kids would really connect with. Um, and the use of children delivering the education is also really good'* (health professional, male); *'I think it'll definitely add a component of something different and new to get them involved rather than just watching a video on a screen (*regarding AR technology)' (health professional, male),

Suggestions for improvement included incorporation of gamification again from children participants, as well as more animation within the intervention – '*A lot of drawing animation is always, always good'* (caregiver, female).

Results of usability (SUS)

All 16 participants who were recruited completed the usability questionnaire. Only one participant did not score all 10 items and as described in the methods, these items were allocated a raw score of 3. SUS scores provided from participants ranged from 60 to 100 with an average of 87.65 and median of 88.75 indicating not only was the system acceptable (scores >70), there was excellent perceived usability of the intervention overall, with mean SUS scores between 85.5 and 90.9 considered within the 'excellent' range when SUS scores have an adjective rating applied (40).

When SUS scores were compared across the three rounds, the mean SUS score was lowest for iteration 2, and the highest mean SUS in iteration 3 (i.e. the final round). Based on Bangor et. al, the SUS mean for iteration 3 was classified as a truly superior system (37) (see table 3).

Table 3. SUS scores per iteration round

Iteration round	SUS score range	SUS mean	SUS median	Standard deviation
1	75 - 100	86.25	85	10.51
2	60 - 95	85.83	90	13
3	70 - 100	90.14	93.75	11.66

When SUS scores were compared across the three participant groups (children with asthma, their caregivers and health professionals), health professionals scored the intervention highest in terms of perceived usability with a mean score of 89.58, and caregivers lowest with a mean

score of 85.5 (see table 4). Of note, all scores were still within the 'excellent' usability range across the three participant groups.

Table 4. SUS scores per participant group

Participant group	SUS score range	SUS mean	SUS median	Standard deviation
Children with asthma	60 - 100	87.5	95	16.96
Caregivers of children with asthma	70 – 97.5	85.5	92.5	12.17
Health professionals	85 - 100	89.58	87.5	5.34

Discussion

Principal Results

This paper is the first to describe the co-design process of an AR asthma inhaler educational intervention for children. End-users were engaged in the development from the beginning of the process, which allowed for a user-centred design. Participants had mostly favourable views of the AR intervention, with ease of use of the technology and the novel nature of AR being able to capture the attention of children for inhaler technique education mentioned at all three iterations. Through use of the iterative co-design process, the preferences of end-users were also able to be incorporated with key suggestions such as the addition of animation and increased interactivity with AR included to later iterations. With this process, it was possible to identify areas which required improvement or were perceived to not be necessary (such as the use of the paper-based resource to trigger the AR intervention) and provide information on the preferences of end-users to inform further development of the intervention. The use of an iterative co-design process was particularly important for the development of this AR intervention in children for two main reasons - 1. Due to the novel nature of AR as an educational delivery mechanism in healthcare education, especially for asthma in children, and 2. evidence showing these design processes increases the efficacy and uptake of the intervention by end-users (18).

Through use of the SUS, this intervention was found to have excellent perceived usability, with an overall mean of 87.6. Interestingly, the second round of interviews had a lower mean SUS score compared with the first, (85.83 compared with 86.25) however these scores were still both within the 'excellent' range and it is possible the slightly lower score was a result of a completely new prototype created. The third iteration had the highest mean of 90.14 indicating a truly superior system, providing encouraging evidence that with the iterative co-design process, the intervention can be continued to be improved on throughout subsequent rounds.

Comparison with Prior Work

This paper aimed to describe a user-centred design and the usability of an AR intervention which was delivered via a smartphone/tablet. To date, there have been no studies identified which described a co-design process for asthma educational interventions which utilise AR or the usability of such developed interventions, as in our current study.

Smartphone apps which have poor usability and do not utilise this design process have lower adoption rates, and despite the increasing use of mobile apps for healthcare education, only a small number of papers recently have described a co-design process or usability testing for asthma apps for children and young people (41). With regards to the co-design process, Sonney et al. recently described in 2022 using a 'human-centred design' for refinement of an app which was designed for asthma monitoring and as a behavioural intervention to promote shared asthma management between a parent and child with asthma (18). Whilst end-users (children 7-11 years and their parents) were involved in the process, their involvement from the outset of design was not apparent (42). Mayoral et. al also recently described end-user involvement in the development of a mobile health app for children with asthma however as with Sonney et al, children and adolescents were not involved until the later stages of its development (43). Other studies such as Davis et al. described a participatory approach from the pre-intervention development phase for an asthma self-management smartphone app, however this was targeted at people 15-25 with asthma, who would likely have differing preferences compared to our patient cohort (17). In regards to usability testing for asthma apps for children, Mayoral et. al also employed the SUS for usability testing however Sage et al utilised semi-structured interviews by a research assistant (21, 43). Whilst there is more recent literature on usability testing for asthma apps aimed at adults and adolescents with asthma, usability testing in children remains scarce (44-46).

Limitations

Limitations for this study firstly lie with the limited generalisability for the intervention. Participants were only recruited if they were primarily English-speaking and were recruited from a tertiary paediatric hospital. Children and their caregivers were recruited during a hospital admission, indicating the end-users recruited were predominantly children who may have had more severe, or more poorly controlled asthma and may have had a stronger desire for interventions to improve their asthma education. Similarly, health professionals were also recruited within the tertiary hospital setting, which may have led to the recruitment of health professionals who see and manage asthmatic patients who have poorer control and are on the more severe end of the spectrum. Although we had intended on purposive sampling, we were limited to the demographic of patients presenting to the site. Midst the recruitment phase, it was noted that children who were younger were presenting and recruited. To ensure purposive sampling was completely adhered to, the decision had to be made as to whether to try and increase the sampling size by adding a second site or adjusting the parameters of the age inclusion criteria. Following consultations with experts in clinical care and experts in technological innovation design, it was decided we would have more targeted information if we focused on the younger cohort alone, and it was likely the intervention would have had different requirements and feedback from older children (13-17 inclusive). Another study for the older cohort is planned.

The small sample size of our study also limited the interpretation of SUS however the usability evaluation of this study was for hypothesis generating purposes. More research is required with a larger sample size evaluating its usability in the clinical setting. Another limitation in evaluation of usability was that whilst the SUS can be used as an aid to understanding the overall level of the usability of an intervention, it does not necessarily identify detailed information on the interventions' effectiveness or efficiency which may have been able to provide more information for improvement on subsequent iterations (47).

Not all feedback from interview rounds were able to be incorporated into the subsequent iterations which provides a further limitation to our study. Due to time constraints, we were not able to make adjustments to a paper free version until iteration 3, so during iteration 2 we continued with the paper-based triggering model. There still might be advocation for a paper-based resource however, such as within hospital settings where pamphlets for education are predominantly used, or for people who are reluctant to rely solely on just technology-based resources. The incorporation of gamification was also not achieved during this study due to time and funding constraints however should be strongly considered for smartphone/tablet asthma education app developers to increase engagement and interactivity with children with asthma. It is possible that had we been able to act on all identified feedback themes, SUS scores may have been higher.

Lastly, this study reports on only the design process and the usability, but for successful uptake and implementation of an intervention on a larger scale, other aspects of the intervention must also be evaluated such as the acceptability of its use, the barriers and facilitators to its use, the feasibility of the intervention as well as its efficacy.

Conclusion

Not only is published research on the use of AR for asthma educational interventions in children scarce, the co-design process of asthma educational interventions development in smartphone/tablet apps and their usability is also infrequently reported. This contributes to the literature by identifying and incorporating the preferences of intended end-users. Key recommendations found were inclusion of animation, increased interactivity, and gamification. This paper highlighted the importance of co-design and showed the improvement in usability scores with incorporation of end-user feedback through subsequent iterations of design. Results from this process are now being used to develop the final AR intervention for evaluation in the clinical setting.

Acknowledgements

The authors would like to thank the participants of this study including the children with asthma, their families and the health care professionals who care for these patients.

Conflicts of Interest

Kristin Carson-Chahhoud is co-founder of a start-up company that will include augmented reality technology as one of the functions in a smartphone application to support smoker quit attempts. At time of manuscript submission, personal financial interest has yet to be attained.

Abbreviations

Application: app
AR: augmented reality
HCP: health care professionals
SUS: system usability scale
TDF: Theoretical domains framework

References

1. O'Dea S. Smartphone subscriptions worldwide from 2016 to 2027 2022 [Available from: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/.
2. Ceci L. Google Play: Numner of abailable medical apps as of Q1 2022 2022 [Available from: https://www.statista.com/statistics/779919/health-apps-available-google-play-worldwide/.
3. Ganesh D, Balaji KK, Sokkanarayanan S, Rajan S, Sathiyanarayanan M, editors. Healthcare Apps for Post-COVID Era: Trends, Challenges and Potential Opportunities. 2022 IEEE Delhi Section Conference (DELCON); 2022: IEEE.
4. Timmers TGC, Janssen L, Kool RB, Kremer JAM. Educating Patients by Providing Timely Information Using Smartphone and Tablet Apps: Systematic Review. Journal of medical Internet research. 2020;22(4):e17342-e.
5. Farzandipour M, Nabovati E, Sharif R, Arani MH, Anvari S. Patient Self-Management of Asthma Using Mobile Health Applications: A Systematic Review of the Functionalities and Effects. Applied clinical informatics. 2017;8(4):1068-81.
6. Hui CY, Walton R, McKinstry B, Jackson T, Parker R, Pinnock H. The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. Journal of the American Medical Informatics Association : JAMIA. 2017;24(3):619-32.
7. Control CfD. Uncontrolled asthma among children, 2012–2014 [Internet]. Centers for Disease Control; 2019 Jul [cited 2019 Oct 2].
8. Enilari O, Sinha S. The Global Impact of Asthma in Adult Populations. Annals of global health. 2019;85(1).
9. Huckvale K, Morrison C, Ouyang J, Ghaghda A, Car J. The evolution of mobile apps for asthma: an updated systematic assessment of content and tools. BMC medicine. 2015;13(1):58-.
10. Burns T, Gottschalk F. Educating 21st century children : emotional well-being in the digital age. Paris: OECD Publishing; 2019.
11. Porche MV, Folk JB, Tolou-Shams M, Fortuna LR. Researchers' Perspectives on Digital Mental Health Intervention Co-Design With Marginalized Community Stakeholder Youth and Families. Frontiers in psychiatry. 2022;13:867460-.
12. Bevan Jones R, Stallard P, Agha SS, Rice S, Werner-Seidler A, Stasiak K, et al. Practitioner review: Co-design of digital mental health technologies with children and young people. Journal of child psychology and psychiatry. 2020;61(8):928-40.
13. Thabrew H, Fleming T, Hetrick S, Merry S. Co-design of eHealth Interventions With Children and Young People. Frontiers in Psychiatry. 2018;9.
14. Martin A, Caon M, Adorni F, Andreoni G, Ascolese A, Atkinson S, et al. A Mobile Phone Intervention to Improve Obesity-Related Health Behaviors of Adolescents Across Europe: Iterative Co-Design and Feasibility Study. JMIR mHealth and uHealth. 2020;8(3):e14118-e.
15. Whale K, Beasant L, Wright AJ, Yardley L, Wallace LM, Moody L, et al. A Smartphone App for Supporting the Self-management of Daytime Urinary Incontinence in

Adolescents: Development and Formative Evaluation Study of URApp. JMIR Pediatr Parent. 2021;4(4):e26212.
16. Li SH, Achilles MR, Spanos S, Habak S, Werner-Seidler A, O'Dea B. A cognitive behavioural therapy smartphone app for adolescent depression and anxiety: co-design of ClearlyMe. The Cognitive Behaviour Therapist. 2022;15:e13.
17. 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):1018-27.
18. Sonney J, Cho EE, Zheng Q, Kientz JA. Refinement of a Parent-Child Shared Asthma Management Mobile Health App: Human-Centered Design Study. JMIR pediatrics and parenting. 2022;5(1):e34117-e.
19. 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-e.
20. Kim S, Park Y, Ackerman MK. Designing an Indoor Air Quality Monitoring App for Asthma Management in Children: User-Centered Design Approach. JMIR formative research. 2021;5(9):e27447.
21. Schneider T, Panzera AD, Couluris M, Lindenberger J, McDermott R, Bryant CA. Engaging Teens with Asthma in Designing a Patient-Centered Mobile App to Aid Disease Self-Management. Telemedicine journal and e-health. 2016;22(2):170-5.
22. Alain A, Adel K, Witold S, Ahmed S. Usability Meanings and Interpretations in ISO Standards. Software quality journal. 2003;11(4):325.
23. Mayes JT, Fowler CJ. Learning technology and usability: a framework for understanding courseware. Interacting with computers. 1999;11(5):485-97.
24. Maramba I, Chatterjee A, Newman C. Methods of usability testing in the development of eHealth applications: A scoping review. International Journal of Medical Informatics. 2019;126:95-104.
25. Bloom BM, Pott J, Thomas S, Gaunt DR, Hughes TC. Usability of electronic health record systems in UK EDs. Emergency Medicine Journal. 2021;38(6):410.
26. Melnick ER, Dyrbye LN, Sinsky CA, Trockel M, West CP, Nedelec L, et al. The Association Between Perceived Electronic Health Record Usability and Professional Burnout Among US Physicians. Mayo Clinic Proceedings. 2020;95(3):476-87.
27. Melnick ER, Harry E, Sinsky CA, Dyrbye LN, Wang H, Trockel MT, et al. Perceived Electronic Health Record Usability as a Predictor of Task Load and Burnout Among US Physicians: Mediation Analysis. J Med Internet Res. 2020;22(12):e23382.
28. Ratwani RM, Savage E, Will A, Fong A, Karavite D, Muthu N, et al. Identifying electronic health record usability and safety challenges in pediatric settings. Health affairs. 2018;37(11):1752-9.
29. Litt HK, Press VG, Hull A, Siros M, Luna V, Volerman A. Association between inhaler technique and confidence among hospitalized children with asthma. Respiratory medicine. 2020;174:106191-.
30. Samady W, Rodriguez VA, Gupta R, Palac H, Karamanis M, Press VG. Critical Errors in Inhaler Technique among Children Hospitalized with Asthma. Journal of Hospital Medicine. 2019;14(6):361-5.
31. Alwashmi MF, Hawboldt J, Davis E, Fetters MD. The Iterative Convergent Design for Mobile Health Usability Testing: Mixed Methods Approach. JMIR mHealth and uHealth. 2019;7(4):e11656-e.
32. Susan Alexander KF, Haley Hoy. Applied Clinical Informatics for Nurses: Jones & Bartlett Learning, LLC; 2019 2019.

33. Faulkner L. Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. Behavior Research Methods, Instruments, & Computers. 2003;35(3):379-83.
34. Lewis JR. The System Usability Scale: Past, Present, and Future. International Journal of Human–Computer Interaction. 2018;34(7):577-90.
35. Brooke J. Sus: a "quick and dirty'usability. Usability evaluation in industry. 1996;189(3).
36. Liang J, Xian D, Liu X, Fu J, Zhang X, Tang B, et al. Usability Study of Mainstream Wearable Fitness Devices: Feature Analysis and System Usability Scale Evaluation. JMIR mHealth and uHealth. 2018;6(11):e11066-e.
37. Bangor A, Kortum PT, Miller JT. An Empirical Evaluation of the System Usability Scale. International Journal of Human–Computer Interaction. 2008;24(6):574-94.
38. Grammarly. Grammarly Inc.; 2022.
39. Australia LF. Inhaler Technique 2022 [Available from: https://lungfoundation.com.au/resources/?condition=9&user_category=31&resource_type=236&search=inhaler.
40. Bangor A, Kortum P, Miller J. Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies. 2009;4(3):114-23.
41. Rochat J, Ehrler F, Siebert JN, Ricci A, Garretas Ruiz V, Lovis C. Usability Testing of a Patient-Centered Mobile Health App for Supporting and Guiding the Pediatric Emergency Department Patient Journey: Mixed Methods Study. JMIR Pediatr Parent. 2022;5(1):e25540.
42. Sonney J, Duffy M, Hoogerheyde LX, Langhauser E, Teska D. Applying Human-Centered Design to the Development of an Asthma Essentials Kit for School-Aged Children and Their Parents. Journal of pediatric health care. 2019;33(2):169-77.
43. Mayoral K, Garin O, Caballero-Rabasco MA, Praena-Crespo M, Bercedo A, Hernandez G, et al. Smartphone App for monitoring Asthma in children and adolescents. Quality of life research. 2021;30(11):3127-44.
44. Farzandipour M, Nabovati E, Arani MH, Akbari H, Sharif R, Anvari S. Enhancing asthma patients' self-management through smartphone-based application: design, usability evaluation, and educational intervention. Appl Clin Inform. 2019;10(05):870-8.
45. Ferreira A, Almeida R, Jácome C, Fernandes J, Fonseca J, Vieira-Marques P, editors. How inspiring is your app: a usability take on an app for asthma medication adherence. IADIS International Conference e-Health; 2019.
46. Murphy J, McSharry J, Hynes L, Molloy GJ. A Smartphone App to Support Adherence to Inhaled Corticosteroids in Young Adults With Asthma: Multi-Methods Feasibility Study. JMIR formative research. 2021;5(9):e28784.
47. Hägglund M, Scandurra I. User Evaluation of the Swedish Patient Accessible Electronic Health Record: System Usability Scale. JMIR Human Factors. 2021;8(3):e24927-e.

Chapter 9.

The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study

---

Antonia O'Connor[1,2], Andrew Tai[1,2,3], Malcolm Brinn[4,5], Amy Hoang[6], Daniele Cataldi[6], Kristin V Carson-Chahhoud[2,4,5]

[1]Respiratory and Sleep Department, Women's and Children's Hospital, [2] School of Medicine, University of Adelaide, Adelaide, South Australia, [3]Robinson Research Institute, The University of Adelaide, [4]Translational Medicine and Technology Research Group, University of South Australia, [5]Australian Centre for Precision Health, South Australian Health and Medical Research Institute, [6]Paediatric Medicine Division, Women's and Children's Hospital, South Australia

Submitted to JMIR Pediatrics and Parenting 2022

Statement of authorship for jointly authored papers within the thesis

Statement of authorship

The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study

---

Publication status: Submitted for publication

Publication details: O'Connor A, Tai A, Brinn, M, Hoang, A, Cataldi, D, Carson-Chahhoud K. The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study. Journal of Medical Internet Research - Pediatrics and Parenting

Principal Author:

Name of principal author (candidate)	Antonia O'Connor		
Contribution to the paper	Gap in knowledge identified and conceived the study to answer clinical question. Planned and designed the method of study to address gap, obtained ethics approval (including governance and SSA), designed semi-structured interviews, participant recruitment and consent, led qualitative interviews, uploaded transcripts into transcription software with corrections of auto-transcripts in accordance with the protocol, collected and analysed data in accordance with pre-specified methodology, synthesis and interpretation of data, wrote manuscript and developed structure and arguments, revisions of manuscript and approved final version. Prepared manuscript in format for journal and submitted for publication. Acted as corresponding author.		
Overall percentage (%)	70%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations of contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/6/22

Co-Author contributions:

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the candidate's thesis
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of co-author	Andrew Tai		
Contribution to the paper	Contributed to design of study and methodology to answer clinical question, contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Malcolm Brinn		
Contribution to the paper	Development of intervention and delivery of the products used in this research, contributed to writing the manuscript, agree with manuscript results and conclusions, made revisions, approved final version and supervised the process.		
Signature		Date	21/06/2022

Name of co-author	Amy Hoang		
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.		
Signature		Date	21/06/2022

Name of co-author	Daniele Cataldi		
Contribution to the paper	Assisted with data collection and analysis. Agree with manuscript results and conclusions, approved final version.		
Signature		Date	23/06/2022

Name of co-author	Kristin Carson-Chahhoud		
Contribution to the paper	Identified gap in knowledge and contributed to design of study and methodology to answer clinical question whilst acting in supervisory role for principal author. Contributed to writing the manuscript, agree with manuscript results and conclusions, jointly developed the arguments and structure for the paper, made critical revisions, approved final version and supervised the process (primary supervisor)		
Signature		Date	21/06/2022

As discussed in Chapter 7, there is a need for qualitative investigation during design of health interventions which have a minimal evidence base to guide development. Whilst results from Chapter 8 identified perceived excellent usability of the developed augmented reality enhanced educational resource for asthma inhaler technique, other aspects such as the acceptability by users also requires evaluation to ensure successful implementation on a larger scale.

Acceptability has been defined as 'a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experienced cognitive and emotional responses to the intervention' (107). It is a necessary component of healthcare interventions and should be considered in their design and evaluation. When deemed acceptable by intervention recipients (e.g. patients), there is a higher likelihood for treatment adherence. When deemed acceptable by those delivering the intervention (e.g. healthcare professionals), the intervention is more likely to be delivered in the manner it was intended to, which can have an impact on the effectiveness of the intervention (107). The TFA is a framework designed to assess the acceptability of healthcare interventions to aid identification of any characteristics of the intervention that may be improved (108). It encompasses seven component constructs which represents acceptability – affective attitude, burden, perceived effectiveness, intervention coherence, opportunity cost and self-efficacy (107).

The importance of evaluating acceptability for the developed augmented reality-enhanced asthma inhaler educational intervention was identified for this study as acceptability not only influences the implementation, but also plays a significant role in the uptake, adherence, intended outcomes and overall effectiveness of developed interventions.

The target sample size of sixteen participants was achieved for this study and participated in semi-structured one-on-one interviews with questions which were based on the TFA. Overall, the intervention was identified to be acceptable to healthcare professionals, children with asthma and their caregivers. The most coded constructs of the TFA within the interviews were 'perceived effectiveness' and 'affective attitude' with the ease of use, accessibility, and interesting concept frequent positive responses. Concerns were raised from healthcare professionals regarding the loss of face-to-face interaction between themselves and families. Technical difficulties of the intervention were identified as a burden to caregivers. Results from this study were used to inform the final prototype of the intervention for incorporation into a comprehensive asthma technology-based resource and future studies to assess clinical effectiveness.

The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative study

O'Connor A[1,2], Tai A[1,2,3], Brinn M[4,5], Hoang A[6], Cataldi D[6], Carson-Chahhoud KV[2,4,5]

[1]*Respiratory and Sleep Department, Women's and Children's Hospital, South Australia, Australia*

[2]*School of Medicine, The University of Adelaide, South Australia, Australia*

[3]*Robinson Research Institute, The University of Adelaide, South Australia, Australia*

[4]*Translational Medicine and Technology Research Group, University of South Australia, South Australia, Australia*

[5]*Australian Centre for Precision Health, South Australian Health and Medical Research Institute, South Australia, Australia*

[6]*Paediatric Medicine, Women's and Children's Hospital, South Australia, Australia*

Corresponding author: Dr. A O'Connor
Email: antonia.chan@sa.gov.au
Phone: (08) 8161 7234

WORD COUNT: 4349

ABSTRACT

Background

Inhaled medications, or inhalers, provide first line pharmacotherapeutic treatment for people with asthma for both acute symptomatic relief, as well as long term management to keep symptoms under control. Good inhaler technique requires only basic instruction and training, yet a recent study identified that 92% of children do not follow all correct steps when using inhalers. There is growing interest in technology-enhanced asthma education with evidence demonstrating improvements to knowledge and treatment adherence. Subsequently, calls to explore the role of technology-based solutions to improve asthma management and disease outcomes are coming from public health experts, health professionals and asthma patients. Augmented reality (AR) technology is one such information delivery mechanism with proven efficacy in educational settings outside of health. Using the camera on a smartphone/tablet device, AR displays digital content onto real-world environment, to create an immersive learning experience.

Objective

To evaluate acceptability of AR as a mechanism to deliver asthma inhaler technique education, from the perspective of children with asthma, their parents and health professionals, examined through the Theoretical Framework of Acceptability (TFA).

Methods

An asthma education resource enhanced with AR technology was created to deliver inhaler technique education for children. An iterative co-design process was undertaken with target end-users for qualitative evaluation in this study. Participants were 8-12 years old with asthma, their caregivers, and health professionals who had experience in managing asthma. Qualitative data was obtained through semi-structured one-on-one interviews. Deductive thematic analysis using the TFA was undertaken using NVivo software 2020 to assess the acceptability of AR as a delivery modality for asthma inhaler technique education.

Results

In a sample of n=16, the use of AR in the created asthma inhaler resource was found to be overall acceptable when responses were examined in accordance with the TFA.
Each of the seven component constructs of the TFA were coded throughout the 16 interviews, with ‘perceived effectiveness’ and ‘affective attitude’ coded most frequently (157 and 63 times respectively). Positive responses included the intervention being accessible, easy to use, interesting and fitting within users’ value systems. Negative responses included the need to maintain interest in children and concerns of the loss of face-to-face interaction with health professionals.

Conclusions

AR appears to be an acceptable modality for delivering asthma education to children when explored using the constructs of the TFA. Whilst some challenges were identified with the use of AR, results were predominantly positive. Future designs of asthma educational interventions involving AR should consider results from this study and further research

should focus on the feasibility, usability and barriers and facilitators of behaviour change to ensure successful implementation and uptake of AR into clinical settings.

Trial Registration: ACTRN12621000306819

Keywords: asthma; asthma education; paediatric asthma; augmented reality

INTRODUCTION

There are currently over 260 million cases of asthma worldwide, with the incidence and prevalence higher in children compared to adults (1, 2). Those who are susceptible can have symptoms of wheezing, coughing and breathlessness (3, 4). If symptoms are poorly controlled in young people, this can lead to long term effects, with the potential for pathological airway remodelling, impaired airway development, and possible reductions in maximal attainable lung function compared to those without asthma (2, 5, 6). To minimise long term airway damage, the use of inhaled medications (i.e. inhalers) are first line management of both acute symptomatic relief, as well as longer term asthma control in both children and adults (7, 8). Current guidelines state inhaler technique education must be provided with satisfactory technique demonstrated prior to the prescription of inhalers with the efficacy of education and training in improving technique supported by a Cochrane systematic review (7, 9).

Despite this, in recent studies where asthma inhaler technique has been assessed in children, 42% of hospitalised patients have missed a critical step, and 92% of children aged 8-16 years are not properly following all correct steps when using their inhaler (10-12). A recent nation-wide survey of over 20,000 young Australians, identified that there was a ten times greater likelihood of seeking online support over health professional advice to manage their stress, indicating their penchant towards technology-based solutions (13). This preference for technology, combined with the growing body of evidence suggesting that technology delivered interventions and asthma education programs can improve knowledge, treatment adherence and health outcomes in children with asthma, highlights the support for using technology-based solutions for inhaler technique education in children to aim to improve engagement and uptake, as well as health outcomes (14-16). The use of mobile technology-based solutions such as smartphone and tablet devices to deliver asthma education and self-management has also already been explored in adults, with systematic reviews identifying improved quality of life and asthma control compared with routine care (17, 18).

One relatively new digital solution is augmented reality (AR) defined as ‘technology which is able to superimpose virtual objects into a real-world setting so that the virtual objects seem to co-exist in the same space in real time’ and is one of the top novel technological innovations in the medical and healthcare industry currently (19, 20). It can be delivered via a smartphone or tablet. It has the benefits of already having proven efficacy in other educational settings and as a behavioural change tool and would allow asthma inhaler technique education to be delivered via a smartphone or tablet through videos and animations (21-26). Given greater than 80% of children aged 5-17 own at least one screen-based device within Australia, this suggests a generation appropriate and accessible delivery modality for asthma inhaler technique education (27). Aside from one study showing improved asthma inhaler technique, limited by evaluation among a non-asthmatic paediatric cohort, AR has not yet been explored in asthma education for children (28). Research on the acceptability and awareness of this technology is paramount to informing future asthma educational interventions and their successful uptake. To address these gaps,

the aim of this study was to evaluate the acceptability of AR as a mechanism to deliver asthma inhaler technique education.

METHODS

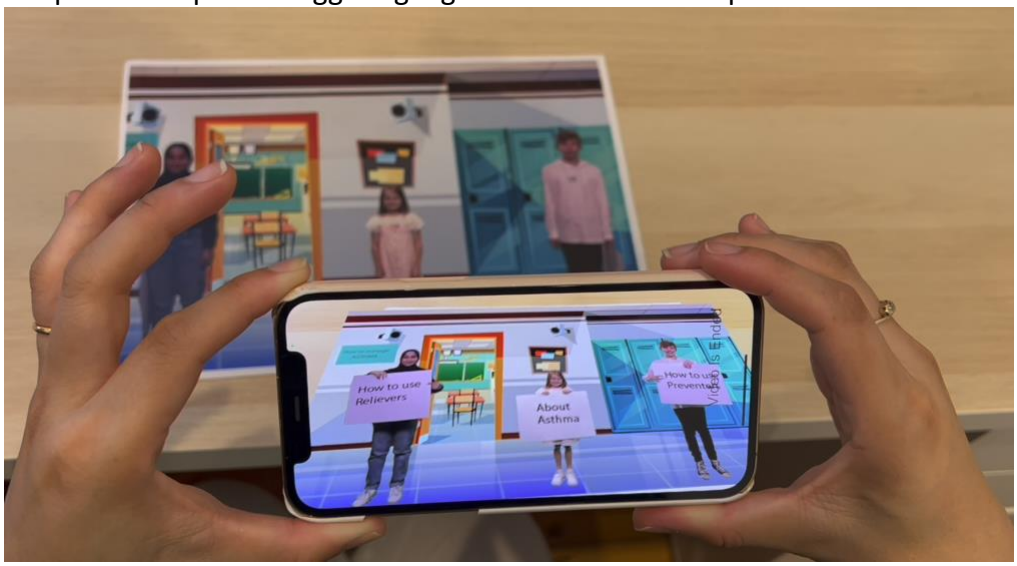
An asthma inhaler technique education resource enhanced by AR technology delivered by a smartphone was co-designed for children with asthma, their caregivers and health care professionals (HCPs) who treat asthma. Qualitative interviews based on the Theoretical Framework of Acceptability (TFA) evaluated the acceptability of AR as a delivery mechanism. A prespecified protocol was published in the Australian New Zealand Clinical Trials Registry (Trial ID: ACTRN12621000306819).

Ethics and governance approval was obtained by the Women's and Children's Hospital Human Research Ethics Committee on the 21st of August 2020 (HREC/20/WCHN/74) and acceptance of approval was obtained by the University of Adelaide on the 20th of October 2021. Informed consent was obtained by all participants prior to interviews being taken.

AR intervention development process

An iterative co-design process with target end-users was undertaken to guide a deeper understanding of their requirements for technology use and enable improvements in the prototype asthma inhaler technique resource (29, 30). The first cohort of participants interacted with an existing cystic fibrosis enhanced AR educational resource to give an example of how AR works. Their feedback was used to create an asthma specific AR-enhanced poster to provide education on inhaler technique. This poster was used to trigger the digital educational content through the smartphone/tablet application (app) (See image 1.) This resource was presented to the next cohort of participants who provided their feedback which was again used to enhance the intervention before being presented to the final cohort for feedback. Co-design processes optimise the uptake of digital interventions in children; therefore, this process was utilised for the intervention development, with this being discussed in more detail in a future paper (31-33).

Figure 1. Paper-based poster triggering digital content on smartphone



Participants and recruitment

Participants included HCPs who manage asthma, children with asthma and caregivers of children with asthma.

Inclusion criteria for HCPs included having worked in their profession (nursing, paediatric general medicine medical officers, general practitioners, respiratory specialists, pharmacists, asthma educators) and having treated patients with asthma regularly for greater than 12 months in the previous five years. Inclusion criteria in the prespecified protocol for children and adolescents with asthma were having a clinical diagnosis of asthma and aged between 8-17 years. Parents and guardians of children with asthma were included if their child had a clinical diagnosis of asthma and were aged 8-17 years. Any participant who was unable to give consent or were non-English speaking were excluded.

Recruitment was within a South Australian paediatric tertiary hospital, conducted by the primary investigator of the study who approached potential participants for screening. They were invited to participate in the study if they met inclusion criteria and provided informed consent.

Participants were recruited from July 2021 until April 2022. Purposive sampling was intended, however midst recruitment it became evident that this approach was unable to be strictly adhered to for representation across the age spectrum. This was due to a combination of the demographic of children being hospitalised for acute asthma treatment as well as minimisation of face-to-face appointments or allowance of patients to attend hospital unless deemed medically necessary during the SARS-CoV-2 pandemic. This greatly diminished the available sample pool of older children. Inclusion criteria was changed half-way through recruitment to children 8-12 years of age.

A target sample size of 15-20 participants was determined to achieve a large enough size to ensure enough breadth and depth of data, but small enough to be able to achieve analysis that was meaningful, which was a similar approach to other qualitative studies (34).

Interviews and data collection

Qualitative data was obtained through one-on-one interviews, conducted by a trained interviewer. Semi-structured moderator guides were used and based on the TFA to aid in specifically assessing acceptability within each group of participants. The beginning of the interview explored previous experiences of asthma education, the use of smartphone and tablet apps for health, and AR. Once prior awareness and experience was assessed, the interviewer demonstrated the AR intervention to the participant and allowed participants to use the intervention themselves. Further interview questions were then asked based on the participants' experience having used it.

Interviews took approximately 20 – 40 minutes per participant and were audio-recorded. All interviews were de-identified and transcribed by an automated transcription service. Interviews were check-backed and corrected by the primary investigator to ensure they

were verbatim. Transcripts were able to be sent back to the participant for validation of content if required.

Statistical analysis

Using the TFA as a coding framework, deductive thematic analysis was undertaken using NVivo software (35). Two researchers (AO and either AH or DC) jointly coded the data into NVivo to improve inter-rater reliability, with any disagreements resolved with discussion.

The TFA is an accepted framework in assessing acceptability of healthcare interventions, with acceptability defined as 'a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experienced cognitive emotional responses to the intervention' (36). The seven component constructs of which it consists of informed the coding scheme. The seven constructs and their definitions are: affective attitude – the individuals feelings of the intervention, burden – the amount of effort required to participate in the intervention, perceived effectiveness – the extent to which the intervention is perceived as likely to achieve its purpose, ethicality – the extent to which the intervention has a good fit with an individual's value system, intervention coherence – the extent to which the participant understands the intervention and how it works, opportunity costs – the extent to which benefits, profits or values must be given up to engage in the intervention, and self-efficacy – the participant's confidence that they can perform the behaviour required to participate in the intervention (36). Affective attitude, burden, perceived effectiveness, and opportunity cost were also coded as 'anticipated' or 'experienced' based on whether interview questions had been asked prior to use of the intervention, or post.

RESULTS

Participant characteristics

Of the 16 potential participants approached, all were recruited and analysed. There was a total of six HCPs, five asthmatic children and their five caregivers (see Table 1a and 1b).

Table 1a. HCP baseline demographics

HCP (Participant ID)	Age (years)	Gender	Occupation	Duration treating asthma (years)
HP001	20 - 30	F	Respiratory Doctor	6 - 10
HP002	41 - 50	F	Nursing	16 - 20
HP003	31 - 40	F	Nursing	11 - 15
HP004	31 - 40	F	Nursing	11 - 15
HP005	31 – 40	M	General Paediatrics Doctor	6 - 10
HP006	31 - 40	M	Respiratory Doctor	0 - 5

Table 1b. Asthmatic children and their caregivers baseline demographics

Asthmatics and their caregivers (Participant ID)	Age (years) AC[a]	CG[b]	Gender AC	CG	Metropolitan vs. rural/remote	Duration of asthma diagnosis (years)	Highest level of education of CG
AC001 + CG001	8-12	41 - 50	F	F	Metropolitan	Unknown	Not disclosed
AC002 + CG002	8-12	41 - 50	F	F	Rural/remote	>5	Year 12
AC003 + CG003	8-12	41 - 50	M	F	Metropolitan	>5	Tertiary education
AC004 + CG004	8-12	31 - 40	M	F	Metropolitan	0 - 2	Tertiary education
AC005 + CG005	8-12	31 - 40	M	F	Metropolitan	0 - 2	< Year 12

[a]Asthmatic children
[b]Caregivers of children with asthma

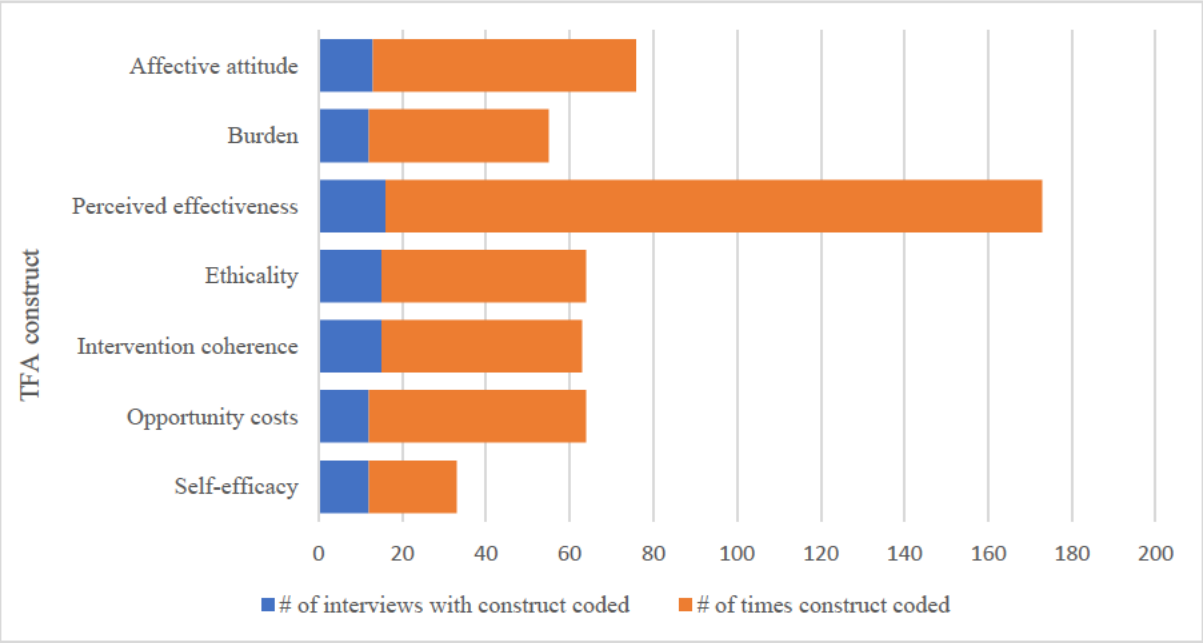
HCPs were split equally amongst medical officers and nursing staff who had treated patients with asthma for at least 12 months in the previous five years. Two of the participants also had a previous asthma educator role (HP002and HP003) whilst another had a paediatric medicine educator role within the ward they were working in (HP004). 66% of HCPs were female whilst the remaining were male. All HCPs reported treating asthma across multiple settings including within the community, inpatient care, outpatient care and within the emergency department.

Asthmatics and their caregivers mostly lived within a metropolitan setting. All asthmatic patients had been diagnosed from either a respiratory specialist or a general paediatrician. 60% of asthmatic patients were male whilst 40% were female. All caregivers were female with a range of educational levels.

Coding Results

All seven component constructs of the TFA were coded throughout the 16 transcripts. The most frequently coded construct was ‘perceived effectiveness’ which was coded over double the number of occasions as the second most coded construct of ‘affective attitude’ which was coded 63 times. The remaining constructs were coded between 21 and 52 times each (see Figure 2).

Figure 2. Coding frequency



Our findings are reported through a narrative synthesis with representative quotes for the seven constructs of the TFA incorporated. Table 2 expands on further illustrative quotes for each construct.

Perceived effectiveness

Overall, perceived effectiveness from participants was positive and was coded in all interviews.

All 16 participants indicated prior to the use of the intervention that asthma education delivered via smartphone/tablet apps and/or using AR as a delivery mechanism would be a useful modality for asthma inhaler technique education (i.e. anticipated effectiveness). When asked why this might be the case, asthmatic patients elaborated that they - '*understand more with technology*' (AC004), and both caregivers and HCPs described the possibility of improving accessibility to education through use of a smartphone or tablet - '*It's right there, you can just go have a look if it's got information on it*' (CG002); '*it's something that it's all part of our life, day-to-day*' (HP003). HCPs also described the possibility of it being a more engaging modality compared to paper-based resources - '*kids are obsessed with devices for starters, not always for a good reason, but I feel like they would, um, they would enjoy accessing this information because it is on a device, and they seem to be very device focused. Um, so it might actually capture their attention and then hopefully that would make it sink in*' (HP002).

After using the AR intervention, all 16 participants reported that AR delivered via a smartphone/tablet would be a useful modality for asthma education (i.e. experienced effectiveness). As postulated, use of a smartphone/tablet device was described as being accessible - '*something like this seems it could be much more easily incorporated into sort of home-based education*' (HP001) and AR thought to add a novelty factor for children to aid in

engagement - '*I think it'll definitely add a component of something different and new to get them involved rather than just watching a video on a screen'* (HP006); '*It was, it was new. It was good'* (CG001).

Affective attitude

Affective attitude involved participants' feelings about the use of the AR intervention. Experienced affective attitude was coded more frequently than anticipated affective attitude (55 and eight times respectively) which would likely reflect unknown feelings towards an intervention prior to experiencing it. Affective attitude was predominantly positive for both anticipated and experienced affective attitude, with participants describing AR as '*cool'* (AC004, HP003), '*fun'* (AC004) and a *'great'* concept (HP004). The ability to immerse participants within the educational resource was also described - *'I think it's like, it feels more, I know that information is probably, the information that's being delivered is the same, but you feel, feel like you're being interacted with, rather than just...there's the info.'* (HP004)

One child with asthma however did describe having negative feelings of having too much knowledge with the use of the intervention - *'..I could start worrying about my asthma. Get more worried'* (AC002) and some participants had concerns over the intervention being boring - *'I think they are okay. But some people might not. Just sit there and go 'Oh this is boring, I don't want to listen to this''* (AC002); *'I thought it was very clever. Just potentially, just boring for little ones'* (HP002).

Intervention coherence

Intervention coherence was the extent to which participants understood the intervention and how it worked. Prior to the use of the intervention, many of the participants did not know what AR was, however after experiencing the AR intervention, despite describing AR as different to what they expected - *'different to how I envisioned'* (HP003); *'I didn't think people would be talking to me. I actually thought it was going to be more reading'* (CG003), most understood the intended purpose of using AR and smartphone/tablet technology to improve asthma inhaler technique and increase engagement and accessibility for asthma education - *'so then I could read up from the information and, you know, explain it to her and explain it to others' (HP001); 'I like the fact that it's just a piece of paper, um, and they can use their own smartphone… this is so simple, like it's just a piece of paper and your own smartphone, and I'm assuming it works with like Android or apple or whatever. So it's really, it's very accessible.'* (HP002).

Ethicality

Ethicality described the extent to which AR and the use of smartphone/tablet technology would be a good fit within the value system of participants. It was coded in 15 transcripts and was predominantly coded when participants were questioned about their personal views on the use of this technology for asthma education. All HCPs reported they would use a similar intervention with AR technology if existing - *'it would certainly be something that I would involve in my day to day practice if that was available to, um, show to patients, some*

parents' (HP006); *'I would, I would love to have something like this to be able to use, especially in a time pressured world. So yeah. Yeah. I'd be very happy for this to be mainstream'* (HP005). All caregivers of children with asthma, and four out of five children with asthma also reported they would use the intervention if it were available to them.

Self-efficacy

Self-efficacy was described predominantly when participants were discussing ease of use of the AR intervention and access to smartphones/tablets and was coded in 12 transcripts. 100% of asthmatic children had access to a smartphone or tablet (either their own individual device or one within the household) and most participants were confident in their own ability to use the intervention with the description of it being *'easy'* to use (AC001, AC003, AC004, AC005, CG001, CG002, CG003, CG005, HP003, HP006). All coding related to self-efficacy was positive, with no concerns raised of the difficulty or inability to use AR via a smartphone/tablet app for asthma inhaler technique education.

Burden

Despite the ease of use of the intervention reported by many participants as above in the self-efficacy construct, there was still burden of use of the AR educational intervention described. Burden is the perceived amount of effort required to participate in the use of the intervention.

Burden which was described by participants, included the inability to hold the attention of children through the educational videos alone – '*It'd be good if it was more interactive'* AC002; '*I do wonder if like, especially for littler kids, if it wouldn't be exciting enough or interesting enough'* (HP002) and technical aspects of the initial iterations of the intervention - *'it looked like there was a little bit of lag sometimes'* (HP001); *'I guess just working out those little things, like going back to the menu or like, how do you get back to that home page?'* (HP003).

The requirement of the paper-based poster required to trigger the digital educational content by holding the phone over it was also described as a burden – *'It would be, it would be good if once it started playing it, you didn't have to hold it there.'* (HP004); '*if you need the paper to use the app and if patients lose the paper, then it… has some issues'* (HP001).

Opportunity cost

Opportunity cost, defined as the extent to which benefits, profits or values must be given up to engage in the intervention was coded in 12 interviews. Opportunity costs were not necessarily explicitly stated but concerns regarding parents requiring to give up their values surrounding screen time if engaging in the intervention were voiced by some HCP participants - *'sometimes… parents are concerned regarding screen time'* and '*some parents may also not like their children using a smartphone, so that might be restrictive to certain patients'* (HP001); '*I think, I think there's, um, I think there's negatives to screens. Um, when it's unsupervised prolonged use that becomes an addiction*' (HP003). Interestingly this was not reported by any of the caregivers.

The concern that the use of the intervention would mean the loss of the face-to-face interaction between families and their HCPs was also expressed – '*You haven't got someone there to answer your questions…and I guess the difference with education being provided here before you go home, 'have you got any questions?' We can answer them.'* (HP003), as was the concern that for the intervention, access to a smartphone/tablet was necessary and so asthmatic sufferers in lower socioeconomic status may be missed - '*some patients and their families may not have access to a smartphone, so that provides limitations in terms of a socioeconomic point of view'* (HP001); '*downsides I guess, is, um, you obviously have to have access to the internet and things like that. So I suppose some disadvantaged people might not have a smartphone or wifi, et cetera.'* (HP006).

Table 2. TFA construct illustrative quotes from interviews

TFA construct	Illustrative quotes
Perceived effectiveness	*'Education in a different form, sort of like an interactive education or a, um, video setting, which might make it more engaging for the patient as well.'* HP001 *'I think it'll definitely add a component of something different and new to get them involved rather than just watching a video on a screen.'* HP006 '*It was very informative.'* PA004
Affective attitude	*'Like if a kid's looking at a piece of paper and then you put your smartphone over it and it comes to life, that's pretty awesome.'* HP002 '*Pretty good, actually interesting. Cause, um, it would take a lot of coding and stuff to actually work on it.'* CH002 *'I used to think it…health apps are like boring and that stuff but virtual [augmented] reality is cool.'* CH004 *'Um, I think it's, it's, uh, it's a fantastic idea, uh, to present the information, um, in that format. Um, I think, I think the, uh, use of augmented reality is a novelty that kids would really connect with.'* HP005
Intervention coherence	*'Um, it was just different to how I envisioned. Um, cool that you can hover over the, the images and then it triggers where you want to learn more from.'* HP003
Ethicality	'*Obviously I would certainly be happy to show people how to access it and, um, you know, just show them that it is something*

	fun and exciting to at least get them excited to then take home and, and be involved with at home.' HP006 *'It would be really good if it goes ahead and it's become something that we can use..'* HP002
Self-efficacy	*'Pretty easy to use.'* CH001 *'Easy to do, Just click.'* PA003 *'Easy to use.'* CH003 *'I think it was easy yeh.'* HP006 *'Um, definitely good that it's not hard to use. You kind of just go into the portal and then the videos come up, I kind of like that you have to move the phone. Um, and yeah. Seems to be pretty easy to use.'* PA005
Burden	*'Um, I do wonder if like, especially for littler kids, if it wouldn't be exciting enough or interesting enough, like as an adult and probably as a teenager as well, that would be fine, but for the little ones it could potentially be boring.'* HP001 '*Also when it does slip back to the menu, not making them sit through it again cause they'll be like, if we want them to watch all of them. Then they'll be like 'oh we've seen this bit'. And then they'll just lose focus.'* HP004 *'I do wonder because um, you have, you have to hold the, uh, the, the phone or tablet up to review the video if, um, um, you know, if, if a kid's not able to do it for that long, that might affect your, uh, ability to educate.'* HP005
Opportunity cost	*'Being able to actually have a hands-on with the puffer and spacer or, your airways or something like that.'* HP003 '*You haven't got someone there to answer your questions. So if like we, we are thinking of things and, and the feedback is there and whatever, and the parent, everyone's individual and everyone's got different backgrounds and different levels of understanding. And I guess the difference with education being provided here before you go home, 'have you got any questions?' We can answer them.'* HP004 *'I guess that's the only negative, is it's not real life. Like it's not, it is augmented reality, not reality. And so, and there are times when you get to the end of asthma education and you go, 'you got any*

	questions?' And they say no, and I go, 'so can you talk to me at what point you would come back to hospital?'. I guess you can check their knowledge rather than just assumed.' HP004 *'Um, it's I guess if we, if we are using this tool, it really, it relies on, um, the family having a device that you can use. Uh, which is probably okay here in Adelaide, but I know that other places I've worked, um, yeah, lots of families don't have smartphones or tablets, so yeah. I guess your uptake is limited by that.'* HP005

DISCUSSION

Principal Findings

This qualitative study evaluated the acceptability of AR as a delivery mechanism for asthma inhaler technique education through a robust framework of acceptability which has been used in the evaluation of other healthcare interventions.

Overall, participants reported positively on the use of AR as a delivery mechanism for asthma inhaler technique and found it to be an acceptable intervention. This is in line with other studies which have examined the acceptability of the use of digital technologies for children and adolescents with asthma who have also had generally positive findings in regards to patient acceptability of interventions (37-39).

The TFA construct of perceived effectiveness was the most coded and was reported on by all participants. Participants found AR to be new and interesting for children which would allow for increased engagement in inhaler technique education, as well as the use of smartphone and tablets as an accessible modality for much of the asthmatic community. In recent years, challenges from the SARS-CoV-2 pandemic highlight the need for alternative healthcare education delivery mechanisms. Therefore, the ability for this intervention to be delivered in the home or other non-clinical settings is advantageous.

Ease of use of a digital health intervention is also important in regards to acceptability, with a recent pilot study by Davis et. al also discussing the importance placed by participants in the ease of use of a co-designed goal-setting asthma app for young people with asthma (32). The ease of AR use was highlighted in the TFA construct of self-efficacy in which participants reported the simplicity of the intervention and the ability to confidently use AR technology independently via a smartphone device. Other forms of modern technologies, for example virtual reality, require additional equipment such as head-mounted displays and/or headphones to create a fully immersive experience, highlighting the relative uncomplicated nature of AR as a benefit in this investigation (40).

Challenges to acceptability included the perceived burden of maintaining the attention of the children through educational videos alone with suggestions such as increased gamification and animation provided by participants to try and combat this. Asthma smartphone apps such as 'AsthmaXcel Adventures' which utilises gamification and

animation have been shown to improve asthma control and knowledge, as well as reduce morbidity such as emergency department visits in paediatric asthmatic patients, strengthening the case to incorporate these into developing AR interventions (41). Technical difficulties of the intervention and the use of the paper-based resource requirement to trigger digital content also provided challenges on the use, which in further iterations will be ironed out to minimise this is as barrier for uptake. The opportunity cost of a lack of face-to-face interaction with HCPs was also identified with the use of AR via smartphone/tablet technology. It is possible this may be overcome via incorporation of a 'chat' function with HCPs within the digital intervention, such as in the mobile health app designed by Kosse et. al which also showed improved adherence to asthma medication in those adolescent asthmatics who utilised this function (42).

Strengths and Limitations of the study

Strengths to this study included the recruitment of likely end-users for the intervention of participants to ensure optimisation of information rich data and rigorous qualitative methodology applied to this evaluation. Gold standard methodology included a pre-specified published protocol, qualitative interview training, transcription of audio files, having two coders to reduce interpretation bias and using a well-established theoretical framework.

This study has several limitations, including generalisability and AR technology limitations. Generalisability was limited in that patients with asthma were excluded if English was not their first language. This precluded the evaluation of acceptability in other ethnic backgrounds, particularly in Aboriginal and Torres Strait Islander children within Australia who have approximately two times a higher asthma prevalence than children who are non-Indigenous (43). Participants were also unable to use the intervention if they had any visual or hearing impairments. As mentioned in the methods section, recruitment inclusion criteria was also changed midst study due to the restrictions of the SARS-CoV-19 pandemic and the diminished sample pool of older children (>12 years). To ensure we adhered to purposive sampling, our options were to increase sampling size or adjust the parameters of our age inclusion criteria. After careful consideration and consultation with both asthma clinical care experts and experts in technological innovation design, it was decided that targeted, more meaningful information would be more likely to be obtained if only the younger cohort was included. It was also felt the older cohort would have different design and content requirements. We therefore did not review acceptability for AR in the adolescent age group however will do so in a future study. Other aspects of purposive sampling such as representation of the three different participant groups and gender were achieved. Recruitment was also only undertaken at a single site, tertiary paediatric hospital, indicating the sample pool may not have had widely differing opinions. Patients and parents recruited may have been those with poorer control or more severe asthma, and HCPs may have been more experienced in managing asthma and providing education to this specific sub-population. The AR intervention itself also had limitations itself due to availability of only a small amount of funding to design and develop the software, content, and scope of information. This may have impacted the feedback received from participants, especially in terms of burden of use.

Conclusion and implications for future research and clinical practice

AR appears to be an acceptable modality for delivery of inhaler education to children with asthma, their caregivers and HCPs who provide care to young people with asthma. AR is a relatively novel technological innovation with only one previous study identified which has explored its use as a delivery mechanism in asthma inhaler technique in children, and no qualitative research on its acceptability undertaken (28). Whilst there have been multiple studies evaluating the acceptability of mobile apps and other digital interventions in asthmatic patients, this is the first study to our knowledge to evaluate the acceptability of AR to deliver asthma inhaler technique education (44-46). This evaluation provides important findings to inform further development, expansion and up-scale of the AR education resource to address issues around inhaler technique education, as well as potential beyond this specific issue. It also identified an appetite for novel technology-based health interventions to deliver best practice self-management and education within the asthma community. Findings may also be used to inform design of future interventions ustilising AR-enabled smartphone/tablet apps to deliver any health care education.

Future designs should consider incorporation of features such as gamification to further increase engagement, as well as ensure a streamlined design with minimal technical difficulties to decrease the perceived burden of use. The possibility of including interactions with health care professionals may also be beneficial to decrease the perceived opportunity cost of loss of the ability of caregivers and children to ask questions, provide feedback as well as knowledge 'check back'.

To ensure successful uptake and implementation into the clinical setting and for broader generalisability, future research should focus on barriers and facilitators to change, the usability of such interventions, the feasibility (through focusing on areas such as practicality and efficacy testing) as well as exploration of the use of AR in other groups who may have suboptimal engagement in asthma inhaler technique education such as adolescents.

Acknowledgements

The authors of this study would like to thank the children, their families and health care professionals who participated in this study.

Conflicts of Interest

Kristin Carson-Chahhoud is co-founder of a start-up company that will include augmented reality technology as one of the functions in a smartphone application to support smoker quit attempts. At time of manuscript submission, personal financial interest has yet to be attained.

Abbreviations

App: Applications
AR: Augmented reality
TFA: Theoretical framework of acceptability
HCP: Health care professional

References

1. Safiri S, Carson-Chahhoud K, Karamzad N, Sullman MJM, Nejadghaderi SA, Taghizadieh A, et al. Prevalence, Deaths, and Disability-Adjusted Life-Years Due to Asthma and Its Attributable Risk Factors in 204 Countries and Territories, 1990-2019. Chest. 2022;161(2):318-29.
2. Dharmage SC, Perret JL, Custovic A. Epidemiology of Asthma in Children and Adults. Frontiers in Pediatrics. 2019;7.
3. National Heart LaBI. Guidelines for the Diagnosis and Management of Asthma (EPR-3). Bethesda, MD: National Heart, Lung, and Blood Institute; 2007. 2020.
4. Mims JW. Asthma: definitions and pathophysiology. International forum of allergy & rhinology. 2015;5(S1):S2-S6.
5. Grad R, Morgan W. Long-term outcomes of early-onset wheeze and asthma. Journal of allergy and clinical immunology. 2012;130(2):299-307.
6. Fehrenbach H, Wagner C, Wegmann M. Airway remodeling in asthma: what really matters. Cell and Tissue Research. 2017;367(3):551-69.
7. 158). SIGNS. British Guideline on the Management of Asthma2019 25/4/2022 [cited July 2019. Available from: https://www.sign.ac.uk/our-guidelines/british-guideline-on-the-management-of-asthma/.
8. Asthma. GIF. Global Strategy for Asthma Management and Prevention 2020 [Available from: www.ginasthma.org.
9. Normansell R, Kew KM, Mathioudakis AG, Normansell R. Interventions to improve inhaler technique for people with asthma. Cochrane database of systematic reviews. 2017;2017(3):CD012286-CD.
10. Litt HK, Press VG, Hull A, Siros M, Luna V, Volerman A. Association between inhaler technique and confidence among hospitalized children with asthma. Respiratory medicine. 2020;174:106191-.
11. Samady W, Rodriguez VA, Gupta R, Palac H, Karamanis M, Press VG. Critical Errors in Inhaler Technique among Children Hospitalized with Asthma. Journal of Hospital Medicine. 2019;14(6):361-5.
12. Sleath B, Ayala GX, Gillette C, Williams D, Davis S, Tudor G, et al. Provider demonstration and assessment of child device technique during pediatric asthma visits. Pediatrics (Evanston). 2011;127(4):642-8.
13. Tiller E, Greenland N, Christie R, Kos A, Brennan N, Di Nicola K. Youth Survey Report 20212021.
14. Al Raimi AM, Chong MC, Tang LY, Chua YP, Al Ajeel LY. The effect of mobile applications in enhancing asthma knowledge among school children with asthma in Malaysia. Journal of pediatric nursing. 2022.
15. Drummond D, Monnier D, Tesnière A, Hadchouel A. A systematic review of serious games in asthma education. Pediatric allergy and immunology. 2017;28(3):257-65.
16. Ramsey RR, Plevinsky JM, Kollin SR, Gibler RC, Guilbert TW, Hommel KA. Systematic Review of Digital Interventions for Pediatric Asthma Management. The Journal of Allergy and Clinical Immunology: In Practice. 2020;8(4):1284-93.
17. Farzandipour M, Nabovati E, Sharif R, Arani MH, Anvari S. Patient Self-Management of Asthma Using Mobile Health Applications: A Systematic Review of the Functionalities and Effects. Appl Clin Inform. 2017;8(4):1068-81.

18. Hui CY, Walton R, McKinstry B, Jackson T, Parker R, Pinnock H. The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. J Am Med Inform Assoc. 2017;24(3):619-32.
19. Akcayir M, Akcayir G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review. 2017;20:1-11.
20. Guevara J. 5 recent tech innovations disrupting the medical and healthcare industry. 2020 [Available from: https://www.healthtechzone.com/topics/healthcare/articles/2020/08/27/446396-5-recent-tech-innovations-disrupting-medical-healthcare-industry.htm.
21. Bacca J, Baldiris S, Fabregat R, Kinshuk. Insights Into the Factors Influencing Student Motivation in Augmented Reality Learning Experiences in Vocational Education and Training. Frontiers in Psychology. 2018;9(1486).
22. Eckert M, Volmerg JS, Friedrich CM. Augmented Reality in Medicine: Systematic and Bibliographic Review. JMIR Mhealth Uhealth. 2019;7(4):e10967.
23. Hrishikesh N, Nair JJ. Interactive learning system for the hearing impaired and the vocally challenged. International Conference on Advances in Computing, Communications and Informatics (ICACCI). 2016:1079-83.
24. Lavoye V, Mero J, Tarkiainen A. Consumer behavior with augmented reality in retail: a review and research agenda. The International review of retail, distribution and consumer research. 2021;31(3):299-329.
25. McGuirt JT, Cooke NK, Burgermaster M, Enahora B, Huebner G, Meng Y, et al. Extended reality technologies in nutrition education and behavior: Comprehensive scoping review and future directions. Nutrients. 2020;12(9):1-14.
26. Santos MEC, Chen A, Taketomi T, Yamamoto G, Miyazaki J, Kato H. Augmented Reality Learning Experiences: Survey of Prototype Design and Evaluation. IEEE transactions on learning technologies. 2014;7(1):38-56.
27. Graham A, Sahlberg P. Growing up Digital Australia: Phase 2 technical report. UNSW, Sydney.: Gonski Instititue for Education.; 2021.
28. Suha A-N, Peter B, Thomas A, Chris J, Fandi I, Mohamed A-M. Examining the Efficacy of a Novel Augmented Reality Mobile Delivery Platform for the Enhancement of Asthma Care Education for Children. International journal of interactive mobile technologies. 2021;15(7):47-68.
29. Alwashmi MF, Hawboldt J, Davis E, Fetters MD. The Iterative Convergent Design for Mobile Health Usability Testing: Mixed Methods Approach. JMIR mHealth and uHealth. 2019;7(4):e11656-e.
30. Susan Alexander KF, Haley Hoy. Applied Clinical Informatics for Nurses: Jones & Bartlett Learning, LLC; 2019 2019.
31. 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. The Journal of asthma. 2018;55(9):1018-27.
32. 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. The Journal of asthma. 2021;58(2):253-61.

33. Sonney J, Cho EE, Zheng Q, Kientz JA. Refinement of a Parent–Child Shared Asthma Management Mobile Health App: Human-Centered Design Study. JMIR Pediatr Parent. 2022;5(1):e34117.
34. Cleary M, Horsfall J, Hayter M. Data collection and sampling in qualitative research: does size matter? Journal of advanced nursing. 2014;70(3):473-5.
35. NVivo. QSR International Pty Ltd; 2020.
36. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Services Research. 2017;17(1):88.
37. Chan AHY, Stewart AW, Harrison J, Black PN, Mitchell EA, Foster JM. Electronic adherence monitoring device performance and patient acceptability: a randomized control trial. Expert review of medical devices. 2017;14(5):401-11.
38. Milne-Ives M, Lam C, Meinert E. Digital Technologies for Monitoring and Improving Treatment Adherence in Children and Adolescents With Asthma: Scoping Review of Randomized Controlled Trials. JMIR pediatrics and parenting. 2021;4(3):e27999-e.
39. Jácome C, Almeida R, Pereira AM, Amaral R, Mendes S, Alves-Correia M, et al. Feasibility and Acceptability of an Asthma App to Monitor Medication Adherence: Mixed Methods Study. JMIR mHealth and uHealth. 2021;9(5):e26442-e.
40. Stromberga Z, Phelps C, Smith J, Moro C. Teaching with Disruptive Technology: The Use of Augmented, Virtual, and Mixed Reality (HoloLens) for Disease Education. Biomedical Visualisation. 2021:147-62.
41. Hsia BB, Singh AKAK, Njeze OO, Cosar EE, Mowrey WBWB, Feldman JJ, et al. Developing and Evaluating ASTHMAXcel Adventures: A Novel Gamified Mobile App for Pediatric Patients with Asthma. Annals of allergy, asthma, & immunology. 2020.
42. Kosse RC, Bouvy ML, Belitser SV, de Vries TW, van der Wal PS, Koster ES. Effective Engagement of Adolescent Asthma Patients With Mobile Health-Supporting Medication Adherence. JMIR mHealth and uHealth. 2019;7(3):e12411-e.
43. Brew B, Gibberd A, Marks GB, Strobel N, Allen CW, Jorm L, et al. Identifying preventable risk factors for hospitalised asthma in young Aboriginal children: a whole-population cohort study. Thorax. 2021;76(6):539-46.
44. Cushing A, Manice MP, Ting A, Parides MK. Feasibility of a novel mHealth management system to capture and improve medication adherence among adolescents with asthma. Patient preference and adherence. 2016;10:2271-5.
45. Farooqui N, Phillips G, Barrett C, Stukus D. Acceptability of an interactive asthma management mobile health application for children and adolescents. Annals of Allergy, Asthma & Immunology. 2015;114(6):527-9.
46. Murphy J, McSharry J, Hynes L, Molloy GJ. A Smartphone App to Support Adherence to Inhaled Corticosteroids in Young Adults With Asthma: Multi-Methods Feasibility Study. JMIR formative research. 2021;5(9):e28784-e.

Discussion and Future Directions

Chapter 10. Discussion

Publications and manuscripts within this thesis described the development of a novel, evidence-based smartphone app that utilised augmented reality to deliver an educational intervention for young people with asthma. Our objective was to co-develop a digitally enhanced intervention to address the long-standing issue of poor inhaler technique and compliance with inhaled therapies for asthma management. This body of work has confirmed our hypothesis that a co-designed augmented reality-enabled prototype, which delivers asthma inhaler technique education to children within a hospital-based setting was usable and acceptable by children with asthma, their caregivers and healthcare professionals with experience in delivering asthma education. We achieved this through five studies, each with a unique aim. A systematic review, end user co-design process and qualitative investigation with three pre-specified lenses (i.e., frameworks), was undertaken to underpin the development of the educational intervention, with aims met as intended within each study.

Our prototype has completed a final iteration and is now being incorporated into a comprehensive model of care intervention which combines multiple technology-enhanced education and self-management tools for people with asthma. The research and prototype developed from this thesis has formed the foundation of the comprehensive model of care which is currently being proposed for funding from the National Health and Medical Research Council (NHMRC) Medical Research Future Fund (MRFF) Chronic Respiratory Conditions grant. This will provide the opportunity to clinically validate and upscale the intervention as a digital self-management tool to improve medication adherence and asthma health related outcomes.

The following sections provide a general discussion and rationale behind the original prototype design process, reports on the significance and contribution of this thesis to current knowledge, the impact of this research on asthma education delivery in young people, the limitations and strengths, and future directions from this research.

10.1 Creation of the prototype intervention

The use of augmented reality is a novel modality for asthma education delivery, as few studies have explored its use in practice (109). To ensure creation of an asthma inhaler educational intervention that was informed by evidence, multiple aspects were considered for intervention design and will be described in this section including rationale of using smartphone and tablet technology to deliver the education, the evidence for incorporation of augmented reality, the co-design process and its importance, and the optimum setting for asthma education delivery.

10.1.1 Description and evolution of the intervention

The augmented reality-enabled intervention prototype which delivers asthma inhaler technique education to children was developed with end users from the outset. Initial interviews were undertaken with children with asthma, their caregivers and healthcare professionals on the concepts of technology-based interventions and augmented reality, with an educational intervention which incorporated augmented reality to deliver education via a smartphone/tablet app on physiotherapy in cystic fibrosis shown as an example. Based on feedback from the end users of the concept of the augmented reality-enabled healthcare app, the needs and requirements for an intervention which delivered asthma inhaler technique were identified. This formed the basis of the design of a bespoke smartphone/tablet app which was built entirely in house and was published on iOS app stores. The initial iteration used augmented reality to bring print resources (a poster featuring images of children) to come to life through the smartphone/tablet device. This then delivered asthma educational content through videos on inhaler technique for multiple asthma inhaler devices, which were filmed in front of a green screen by young people with asthma. Through the co-design process described in Chapter 8, the intervention evolved into a smartphone/tablet app that no longer required a print resource to trigger the augmented reality technology, but instead involved a virtual room dropped into the users' personal environment which contained videos on asthma educational content. Animation was also included in videos based on feedback.

Currently, there is only one similar intervention that has been designed for asthma inhaler technique education for children which utilises augmented reality technology in a training app (MySpira) (110). After use of the augmented reality intervention, asthma inhaler

technique improved compared to the study arm that was randomised to traditional educational materials such as pamphlets (98). This was based on questionnaires administered prior to use of the intervention, then immediately post. Of note, no participants in either group had asthma, and the design process of the intervention was not described. The study did demonstrate however, that this technology was effective, supporting our overall objective of the co-design of an augmented reality-technology enabled asthma inhaler educational intervention developed for young people with asthma.

10.1.2 Technology as the delivery mechanism

Through exploration of the barriers and facilitators of asthma education delivery, results from Chapter 5 and 7 indicated that technological interventions to improve asthma education delivery, including inhaler technique, would be well received by healthcare professionals, adults and children with asthma, and caregivers of those with asthma. Technological interventions to provide education and information to patients and improve the communication between patients and healthcare professionals are also known as 'information and communication technologies' (111, 112). These technologies include smartphone and tablet devices, which can be utilised for appointment reminders via text messages, telemedicine appointments to improve access to healthcare, and most commonly used through mobile apps (113). The use of these devices for self-management and education already has proven efficacy in chronic diseases, with improved disease related outcomes identified in systematic reviews (114). These include improvements of glycaemic control in patients with diabetes mellitus and fewer symptoms complaints with a relative risk reduction of death and hospitalisation in patients with congestive heart failure (114).

As discussed in Chapter 1.4.1, the use of smartphone and tablet devices has also been employed for asthma, with self-management and education delivery predominantly through mobile apps. These may provide disease specific information, asthma support as well as self-management tools including asthma action plans and symptom diaries (63). In the most recent systematic review in 2017 on the effects of mobile apps on asthma self-management, 10 identified studies showed there was an overall statistically significant improvement in asthma control and a positive impact on quality life (58). Also discussed in Chapter 1.4.1 were the benefits of using smartphone and tablet applications for asthma education and self-management in adolescents including the accessibility of mobile

devices, the increased connectedness of this age group with the internet, and improved ability to engage this demographic. The knowledge gained from this review, combined with the results from Chapters 5 and 8, underpinned the reasoning for the use of smartphone and tablet device technology via an app, for delivery of inhaler education for young people with asthma.

There are currently approximately 100,000 apps related to healthcare available, with this continuing to increase (115). Although many young people use apps on their mobile devices, evidence shows that 47 – 60% of adolescents hardly ever, or never have used a health-related app, despite at least 20% having downloaded one (105, 116). To maximise uptake by our target population of children and adolescents with asthma of a healthcare technology-based intervention, other considerations needed to be addressed. It is possible current health-related technology-based interventions are perceived as too difficult to use, integration of the intervention into routine clinical care is poor, or it has not been designed with the end user in mind. Designing such technology-based interventions may be challenging, with the preferences for selection of usage of apps markedly differing between children, their parents, industry stakeholders and policy makers (117). What has been identified, however, by both the asthma community and experts in the field, is a novel technology enhanced intervention is required for improvement of asthma management.

10.1.3 Incorporation of augmented reality

The potential use of augmented reality as one such novel technology enhanced intervention, was perceived as useful in Chapter 5 by patients with asthma, healthcare professionals who were experienced in managing asthma, and key community stakeholders. As previously described, augmented reality has been defined as 'technology able to superimpose virtual objects into a real-world setting so that the virtual objects seems to co-exist in the same space in real time' (71). With its ability to deliver education and information via a smartphone/tablet device through animations and graphics, and to capitalise on the novelty and convenience of this technology, which is readily available and cost-effective, the incorporation of augmented reality into the intervention was thought of as a good opportunity. Results from Chapter 8 supported the inclusion of augmented reality into the asthma inhaler educational intervention, with children with asthma, their caregivers and healthcare professionals reporting excellent usability of the intervention indicated by results from the SUS. Results from Chapter 9 also supported its inclusion,

with overall positive reports after use of the augmented reality-enhanced intervention received, and identification of it being an acceptable modality for delivery of inhaler education.

The exploration of augmented reality for asthma inhaler technique education delivery for children has only been described in one other recent study as mentioned above in section 10.1.1. Whilst the results are promising, the efficacy has not yet been explored for education in children with asthma. In addition, given the novel nature of augmented reality as a concept of delivery of asthma education to patients and their families, undertaking qualitative investigation is imperative to ensure successful design, uptake, implementation, and maintenance of the educational interventions developed incorporating its use. Kim et al. in 2021 reported on expectations of teachers, parents and children with asthma of an augmented reality incorporated asthma education program (118). Similar to results from our investigation in Chapter 5, the use of augmented reality was perceived as useful for asthma education within this study. Specifically, the incorporation would be engaging and exciting for school-aged students, and with involvement of a child or their family in the augmented reality content, interest and motivation would be stimulated (118). Whilst results from Kim et. al provide important information such as user preferences to be able to guide future development of novel interventions, the qualitative and mixed method results in this thesis presented in Chapters 8 and 9 contribute feedback based on real lived experiences with the intervention, which has been used to better inform intervention re-design for our final prototype.

10.1.4 Importance of iterative co-design in technology-based intervention development

Using results from this thesis presented in Chapters 8 and 9, which included the identification and understanding of preferences from children with asthma, their caregivers and healthcare professionals, the initial design of the augmented reality-enabled asthma inhaler education intervention was able to be improved on. The inclusion of children as actors within videos for relatability, use of animation, more augmented reality content to increase engagement and interest and more education provided on the disease process of asthma and triggers were valued. The removal of the requirement of a paper-based resource to trigger the augmented reality digital content was also undertaken to reduce the perceived burden of its requirement.

Despite being identified as a fundamental design principle of mobile health technology interventions from both users (young people with chronic disease) and implementers (health policy makers, clinicians and researchers) in a 2017 systematic review, this co-design process for development of asthma educational interventions, in which the understanding of end users needs are incorporated is still infrequently described (119-124). In adolescents with mental health disorders, more than 70% of technology interventions targeted at this demographic has not reported on the involvement of users in design and development (125). Co-design is defined as 'the creativity of designers and people not trained in design, working together in the design development process' (126). The importance of its use, especially for development of technology-based resources is two-fold – it facilitates necessary collaboration between a diverse group of stakeholders such as healthcare professionals, policy makers and patients, whilst also ensuring the intervention is underpinned by best practice and expert knowledge (127). Without this collaboration and an in-depth understanding of the users' needs, interventions may be created which are inferior and less engaging (128). Continuous adjustments and improvements are also required when designing health interventions (129). Using an iterative co-design process effectively incorporates both these requirements and integrates the preferences of users from either the outset of intervention development, or during the re-design phases, with alterations and improvements of components made, allowing for continuous quality improvement (127, 129).

With the aim to develop an intervention which had the highest likelihood of successful uptake, and ultimately effectiveness on improved asthma education, the iterative co-design process was used. With the dearth of literature surrounding iterative co-design for asthma inhaler educational intervention development, it is important this process was described to form a precedence for others undergoing technology-based health education intervention development, and to assist and inform others undertaking similar processes. However, not even the most rigorous end user co-design process can make up for an intervention with fundamental and potentially avoidable flaws. Therefore, to increase the likelihood of effectiveness, every aspect of intervention development had to be underpinned by evidence-based recommendations and research. For content, this was achieved by using the latest evidence-based clinical guidelines for asthma management (130). For delivery mechanism, augmented reality technology was ultimately chosen as the education delivery vehicle following a review of available evidence combined with feedback from the asthma

community as described above in sections 10.1.2 and 10.1.3. However, identifying the best setting in which to deliver the intervention was less clear.

10.1.5 Identification of setting for delivery of augmented reality-enabled intervention

Several motives informed our ultimate choice of the hospital setting for intervention delivery. Building on our existing body of research activities was one factor, as the qualitative investigation reported in Chapter 5 included people with asthma recruited through an adult hospital. However, this investigation was limited to the adult population, meaning a gap in the evidence for young people remained. Another consideration was the PhD candidate's profession, being a paediatric respiratory advanced trainee based in a children's hospital. Therefore, a hospital environment for education delivery would be somewhat easier due to the candidate's unique insight, knowledge and lived experience in this environment. However, none of these factors would provide adequate justification for selecting the hospital environment if the evidence base suggested that an alternative setting would be more effective.

For these reasons, a stepwise process to identify the optimal setting for asthma education delivery was considered imperative to development of an effective, evidence-based intervention. Firstly, following a brief scoping activity to identify the most common settings where asthma education would be delivered to young people, the published literature was screened for evidence of effectiveness and currency of this evidence, to fill gaps in our existing knowledge. For example, up to date published evidence was found for the school setting where a Cochrane review had been published in 2019, being the year prior to commencing this PhD (103). Whilst the review showed that school-based programs improved asthma health related outcomes, such as hospitalisations and emergency department visits, this was reliant on the ability for the child to attend school. Meaning those children too young, or facing early adversity and barriers, such as lack of transport, would not be reached via this setting (103, 131).

We had existing knowledge about the hospital setting, as the primary supervisor (Carson-Chahhoud) had just completed a relevant systematic review commissioned by Asthma Australia to underpin their 10-year strategic plan (132). This review demonstrated evidence of effectiveness for education delivery in the hospital setting to reduce asthma exacerbations and future hospital admissions. A commonly held theory as to why patients

and families may be more susceptible to educational interventions during hospitalisation, is because it presents a 'teachable moment', i.e. when consequences of an asthma exacerbation are the most obvious (133, 134). However, we still had reservations about the hospital setting due to a.) competing time pressures on healthcare professionals to deliver a comprehensive intervention, b.) other priorities to be addressed as part of best practice clinical service delivery, and c.) the potential impacted ability of families to fully understand and comprehend the delivered education, given they would be more focussed on the acute illness (135, 136).

While a Cochrane review of education delivered in the home-based setting was identified, it was last updated in 2011, meaning the content and recommendations were almost a decade out of date at the time we undertook this activity. Furthermore, concluding recommendations were not strong, as the evidence identified inconsistencies about whether home-based asthma education was superior to control environments e.g., usual care (137). Our scoping search also found that several home-based education studies had been undertaken since 2011, meaning there was an opportunity to strengthen the evidence base and provide up to date recommendations about education in this setting. In addition, with increasing awareness about the impact of a child's environment on asthma severity and morbidity, such as their family and neighbourhood, the ability to address potentially modifiable factors was highlighted (138, 139). The ultimate justification for considering an update of this Cochrane review came as a consequence of the SARS-CoV-2 pandemic. Alternatives to health service visits were increasingly called for by asthma patients, as social distancing requirements and community lockdowns restricted access to these vital services, causing the delivery of quality healthcare to deteriorate (140, 141).

An update of the Cochrane systematic review for home-based education interventions in young people was therefore undertaken to address the gaps in our knowledge and strengthen the evidence base for global consumption. As presented in Chapter 6, despite n=13 new studies bringing the total evidence base up to n=25, the recommendations held, being no conclusive evidence for superior efficacy with home-based asthma education interventions compared to standard care or education delivered outside the home. Although this review did not provide sufficient evidence for our intervention to be developed for home-based delivery, it did identify new knowledge about this setting to inform other home-based programs. Moreover, as this was a Cochrane review update as opposed to generation of a standard systematic review published in another journal, our findings that

identify effective components of home-based interventions are more likely to inform clinical care, policy, and practice worldwide.

10.2 Contribution to knowledge and significance of impact

The Cochrane Collaboration is known to produce, maintain and promote high quality and accessible systematic reviews which impact health-care policy and clinical practice (142, 143). In 2021, MEDLINE indexed over 1.2 million new articles for that year, equating to over 3,000 articles per day (144). Meaning the frequency with which new literature becomes available, makes it near impossible for researchers, clinicians, patients and policy makers to keep up to date with the latest developments in any field (145). Structured systematic reviews are more reliable than traditional literature reviews for summation of this literature, due to their rigorous methodology and reporting standards enabling reproducibility (146-148). The traditional literature review is another common approach of summation and presentation of current evidence, which can be utilised by healthcare professionals to inform health-care decision making, however can be subject to bias based on the author's previous experience and knowledge (147). Using rigorous Cochrane methodology such as pre-published protocols and strict quality criteria for included studies, the impact of bias is reduced over the review process (143).

Despite not identifying conclusive evidence that asthma educational interventions delivered within the home were more effective on asthma-related health outcomes, compared to standard care or education delivered outside the home, the Cochrane systematic review did provide important information to provide recommendations for policy makers to inform possible alternative delivery of care models for children with asthma. Almost 50% of the new included studies utilised community health workers (CHWs) to deliver asthma education. The World Health Organisation (WHO) definition of a CHW is 'health workers who have received some training (up to two years) but are not considered health professionals, and who are based in communities, meaning they provide services outside of health facilities or at peripheral facilities not staffed by health professionals' (149). Studies which deployed CHWs had high completion rates of their intervention (at least 75% of participants partially completing the intervention), suggesting successful implementation and maintenance of their program. As well as this, the majority of these studies had a significant intervention effect in one or more secondary outcomes, demonstrating clinical effectiveness. One study also demonstrated the cost-effectiveness of

a CHW comparative to an education session within a clinic ($61 USD less per session) (150). For the Australian health care system and policy makers, the possible feasibility of CHWs for asthma education delivery and reduction in direct and indirect medical system costs should be explored. CHWs have already been highlighted by WHO as a key strategy to reduce health inequity with their ability to reach marginalised populations with both cultural and geographic proximity (149, 151). A recent systematic review of 167 studies also highlighted that broadly, programmes involving CHWs are effective in reaching marginalised group such as those with limited education, of lower socioeconomic status, rural communities and other vulnerable groups (152). Whilst the clinical effectiveness of the programmes were not evaluated, their ability to extend healthcare access to disadvantaged populations who previously were falling beyond the reach of institution-based formal services is important and may reduce health inequity (152). In relation to children with asthma, this is important in Australia, where asthma prevalence and hospitalisation rates for Aboriginal and Torres Strait Islander peoples are almost double that of age-standardised non-Indigenous Australians (153). Additionally, children living in the lowest socioeconomic areas have 1.5 times the prevalence compared to those living in the highest socioeconomic areas (9). A CHW program delivered in the home, or other community setting, should be strongly considered by policy makers for delivery of asthma education in an attempt to improve asthma outcomes in vulnerable populations.

The systematic review also provided further information and knowledge by providing recommendations to guide future research for asthma education delivery. Firstly, being able to identify specific components which are linked with improved outcomes needs to be evaluated. This may be achieved by having multiple intervention arms within trials, which compare similar programs with slight variations (such as duration of interventions). Using healthcare utilization as an outcome, such as emergency department visits and hospitalisations is also recommended, with its ability to contribute to evidence of both clinical effectiveness of the intervention as well as cost effectiveness to strengthen the case for interventions to be included in policy and healthcare budgets.

This thesis was also able to provide new knowledge surrounding the iterative co-design for an asthma inhaler technique educational intervention which can strengthen the evidence base regarding the use of this process for other healthcare interventions being developed (Chapter 8). The importance of qualitative methods and requirement for consumer input to ensure their needs are met is also emphasised. The thesis also highlights important

considerations for creating effective technology-based asthma educational interventions by utilising the preferences, barriers and facilitators of end users identified via mixed-method studies (Chapters 5, 7, 8 and 9). The usability and acceptability of use of augmented reality as an educational delivery modality in asthma care has also been identified, strengthening the case for its incorporation into not only asthma inhaler technique education, but also raising the potential of its use amongst other educational healthcare interventions.

The results from this thesis have been presented to Asthma Australia, being Australia's national peak consumer body. The discussion was to form a partnership with Asthma Australia to help support their agenda around technology-based innovation to support asthma care, and to ensure that the resources we have developed will be used and have a positive impact in practice. The outcome of these conversations confirmed a shared interest and development of a plan to collaborate long-term to produce technology-based solutions for asthma care, and to incorporate the final iteration of the prototype described in this thesis into a comprehensive asthma educational resource (described in more detail in section 10.4 Future Directions). A formal partnership with $50k cash and additional in-kind co-contribution has been submitted through the formal evaluation process for cofounding of the NHMRC MRFF grant for upscale and expansion of the comprehensive asthma educational resource, with outcomes known by the beginning of 2023. This will directly contribute to the patient care and service delivery of those with asthma if successful.

10.3 Limitations and strengths

For the Cochrane systematic review, it is possible that some relevant information was not identified and included during the search. Whilst using rigorous Cochrane methodology included searching the grey literature, contacting authors and reviewing online clinical trial registries, it is still possible that relevant studies may have been missed. In addition, only randomised controlled trials were eligible for inclusion. Whilst this ensures the quality of the review and the level of evidence being produced is maximised, studies which may have had potentially relevant information, albeit of lower quality, may have been excluded. Lastly, there was a significant amount of heterogeneity between studies. This included the study aims, the intervention delivered, and the clinical population included. Due to this, it was difficult to pool results together to give a meaningful conclusion to the study questions

raised. Positively, recommendations were able to be provided regarding future research directions and gaps to address.

The qualitative and mixed method studies undertaken as part of this thesis encountered limitations which were described in more detail in Chapters 5, 7, 8 and 9. One of the major limitations throughout was the limited diversity and generalisability of the results. In Chapter 5, participants were recruited from a single adult hospital site, and in Chapters 7, 8 and 9, participants were recruited from a single tertiary paediatric centre. This may mean recruited patients had similar demographics including socioeconomic status, level of schooling and employment. English as a first language was also part of the inclusion criteria for Chapters 7, 8, 9 which would have excluded children who had other cultural and linguistic backgrounds. This is of particular importance in Australia where Aboriginal and Torres Strait Islander people have a higher prevalence of asthma than non-Indigenous children by almost two-fold (154). In addition, due to the change in the inclusion criteria halfway through recruitment, children >12 were not recruited for Chapters 7, 8 and 9. This decision was made with careful consideration by the study team, guided by asthma clinical care and technological design experts. Whilst limiting the results to being relevant for children 8-12 years inclusive, a smaller age range was thought to lead to more in-depth analysis, and older children were likely to have identified different requirements for the intervention development.

The studies also utilised purposive sampling for recruitment. Whilst there is the inherent risk of bias in selection, purposive sampling is commonly used in qualitative and implementation research to aid in the identification of cases who are information-rich and gain insights from specific populations (155). For Chapters 5, 7, 8 and 9, the sample cohort which was reviewed was typical of other qualitative research and the use of two researchers to code and analyse data was used to minimise researcher bias. The small sample size also limited the interpretation and evaluation for usability of the intervention in Chapter 8, however this was secondary to the target sample size needing to be achieved for other qualitative investigation, and formal usability testing will be addressed in a future larger study.

An additional limitation of the research presented in this thesis was the funding, resources, and time constraints available for the development of the augmented reality-enabled educational intervention in Chapter 8. Due to this, incorporation of all feedback from the

co-design process was unable to be added to the prototype, including gamification, which may have influenced results of acceptability and usability perceived by end users. The feedback has been re-reviewed for a final iteration for incorporation into a more comprehensive asthma management tool which will be discussed in the below section of 10.4.

The research in this thesis followed gold standard mixed method research guidelines. The use of an iterative co-design process to ensure consumer-rich driven development, a pre-specified published protocol, theoretical underpinning with the Triandis model of interpersonal behaviour, validated frameworks of the TDF and TFA as well as triangulation of data in this thesis were particular strengths to ensure rigour (109). In addition, the use of semi-structured moderator guides, qualitative interview training, member checking and two researchers used for coding were best practice methods to ensure trustworthiness of results. Specific strengths of the qualitative and mixed methods investigation are described in more detail within the manuscripts of Chapters 5, 7, 8 and 9.

10.4 Future directions

To continue building on the findings and outcomes of this thesis, future research and clinical care, identification of how to enable successful implementation, upscale and expansion of the developed augmented reality-enabled asthma inhaler technique educational resource into the clinical setting and practice is required.

As discussed previously, the final prototype of the augmented reality-enabled asthma inhaler technique educational intervention has been incorporated into an asthma resource package which comprises of other technology-enhancing asthma education and self-management tools for people with asthma and healthcare professionals. This package involves an 80-page patient education and self-management asthma workbook embedded with augmented reality technology which can deliver digital educational content to improve health literacy, inhaler technique and provide treatments (e.g. acceptance and commitment therapy by a clinical psychologist for asthma patients with anxiety) via a smart phone app. In combination with workshops being developed and delivered to key stakeholders and policy makers, and education delivery sessions to healthcare professionals inclusive of provisions of education on national key priorities in asthma, a comprehensive asthma model of care will be formed. The overall aim is to successfully

implement the technology-enhancing asthma resource package into clinical practice and policy to address poor asthma outcomes in children, and ensure this is sustainable.

To successfully implement this intervention into the clinical world, key stakeholders and policymakers will be required to drive change. We recommend key stakeholders and policy makers be recruited from government, asthma organisations (Lung Foundation, Asthma Australia) and clinical care (state hospital leaders and executive) to participate in workshops guided by Kotter's Model of Change (156). The use of this model can be applied at local, institutional, system-wide and multi-system levels and as a framework to drive organisational change and action (157). There is strong evidence of its ability to do so within healthcare and is the most commonly applied change management methodology (157-160). Workshops could be delivered two-monthly over six months to show the combined asthma resource package to stakeholders and policy makers. Using Kotter's model, workshops would utilise steps three to eight of the Kotter's model, which would involve creating a vision for use of the combined resource package in practice, communicating that vision, empowering others to act on that vision, planning for and creating short-term wins, consolidating improvements, producing more change and institutionalising new approaches. Workshops would also be used to identify opportunities, facilitators, and barriers for implementation success of the package in clinical service delivery in order to sculpt an actional framework and support a feasibility and pilot study.

Healthcare professionals would also be required to facilitate the integration of the resource into clinical practice. This may be through delivery of education workshops, built off models already pilot tested within SA hospitals, and include how to use our asthma resource package to complement current service delivery for asthma care.

A feasibility and pilot study of the technology-based comprehensive asthma resource would then be undertaken. The feasibility and pilot study would identify and address any potential problems with the intervention itself and implementation strategy prior to nationwide dissemination. This is a separate process to the fully powered RCT we are proposing in a current MRFF submission to evaluate the intervention effectiveness of the asthma package. This process is a key phase in complex intervention research as deemed by the Medical Research Council and National Institute of Health Research which is necessary to avoid any potential issues such as delivery of the intervention which may

undermine the success of full scale clinical service delivery (161) (162). We proposed and developed a feasibility and pilot study to undertake and submitted this proposal as an Expressions of Interest for the Channel 7 Children's Research Foundation Grant (Appendix 4). We proposed this be performed across two hospitals in SA with the aim to evaluate the feasibility and practicality of delivery of our model of care within the paediatric hospital setting.

We recommend outcomes be based on the RE-AIM (reach, effectiveness, adoption, implementation and maintenance) framework, because it is one of the most applied frameworks in evaluation of implementation (163). This would include outcomes such as level of reach (e.g. how many young people with asthma get the resource) and implementation (e.g. degree of resource use and improvements to asthma care).

As well as conducting the feasibility and pilot study, the comprehensive asthma model of care involving the developed augmented reality-enabled prototype which delivers asthma inhaler education is aiming to be built upon and upscaled to improve asthma care and service delivery. Applications to secure funding are currently underway for this with my involvement as an associate investigator for an NHMRC MRFF grant. We also want to expand on additional components that have not been included within this MRFF application including training of healthcare professionals who will play a key role in incorporation of the model of care into the clinical setting, expansion into the community and pharmacies. To do this, we are continuing to apply for future NHMRC schemes including Clinical Trials and Cohort Studies Grants and partnership funding.

Other approaches which are being considered for funding to aid in upscaling and expansion of the model of care include exploration of commercialisation, marketing approaches, and government funding. These pathways are important to consider due to the expertise commercial organisations and private industry may be able to provide. Most digital health solutions are led by commercial organisations and the private industry, who are able to utilise skills and experience in production of usable and engaging products (164). This can be problematic in that commercial industry-led development lacks scientific scrutiny and rigour which can only be obtained with formal evaluation of efficacy and publication of peer-reviewed research. This may lead to interventions created which are not necessarily useful. Healthcare and academic institutions who have knowledge of usual clinical care pathways, specifics of disease progression and

management and accessibility to potential end users of interventions should work closely with commercial institutions to facilitate integration of interventions into standard clinical care and co-design such interventions (164). The research from this PhD was undertaken from a clinical and academic perspective with future research planned to evaluate clinical efficacy. Whilst important for this to be performed, it has long been stated that it takes 17 years from when research is finished until it can be translated into the clinical setting, meaning the majority of research outcomes remains inaccessible for the people the research was intended for (165). Given this, combining the clinical and academic backgrounds from the research performed for this thesis with commercial organisations and private industry will improve the chance of a successful product which can be implemented effectively and rapidly.

The findings presented from this thesis has strengthened the evidence base for the development of technology-based healthcare interventions, particularly in the use of augmented reality technology. Moreover, the creation of the novel, evidence-based augmented reality enabled smartphone app has also underpinned a comprehensive asthma model of care which combines multiple technology-enhanced education and self-management tools for people with asthma which will be upscaled and used in the next phase of research essential to improve provision of clinical care for children with asthma.

Chapter 11. Conclusions

This doctorate facilitated the development of a novel augmented reality technology-enabled prototype intervention, delivering inhaler technique education for children with asthma for delivery in the hospital environment. Using an iterative co-design process, the intervention was created in partnership with end users, producing evidence of good acceptability and usability among children with asthma, their caregivers and healthcare professionals with experience in delivering asthma education.

The systematic process of building this intervention according to evidence-based recommendations and community voice, followed gold-standard practices for qualitative research and evidence synthesis. Detailed protocols and methodology guiding the iterative co-design process have been described in detail to facilitate reproducibility of our approach for others embarking on similar co-design activities for health and technology-based interventions. How the prototype evolved over time in response to community feedback is also presented in detail, addressing issues with poor transparency in community co-design to develop such interventions.

Contemporary public health priorities, such as requirements for social distancing and remote healthcare provision as a result of the SARS-CoV-2 pandemic, presents an opportunity for alternative and innovative solutions. This thesis has identified several opportunities for further investigation, thanks to a stronger evidence base to underpin recommendations for public policy, clinical service delivery and further research. For example, the role of home asthma education for delivery by community-based health care workers, per the Cochrane review. Another remote education delivery mechanism is the burgeoning field of technology, as highlighted across the various publications presented. Specifically, the potential for smartphone and tablet devices that can facilitate delivery of the latest innovations in technology-based engagement, such as augmented reality. However, with the fifth industrial revolution dawning, this is likely just the beginning.

With creation of the first evidence-based augmented reality-enabled asthma self-management prototype, we are now in the position to potentially disrupt education delivery and health communication. A novel solution to the long-standing issue of poor inhaler technique amongst asthmatic children is now being upscaled and evaluated as a

comprehensive and practical clinical tool. Given 90% of people with asthma not using their inhalers correctly, this is a timely solution for this persistent, costly, and preventable issue. One that may finally begin to address Australia's leading burden of disease in young people.

Appendices

Appendix 1: Women's and Children's Health Network Human Research Ethics Committee Approval Letter

Government of South Australia | Health Women's and Children's Health Network | Women's & Children's Hospital

Research Secretariat
Women's and Children's Health Network

21 August 2020

Dr Antonia Chan
Respiratory Medicine
WCHN

Dear Dr Chan

Re: Augmented Reality as a Delivery Mechanism for Education and Behavioural Change in Children and Adolescents with Asthma – A Qualitative Study. Low Negligible Risk. HREC/20/WCHN/ 74. Ethics Expiry date 31 August 2023

Lead HREC for the above study for the following institutions/sites:

Women's and Children's Health Network

Thank you for your letter dated 18 August 2020 in response to matters raised following the expedited review of the above Low and Negligible Risk application by the Chair and two members of the WCHN HREC. I am pleased to advise that the application has been granted full ethics approval and meets the requirements of the *National Statement on Ethical Conduct in Human Research*.

Specifically, the following documents have been noted/approved:

Document	*Version*	*Date*
HREA Application: AU/1/CD5B314		6 July 2020
AR Qualitative Protocol (Phase 2)	1.1	18 Aug 2020
PICF (Health Professionals)	1.1	18 August 2020
PICF (ParentsGuardians)	1.1	18 August 2020
PICF (Children)	1.1	18 August 2020
Letter of Invitation – WCH (ParentsGuardians-Hospital)	1.1	18 August 2020
Moderator Guide (Health Professionals) – v1.1 dated 18.08.20	1.1	18 August 2020
Moderator Guide (Children and Adolescents with Asthma)	1.1	18 August 2020
Moderator Guide (Parents and Guardians of Children and Adolescents with Asthma)	1.1	18 August 2020
Recruitment Flyer Asthma Community	1.1	18 August 2020
Approval for poster to be displayed email trail		
AR Inhaler Chart – Lung Foundation Australia		
Asthma AR Inhaler Chart example		

This letter constitutes advice on ethical consideration only. You must not commence this research project at a site until you have obtained separate research governance approval from the site concerned. A copy of this letter should be forwarded to all site investigators for submission to the relevant Research Governance Officer.

At the WCHN, or any other SA Health site, separate authorisation from the Chief Executive or delegate of that site must be obtained through a Site Specific Assessment (SSA) request. For information on this process at the WCHN, please contact the WCHN Research Governance Officer, Dr Carmel Murone (telephone 8161 6688, email carmel.murone@sa.gov.au).

I remind you approval is given subject to:

- immediate notification of any serious or unexpected adverse events to participants;
- immediate notification of any unforeseen events that might affect continued ethical acceptability of the project;
- submission of any proposed changes to the original protocol. Changes must be approved by the Committee before they are implemented;
- immediate advice, giving reasons, if the protocol is discontinued before its completion;
- submission of an annual report on the progress of the study, and a final report when it is completed to the WCHN Research Governance Officer. It is your respons bility to provide these reports, without reminder. The proforma for the report may be found on the WCHN Research Governance and Ethics website.

Approval is given for three years only. If the study is more prolonged than this, an extension request should be submitted unless there are significant modifications, in which case a new submission may be required. Please note the expiry date in the title above and include it in any future communications.

The WCHN HREC wishes you every success with your research.

Yours sincerely

TAMARA ZUTLEVICS (DR)
CHAIR
WCHN HUMAN RESEARCH ETHICS COMMITTEE

Appendix 2: Women's and Children's Health Network Site Specific Assessment Approval Letter

12 October 2020

Government of South Australia
Women's and Children's Health Network

Women's & Children's Hospital

Research Secretariat
Level 2, Samuel Way Building
72 King William Rd
North Adelaide SA 5006
Tel 08 8161 6688
Fax 08 8161 6521

Dr Antonia Chan
Women's and Children's Hospital
72 King William Road
NORTH ADELAIDE SA 5006

Dear Antonia,

SSA/20/WCHN/092
HREC/20WCHN/74
Augmented Reality as a Delivery Mechanism for Education and Behavioural Change in Children and Adolescents with Asthma – A Qualitative Study

Site Specific Assessment Review
Thank you for submitting an application for research governance authorisation of this project. I am pleased to inform you that authorisation has been granted for this study to commence at the Women's and Children's Health Network.

In authorising this project, the following documentation was considered:

1. SSA submission AU/12/F16B311, dated 21 July 2020
2. Protocol v1.1, dated 18 August 2020
3. Recruitment Flyer v1.1, dated 18 Aug 2020
4. WCHN Corporate Communications approval to display poster
5. PICF – Health Professionals v1.1, dated 18 Aug 2020
6. PICF – Parent/Guardian v1.1, dated 18 Aug 2020
7. PICF – Children v1.1, dated 18 Aug 2020
8. Letter of invitation v1.1, dated 18 Aug 2020
9. WCHN HREC Approval Letter, dated 21 Aug 2020
10. Working With Children Checks for
    a. Kristin Carson-Chahoud, expires 11 Oct 2024
11. Confidentiality Agreement for
    a. Kristin Carson-Chahoud
    b. Zoe Kopsaftis
12. UniSA Certificate of Insurance, expires 1 Nov 2020

Agreement
Further to our correspondence regarding an agreement. It will be up to the University of South Australia (UniSA) to protect its Intellectual Property in the study. In order to do this, we recommend that UniSA enters into an agreement with WCHN, however, as the risk sits with UniSA, we can authorise the study to start at WCHN whilst UniSA considers its position.

Terms and conditions of governance authorisation
Please read the terms and conditions of Women's and Children's Health Network (**WCHN**) governance authorisation as researchers have a responsibility to comply with reporting requirements and other conditions. Failure to comply may have significant implications for the ongoing authorisation of the Study at the Women's and Children's Hospital (**WCH**). For example, failure to provide an annual report within the specified timeframe or failure to ensure that all non-WCHN staff and students satisfy the WCHN Confidentiality Agreement and Working With Children Check (WWCC) requirements may lead to the withdrawal of site authorisation and suspension of the Study, and may result in further serious consequences.

The WCHN Human Research Ethics Committee stipulated certain conditions for ethical approval of this study at the Women's and Children's Health Network. This authorisation imposes the following additional conditions:

1. Authorisation of the Study is limited to the site or sites identified in this letter.
2. Authorisation of the Study is granted until 31 Aug 2023 or until the project is complete, whichever is earlier.
3. The Study must be conducted in accordance with the conditions of ethical approval provided by the lead Human Research Ethics Committee (**HREC**) reviewing the Study, SA Health policies and in conjunction with all applicable standards, including the *National Statement on Ethical Conduct in Human Research* (2007 and updates) and the *Australian Code for the Responsible Conduct of Research* (2007 and updates).
4. In light of the August 2018 directive from the South Australian Chief Medical Officer, access to case notes without consent at the WCHN must **only** be by a member of the team directly caring for the patient.
5. Where non-WCHN staff or students are involved in the Study, that person or those persons must execute a WCHN Confidentiality Agreement. This requirement applies to all non-WCHN staff and students identified in the SSA submission and to any and all non-WCHN staff or students involved in the Study at any time in the future. Non-WCHN staff or students are not authorised to perform any acts in relation to the Study without the Research Governance Officer reviewing and approving a WCHN Confidentiality Agreement.
6. Any non-WCHN staff or students working on the Study, whether identified in the initial SSA submission or in future, who visit the WCHN site for any amount of time or who have access to any identifiable WCHN patient information (WCHN patients under the age of 18 years) must provide the Research Governance Officer with evidence of a current Department for Communities and Social Inclusion (**DCSI**) Child-Related Employment Screening check or more recently a Department of Human Services (DHS) Working with Children Check (WWCC), in accordance with SA Health policy and WCHN Human Resources requirements. Non-WCHN staff or students are not authorised to be on the site or access any identifiable WCHN patient data (WCHN patients under the age of 18 years) without the Research Governance Officer reviewing and approving a current Child-Related Screening check.
7. The Research Governance Officer must be included in all relevant correspondence regarding the Study, including correspondence between the WCHN site and the lead HREC for studies approved under National Mutual Acceptance. This includes, but is not limited to, all correspondence relating to:
    a. protocol amendment applications;
    b. protocol deviations or violations at WCHN sites;
    c. Serious Adverse Events at WCHN sites;
    d. notification of study close out, study withdrawal or study completion;
    e. extension of approval requests; and
    f. anything that may change the ethical or scientific integrity of the Study.
8. An Annual Report must be provided to the Research Governance Officer within 30 days of each anniversary of the initial lead HREC approval date for the duration of lead HREC approval. The Annual Report may be submitted on the current WCHN Annual Report form or the Annual Reporting template of the lead HREC. Failure to provide an Annual Report within the required timeframe may result in authorisation for the Study being suspended or withdrawn at the discretion of the Executive Director, Corporate Services, WCHN, the Director, Research Secretariat, WCHN or delegate.
9. Where University personnel are involved in the Study, the Principal Investigator must notify the University that WCHN HREC has approved the Study and WCHN research governance has authorised the Study. Prior to commencing the Study, the Principal Investigator must ensure all University requirements are complied with, including any indemnity and insurance requirements.

Additional condition of WCHN research governance authorisation – Data access and information disclosure

WCHN provides no consent for the data it has provided for this study to be used for any purpose which can generate a financial return from a third party either by the use of the data as standalone data or as a collection of data, except or unless WCHN has provided express written consent for such purpose to occur.

SA Health insurance

I confirm that based on the information provided by you, the Department for Health and Wellbeing's insurance arrangements will indemnify SA Health staff involved in the study.

The provision of this insurance is based on you maintaining ethics approval and ensuring that persons performing treatment or testing are qualified to perform such treatment or testing, or in the case of students they are appropriately supervised by persons that are qualified.

SA Health insurance does not include cover for deliberate breaches of confidentiality, wilful misconduct, or the misuse of information, fraud or similar risks.

Please contact me if you have any queries about the consideration of your Site Specific Assessment.

Please quote the SSA reference number in any correspondence about the Study.

I wish you every success in your research.

Yours sincerely

Carmel Murone, PhD
Research Governance Officer
Women's and Children's Health Network
Research Secretariat
P: (08) 8161 6688
E: carmel.murone@sa.gov.au

Key dates:

Annual Report due (every year):	August
WCHN research governance expiry date:	31 Aug 2023
External indemnity expiry date: It is the responsibility of the PI to provide updated certificate of insurance when the current one expires	1 Nov 2020

Appendix 3: Moderator guides for semi-structured interviews

One-on-one interview semi-structured moderator guide: Health professionals

Location

TBA

Welcome/what we are trying to achieve

Thank you for agreeing to do this interview. As you know we are doing research to investigate whether delivery of asthma education, especially inhaler technique, through augmented reality (AR) delivered via a smartphone or tablet application may be an effective, generational appropriate tool for children and adolescents with asthma.

Our team is trying to understand more about current asthma education practice, and your thoughts about whether this tool maybe useful. We are conducting these interviews to determine facilitators and barriers of the AR tool as well as evaluate perceptions of usability, and appropriateness to reach the target audience. We will talk briefly about your experience giving asthma education to young people, then you will have an opportunity to trial the AR tool for yourself, after which time we will discuss your opinions on the tools.

Honesty/audio taping

It is very important that we get your honest opinions and there are no wrong answers to what we will be talking about. We will be audio taping the session for transcription purposes. You will not be individually identified in any of our presentations or publications. This is protected research and remember that everything discussed in this interview and your specific opinions will remain completely anonymous.

Some generic probes

You mentioned _____, tell me more about that.

You mentioned _____, what was that like for you?

You talked about _____, describe that experience in as much detail as possible.

What else happened?

What were your feelings about that?

Can you explain what you mean by_____?

It sounds like you're saying…….

ONE-ON-ONE INTERVIEW QUESTIONS

Knowledge, skills and role

1. Do you personally deliver asthma education to patients with each interaction?
    a. If so – why/why not?
2. What type of asthma education do you deliver? E.g. information about the disease process of asthma, information about inhalers and other forms of management
3. Do you personally use a guideline or guidelines, or specific resources to underpin your asthma education for patients and if so which one/s?
4. Do you feel current asthma resources are useful or effective in helping deliver asthma education to patients or are they missing relevant information?
    a. How could they be improved?
5. Do you believe health professionals across the board have the skills necessary to deliver effective asthma education?
6. Do you feel that you are lacking any knowledge or skills necessary to adequately manage asthma?
7. Can you explain your current knowledge around correct asthma inhaler technique?
8. How would you describe your role in the education of asthma patients?
9. Who else should be involved or who do you think should be doing more?
    b. How do you think this can be achieved?
10. Whose role is it to ensure patients are using their prescribed inhalers correctly?

Beliefs about capabilities and consequences

11. Are you confident that you in delivering education to asthma patients?
12. What do you think are the primary factors that limit your ability to deliver education, if any?
13. What do you think are the primary factors that improve your ability to deliver education, if any?
14. Do you believe that your colleagues and those around you are confident in delivering education?
    c. Why, why not?

Organisation

15. Do you feel you have support to spend the time necessary with individual asthmatics in your organisation?

    d. What are your time restrictions and who sets these restrictions?

Optimism, intentions and goals

16. Are you optimistic that asthma education will improve in South Australia? Why, why not?

17. Do you know of any current intentions by your organisation, another organisation or even yourself, to do something about improving asthma education?

18. How often do you manage to provide asthma patients with all the relevant information they need during a single consultation?

    e. How do you currently prioritise your tasks within your interaction with the patient?

Innovation and innovation strategy

19. Do you know of any recent innovations in asthma care that are in development or being used in practice?

20. Have you heard of augmented reality? What is it?

21. Do you think smartphone technology could be a useful tool to improve asthma education?

    f. Why / Why not?

BREAK TO DEMONSTRATE AR TOOL AND ALLOW PARTICIPANT TO USE

---

22. Was it what you expected? Why or why not?

23. What do you think of AR now?

24. What did you like about the AR resources?

25. What did you think of the design of the tool?

26. Did you find it easy to use? Why or why not?

27. How could we improve on this initial design?

28. What did you think about the content of the tools?
29. How could we make the AR tools better or more engaging?
30. How did the tools make you feel?
31. Do you think the videos are too long or too short, or just right?
32. Do you think AR tools could be useful for learning? Why or why not?
33. What do you think are the downsides of using the technology?
34. What kind of content do you think we need for someone with asthma?

Patient

35. Do you think these tools are an attractive option for young people? Why or why not?
36. Are there any other technology based tools that we should be considering to deliver information?

Positive Emotions and Negative Emotions

37. Would you use AR tools personally? Why/why not?
    g. How does it make you feel?

Closing comments

Please tell us about anything else you feel is important for us to know

Thank you for your time.

One-on-one interview semi-structured moderator guide: Children and Adolescents with Asthma

Location

TBA

Welcome/what we are trying to achieve

Thank you for agreeing to do this interview. As you know we are doing research to investigate whether delivery of asthma education, especially inhaler technique, through augmented reality (AR) delivered via a smartphone or tablet application may be an effective, generational appropriate tool for children and adolescents with asthma.

Our team is trying to understand more about current asthma education practice, and your thoughts about whether this tool maybe useful. We will demonstrate the use of this tool, and invite you to also trial it yourself. We would like your honest opinions about the AR tool, including why it may be easy or hard to use and what you like and don't like about it.

Honesty/audio taping

It is very important that we get your honest opinions and there are no wrong answers to what we will be talking about. We will be audio taping the session for transcription purposes. You will not be individually identified in any of our presentations or publications. This is protected research and remember that everything discussed in this interview and your specific opinions will remain completely anonymous.

Some generic probes

You mentioned _____, tell me more about that.

You mentioned _____, what was that like for you?

You talked about _____, describe that experience in as much detail as possible.

What else happened?

What were your feelings about that?

Can you explain what you mean by_____?

It sounds like you're saying…….

ONE-ON-ONE INTERVIEW QUESTIONS

Experience of asthma and education

1. Do you receive asthma education each time you go to the hospital/doctor?
2. Multiple studies have shown that asthma education is not done well by health professionals, and 90% of people with asthma are still not using their medications or devices correctly – why do you think that might be?
3. What type of asthma education do you receive? E.g. information about the disease process of asthma, information about inhalers and other forms of management
4. Do you receive asthma resources, and are they useful or effective in helping you understand your asthma and treatment, or are they missing relevant information?
    a. How could they be improved?
5. Where do you receive education about asthma?
    b. Is it usually in hospital/at the doctor's? Or elsewhere? If elsewhere – where?
6. Can you explain your current knowledge around correct asthma inhaler technique?

Broad technology questions

7. Do you use or have access to a smartphone or tablet?
8. How much time per day do you think you spend using a smartphone or tablet?
9. Do you use any apps relating to health? Including for asthma?
10. Do you think apps can be useful when it comes to health? Why or why not?

Innovation and innovation strategy

11. Have you heard of augmented reality? What is it?
12. Do you think smartphone technology could be a useful tool to improve asthma education?
    c. Why / Why not?

BREAK TO DEMONSTRATE AR TOOL AND ALLOW PARTICIPANT TO USE

---

13. Was it what you expected? Why or why not?

14. What do you think of AR now?
15. What did you like about the AR resources?
16. What did you think of the design of the tool?
17. Did you find it easy to use? Why or why not?
18. How could we improve on this initial design?
19. What did you think about the content of the tools?
20. How could we make the AR tools better or more engaging?
21. How did the tools make you feel?
22. Do you think the videos are too long or too short, or just right?
23. Do you think AR tools could be useful for learning? Why or why not?

Patient

24. Do you think these tools are an attractive option for young people? Why or why not?
25. Are there any other technology based tools that we should be considering to deliver information?

Positive Emotions and Negative Emotions

26. Would you use AR tools personally? Why/why not?
    d. How does it make you feel?

Closing comments

Please tell us about anything else you feel is important for us to know

Thank you for your time.

One-on-one interview semi-structured moderator guide: Parents/Guardians of Children/Adolescents with Asthma

Location

TBA

Welcome/what we are trying to achieve

Thank you for agreeing to do this interview. As you know we are doing research to investigate whether delivery of asthma education, especially inhaler technique, through augmented reality (AR) delivered via a smartphone or tablet application may be an effective, generational appropriate tool for children and adolescents with asthma.

Our team is trying to understand more about current asthma education practice, and your thoughts about whether this tool maybe useful. We will demonstrate the use of this tool, and invite you to also trial it yourself. We would like your honest opinions about the AR tool, including why it may be easy or hard to use and what you like and don't like about it.

Honesty/audio taping

It is very important that we get your honest opinions and there are no wrong answers to what we will be talking about. We will be audio taping the session for transcription purposes. You will not be individually identified in any of our presentations or publications. This is protected research and remember that everything discussed in this interview and your specific opinions will remain completely anonymous.

Some generic probes

You mentioned _____, tell me more about that.

You mentioned _____, what was that like for you?

You talked about _____, describe that experience in as much detail as possible.

What else happened?

What were your feelings about that?

Can you explain what you mean by_____?

It sounds like you're saying…….

ONE-ON-ONE INTERVIEW QUESTIONS

Experience of asthma and education

1. Do you receive asthma education each time you go to the hospital/doctor with your child?
2. Multiple studies have shown that asthma education is not done well by health professionals, and 90% of people with asthma are still not using their medications or devices correctly – why do you think that might be?
3. What type of asthma education do you both receive? E.g. information about the disease process of asthma, information about inhalers and other forms of management
4. Do you receive asthma resources, and are they useful or effective in helping you understand your asthma and treatment, or are they missing relevant information?
    a. How could they be improved?
5. Where do you both receive education about asthma?
    b. Is it usually in hospital/at the doctor's? Or elsewhere? If elsewhere – where?
6. Can you explain your current knowledge around correct asthma inhaler technique?

Broad technology questions

7. Does your child have access to a smartphone or tablet?
8. How much time per day do you think they spend using a smartphone or tablet?
9. Do you know if they use any apps relating to health? Including for asthma?
10. Do you think apps can be useful when it comes to health? Why or why not?

Innovation and innovation strategy

11. Have you heard of augmented reality? What is it?
12. Do you think smartphone technology could be a useful tool to improve asthma education?
    c. Why / Why not?

BREAK TO DEMONSTRATE AR TOOL AND ALLOW PARTICIPANT TO USE

---

13. Was it what you expected? Why or why not?
14. What do you think of AR now?
15. What did you like about the AR resources?
16. What did you think of the design of the tool?
17. Did you find it easy to use? Why or why not?
18. How could we improve on this initial design?
19. What did you think about the content of the tools?
20. How could we make the AR tools better or more engaging?
21. How did the tools make you feel?
22. Do you think the videos are too long or too short, or just right?
23. Do you think AR tools could be useful for learning? Why or why not?

Patient

24. Do you think these tools are an attractive option for young people? Why or why not?
25. Are there any other technology based tools that we should be considering to deliver information?

Positive Emotions and Negative Emotions

26. Would you use AR tools personally? Why/why not?
    d. How does it make you feel?

Closing comments

Please tell us about anything else you feel is important for us to know

Thank you for your time.

Appendix 4: Channel 7 Children's Research Foundation Grant Expression of Interest

EOI for Channel 7 Children's Research Foundation Grant

SECTION A: Chief Investigator
Title: Dr.
First Name: Antonia
Surname: O'Connor
Academic Qualifications: MBBS
Conferring Institution: University of Adelaide
Year conferred: 2014
Position Title: Paediatric Respiratory Fellow
Department: Respiratory Department, Women's and Children's Hospital, Adelaide
Phone number: 0402529552
Email: antonia.chan@sa.gov.au

SECTION B: Associate Investigator/s:
Title: Associate Professor
First name: Kristin
Surname: Carson-Chahhoud
Academic Qualifications: PhD
Institution: University of South Australia, University of Adelaide
Time on this project (%): 5%

SECTION B: Associate Investigator/s:
Title: Ms
First name: Kelsey
Surname: Sharrad
Academic Qualifications: Bachelor of Food and Nutrition Sciences, Part-time masters candidate
Institution: Deakin University
Time on this project (%): 5%

SECTION B: Associate Investigator/s:
Title: Dr.
First name: Malcolm
Surname: Brinn
Academic Qualifications: PhD (anatomy/neuroscience), Bachelor of Health Science (Hons Anat), Bachelor of Health Science (Life Sc)
Institution: University of Adelaide, Flinders University
Time on this project (%): 5%

SECTION B: Associate Investigator/s:
Title: Dr.
First name: Andrew
Surname: Tai
Academic Qualifications: Bachelor of Medicine & Bachelor of Surgery (MBBS); PhD

Institution: University of Adelaide, University of Melbourne
Time on this project (%): 5%

SECTION C: Project

PROJECT TITLE
Eight steps to better breathing – Using Kotter to instigate sustainable improvements in asthma management in children: a real-world evaluation

RESEARCH CATEGTORY
Clinical Study

DISCIPLINE
Paediatrics

SIGNIFICANCE
Briefly describe the potential significance of the project, and its relevance to the health and well-being of children, in non-technical terms. This summary may be used in future media releases, on the website, and/or the annual report.

Concerningly, 13% of South Australians have asthma, over double the global prevalence. South Australian children with asthma have the highest rates of hospitalisation nationwide. Although asthma is not curable, symptom control can effectively reduce the burden of disease for both patient and supporting health systems. We have developed comprehensive evidence based digital content, education, and self-management tools, that can address multiple factors that contribute to poor outcomes in this population. This project aims to determine how we can successfully implement these tools into an effective model of care that addresses clinical practice and policy whilst being sustainable and scalable.

WHICH, IF ANY, OF THE FOLLOWING CRF RESEARCH PRIORITIES DO YOU CONSIDER THIS RESEARCH PROPOSAL ADDRESSES? (more than one box can be checked as relevant; not essential to address a particular research priority)

1. Improving fetal development including preventing pre-term birth
2. *Improving systems of care and education for children*
3. *Supporting young minds and improving children's mental health*
4. *Tackling chronic illness and disability*
5. Does not address a priority theme

SUMMARY OF AIMS, HYPOTHESES, BRIEF RESEARCH PLAN AND BUDGET

AIMS

A comprehensive model of care will be designed involving a resource derived from already developed technology-enhancing asthma education and self-management tools, workshops with key stakeholders and policy makers, and education delivery to health care professionals inclusive of national key priorities in asthma.

We aim to determine if this model of care can be successfully implemented into clinical practice and policy to inform a sustainable and nationwide upscale and expansion in two parts:

1. Use Kotter's Eight Step Change Model to trigger organisational change and action in key stakeholders and policymakers at local and national levels, to enable the sustainable implementation of our comprehensive asthma model within the clinical setting
2. Via a feasibility and randomised controlled pilot study: Evaluate the feasibility/practicality of delivery of our model-of-care within the paediatric hospital setting and obtain essential data to inform a statistically powered trial for children with asthma

HYPOTHESIS

Stage 1: Three-rounds of evidence translation workshops guided by Kotter's change model will be undertaken with key stakeholders and policymakers, producing:

1. An actionable framework that defines opportunities, enablers, and barriers increasing implementation of evidence-based asthma recommendations in clinical service delivery (i.e., effective translation of our comprehensive model of care), and
2. Engagement, empowerment and activation of stakeholder/policymaker participants to successfully implement identified recommendations, by 12-month follow-up.

Stage 2: Implementation of our comprehensive model of care for children with asthma across three South Australian hospitals will identify:

1. Essential pilot/feasibility data informing scale-up and expansion for funding applications in 2023-24.

BRIEF RESEARCH PLAN

Model-of-care consolidation (Jan-Apr 2023): Asthma education/self-management resources, and health professional (HP) one-hour education session

Building on our community co-designed asthma education and self-management resources, we will consolidate these into one comprehensive package for both patient and HP use.

An 80-page patient education and self-management asthma workbook is embedded with novel augmented reality technology, enabling delivery of digital content via a smartphone. This can address known education barriers associated with: poor health literacy by using video content, low interest by using gamification, and access barriers by delivering treatments directly via the app (e.g., acceptance and commitment therapy by a clinical psychologist).

A one-hour HP education workshop will build off models already pilot tested in South Australian (SA) hospitals, including an update on evidence-based asthma recommendations

for care, advice on how to implement them, and instructions on how to use our patient education/self-management to complement current service delivery.

Stage 1 (Apr23-Apr24): Delivery of workshops and evaluation of Kotter's change model

To ensure successful implementation and sustainability of our care model in the hospital setting, we will recruit key SA stakeholders and policy makers from government, asthma organisations (Lung Foundation, Asthma Australia) and clinical care (WCH and SA Health leaders and executive) to participate in workshops guided by Kotter's model of change.

Three workshops two-months apart with approximately 10 stakeholders total will be shown our model-of-care resources and asked to identify:

a) Opportunities, enablers, and barriers that may increase implementation of our resources delivering evidence-based asthma recommendations in clinical service delivery (i.e., effective translation of our comprehensive model-of-care), which can then be sculpted into an actional framework to support implantation in stage 2, and
b) How to: create a vision for use of this model in practice; communicate that vision; empower others to act on that vision; plan for and create short-term wins; consolidate improvements and produce more change and institutionalise new approaches (i.e., steps 3-8 of Kotter's model)

Success of Kotter's model to increase implementation of best-practice asthma recommendations into service delivery will be determined by mixed-method surveys and one-on-one interviews with stakeholder participants and representatives of end-users within these organisations 12-months post-workshop commencement.

Stage 2 (Sep23-Sep24): Evaluation of comprehensive asthma model-of-care
The framework from Stage:1a will inform implementation of our model-of-care as a feasibility and pilot study, across two hospitals in SA, to inform up-scale and expansion of a statistically powered randomised controlled trial. Hospitals will be randomised to HP training session about capturing data for asthma, or our model-of-care training session plus patient resources they can give to patients.

Data collection: Baseline and 12-months
Outcomes: The RE-AIM (reach, effectiveness, adoption, implementation, and maintenance) framework will identify key feasibility measures to inform up-scale and expansion. We have successfully used this framework in a previous feasibility/pilot study across two SA hospitals for a smoking cessation study (manuscript in production). This will include outcomes such as level of reach (e.g., how many young people with asthma get the resource) and implementation (e.g., degree of resource use and improvements to asthma care).

BRIEFLY DESCRIBE HOW THE RESEARCH OUTCOMES WILL IMPROVE HEALTH, EDUCATION OR WELFARE OUTCOMES FOR CHILDREN

South Australian children have had long standing issues with poor asthma outcomes, with the highest rates of hospitalization nationwide. This is likely multifactorial in nature however poor health literacy, suboptimal self-management skills including incorrect inhaler

technique, and inadequately managed co-morbid anxiety/depression all contribute and are key priorities in management.

Over our last eight years of research, multiple technology-enhanced asthma education and self-management tools have been developed. Using this grant, we propose to combine these into one comprehensive resource which addresses the above key priorities. By utilising augmented reality to deliver this education, skills training and cognitive based therapy via smartphone applications, we are using an accessible and innovative technology which has already been shown to be an acceptable delivery mechanism and has been used in other areas of education and health.

We aim to successfully implement this intervention into the clinical world and make this sustainable, via our proposed asthma care model involving key stakeholders and policymakers to drive change, as well as health care professionals to facilitate integration. If achieved, our research will improve health outcomes for children with asthma by improving health literacy, self-management skills and address the significant impact mental health has on asthma morbidity and mortality.

RELATED RESEARCH

Provide details of any similar peer-reviewed research being undertaken in this field by others. Provide references (with comment on the referenced research if considered helpful) to similar work being done in the field of the application by other researchers in Australia. The question is not related to research done (or to be done) by the applicant.

The use of Kotter's Change Model (KCM) as a framework for driving organisational change has strong evidence, including within healthcare (1). With the ability for it to simultaneously collect essential information such as exploration of the need for change from key individuals and leaders, and directly engage and empower participants, it has been proven to be a well adopted framework for invoking change at local, institutional, system-wide and multi-system levels. This has been best demonstrated in a recent systematic review which included studies which utilised change management methodologies within the context of healthcare (2). KCM was the most commonly applied change management methodology applied in almost 50% of studies and many of the studies which adopted KCM had positive outcomes including reductions in surgical wound site infections, improved patient satisfaction and timelier access to specialist appointments (2). Recently, the successful use of KCM as a change management tool was also reported to reduce surgical instrumentation inventory within high volume surgical centres, which resulted in significant cost savings of almost CA$100,000 per year for the included centres (3). It has also been successfully utilised to engage leaders within the United States to empower and implement major system changes which resulted in reduction in teenage pregnancy within a community by 65% (4). On an international scale, the use of KCM has also been successful in achieving multi-country endorsement of an integrated care pathway which utilises mobile technology for those with allergic rhinitis and asthma multimorbidity, including it's addition to multiple national programs and within treatment classifications (5). In regards to service delivery change in asthma specifically, the literature is scarce, however the success of utilisation of

KCM was also recently reported within a small hospital in Nigeria in decreasing emergency department visits and increasing attendance of clinic visits in children with asthma (6).

References

1. Kotter, J.P., *Leading change*. 2012: Harvard Business Review Press, p. 1-194.
2. Harrison 2021 DOI: 10.2147/JHL.S289176
3. Toor 2022 DOI: 10.1016/j.jcjq.2021.09.011
4. Caulfield 2019 DOI: https://doi.org/10.1002/nml.21399
5. Bousquet 2019 DOI: https://doi.org/10.1016/j.jaci.2018.08.049
6. Onubogu 2019 DOI: 10.4236/ojrd.2019.91003

PROJECT DURATION
2 years

BUDGET ESTIMATE
100000

SECTION D: RECIPIENT
Administering Institution: University of Adelaide
Research secretariat contact: Dr. Dale Godfrey

SECTION E: PERSON AUTHORISING EXPRESSION OF INTEREST

Title: Dr.
First name: Andrew
Surname: Tai
Position title: Paediatric Respiratory and Sleep Consultant Physician, Head of Respiratory and Sleep Department
Insitution: Women's and Children's Health Network
Phone number – authorizer: (08) 8161 7234
Email: Andrew.tai@sa.gov.au

References

1. Diamant Z, Diderik Boot J, Christian Virchow J. Summing up 100 years of asthma. Respiratory Medicine. 2007;101(3):378-88.

2. Holgate ST. A brief history of asthma and its mechanisms to modern concepts of disease pathogenesis. Allergy, asthma & immunology research. 2010;2(3):165-71.

3. Cserháti E. The history of bronchial asthma from the Renaissance till the beginning of the twentieth century. Acta Physiologica Hungarica. 2005;92(2):181-92.

4. Salter HH. On asthma: its pathology and treatment: Churchill; 1868.

5. Dharmage SC, Perret JL, Custovic A. Epidemiology of Asthma in Children and Adults. Frontiers in Pediatrics. 2019;7.

6. Ebmeier S, Thayabaran D, Braithwaite I, Bénamara C, Weatherall M, Beasley R. Trends in international asthma mortality: analysis of data from the WHO Mortality Database from 46 countries (1993–2012). The Lancet. 2017;390(10098):935-45.

7. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention. 2022.

8. Global Asthma Network. The Global Asthma Report 2014. Auckland, New Zealand. 2014;769:28-36.

9. Australian Institute of Health and Welfare. Australian's Children. Canberra; AIHW 2020.

10. Australian Institute of Health and Welfare. Asthma Web Report. Canberra; AIHW; 2020 25 August 2020.

11. Global Initiative For Asthma. Global Strategy for Asthma Management and Prevention 2020 [Available from: www.ginasthma.org.]

12. Dinakar C, Chipps BE, Matsui EC, Abramson SL, Irani A-M, Kim JS, et al. Clinical tools to assess asthma control in children. Pediatrics. 2017;139(1).

13. Taylor D, Bateman E, Boulet L, Boushey H, Busse W, Casale T, et al. A new perspective on concepts of asthma severity and control. European Respiratory Journal. 2008;32(3):545-54.

14. Deschildre A, Pin I, El Abd K, Belmin-Larrar S, El Mourad S, Thumerelle C, et al. Asthma control assessment in a pediatric population: comparison between GINA/NAEPP guidelines, Childhood Asthma Control Test (C-ACT), and physician's rating. Allergy. 2014;69(6):784-90.

15. Fleming L, Murray C, Bansal AT, Hashimoto S, Bisgaard H, Bush A, et al. The burden of severe asthma in childhood and adolescence: results from the paediatric U-BIOPRED cohorts. European Respiratory Journal. 2015;46(5):1322-33.

16. Control CfD. Uncontrolled asthma among children, 2012–2014 [Internet]. Centers for Disease Control; 2019 Jul [cited 2019 Oct 2].

17. Aschalew A, Kebed RA, Demie TG, Weldetsadik AY. Assessment of level of asthma control and related factors in children attending pediatric respiratory clinics in Addis Ababa, Ethiopia. BMC Pulmonary Medicine. 2022;22(1):70.

18. Licari A, Brambilla I, Marseglia A, De Filippo M, Paganelli V, Marseglia GL. Difficult vs. severe asthma: definition and limits of asthma control in the pediatric population. Frontiers in pediatrics. 2018;6:170.

19. Kansen HM, Le TM, Uiterwaal CS, van Ewijk BE, Balemans WA, Gorissen DM, et al. Prevalence and predictors of uncontrolled asthma in children referred for asthma and other atopic diseases. Journal of asthma and allergy. 2020;13:67.

20. Boulet LP. Influence of comorbid conditions on asthma. European Respiratory Journal. 2009;33(4):897.

21. Scottish Intercollegiate Guidelines Network (SIGN 158). British Guideline on the Management of Asthma. 2019 25/4/2022 [cited July 2019. Available from: https://www.sign.ac.uk/our-guidelines/british-guideline-on-the-management-of-asthma/.]

22. Pedersen S, Dubus JC, Crompton GK. The ADMIT series--issues in inhalation therapy. 5) Inhaler selection in children with asthma. Primary care respiratory journal. 2010;19(3):209-16.

23. Román-Rodríguez M, Metting E, Gacía-Pardo M, Kocks J, van der Molen T. Wrong inhalation technique is associated to poor asthma clinical outcomes. Is there room for improvement? Current Opinion in Pulmonary Medicine. 2019;25(1).

24. Brocklebank D, Ram F, Wright J, Barry P, Cates C, Davies L, et al. Comparison of the effectiveness of inhaler devices in asthma and chronic obstructive airways disease: a systematic review of the literature. Health technology assessment (Winchester, England). 2001;5(26):1-149.

25. Haughney J, Price D, Barnes NC, Virchow JC, Roche N, Chrystyn H. Choosing inhaler devices for people with asthma: Current knowledge and outstanding research needs. Respiratory medicine. 2010;104(9):1237-45.

26. Gillette CP, Rockich-Winston NMSP, Kuhn JA, Flesher SMD, Shepherd MMD. Inhaler Technique in Children With Asthma: A Systematic Review. Academic pediatrics. 2016;16(7):605-15.

27. National Heart Lung Blood Institute. Guidelines for the Diagnosis and Management of Asthma (EPR-3). 2007. 2020.

28. Melani AS. Inhaler technique in asthma and COPD: challenges and unmet knowledge that can contribute to suboptimal use in real life. Expert Review of Clinical Pharmacology. 2021;14(8):991-1003.

29. Zambelli-Simões L, Martins MC, Possari JCC, Carvalho GB, Coelho ACC, Cipriano SL, et al. Validation of scores of use of inhalation devices: Valoration of errors. J Bras Pneumol. 2015;41(4):313-22.

30. Vanderman AJ, Moss JM, Bailey JC, Melnyk SD, Brown JN. Inhaler misuse in an older adult population. Consultant Pharmacist. 2015;30(2):92-100.

31. Sadowski CA, Cor K, Cave A, Banh HL. Administration Technique and Acceptance of Inhaler Devices in Patients With Asthma or COPD. The Annals of pharmacotherapy. 2015;49(6):639-48.

32. Price DB, Roman-Rodriguez M, McQueen RB, Bosnic-Anticevich S, Carter V, Gruffydd-Jones K, et al. Inhaler Errors in the CRITIKAL Study: Type, Frequency, and Association with Asthma Outcomes. J Allergy Clin Immunol Pract. 2017;5(4):1071-81 e9.

33. Price D, Bosnic-Anticevich S, Briggs A, Chrystyn H, Rand C, Scheuch G, et al. Inhaler competence in asthma: Common errors, barriers to use and recommended solutions. Respiratory medicine. 2012;107(1):37-46.

34. Al-Jahdali H, Ahmed A, Al-Harbi A, Khan M, Baharoon S, Bin Salih S, et al. Improper inhaler technique is associated with poor asthma control and frequent emergency department visits. Allergy, asthma, and clinical immunology. 2013;9(1):8-.

35. Capanoglu M, Dibek Misirlioglu E, Toyran M, Civelek E, Kocabas CN. Evaluation of inhaler technique, adherence to therapy and their effect on disease control among children with asthma using metered dose or dry powder inhalers. The Journal of asthma. 2015;52(8):838-45.

36. Padmanabhan M, Tamilarasu K, Rajaram M, Batmanabane G. Inadequate inhaler technique, an everlasting problem, is associated with poor disease control – A cross sectional study. Advances in respiratory medicine. 2019;87(4):217-25.

37. Basheti IA, Armour CL, Bosnic-Anticevich SZ, Reddel HK. Evaluation of a novel educational strategy, including inhaler-based reminder labels, to improve asthma inhaler technique. Patient Education and Counseling. 2008;72(1):26-33.

38. Crane MA, Jenkins CR, Goeman DP, Douglass JA. Inhaler device technique can be improved in older adults through tailored education: Findings from a randomised controlled trial. npj Prim Care Respir Med. 2014;24.

39. Hammerlein A, Muller U, Schulz M. Pharmacist-led intervention study to improve inhalation technique in asthma and COPD patients. Journal of Evaluation in Clinical Practice. 2011;17(1):61-70.

40. Levy ML, Hardwell A, McKnight E, Holmes J. Asthma patients' inability to use a pressurised metered-dose inhaler (pMDI) correctly correlates with poor asthma control as defined by the Global Initiative for Asthma (GINA) strategy: A retrospective analysis. Primary care respiratory journal. 2013;22(4):406-11.

41. Normansell R, Kew KM, Mathioudakis AG. Interventions to improve inhaler technique for people with asthma. Cochrane Database Syst Rev. 2017;3:CD012286.

42. Basheti IABS, Reddel HKMPF, Armour CLBP, Bosnic-Anticevich SZBP. Improved asthma outcomes with a simple inhaler technique intervention by community pharmacists. Journal of allergy and clinical immunology. 2007;119(6):1537-8.

43. Melani AS, Bonavia M, Cilenti V, Cinti C, Lodi M, Martucci P, et al. Inhaler mishandling remains common in real life and is associated with reduced disease control. Respiratory medicine. 2011;105(6):930-8.

44. Klijn SL, Hiligsmann M, Evers SMAA, Román-Roíguez M, van der Molen T, van Boven JFM. Effectiveness and success factors of educational inhaler technique interventions in asthma & COPD patients: a systematic review. NPJ primary care respiratory medicine. 2017;27(1):24-10.

45. McCrossan P, Mallon O, Shields MD, Russell C, Kennedy L, O'Donoghue D. How we teach children with asthma to use their inhaler: a scoping review. Italian Journal of Pediatrics. 2022;48(1):52.

46. Almomani BA, Al-Qawasmeh BS, Al-Shatnawi SF, Awad S, Alzoubi SA. Predictors of proper inhaler technique and asthma control in pediatric patients with asthma. Pediatric pulmonology. 2021;56(5):866-74.

47. Litt HK, Press VG, Hull A, Siros M, Luna V, Volerman A. Association between inhaler technique and confidence among hospitalized children with asthma. Respiratory medicine. 2020;174:106191-.

48. Samady W, Rodriguez VA, Gupta R, Palac H, Karamanis M, Press VG. Critical Errors in Inhaler Technique among Children Hospitalized with Asthma. Journal of Hospital Medicine. 2019;14(6):361-5.

49. Sanchis J, Gich I, Pedersen S. Systematic Review of Errors in Inhaler Use: Has Patient Technique Improved Over Time? Chest. 2016;150(2):394-406.

50. Kane JM. Technology-based interventions in health care. Epidemiology and psychiatric sciences. 2014;23(4):323-6.

51. Free C, Phillips G, Felix L, Galli L, Patel V, Edwards P. The effectiveness of M-health technologies for improving health and health services: a systematic review protocol. BMC research notes. 2010;3(1):250-.

52. Amdie F, Woo K. The use of mHealth technology for chronic disease management the challenges and opportunities for practical application. Wounds Int. 2020;11:32-8.

53. Adans-Dester CP, Bamberg S, Bertacchi FP, Caulfield B, Chappie K, Demarchi D, et al. Can mHealth Technology Help Mitigate the Effects of the COVID-19 Pandemic? IEEE Open Journal of Engineering in Medicine and Biology. 2020;1:243-8.

54. Yi JY, Kim Y, Cho Y-M, Kim H. Self-management of chronic conditions using mHealth interventions in Korea: a systematic review. Healthcare informatics research. 2018;24(3):187-97.

55. Lee J-A, Choi M, Lee SA, Jiang N. Effective behavioral intervention strategies using mobile health applications for chronic disease management: a systematic review. BMC medical informatics and decision making. 2018;18(1):1-18.

56. Lau N, Waldbaum S, Parigoris R, O'Daffer A, Walsh C, Colt SF, et al. eHealth and mHealth Psychosocial Interventions for Youths With Chronic Illnesses: Systematic Review. JMIR Pediatr Parent. 2020;3(2):e22329.

57. Triantafyllidis A, Kondylakis H, Votis K, Tzovaras D, Maglaveras N, Rahimi K. Features, outcomes, and challenges in mobile health interventions for patients living with chronic diseases: A review of systematic reviews. International journal of medical informatics. 2019;132:103984.

58. Farzandipour M, Nabovati E, Sharif R, Arani MH, Anvari S. Patient Self-Management of Asthma Using Mobile Health Applications: A Systematic Review of the Functionalities and Effects. Appl Clin Inform. 2017;8(4):1068-81.

59. Hui CY, Walton R, McKinstry B, Jackson T, Parker R, Pinnock H. The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. J Am Med Inform Assoc. 2017;24(3):619-32.

60. Ferrante G, Licari A, Marseglia GL, La Grutta S. Digital health interventions in children with asthma. Clinical and experimental allergy. 2021;51(2):212-20.

61. Doshi H, Hsia B, Shahani J, Mowrey W, Jariwala SP. Impact of Technology-Based Interventions on Patient-Reported Outcomes in Asthma: A Systematic Review. The Journal of Allergy and Clinical Immunology: In Practice. 2021;9(6):2336-41.

62. Huckvale K, Car M, Morrison C, Car J. Apps for asthma self-management: a systematic assessment of content and tools. BMC medicine. 2012;10(1):144-.

63. 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. 2020;26(1):342-53.

64. Wu AC, Carpenter JF, Himes BE. Mobile health applications for asthma. The Journal of Allergy and Clinical Immunology: In Practice. 2015;3(3):446-8. e16.

65. Burns T, Gottschalk F. Educating 21st century children : emotional well-being in the digital age. Paris: OECD Publishing; 2019.

66. Neumann MM. Young children and screen time: Creating a mindful approach to digital technology. Australian educational computing. 2015;30(2).

67. Tiller E, Greenland N, Christie R, Kos A, Brennan N, Di Nicola K. Youth Survey Report 20212021.

68. Al Raimi AM, Chong MC, Tang LY, Chua YP, Al Ajeel LY. The effect of mobile applications in enhancing asthma knowledge among school children with asthma in Malaysia. Journal of pediatric nursing. 2022.

69. Drummond D, Monnier D, Tesnière A, Hadchouel A. A systematic review of serious games in asthma education. Pediatric allergy and immunology. 2017;28(3):257-65.

70. Ramsey RR, Plevinsky JM, Kollin SR, Gibler RC, Guilbert TW, Hommel KA. Systematic Review of Digital Interventions for Pediatric Asthma Management. The Journal of Allergy and Clinical Immunology: In Practice. 2020;8(4):1284-93.

71. Akcayir M, Akcayir G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review. 2017;20:1-11.

72. GlobalData. Thematic Sentiment Analysis, Q4 2021 - Thematic Research. London: GlobalData; 2022.

73. Sounderajah V, Patel V, Varatharajan L, Harling L, Normahani P, Symons J, et al. Are disruptive innovations recognised in the healthcare literature? A systematic review. BMJ Innovations. 2021;7(1):208.

74. Guevara J. 5 recent tech innovations disrupting the medical and healthcare industry. 2020 [Available from: https://www.healthtechzone.com/topics/healthcare/articles/2020/08/27/446396-5-recent-tech-innovations-disrupting-medical-healthcare-industry.htm.]

75. Bacca J, Baldiris S, Fabregat R, Kinshuk. Insights Into the Factors Influencing Student Motivation in Augmented Reality Learning Experiences in Vocational Education and Training. Frontiers in Psychology. 2018;9(1486).

76. Eckert M, Volmerg JS, Friedrich CM. Augmented Reality in Medicine: Systematic and Bibliographic Review. JMIR Mhealth Uhealth. 2019;7(4):e10967.

77. Hrishikesh N, Nair JJ. Interactive learning system for the hearing impaired and the vocally challenged. International Conference on Advances in Computing, Communications and Informatics (ICACCI). 2016:1079-83.

78. Lavoye V, Mero J, Tarkiainen A. Consumer behavior with augmented reality in retail: a review and research agenda. The International review of retail, distribution and consumer research. 2021;31(3):299-329.

79. McGuirt JT, Cooke NK, Burgermaster M, Enahora B, Huebner G, Meng Y, et al. Extended reality technologies in nutrition education and behavior: Comprehensive scoping review and future directions. Nutrients. 2020;12(9):1-14.

80. Santos MEC, Chen A, Taketomi T, Yamamoto G, Miyazaki J, Kato H. Augmented Reality Learning Experiences: Survey of Prototype Design and Evaluation. IEEE transactions on learning technologies. 2014;7(1):38-56.

81. Klopfer E, Squire K. Environmental Detectives—The Development of an Augmented Reality Platform for Environmental Simulations. Educational technology research and development. 2008;56(2):203-28.

82. Sumadio DD, Rambli DRA, editors. Preliminary Evaluation on User Acceptance of the Augmented Reality Use for Education2010: IEEE.

83. María Blanca Ibáñez ÁDS, Diego Villarán, Carlos Delgado Kloos. Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. Computers & Education. 2014;71:1-13.

84. Fidan M, Tuncel M. Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. Computers & Education. 2019;142:103635.

85. Sahin D, Yilmaz RM. The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Computers & Education. 2020;144:103710.

86. Phon DNEA, M. B.; Halim N. D. A. Collaborative Augmented Reality in Education: A Review. International Conference on Teaching and Learning in Computing and Engineering. 2014:78-83.

87. Tosti H.C. Chiang SJHY, Gwo-Jen Hwang. Students' online interactive patterns in augmented reality-based inquiry activities. Computers & Education. 2014;78: 97-108.

88. Verma JP, Verma P. Determining Sample Size and Power in Research Studies A Manual for Researchers. 1st ed. 2020. ed. Singapore: Springer Singapore; 2020.

89. Garzón J, Pavón J, Baldiris S. Systematic review and meta-analysis of augmented reality in educational settings. Virtual Reality. 2019;23(4):447-59.

90. Khan T, Johnston K, Ophoff J. The Impact of an Augmented Reality Application on Learning Motivation of Students. Advances in Human-Computer Interaction. 2019;2019:7208494.

91. Suzuki E, Narumi T, Sakurai S, Tanikawa T, Hirose M, editors. Changing Drinking Behavior and Beverage Consumption Using Augmented Reality. Human Interface and the Management of Information Information and Knowledge Design; 2015 2015//; Cham: Springer International Publishing.

92. Lacka E. Assessing the impact of full-fledged location-based augmented reality games on tourism destination visits. Current Issues in Tourism. 2020;23(3):345-57.

93. Tang KS, Cheng DL, Mi E, Greenberg PB. Augmented reality in medical education: a systematic review. Canadian medical education journal. 2020;11(1):e81.

94. Moro C, Phelps C, Redmond P, Stromberga Z. HoloLens and mobile augmented reality in medical and health science education: A randomised controlled trial. British Journal of Educational Technology. 2021;52(2):680-94.

95. Kuehn BM. Virtual and augmented reality put a twist on medical education. Jama. 2018;319(8):756-8.

96. Bacca J, Baldiris S, Fabregat R, Graf S. Augmented reality trends in education: a systematic review of research and applications. 2014.

97. Kim H, Xie B. Health literacy in the eHealth era: A systematic review of the literature. Patient Education and Counseling. 2017;100(6):1073-82.

98. Suha A-N, Peter B, Thomas A, Chris J, Fandi I, Mohamed A-M. Examining the Efficacy of a Novel Augmented Reality Mobile Delivery Platform for the Enhancement of

Asthma Care Education for Children. International journal of interactive mobile technologies. 2021;15(7):47-68.

99. Deloitte Access Economics. The Hidden Cost of Asthma2015:[1-120 pp.]. Available from: file:///C:/Users/carsonk/Downloads/deloitte-au-economics-hidden-cost-asthma-241115.pdf [date accessed 19/03/2019].

100. Australian Institute of Health and Welfare. Australia's Health 2018. Australia's Health series no 16 [Internet]. 2018; AUS 221.

101. Asher MI, García-Marcos L, Pearce NE, Strachan DP. Trends in worldwide asthma prevalence. Eur Respir J. 2020;56(6).

102. Asher MI, Rutter CE, Bissell K, Chiang C-Y, El Sony A, Ellwood E, et al. Worldwide trends in the burden of asthma symptoms in school-aged children: Global Asthma Network Phase I cross-sectional study. The Lancet. 2021;398(10311):1569-80.

103. Harris K, Kneale D, Lasserson TJ, McDonald VM, Grigg J, Thomas J. School-based self-management interventions for asthma in children and adolescents: a mixed methods systematic review. Cochrane Database of Systematic Reviews. 2019(1).

104. Cowdell F, Dyson J. How is the theoretical domains framework applied to developing health behaviour interventions? A systematic search and narrative synthesis. BMC Public Health. 2019;19(1):1180.

105. Wartella E, Rideout V, Montague H, Beaudoin-Ryan L, Lauricella A. Teens, Health and Technology: A National Survey. Media and communication (Lisboa). 2016;4(3):13-23.

106. Lewis JR. The System Usability Scale: Past, Present, and Future. International Journal of Human–Computer Interaction. 2018;34(7):577-90.

107. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Services Research. 2017;17(1):88.

108. Sekhon M, Cartwright M, Francis JJ. Development of a theory-informed questionnaire to assess the acceptability of healthcare interventions. BMC Health Services Research. 2022;22(1):279.

109. O'Connor A, Tai A, Kopsaftis Z, Carson-Chahhoud K. Qualitative Study Protocol: Augmented Reality Technology to Deliver Asthma Inhaler Technique Training for Children and Adolescents With Asthma. International journal of qualitative methods. 2021;20:160940692110422.

110. Janes C, Andrews T, Adbel-Maguid M. Designing an Augmented Reality Smartphone Application for the Enhancement of Asthma Care Education. Advances in Intelligent Systems and Computing. Cham: Springer International Publishing; 2018. p. 11-7.

111. Calderón J, Cherrez A, Ramón GD, Lopez Jove O, Baptist A, Matos E, et al. Information and communication technology use in asthmatic patients: a cross-sectional study in Latin America. ERJ open research. 2017;3(3):5.

112. Free C, Phillips G, Felix L, Galli L, Patel V, Edwards P. The effectiveness of M-health technologies for improving health and health services: a systematic review protocol. BMC Research Notes. 2010;3(1):250.

113. Alquran A, Lambert KA, Farouque A, Holland A, Davies J, Lampugnani ER, et al. Smartphone Applications for Encouraging Asthma Self-Management in Adolescents: A

Systematic Review. International journal of environmental research and public health. 2018;15(11):2403.

114. Marcolino MS, Oliveira JAQ, D'Agostino M, Ribeiro AL, Alkmim MBM, Novillo-Ortiz D. The Impact of mHealth Interventions: Systematic Review of Systematic Reviews. JMIR Mhealth Uhealth. 2018;6(1):e23.

115. Tangari G, Ikram M, Ijaz K, Kaafar MA, Berkovsky S. Mobile health and privacy: cross sectional study. BMJ (Online). 2021;373:n1248-n.

116. Chan A, Kow R, Cheng JK. Adolescents' perceptions on smartphone applications (apps) for health management. Journal of mobile technology in medicine. 2017;6(2):47-55.

117. Dias P, Brito R. Criteria for selecting apps: Debating the perceptions of young children, parents and industry stakeholders. Computers & Education. 2021;165:104134.

118. Kim Y, Ju H. Needs and expectations for an AR program for asthma education for school-age children in South Korea: The perspectives of children, parents, and teachers. Child health nursing research. 2021;27(4):365-76.

119. 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):1018-27.

120. Kim S, Park Y, Ackerman MK. Designing an Indoor Air Quality Monitoring App for Asthma Management in Children: User-Centered Design Approach. JMIR formative research. 2021;5(9):e27447.

121. 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-e.

122. Schneider T, Panzera AD, Couluris M, Lindenberger J, McDermott R, Bryant CA. Engaging Teens with Asthma in Designing a Patient-Centered Mobile App to Aid Disease Self-Management. Telemedicine journal and e-health. 2016;22(2):170-5.

123. Sonney J, Duffy M, Hoogerheyde LX, Langhauser E, Teska D. Applying Human-Centered Design to the Development of an Asthma Essentials Kit for School-Aged Children and Their Parents. Journal of pediatric health care. 2019;33(2):169-77.

124. Slater H, Campbell JM, Stinson JN, Burley MM, Briggs AM. End User and Implementer Experiences of mHealth Technologies for Noncommunicable Chronic Disease Management in Young Adults: Systematic Review. J Med Internet Res. 2017;19(12):e406.

125. Bergin AD, Vallejos EP, Davies EB, Daley D, Ford T, Harold G, et al. Preventive digital mental health interventions for children and young people: a review of the design and reporting of research. NPJ digital medicine. 2020;3(1):1-9.

126. Sanders EBN, Stappers PJ. Co-creation and the new landscapes of design. CoDesign. 2008;4(1):5-18.

127. Noorbergen TJ, Adam MTP, Teubner T, Collins CE. Using Co-design in Mobile Health System Development: A Qualitative Study With Experts in Co-design and Mobile Health System Development. JMIR Mhealth Uhealth. 2021;9(11):e27896.

128. Li SH, Achilles MR, Spanos S, Habak S, Werner-Seidler A, O'Dea B. A cognitive behavioural therapy smartphone app for adolescent depression and anxiety: co-design of ClearlyMe. The Cognitive Behaviour Therapist. 2022;15:e13.

129. Baker TB, Gustafson DH, Shah D. How can research keep up with eHealth? Ten strategies for increasing the timeliness and usefulness of eHealth research. Journal of medical Internet research. 2014;16(2):e36-e.

130. National Asthma Council Australia. Australian Asthma Handbook, Version 2.2. Melbourne: National Asthma Council Australia; 2022 [Available from: http://www.asthmahandbook.org.au.]

131. Fernandes JC, Biskupiak WW, Brokaw SM, Carpenedo D, Loveland KM, Tysk S, et al. Outcomes of the Montana Asthma Home Visiting Program: A home-based asthma education program. Journal of Asthma. 2019;56(1):104-10.

132. Carson-Chahhoud K, Kopsaftis Z, Brinn M, Sharrad K, Esterman A, Bell R, et al., editors. Halving avoidable asthma presentations by 2030: A rapid evidence review. RESPIROLOGY; 2022: WILEY 111 RIVER ST, HOBOKEN 07030-5774, NJ USA.

133. Flocke SA, Clark E, Antognoli E, Mason MJ, Lawson PJ, Smith S, et al. Teachable moments for health behavior change and intermediate patient outcomes. Patient education and counseling. 2014;96(1):43-9.

134. Kells M, Rogers J, Oppenheimer SC, Blaine K, McCabe M, McGrath E, et al. The Teachable Moment Captured: A Framework for Nurse-led Smoking Cessation Interventions for Parents of Hospitalized Children. Public health nursing. 2013;30(5):468-73.

135. Akinbami LJ, Salo PM, Cloutier MM, Wilkerson JC, Elward KS, Mazurek JM, et al. Primary care clinician adherence with asthma guidelines: the National Asthma Survey of Physicians. The Journal of asthma. 2020;57(5):543-55.

136. Guastaferro K, Self-Brown S, Shanley JR, Whitaker DJ, Lutzker JR. Engagement in Home Visiting: An Overview of the Problem and How a Coalition of Researchers Worked to Address this Cross-model Concern. Journal of child and family studies. 2018;29(1):4-10.

137. Welsh EJ, Hasan M, Li P, Welsh EJ. Home-based educational interventions for children with asthma. Cochrane database of systematic reviews. 2011;2014(9):CD008469-CD.

138. Sharrad KJ, Kopsaftis ZA, Carson-Chahhoud KV, Stallman HM. The modifiable biopsychosocial drivers of psychological distress for adolescents with asthma: Implications for Clinical Care. Paediatric respiratory reviews. 2021.

139. Stempel H, Federico MJ, Szefler SJ. Applying a biopsychosocial model to inner city asthma: Recent approaches to address pediatric asthma health disparities. Paediatric respiratory reviews. 2019;32:10-5.

140. Eguiluz-Gracia I, van den Berge M, Boccabella C, Bonini M, Caruso C, Couto M, et al. Real-life impact of COVID-19 pandemic lockdown on the management of pediatric and adult asthma: A survey by the EAACI Asthma Section. Allergy (Copenhagen). 2021;76(9):2776-84.

141. Papadopoulos NG, Custovic A, Deschildre A, Mathioudakis AG, Phipatanakul W, Wong G, et al. Impact of COVID-19 on Pediatric Asthma: Practice Adjustments and Disease Burden. The journal of allergy and clinical immunology in practice (Cambridge, MA). 2020;8(8):2592-9.e3.

142. Bunn F, Trivedi D, Alderson P, Hamilton L, Martin A, Iliffe S. The impact of Cochrane Systematic Reviews: a mixed method evaluation of outputs from Cochrane

Review Groups supported by the UK National Institute for Health Research. Systematic Reviews. 2014;3(1):125.

143. Chandler J CM, Thomas J, Higgins JPT, Deeks JJ, Clarke MJ. Chapter I: Introduction. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). . Cochrane Handbook for Systematic Reviews of Interventions Cochrane; 2022.

144. National Library of Medicine. Citations Added to MEDLINE by Fiscal Year [updated May 27, 2022. Available from: https://www.nlm.nih.gov/bsd/stats/cit_added.html#1.]

145. Pontis S, Blandford A, Greifeneder E, Attalla H, Neal D. Keeping up to date: An academic researcher's information journey. Journal of the Association for Information Science and Technology. 2017;68(1):22-35.

146. Li L, Smith HE, Atun R, Tudor Car L. Search strategies to identify observational studies in MEDLINE and Embase. Cochrane Database of Systematic Reviews. 2019(3).

147. Aromataris E, Pearson A. The Systematic Review: An Overview. AJN The American Journal of Nursing. 2014;114(3).

148. Altman DG, Egger M, Davey Smith G. Systematic reviews in health care meta-analysis in context. 2nd ed. ed. London: BMJ; 2001.

149. World Health Organization. WHO guideline on health policy and system support to optimize community health worker programmes: World Health Organization; 2018.

150. Martin MA, Pugach O, Mosnaim G, Weinstein S, Rosales G, Roy A, et al. Community Health Worker Asthma Interventions for Children: Results From a Clinically Integrated Randomized Comparative Effectiveness Trial (2016–2019). American journal of public health (1971). 2021;111(7):e1-e10.

151. Tulenko K, Mgedal S, Afzal MM, Frymus D, Oshin A, Pate M, et al. Community health workers for universal health-care coverage: from fragmentation to synergy. Bulletin of the World Health Organization. 2013;91:847-52.

152. Ahmed S, Chase LE, Wagnild J, Akhter N, Sturridge S, Clarke A, et al. Community health workers and health equity in low- and middle-income countries: systematic review and recommendations for policy and practice. International Journal for Equity in Health. 2022;21(1):49.

153. Skinner A, Falster K, Gunasekera H, Burgess L, Sherriff S, Deuis M, et al. Asthma in urban Aboriginal children: A cross-sectional study of socio-demographic patterns and associations with pre-natal and current carer smoking. Journal of paediatrics and child health. 2020;56(9):1448-57.

154. Brew B, Gibberd A, Marks GB, Strobel N, Allen CW, Jorm L, et al. Identifying preventable risk factors for hospitalised asthma in young Aboriginal children: a whole-population cohort study. Thorax. 2021;76(6):539-46.

155. Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. Administration and policy in mental health and mental health services research. 2013;42(5):533-44.

156. Kotter JP. Leading change. Boston: Harvard Business School Press; 1996.

157. Harrison R, Fischer S, Walpola RL, Chauhan A, Babalola T, Mears S, et al. Where Do Models for Change Management, Improvement and Implementation Meet? A

Systematic Review of the Applications of Change Management Models in Healthcare. Journal of healthcare leadership. 2021;13:85-108.

158. Caulfield JL, Brenner EF. Resolving complex community problems: Applying collective leadership and Kotter's change model to wicked problems within social system networks. Nonprofit management & leadership. 2020;30(3):509-24.

159. Hellings PW, Agache I, Ansotegui IJ, Bewick M, Bindslev-Jensen C, Correia de Sousa J, et al. Allergic Rhinitis and its Impact on Asthma (ARIA) Phase 4 (2018): Change management in allergic rhinitis and asthma multimorbidity using mobile technology. Journal of allergy and clinical immunology. 2019;143(3):864-79.

160. Toor J, Du JT, Koyle M, Abbas A, Shah A, Bassi G, et al. Inventory Optimization in the Perioperative Care Department Using Kotter's Change Model. The Joint Commission Journal on Quality and Patient Safety. 2022;48(1):5-11.

161. Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. BMJ. 2021;374:n2061.

162. Eldridge SM, Ashby D, Feder GS, Rudnicka AR, Ukoumunne OC. Lessons for cluster randomized trials in the twenty-first century: a systematic review of trials in primary care. Clinical Trials. 2004;1(1):80-90.

163. Glasgow RE, Harden SM, Gaglio B, Rabin B, Smith ML, Porter GC, et al. RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review. Frontiers in Public Health. 2019;7.

164. Hill C, Martin JL, Thomson S, Scott-Ram N, Penfold H, Creswell C. Navigating the challenges of digital health innovation: considerations and solutions in developing online and smartphone-application-based interventions for mental health disorders. The British Journal of Psychiatry. 2017;211(2):65-9.

165. Morris ZS, Wooding S, Grant J. The answer is 17 years, what is the question: understanding time lags in translational research. Journal of the Royal Society of Medicine. 2011;104(12):510-20.