School-based self-management interventions for asthma among primary school children

School-based self-management interventions for asthma among primary school children: A systematic review

Siti Nurkamilla Ramdzan, MMed[1,2], Julia Suhaimi, MMed[1], Katherine M. Harris, PhD[3], Ee Ming Khoo, MD[1], Su May Liew, DPhil[1], Steve Cunningham, PhD[2], Hilary Pinnock, MD*[2] on behalf of RESPIRE collaborators

[1]*Department of Primary Care Medicine, Faculty of Medicine, University of Malaya, Malaysia*

[2]*NIHR Global Health Research Unit on Respiratory Health (RESPIRE), Usher Institute, University of Edinburgh, United Kingdom*

[3] *Centre for Child Health, Blizard Institute, Queen Mary University of London, London, E1 2AT*

Address for correspondence
*Professor Hilary Pinnock
NIHR Global Health Research Unit on Respiratory Health (RESPIRE),
Usher Institute,
The University of Edinburgh.
Doorway 3, Medical School, Teviot Place,
Edinburgh EH8 9AG, UK
Tel: 0131 650 9474
Email: Hilary.Pinnock@ed.ac.uk

Main text word count: 3177(excluding abstract, main headings, tables, references, and additional information e.g. acknowledgement, funding, competing interest)

Abstract

A Cochrane review of school-based asthma interventions (combining all ages) found improved health outcomes. Self-management skills, however, vary according to age. We assessed effectiveness of primary school-based self-management interventions and identified components associated with successful programmes in children aged 6-12 years. We updated the Cochrane search (March 2020) and included the Global Health database. Two reviewers screened, assessed risk-of-bias and extracted data. We included 23 studies (10,682 participants); four at low risk-of-bias. Twelve studies reported at least one positive result for an outcome of interest. All 12 positive studies reported parental involvement in the intervention, compared to two-thirds of ineffective studies. In 10 of the 12 positive studies, parental involvement was substantial (e.g. attending sessions; phone/video communication) rather than being provided with written information. School-based self-management intervention can improve health outcomes and substantial parental involvement in school-based programmes seemed important for positive outcomes among primary school children.

Word count: 147 (Maximum: 150)

Keywords: systematic review, school-based, self-management, primary school children, and parental involvement

Introduction

Asthma, the commonest long-term condition among children, causes significant morbidity and mortality globally[1]. Asthma guidelines recommend supported self-management to improve asthma control and reduce the use of urgent healthcare services[2-4]. Supported self-management, which includes discussion about self-management and provision of a personalised asthma action plan supported by regular asthma review, can be delivered effectively in diverse cultural and demographic groups[5,6].

School-based asthma self-management interventions have been reported to improve asthma control and reduce school absenteeism and asthma exacerbations[7-11]. However, most systematic reviews analysed combined data from primary and secondary schools (5-18 years)[7-10]. One scoping review conducted in 2014 focused on primary school children, but the aim was to identify research gaps rather than assess outcomes[11]. The Cochrane review (Harris, 2019) used meta-analyses to assess intervention effectiveness and qualitative comparative analysis to examine the components of successful implementations[7]. The authors identified a number of components as being important: theoretical underpinning, parental involvement, child satisfaction and conducting the intervention during lesson time. However, the Cochrane review included interventions directed at children and adolescents (5-18 years), and did not distinguish the components associated with effective interventions in primary school children, which may differ from adolescents[7]. Educational intervention needs to be age-appropriate as primary school children will have less autonomy and capability to self-manage asthma compared to adolescents[12]. Thus, we aimed to review the effectiveness of school-based self-management interventions for

primary school children with asthma and to examine the components associated with successful programmes.

Results

Figure 1 illustrates the article selection process using the PRISMA diagram. We included 23 studies; 16 studies from the Cochrane review [13-28], five studies from the updated database search[29-33] and two studies from the pre-publication update[34,35]. The total number of participants was 10,682. Some studies did not report numbers in each group so we cannot provide number by allocation[13,14,24]. We contacted all authors for information not reported in the papers, and nine (39%) responded[13,14,25,27,29,30,32-34].

Characteristics of included studies

The interventions were conducted from 1992 to 2019. Seventeen studies were randomised controlled trials (RCTs) (14 cluster RCT [13-15,18-26,31,32], three individual RCTs [27,29,34]), three were non-randomised studies[28,30,35] and three were uncontrolled pre-and-post studies[16,17,33]. Fifteen studies were conducted in the United States[15-18,21,23-25,27-31,34,35], four in Canada [13,14,19,20], one each in Spain [32] and United Kingdom [26], and two in low- and middle- income countries (China and Thailand)[22,33]. All but one[17] of the studies in the United States were conducted in minority populations[15,16,18,21,23-25,27-31,34,35], two Canadian studies were conducted in majority population[19,20]; none of the others[13,14,22,26,32,33] reported ethnicity of population studied.

Overall intervention characteristics

The programmes were used to deliver self-management intervention varied. Eight studies used standard programmes (Open Airway for School (OAS) or tailored

OAS[15,17,21-24,28,29], four studies used Roaring Adventures of Puff (RAP) or tailored RAP[13,14,19,20], and the other studies developed novel interventions[16,18,25-27,29-35]. The programmes ranged from one to eight sessions, and all were delivered by healthcare personnel, (school nurse, asthma educator, community nurse, respiratory therapist, physician) except for two that were delivered by trained school teachers[22,32]. Fifteen studies delivered the intervention in group sessions[13-17,19-26,28,34], four used individual face-to-face sessions[27,29,30,35], one used individual computer-assisted programme[18] and another used individual telemedicine sessions[31]. Two studies were unclear[23,33].

Risk of bias in the included studies

The overall RoB is given in summary Table 2 (first column) and illustrated in the Harvest plot (Figure 2). Details of the RoB are in Supplementary Table 5. Four studies had low overall risk of bias[13,14,20,32], eleven had high risk of bias [15-17,21,27-30,33-35] and eight were unclear[18,19,22-26,31]. Only seven (30%) studies were categorised at low risk in random sequence generation[13,14,20,21,23,32,34]. All uncontrolled studies were categorised as high-risk in four domains (random sequence generation, allocation concealment, baseline outcome similar and baseline character similar)[16,17,33].

Effectiveness of interventions

The effect of the interventions on each outcome of interest is detailed in Table 2, with an explanation of how the direction of the effect was interpreted and the overall effect of the study assessed. Twelve studies (two at low risk-of-bias) were assessed as having an overall positive (beneficial) effect[13-17,21,22,29,30,33-35] and eleven studies (two at low risk-of-bias) as having no effect[18-20,23-28,31,32]. No study was categorised as harmful or mixed effect. The Harvest plot (Figure 2) illustrates the effect of varying degrees of

parental involvement on school absenteeism, asthma control and urgent healthcare use.

Study components according to CFIR sub-domains

The CIFR domains addressed in the studies are summarised in column 2 in Table 2. Cicutto et al.[13] was the only study that explicitly addressed all the CFIR sub-domains in their intervention; in contrast, Spencer et al.[17] addressed only two sub-domains. All included studies used and measured the impact of at least one specific component in their intervention, e.g. information provision assessed as improvement of knowledge and self-management behaviour. The other commonly addressed sub-domain was parental involvement (19/23)[13-25,29-31,33-35], though this varied in intensity (We use the term 'parents' to describe parents, guardians or other care-givers). See Supplementary Table 3 for definitions of involvement. Some studies had substantial involvement e.g. parents attending session or actively involved in phone/video communication [13-15,17,19-22,24,25,29-31,33,35], while others had minimal parental involvement e.g. passive information in a letter [16,18,23,29,34]. Ten studies used theory to guide the development of the interventions; six used social cognitive theory [13,14,18-20,22], two used Orem self-care theory [28,34], one used life stress model [29], and another was guided by Bruhn's theoretical model[25]. Nine studies considered access to healthcare of their study population[13-15,24,25,27,30,32,33].

Association of CFIR sub-domains and effectiveness

Table 3 is a summary matrix comparing use of the 12 CFIR sub-domains in studies with overall positive or no effect (See Supplementary Table 4 for more detail). The

number of CFIR sub-domains used varied widely (2 to 12) and was similar in the studies with positive/no effect.

All studies with positive effects (12/12) reported parental involvement in their intervention[13-17,21,22,29,30,33-35] compared to seven studies with no effects (7/11)[18-20,23-25,31]. The Harvest plot (Figure 2) illustrates the direction of effect with the varying degrees of parental involvement of each study intervention. Studies without parental involvement (including one at low RoB[32]) showed no effect in any of the outcomes of interest[26-28,32]. Of the five interventions with minimal parental involvement[16,18,23,29,34], the three positive studies were at high RoB and of short duration (≤ 6months), and either small in sample (study population less than 100 children)[29,34] or pre/post design[16]. Studies with substantial parental involvement [13-15,17,19-22,24,25,29-31,33,35] were the only studies to report reduction in absenteeism, though impact on clinical outcomes varied. Cicutto et al.[13] (cluster RCT at low risk of bias, 170 schools and 1316 children), an example of a study that included parents in care coordination and a showcase at school, had positive effects in school absenteeism and urgent healthcare service use at 12 months. No difference was found in other CFIR subdomains between studies with positive and no effects.

Discussion

Summary of main findings

We identified 23 studies (four at low RoB) that evaluated the effectiveness of school-based asthma self-management intervention among primary school children. Twelve of the studies were categorised as being overall positive, though individual outcomes varied; no study reported overall negative impact. The number of CFIR sub-domains

addressed varied between studies, but the only component that seemed to be associated with positive outcomes was substantial parental involvement. This was particularly apparent in studies at low RoB.

Interpretation of findings in relation to previously published work

We found substantial parental involvement to be a crucial component of a school-based asthma self-management intervention among primary school children. Reviews that included interventions targeted at teenagers, in whom parental influence might be expected to be less important, have reached similar conclusions[7,8]. Parental involvement was also found to be important in other school-based interventions for obesity prevention studies[36,37], self-management of mental health/disorders [38], and academic enhancement[39].

However, we did not find other components of interventions (theory-driven, conducted during lesson time, and child satisfaction) to be essential for successful intervention, as was found in the Cochrane review[7]. The differences in the findings were most probably due to a difference in the age group of the children as the Cochrane review included studies among older school children. Our review defined fun, interactive delivery of intervention, as a strategy promoting child satisfaction and engagement, whereas the Cochrane review examined measurement of child satisfaction, an evaluation used mainly in studies targeting adolescents[7]. Primary school children had good participation rates when the sessions were conducted during school hours including during recess, in contrast to adolescents who were less willing to devote their free time including during recess[7,13,16]. Social cognitive and Orem self-care theories were the most used theories, adapted from adults which focuses on self-efficacy and

175 skills of individuals[40-42]. These theories may be suitable for interventions targeting
176 parents and adolescents, but may not be age-appropriate for primary school children
177 with limited decision-making abilities and independent self-management skills[12,43].
178
179 Primary school years are a critical time for children as they spend increasing time
180 away from their parents and begin to learn asthma self-management for
181 themselves[44,45]. Six-year-old children can express opinions, typically reflecting their
182 parents' actions and views[44]. Over primary school years, they learn from their own
183 experiences and gain the confidence to make independently decisions[44,45]. Although
184 involving parents to support and empower their children's self-management behaviour
185 is a key concept in the clinical management of children[2,3], direct parental involvement
186 was not always included in school-based intervention among primary school
187 children[27,28,32]. A key challenge for involving parents is the difficulty of engaging them
188 to attend session(s) delivered in school[24,46]. With the ease of modern
189 telecommunication, alternative methods of engagement such as the use of telephone
190 calls or video sessions could be explored as a convenient alternative to enable
191 substantial parental involvement in the intervention[31,47].
192
193 Although parental involvement is important, an aim of a school-based intervention is to
194 shift the focus of self-management education from parents to children[48,49]. Studies in
195 this review included up to eight educational sessions for children compared to only one
196 to two sessions for parents[13,27,30]. A recent school-based health intervention has
197 recommended the socio-ecological theory where children are the primary focus of an
198 intervention that also involves the children's social network, e.g. parents, teachers,
199 friends and the school plan/policy[48,50]. Schools could be an ideal setting for this

approach, smoothing children's transition to independent self-management by being located in the child's environment and including parents as part of the children's social network[51-53]. Schools also provide a platform for interactive fun groups activities and peer support for children with similar conditions, which could reduce stigma and support self-management practices[13,32].

The effectiveness of self-management also depends on access and adherence to evidence-based treatments such as controller asthma medications, which is conventionally delivered in healthcare settings[2,5]. 'Access to healthcare', however, was a sub-domain least likely to be addressed in the studies included in this review. Although most US-based studies were conducted among minority deprived populations, in whom poor health outcomes may be due to the large disparities in healthcare provision[54], only five studies reported the access of the children to effective controller medication[15,24,25,27,30]. Even in countries with universal health coverage, such as Canada and United Kingdom, equitable access to high quality healthcare for children cannot be assumed[55]. In low- and middle-income countries, socio-cultural beliefs, physical inaccessibility and lack of education and information are extremely common barriers to healthcare despite universal health coverage[56,57]. Similar barriers are widely described in the US[30,31,34]. Encouragingly, bridging school-based education with the children's healthcare providers has been a core component of recent school-based interventions[53,58].

Strengths and limitations

A strength of this review is that we used comprehensive search terms similar to the Cochrane review and searched seven relevant databases. Two reviewers conducted

full text screening and data collection was duplicated. A pre-publication update was performed to ensure the findings was up to date this review.

This review has some limitations. Despite a rigorous search strategy, it is possible that we may miss some studies. The screening of title and abstract was conducted by one reviewer, but good agreement resulted after training. Only two studies were conducted in low- and middle-income countries and many studies (15/23) were conducted in the US, reducing generalisability of the review. The included studies were variable in methodologies, instrumentation and data analysis. However, three low RoB studies coincided with the findings and some variability was illustrated in the Harvest plot with the other details described in Table 2. Poor reporting of interventions was a challenge and we may have overlooked some intervention components that were not explicitly described. We contacted all the authors to reduce the number of missing information and obtained 39% responses.

Implications for policy, practice and research

A multi-level intervention focusing on the children and involving their social network could provide a useful self-management interventions framework for primary school children and their parents. Specifically, there is a gap in our current understanding of school-based self-management education in younger children in low- and middle-income countries. Future research needs to focus on implementation strategies and effectiveness using this framework. Partnership between schools, parents and healthcare services could create a pragmatic and effective school plan/policy to improve asthma control among children.

Conclusions

School-based self-management interventions for asthma among primary education children can improve asthma outcomes and reduce absenteeism. Parental participation is an important component in this age group, but other features highlighted in secondary school interventions proved less relevant, perhaps reflecting the greater role of parents in younger children.

Methods

This systematic review follows Cochrane methodology[59], and PRISMA reporting standards. The protocol is registered with the PROSPERO database (registration number: CRD42019131955).

Study eligibility criteria

We used a Population, Intervention, Comparator/Control, Outcomes and Study Design (PICOS) strategy to define eligible studies (Table 1)[60], using definitions similar to the Cochrane review[3,7,61]. Self-management intervention was defined as the active transfer of information to children with asthma to enhance their self-management skills; this was interpreted with reference to components of self-management recommended by global guidelines (Table 1)[2,3]. In line with the Cochrane review, we included non-randomised trials to capture a broader range of studies and thence components used.

Outcomes of interest

We chose three outcomes of interest (school absenteeism and two health outcomes - asthma control and urgent use of healthcare services) to reflect the impact on children with poorly controlled asthma[2,7,61].

Search strategy

The details of the search terms and databases used are in Supplement Table 1. The Cochrane review conducted searches in August 2017 using search terms developed by the Cochrane Airway Information Specialist in 23 electronic databases from 1995 onwards and included 55 papers[7]. Using the same search terms, with no language limitations, we updated the search in February 2019 in six-core databases (CENTRAL, MEDLINE, Embase, PsycINFO, CINAHL, AMED)[7]. In addition, we searched the Global Health database using similar search terms without date limits to include studies from low- and middle-income countries. We included all studies identified in the review that met our eligibility criteria (principally excluding those not delivered to primary school children). We checked the reference list and undertook forward citation of studies in the Cochrane review conducted among primary school children[62].

A pre-publication update was conducted on 17th March 2020 using forward citation of the Cochrane review (published 28 January 2019)[7] and all the studies included in this review[62].

Study selection and data extraction

We imported the list of articles from the electronic databases into Endnote software (version 7) to facilitate screening, de-duplication and overall management of the results. SNR and JS independently screened a random selection of 10% of the titles and abstracts[5]. A 96.3% agreement was achieved prior to discussion, which reached total agreement after clarification of the screening criteria. SNR then completed title and abstract screening. Both reviewers independently conducted full-text screening (which included all the studies in the Cochrane review and those satisfying title and abstract screening), met to discuss discrepancies and decided on the final included

papers. Supplementary Table 2 lists studies excluded from this review. A modified Cochrane data extraction form was used for duplicate data extraction (SNR and JS)[63]. SNR contacted authors for missing data by email and any further information received was added to the data extraction forms[59].

At all stages, any discrepancies not resolved by discussion between the two reviewers were arbitrated by the study team (HP, KEM, LSM, SC).

Risk of bias of included studies

We used the Cochrane Effective Practice and Organisation of Care (EPOC) Risk of Bias (RoB) tool[64] to categorise risk into low, high and unclear risk in nine domains, which were then used to generate an overall assessment of the RoB for each study. The Cochrane EPOC RoB tool applies to randomised trials and non-randomised trials.[64] Studies with at least one high-risk domain were summarised as high risk; studies with no high-risk domains but at least one unclear domain were summarised as unclear risk and studies at low risk in all domains were summarised as low risk[64].

Data handling

The Consolidated Framework for Implementation Research (CFIR) is a comprehensive framework that systematically identifies factors (sub-domains) that influence the effectiveness of implementation in multi-level interventions[65]. Supplementary Table 3 outlines the 12 CFIR sub-domains. We used CFIR sub-domains to identify context and components in each study (e.g. intervention characteristics, features of the setting and strategies for implementation) that might influence effectiveness of the interventions[66,67].

We used a structured approach to divide the studies into four categories according to the change in the outcomes of interest[68]. This was a two-step process.

First, we determined the direction of effect in each of the three outcomes of interest (school absenteeism; asthma control; urgent use of healthcare service) for each included study. In some studies, several measures mapped to each outcome of interest: for example, emergency room visits and hospitalisation are both measures of unscheduled care potentially with conflicting findings. The rules at the top of Table 2 define how we prioritised outcomes defined as 'primary' in the included study, outcomes measured with a validated instrument, and results that were clinically as well as statistically significant. The table then describes how the decision process was applied for each outcome of interest in each study.

Second, we categorised the overall effect of the intervention in each study as positive, negative, no effect or mixed effects, as follows:

- Positive (beneficial): Studies with a positive effect in ≥ 1 of the outcomes and no negative effects.
- Negative (harmful): Studies with a negative effect in ≥ 1 of the outcomes and no positive effects.
- No effect: Studies with no positive effects in any of the outcomes.
- Mixed: Studies with at least one positive and one negative outcome.

Data synthesis

Our preliminary scoping suggested that the studies would be heterogenous in terms of context, components delivered and study design, so we undertook a narrative analysis. We used a Harvest plot[69] (coded to indicate number of participants, RoB and

follow-up duration) to illustrate the effectiveness of the interventions on the three outcomes of interest for each study. A Harvest plot graphically displays not only outcomes but also the weight of the evidence in complex and diverse studies by illustrating selected methodological criteria[69]. We used a matrix to examine the association of the CIFR sub-domains with the overall effectiveness of the interventions. Supplementary Table 4 lists the CFIR sub-domains and how we interpreted them in our analysis.

Data Availability

All data that support the findings of this systematic review are already in the public domain.

Acknowledgements

We would like to acknowledge all the authors of included studies who provided the information to aid in synthesising the data. We also acknowledge the RESPIRE collaborators which includes Ahmed Ehsanur Rahman, Anand Kawade, Parag Khatavkar, Sanjay Juvekar, Colin Simpson, Nik Sherina Hanafi, Kit Chan, Wong Li Ping, Sajid Soofi, Osman M Yusuf, Shahida O Yusuf, Rita Isaac and the RESPIRE members who contributed to this paper: Aziz Sheikh, Monica Fletcher and Sian Williams.

Funding

SNR is a PhD student at the University of Edinburgh with the NIHR Global Health Research Unit on Respiratory Health (RESPIRE). RESPIRE is funded by the National Institute of Health Research using Official Development Assistance (ODA) funding. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

Competing interest

None declared.

Author contributions

All authors contributed to study conception. SNR and JS performed screening, data extraction of the included studies. All authors (SNR, JS, KMH, EMK, SML, SC, HP) contributed to the interpretation of data. SNR drafted the manuscript and all authors provided critical revisions and editing of the manuscript.

References

1. Global Asthma Network. The Global Asthma Report. (Auckland, New Zealand, 2018).
2. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention (updated 2020). (2020).
3. Scottish Intercollegiate Guidelines Network/British Thoracic Society. SIGN 158 British guideline on the management of asthma. (Scottish Intercollegiate Guidelines Network/British Thoracic Society, London, 2019).
4. Lougheed, M.D.*, et al.* Canadian Thoracic Society Asthma Management Continuum--2010 Consensus Summary for children six years of age and over, and adults. *Can Respir J* **17**, 15-24 (2010).
5. Pinnock, H.*, et al.* Systematic meta-review of supported self-management for asthma: a healthcare perspective. *BMC Med* **15**, 64 (2017).
6. Pinnock, H. Supported self-management for asthma. *Breathe (Sheffield, England)* **11**, 98-109 (2015).
7. Harris, K.*, et al.* School‐based self‐management interventions for asthma in children and adolescents: a mixed methods systematic review. *Cochrane Database of Systematic Reviews* (2019).
8. Walter, H.*, et al.* Effectiveness of school-based family asthma educational programs on quality of life and asthma exacerbations in asthmatic children aged five to 18: a systematic review. *JBI Database of Systematic Reviews and Implementation Reports* **14**, 113-138 (2016).
9. Isik, E., Fredland, N.M. & Freysteinson, W.M. School and Community-based Nurse-led Asthma Interventions for School-aged Children and Their Parents: A Systematic Literature Review. *Journal of Pediatric Nursing: Nursing Care of Children and Families* **44**, 107-114 (2019).
10. Carvalho Coelho, A.C., Barretto Cardoso, L.S., de Souza-Machado, C. & Souza-Machado, A. The Impacts of Educational Asthma Interventions in Schools: A Systematic Review of the Literature. *Can Respir J*, 8476206 (2016).
11. Al Aloola, N.A., Naik-Panvelkar, P., Nissen, L. & Saini, B. Asthma interventions in primary schools – a review. *Journal of Asthma* **51**, 779-798 (2014).
12. Orrell-Valente, J.K., Jarlsberg, L.G., Hill, L.G. & Cabana, M.D. At what age do children start taking daily asthma medicines on their own? *J Pediatr* **122**, e1186-1192 (2008).
13. Cicutto, L., To, T. & Murphy, S. A Randomized Controlled Trial of a Public Health Nurse-Delivered Asthma Program to Elementary Schools. *Journal of School Health* **83**, 876-884 (2013).
14. Cicutto, L.*, et al.* Breaking the access barrier: evaluating an asthma center's efforts to provide education to children with asthma in schools. *Chest* **128**, 1928-1935 (2005).
15. Levy, M., Heffner, B., Stewart, T. & Beeman, G. The efficacy of asthma case management in an urban school district in reducing school absences and hospitalizations for asthma. *The Journal of school health* **76**, 320-324 (2006).
16. Magzamen, S., Patel, B., Davis, A., Edelstein, J. & Tager, I.B. Kickin' Asthma: school-based asthma education in an urban community. *The Journal of school health* **78**, 655-665 (2008).
17. Spencer, G.A., Atav, S., Johnston, Y. & Harrigan, J.F. Managing Childhood Asthma: The Effectiveness of the Open Airways for Schools Program. *Family & Community Health* **23**, 20-30 (2000).

18. Bartholomew, L.K.*, et al.* Partners in school asthma management: evaluation of a self-management program for children with asthma. *The Journal of school health* **76**, 283-290 (2006).
19. McGhan, S.L.*, et al.* Evaluation of an education program for elementary school children with asthma. *J Asthma* **40**, 523-533 (2003).
20. McGhan, S.L.*, et al.* A children's asthma education program: Roaring Adventures of Puff (RAP), improves quality of life. *Can Respir J* **17**, 67-73 (2010).
21. Clark, N.M.*, et al.* Effects of a comprehensive school-based asthma program on symptoms, parent management, grades, and absenteeism. *Chest* **125**, 1674-1679 (2004).
22. Clark, N.M.*, et al.* A trial of asthma self-management in Beijing schools. *Chronic illness* **1**, 31-38 (2005).
23. Clark, N.M.*, et al.* An evaluation of asthma interventions for preteen students. *The Journal of school health* **80**, 80-87 (2010).
24. Gerald, L.B.*, et al.* Outcomes for a comprehensive school-based asthma management program. *The Journal of school health* **76**, 291-296 (2006).
25. Horner, S.D., Brown, A., Brown, S.A. & Rew, D.L. Enhancing Asthma Self-Management in Rural School-Aged Children: A Randomized Controlled Trial. *The Journal of rural health : official journal of the American Rural Health Association and the National Rural Health Care Association* **32**, 260-268 (2016).
26. McCann, D.C., McWhirter, J., Coleman, H., Calvert, M. & Warner, J.O. A controlled trial of a school-based intervention to improve asthma management. *The European respiratory journal* **27**, 921-928 (2006).
27. Persaud, D.I.*, et al.* An asthma self-management program for children, including instruction in peak flow monitoring by school nurses. *J Asthma* **33**, 37-43 (1996).
28. Velsor-Friedrich, B., Pigott, T. & Srof, B. A practitioner-based asthma intervention program with African American inner-city school children. *Journal of pediatric health care : official publication of National Association of Pediatric Nurse Associates & Practitioners* **19**, 163-171 (2005).
29. Marsland, A.L.*, et al.* A randomized pilot trial of a school-based psychoeducational intervention for children with asthma. *Clinical and experimental allergy : journal of the British Society for Allergy and Clinical Immunology* **49**, 591-602 (2019).
30. Szefler, S.J.*, et al.* Building Bridges for Asthma Care: Reducing school absence for inner-city children with health disparities. *J Allergy Clin Immunol* **143**, 746-754.e742 (2019).
31. Perry, T.T.*, et al.* Results of an asthma education program delivered via telemedicine in rural schools. *Ann Allergy Asthma Immunol* **120**, 401-408 (2018).
32. Praena-Crespo, M., Aquino-Llinares, N., Fernandez-Truan, J.C., Castro-Gomez, L. & Segovia-Ferrera, C. Asthma education taught by physical education teachers at grade schools: A randomised cluster trial. *Allergologia et immunopathologia* **45**, 375-386 (2017).
33. Suwannakeeree, P., Deerojanawong, J. & Prapphal, N. School-Based Educational Interventions Can Significantly Improve Health Outcomes in Children with Asthma. *Journal of the Medical Association of Thailand = Chotmaihet thangphaet* **99**, 166-174 (2016).

34. Isik, E., Fredland, N.M., Young, A. & Schultz, R.J. A School Nurse-Led Asthma Intervention for School-Age Children: A Randomized Control Trial to Improve Self-Management. *The Journal of school nursing : the official publication of the National Association of School Nurses*, 1059840520902511 (2020).
35. Simoneau, T.*, et al.* A School Nurse-Led Asthma Program Reduces Absences: Evaluation of Easy Breathing for Schools. *Academic pediatrics* **20**, 73-80 (2020).
36. Verjans-Janssen, S.R.B., van de Kolk, I., Van Kann, D.H.H., Kremers, S.P.J. & Gerards, S. Effectiveness of school-based physical activity and nutrition interventions with direct parental involvement on children's BMI and energy balance-related behaviors - A systematic review. *PLoS One* **13**, e0204560 (2018).
37. Golley, R.K., Hendrie, G.A., Slater, A. & Corsini, N. Interventions that involve parents to improve children's weight-related nutrition intake and activity patterns – what nutrition and activity targets and behaviour change techniques are associated with intervention effectiveness? *Obesity Reviews* **12**, 114-130 (2011).
38. Shucksmith, J., Jones, S. & Summerbell, C. The Role of Parental Involvement in School-Based Mental Health Interventions at Primary (Elementary) School Level. *Advances in School Mental Health Promotion* **3**, 18-29 (2010).
39. Lara, L. & Saracostti, M. Effect of Parental Involvement on Children's Academic Achievement in Chile. *Front Psychol* **10**, 1464-1464 (2019).
40. Bandura, A. Social Cognitive Theory. in *Annals of child development*, Vol. 6 (1989).
41. Ng, C.Y.*, et al.* Theory-Based Health Behavior Interventions for Pediatric Chronic Disease Management: A Systematic Review. *JAMA Pediatr* **172**, 1177-1186 (2018).
42. Orem, D. *Nursing: Concepts of practice*, (Mosby, 2001).
43. Horner, S.D. Using the Open Airways curriculum to improve self-care for third grade children with asthma. *The Journal of school health* **68**, 329-333 (1998).
44. Buford, T.A. Transfer of asthma management responsibility from parents to their school-age children. *Journal of pediatric nursing* **19**, 3-12 (2004).
45. Ramdzan, S.N.*, et al.* How young children learn independent asthma self-management: a qualitative study in Malaysia. *Archives of Disease in Childhood* **105**, 819 (2020).
46. Okely, A.D. & Hammersley, M.L. School-home partnerships: the missing piece in obesity prevention? *The Lancet Child & Adolescent Health* **2**, 5-6 (2018).
47. Frey, S.M., Milne Wenderlich, A. & Halterman, J.S. New Opportunities With School-Based Telehealth: Convenient Connections to Care. *JAMA Pediatrics* **173**, 1017-1018 (2019).
48. Nuss, H.J.*, et al.* Applying the Social Ecological Model to Creating Asthma-Friendly Schools in Louisiana. *The Journal of school health* **86**, 225-232 (2016).
49. Kirk, S.*, et al.* The effectiveness of self-care support interventions for children and young people with long-term conditions: a systematic review. *Child: care, health and development* **39**, 305-324 (2013).
50. Van Koperen, T.M.*, et al.* Characterizing the EPODE logic model: unravelling the past and informing the future. *Obesity reviews : an official journal of the International Association for the Study of Obesity* **14**, 162-170 (2013).

51. Mukamana, O. & Johri, M. What is known about school-based interventions for health promotion and their impact in developing countries? A scoping review of the literature. *Health Education Research* **31**, 587-602 (2016).
52. Szefler, S.J.*, et al.* A worldwide charter for all children with asthma. *Pediatric Pulmonology* **55**, 1282-1292 (2020).
53. Cicutto, L.*, et al.* Building Bridges for Asthma Care Program: A School-Centered Program Connecting Schools, Families, and Community Health-Care Providers. *The Journal of school nursing : the official publication of the National Association of School Nurses*, 1059840518805824 (2018).
54. Holsey, C.N., Collins, P. & Zahran, H. Disparities in Asthma Care, Management, and Education Among Children With Asthma. *Clin Pulm Med* **20**, 172-177 (2013).
55. Cylus, J. & Papanicolas, I. An analysis of perceived access to health care in Europe: How universal is universal coverage? *Health Policy* **119**, 1133-1144 (2015).
56. Sanogo, N.A., Fantaye, A.W. & Yaya, S. Universal Health Coverage and Facilitation of Equitable Access to Care in Africa. *Frontiers in public health* **7**, 102 (2019).
57. Kan, X.H.*, et al.* Asthma as a hidden disease in rural China: opportunities and challenges of standard case management. *Public Health Action* **2**, 87-91 (2012).
58. Frey, S.M. & Halterman, J.S. Improving Asthma Care by Building Bridges Across Inpatient, Outpatient, and Community Settings. *JAMA Pediatrics* **171**, 1043-1044 (2017).
59. Higgins JPT, Green S. & (editors). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]*, (The Cochrane Collaboration,, 2011).
60. Santos, C.M.C., Pimenta, C.A.M. & Nobre, M.R.C. The PICO strategy for the research question construction and evidence search. *Revista Latino-Americana de Enfermagem* **15**, 508-511 (2007).
61. Reddel, H.K.*, et al.* An official American Thoracic Society/European Respiratory Society statement: asthma control and exacerbations: standardizing endpoints for clinical asthma trials and clinical practice. *Am J Respir Crit Care Med* **180**, 59-99 (2009).
62. Greenhalgh, T. & Peacock, R. Effectiveness and efficiency of search methods in systematic reviews of complex evidence: audit of primary sources. *BMJ* **331**, 1064 (2005).
63. Cochrane Effective Practice and Organisation of Care (EPOC). EPOC Resources for Review authors. in *Screening, data extraction and management* (2017).
64. Cochrane Effective Practice and Organisation of Care (EPOC). Suggested risk of bias criteria for EPOC reviews. EPOC Resources for review authors. (2017).
65. Damschroder, L.J.*, et al.* Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implementation Science* **4**, 50 (2009).
66. Snilstveit, B., Oliver, S. & Vojtkova, M. Narrative approaches to systematic review and synthesis of evidence for international development policy and practice. *Journal of Development Effectiveness* **4**, 409-429 (2012).
67. Keith, R.E., Crosson, J.C., O'Malley, A.S., Cromp, D. & Taylor, E.F. Using the Consolidated Framework for Implementation Research (CFIR) to produce

actionable findings: a rapid-cycle evaluation approach to improving implementation. *Implement Sci* **12**, 15 (2017).
68. Burns, J.*, et al.* Looking beyond the forest: Using harvest plots, gap analysis, and expert consultations to assess effectiveness, engage stakeholders, and inform policy. *Research synthesis methods* **9**, 132-140 (2018).
69. Ogilvie, D.*, et al.* The harvest plot: a method for synthesising evidence about the differential effects of interventions. *BMC medical research methodology* **8**, 8 (2008).

Figure Legends

Figure 1: PRISMA diagram of selection process

Figure 2: Harvest plot illustrating the effectiveness on school absenteeism, asthma control and urgent healthcare services across parental involvement for school-based self-management asthma educational intervention.

Table 1: PICO study strategy and definition of terminology	
Participant/population	Children with asthma aged 6-12 years
Intervention	School-based self-management education intervention. Definition as active transfer of information to enhance self-management of asthma containing at least one of the core-components of self-management education[2,3]: • A basic explanation about asthma, triggers and the factors that influence control • Training about correct inhalation technique • Information on the importance of the child's adherence to the prescribed medication regimen • Written asthma action plan Children with asthma had to be the primary target for the intervention, though others (such as peers without asthma, parents, school staff) could also be included.
Comparator(s)	Standard care or other (non-asthma, or not related to self-management or delayed intervention) education intervention or none
Outcomes	School absenteeism or/and asthma control or/and urgent use of healthcare service The definition of the three categories of outcomes of interest were guided by the American Thoracic Society/European Respiratory Society statement[61]: 1. School absenteeism: Number of days a participant was absent from school (priority due to asthma). 2. Asthma control: Clinical level of asthma control based on symptoms and capability to perform daily activities measured using asthma symptoms questionnaire/asthma diary with/without objective validation of asthma control, e.g. peak flows or lung function test. 3. Urgent use of healthcare service: Number of an unscheduled visit to a general practitioner and/or emergency department due to asthma, and the number of days of hospitalisation due to asthma.
Setting	School (primary, elementary or middle school)
Study designs	Experimental study e.g. randomised controlled trial (RCT), cluster RCT, non-randomised study and uncontrolled before-and-after study.

Table 2: Summary of study, CFIR domains and researchers' interpretation of included studies

Where outcomes within a category were conflicting, the decision process attached priority as follows:

- Defined primary outcomes in an adequately powered study
- Outcomes which were measured with a validated instrument (as opposed to responses of non-validated instrument)
- Outcomes that were clinically as well as statistically significant (e.g. defined as minimum clinically important difference)
- Outcomes which were measured using continuous versus categorical/dichotomy scale (e.g. days of school absenteeism versus yes/no to school absenteeism in a year)
- Outcomes reported by children as opposed to parents (in the absence of a validated instrument which measured both)

Finally, if there were any remaining doubts, the authors' interpretation was considered as providing the context for our decision

Citation design, size, risk of bias, and intervention	CIFR domains ([x] indicates component of study not fulfilling criteria)	Reported outcomes (* indicates primary outcome if stated)	Researchers' interpretation for Harvest plot
STUDIES WITH OVERALL POSITIVE EFFECT			
Cicutto, 2005[14] cRCT FU:12m Canada. Urban 26 schools: 256 children, Age: 6-11yrs Intervention: Roaring Adventures of Puff RoB: Low	**Intervention characteristics** Social cognitive theory and self-regulation Based on Canadian guideline Involved HCPs and families in development Tailored at individual level **Outer setting** Parents attended showcase + homework Universal Health Coverage Communicated/coordinated with HCP **Inner setting** [x] Only permission/advertisement at schools Delivered mostly during lunch/class time **Individual characteristics** Self-efficacy assessed **Process** Fidelity: Implemented as designed Puppetry, games, role-play, model building, etc	**School absenteeism** *Days lost from school:* Significant between group difference • Mean (SD) days/yr: I: 3.0 ±4.4 vs C: 4.3 ±5.7 ($p<0.05$)	Significant reduction in missed school in intervention group **Illustrated as positive effect**
		Asthma control Not reported	
		*** Urgent use of healthcare services** *Number of urgent health care visits (ED, walk-in or same-day visits)* Significant between group difference • Mean (SD) visits/yr: I: 1.7 (1.9) vs C: 2.5 (2.5), $p<0.01$	Significant reduction in urgent healthcare visits in intervention group **Illustrated as positive effect**
Cicutto, 2013[13] cRCT FU:12m Canada.	**Intervention characteristics** Social cognitive theory Based on Canadian guidelineDeveloped by schools	**School absenteeism** *Proportion of children with asthma-related absence.* Significant between-group reduction in proportion with	Significant reduction in absenteeism in intervention group **Illustrated as consistently positive**

170 schools; 1316 children, Age 6-11yrs Intervention: Roaring Adventures of Puff + asthma resource kit RoB: Low	Locally tailored **Outer setting** Parents attended showcase + coordination of care Universal health coverage Letter to HCP via family **Inner setting** Resource kit and school community session Delivered during lunch time **Individual characteristics** Inhaler technique assessed **Process** Fidelity: Implemented as designed Interactive games, puppetry, art, skits, homework	• any school absence: I: 50% vs C: 60% (p=0.01) • >20 missed school days: I: 1.4% vs C: 4.5% p-value= 0.01	**effect.**
		Asthma control Not reported	
		* **Urgent use of healthcare services** *Proportion of children attending urgent care.* Significant between-group reduction in: • * Any urgent care: I: 41.3% vs C: 51.4% (p=0.0001) • Unscheduled physician's visit: I: 24.1% vs 31.2% (p=0.001) • ED attendances: I: 8.2% vs 2.8% (p=0.02) Walk-in clinic use: I: 18.4% vs 21.6%, p=NS	Significant reduction in use of healthcare resources in intervention group. **Illustrated as positive effect**
Clark, 2005[22] cRCT. FU:12m China. Urban/rural. 21 schools: 639 children, Age 7-11 Intervention: Tailored Open Airway for School RoB: Unclear	**Intervention characteristics** Social cognitive theory Based on GINA & NAEPP Adapted to local needs **Outer setting** School fair for parents with Q& A session [x] HCP requested to provide PAAP **Inner setting** Session for school principals and counsellors **Individual characteristics** Parent management index of items **Process** [x] Fidelity: good except for HCP response Games, problem solving exercises	**School absenteeism** *Days lost from school:* Significant between group reduction in: • adjMean diff days/yr *I: -0.32 vs C: -0.56 (p=0.02)*	Significantly fewer days lost from school in the intervention group. **Illustrated as positive effect**
		Asthma control *Days with symptoms:* No significant between group difference • adjMean diff days/yr I: -9 vs C: -6 p=0.13	No significant effect of the intervention on days with symptoms. **Illustrated as no effect**
		Urgent use of healthcare services *Number of hospitalisations or ED visits:* no significant between group difference in odds of a reduction in: • Hospitalisations: adjOR 1.43 (p=0.36) • ED attendances: adjOR 1.00 (p=0.98)	No significant effect of intervention on hospitalisations or ED visits. **Illustrated as no effect**
Clark, 2004[21] cRCT, FU: 24m USA: Urban, minority 14 schools: 835 children, Age: 7-11yrs Intervention: Tailored Open Airway for School plus	**Intervention characteristics** Tailored to local needs **Outer setting** School fair and assignments to include parents [x] contact HCP (not successfully done) **Inner setting** Session with principle and counsellors **Individual characteristics** Parent management index	**School absenteeism** *Proportion of children with asthma-related absence.* Significant between-group reduction in: • School absence: I: reported 8% fewer absences than C (p<0.05)	Significant reduction in asthma related absence in intervention group. **Illustrated as positive effect**
		Asthma control *Proportion reporting symptoms.* Significant between-group difference in the relative change of adjusted: • Day symptoms: I reported 17% fewer symptoms than C (p=0.0001) (Persistent symptoms; 14% fewer; Intermittent symptoms 22% fewer)	Unclear definitions of 'symptomatic', contradicting results, and limited reporting of data (no absolute values) **Illustrated as no effect but hatched**

RoB: High	**Process** [X] one key element not successful (contact HCP)	• Night symptoms: I reported 40% more symptoms than C (p<0.0001) (Persistent symptoms; 14% fewer; Intermittent symptoms 255% more)	**to indicate inconsistency**
		Urgent use of healthcare services Not reported	
Isik, 2020[34] RCT FU: 12 weeks USA, Urban minority 8 schools: 73 children Age: 7-12yrs Intervention: School Nurse-led RoB: High	**Intervention characteristics** Orem self-care theory Based on ALA guideline Developed with school nurse Tailored to children's condition **Outer setting** Parental received information sheet [X] assessment of asthma care access [X] Coordination with HCP **Inner setting** [X] school staff participation Delivered during school hours **Individual characteristics** Asthma management plan **Process** Fidelity: implemented as planned Storytelling, colouring, drawing, etc	**School absenteeism** *Number of absences.* No significant between group difference in: • mean (SD) all cause absences I: 1.3 (1.6) vs C:1.8 (1.5), p=0.179	No significant effect of intervention on all cause of school absenteeism **Illustrated as no effect.**
		Asthma control *Validated symptom score and control*. Significant difference between group difference at baseline to 6 week and baseline to 12 weeks in: • Mean ACQ scores: *F* (2, 138) = 14.2, p< 0.001	No data provided: Authors stated significant improvement in symptoms in intervention group **Illustrated as positive effect**
		Urgent healthcare services Not reported	
Levy, 2006[15] cRCT, step wise FU: 12m USA, Urban minority 20 schools: 329 children, Age: 6-10yrs Intervention: Open Airway for School plus RoB: High	**Intervention characteristics** Based on US guideline **Outer setting** Parents in coordination care + follow-up calls 80% of children were insured Contacted HCP **Inner setting** Training for school staff + dialogues if needed **Individual characteristics** Asthma knowledge **Process (none)**	***School absenteeism** *Days lost from school:* Significant between group difference in: • Mean days/school yr: 4.38 vs C:8.18	No p value provided: Authors stated 'significant improvement in school attendance'. **Illustrated as positive effect**
		Asthma control Not reported	
		***Urgent healthcare services** Significant between-group difference mean number of visits in • Mean (SD) Urgent/ED visits. I:1.36 (0.49) vs C: 1.59 (1.0), p<0.0001 • Mean days in hospital, I: 0.18 (0.73) vs C: 0.45 (1.06), p <0.05	Significant fewer in urgent care, ED visits and hospitalisations in intervention group **Illustrated as consistently positive effect**

Magzamen, 2008[16] Uncontrolled study FU: 3 m USA, Urban minority 18 schools: 990 children (3-yr groups), Age:11-12 yrs Intervention: Kickin' Asthma [Delivered to three year groups (YG1/2/3) RoB: High	**Intervention characteristics** School staff and children involved in development Developed by local schools **Outer setting** Customised letter to parents **Inner setting** [X] School staff delivered/received intervention Delivered during lunchtime **Individual characteristics** Asthma management behaviour + spacer technique **Process** Skits, games, videos, role-play	**School absenteeism** *Days lost from school:* Variable within-group impact in the three-year groups (YG) in: • Days /3m mean diff (SE): YG1 (reduced): -0.54 (0.30), p<0.03; YG2 (no effect): -0.26 (0.12), p<0.1; YG3 (no effect): -0.08 (0.13) p=0.44	Significant reduction in school absenteeism in one of the three-year groups. **Illustrated as no effect but hatched to indicate inconsistency**
		Asthma control *Activity limitation past 4 weeks.* Significant within-group reduction in all year groups (YGs) • Days/4w mean diff (SE) YG1: -0.70 (0.36), p<0.006; YG2: -0.62 (0.34), p<0.0001; YG3: -1.12 (0.37) p<0.0001 *Night-time symptoms past 4 weeks.* Significant within-group reduction in all year groups (YGs) • Nights/4w mean diff (SE) YG1: -0.99 (0.29), p<0.006; YG2: -0.68 (0.29), p<0.0001; YG3: -0.43 (0.40) p=0.005	Significant reduction in asthma symptoms in all year groups after intervention **Illustrated as consistently positive effect**
		Urgent healthcare services *Episodes of urgent care*. *Significant within-group* reduction in all year groups (YGs) *in odds of:* • One or more ED visit or hospitalisation: OR (95% CI): YG1: 3.13 (1.41-6.92), YG2: 3.83 (2.03-7.23), YG3: 2.36 (1.26-4.40) • One or more unscheduled GP visit OR (95% CI): YG1: 3 .00 (1.41-6.39), YG2: 2.5 (1.59-3.93), YG3: 1.21(0.74-2.00)	Significant reduction in ED, hospitalisations and unscheduled GP visits in all year groups after intervention **Illustrated as consistently positive effect**
Marsland, 2019[29] RCT, FU: 4 m USA, Urban minority 12 schools: 104 children Age: 8-14 (mean: 10.6) Intervention: I Can Cope (ICC) and Open Airway for Schools (OAS) RoB: High	**Intervention characteristics** ICC: Life-stress theory [X] based on evidence-based guideline ICC: Developed with HCP and school nurse [X] tailored to culture/beliefs **Outer setting** ICC: Parental attended session + received letter/call OAS: Based on US guideline [X] assessment of asthma care [X] coordination with HCP **Inner setting** ICC: Teachers involved in development and coordination Delivered during school hours	**School absenteeism** Not measured	
		Asthma control *Validated asthma control rated by child.* Significant between-group difference in mean score post-intervention: CHSDA-C Mean (SD): ICC:1.2 (2.0) vs C:2.6 (2.3), p<0.05; OAS: 1.4 (2.1) vs C: 2.6 (2.3), p<0.05 *Asthma control rated by parents.* No significant between-group difference in mean score post-intervention • CHSA Mean (SD) I: 1.2 (1.3) vs C: 1.7 (2.2) p=NS; OAS: 1.4 (2.1) vs 1.7 (2.2)	Children reported asthma prioritised due to the age of the children. Significant reduction in asthma control in intervention groups **Illustrated as positive but inconsistent (Hatched)**

	Individual characteristics Management self-management score **Process** Fidelity: implemented as planned ICC: Games and interactive activities, OAS: Games and stories		
		Urgent healthcare services Not reported	
Simoneau, 2020[35] Non-randomised study FU: 12 m USA, Urban minority 15 schools; 251 children Intervention: Easy Breathing for Schools RoB: High	**Intervention characteristics** Based on opinion from nurse, parents and HCPs **Outer setting** Parent attended session at school Communication with child HCP **Inner setting** School nurse delivered intervention **Individual characteristics** Inhaler technique delivered and assessed **Process** [X] Fidelity: only 25% implemented 3 core elements	***School absenteeism** *Days lost from school:* Significantly lower between-group risk of: • Days absent: adjRR=0.75 (95%CI 0.67 to 0.85) p<0.001	Adjusted for sex, ethnicity, age, and school year. 25% fewer absences in intervention group. **Illustrated as positive effect**
		Asthma control Not reported	
		Urgent healthcare services Not reported	
Spencer, 2000[17] Uncontrolled study FU: 6 m USA. 40 schools: 369 children, Age: 6-13 yrs Intervention: Open Airway for School RoB: High	**Intervention characteristics** (None) **Outer setting** Parent attended session at school **Inner setting** (None) **Individual characteristics** Management of asthma symptoms **Process** (None)	**School absenteeism** *Parent-reported absences*. No significant within-group difference • % with ≥1 absence/6m: Pre: 53% vs post: 53%, p=NS *School days missed (nurse-reported)* Significant within-group reduction: • Mean days/6m. Pre: 5.50 vs post: 3.73. (p<0.001)	Significant effect of intervention on missed school days, but not proportion with an absence. **Illustrated as positive effect but hatched to illustrate inconsistency**
		***Asthma control** *Asthma symptoms. Significant within group difference improvement* • Mean score: Pre: 25.9 vs post: 23.9 (p<0.001)	Significant reduction in non-validated symptom score **Illustrated as positive effect**
		Urgent healthcare services *Parent-reported events* Significant within-group difference in: • % with ≥1 ED visit/6m: Pre: 33% vs post: 18%, p<0.001 • % with ≥1 hospitalisation: Pre: 14% vs post: 7%, p=0.002 *Event (nurse-reported) Significant within-group difference in:* • Number of ED visits (Mean): Pre: 0.71 vs post: 0.18, p<0.001 • Number of hospitalisations (Mean): Pre: 0.14 vs post:0.04, p<0.013	Significant reduction in ED visits and hospitalisation after intervention **Illustrated as consistently positive effect**

Citation design, size, risk of bias, and intervention	CIFR domains	Reported outcomes (* indicate primary outcome if stated)	Researchers' interpretation for Harvest plot
Suwannakeeree, 2016[33] Uncontrolled study FU:6 m Thailand, Urban 1 school: 29 children Age: 6-12 (extracted sub-analysis) Intervention: Asthma Friendly School Initiative RoB: High	**Intervention characteristics** Based on US guideline Individually tailored to each child **Outer setting** Parents attended sessions at school Medication provided to all participants Sent spirometry results + other information to HCP **Inner setting** Teachers were trained asthma management plan Delivered during school hours **Individual characteristics** Asthma management behaviour **Process** X fun interactive activity	**School absenteeism** *School absences*. Significant within-group difference • % (n) with ≥1 absence/6m: Pre: 48% (14) vs post: 17% (5) p=0.004	Significant reduction in missed school after intervention **Illustrated as positive effect**
		***Asthma control** *Symptoms.* Significant within-group increase in proportion with: • Day symptoms ≤2/wk %(n): Pre: 48% (14) vs post: 90% (26), p<0.001 • No night symptom %(n): Pre: 59% (17) vs post: 83% (24), p = 0.020 *SABA use:* No significant within-group difference in proportion using • SABA ≤2/wk % (n): Pre: 100% (29) vs post: 90% (26) p=0.25	Significant reduction in asthma symptoms but no significant effect on bronchodilator use after intervention **Illustrated as positive effect but hatched to show inconsistency**
		***Urgent healthcare services** *ED visits.* Significant within-group reduction n proportion with: • ≥1 ED visit % (n): Pre: 59% (17) vs post: 21% (6), p=0.002	Significant reduction in ED visit after intervention **Illustrated as positive effect**
Szefler, 2019[30] Non–randomised study, FU: 12m USA, minority 463 children, Age: 5-14 (89.7% between 6-12) Intervention: Building Bridges RoB: High	**Intervention characteristics** Based on NAEPP guideline School staff and nurse involved in development Tailored to culture/beliefs **Outer setting** Parental attended session 85% participant had medical insurance Letter to HCP **Inner setting** School nurses delivered intervention Delivered during school hours **Individual characteristics** Inhaler technique score **Process** Fidelity: implemented as planned Interactive session	**School absenteeism*** *School days missed.* Significant between-group reduction in absenteeism • Mean % school days missed: I: 9% vs C: 12% p<0.001.	Significant reduction in absenteeism in intervention group **Illustrated as positive effect**
		Asthma control *Validated control test:* Significant within-group increase in ACT: • ACT Mean (SD): Pre: 19.5 (0.2) vs post: 21.1 (0.2), p<0.01 *Proportion poorly controlled:* Significant within-group reduction in proportion of children below the ACT threshold for good control • % with ACT score ≤19: Pre: 43% vs post: 29%, p <0.01	Significant reduction in asthma control after intervention **Illustrated as positive effect**
		Urgent healthcare services Not reported	

STUDIES WITH OVERALL NO EFFECT			
McGhan, 2010[20] cRCT FU: 12m Canada, Majority 34 schools: 266 children, Age: 6-13 (8.6) Intervention: Roaring Adventures of Puff RoB: Low	**Intervention characteristics** Social cognitive theory Based on Canadian guideline **Outer setting** Parents attended session at school Letter + communication with HCP **Inner setting** Session for teachers **Individual characteristics** Medication use and management behaviour **Process** Puppetry, games, videos, role-play, etc	**School absenteeism** School days missed. No significant between-group difference in • Missed school days/yr (Mean): I: 4.0 vs C: 2.5 (NS)	No significant effect of intervention on missed school days **Illustrated as no effect**
		Asthma control Not reported	
		Urgent healthcare services No significant between group difference in mean of: • Unscheduled visit (Mean): I: 1.2 vs C: 0.7 (NS) • ED visits (Mean): I: 0.2 vs C: 0.07 (NS)	No significant effect of intervention on unscheduled visits and ED visits. **Illustrated as consistently no effect**
Praena-Crespo, 2017[32] cRCT FU: 6 months Spain 97 schools:381 children Age: 10-12yrs Intervention: Asthma, Sport and Health programme RoB: Low	**Intervention characteristics** [X] Evidence-based (used expert consensus) Developed jointly with teachers and HCP Tailored to Spanish children **Outer setting** [X] Parental involvement Universal Health Coverage Coordination with HCPs using forms **Inner setting** PE teachers delivered intervention Delivered during PE period **Individual characteristics** Newcastle asthma knowledge questionnaire **Process** Implemented as planned Video and slides presentation	**School absenteeism** *School attendance from Education authority*. "The intervention programme decreases absenteeism, without reaching significance"	No data provided: authors stated no significant between group difference **Illustrated as no effect**
		Asthma control *Validated asthma control questionnaire* No significant between-group difference in: • CAN score Mean (95%CI): I: 11.25 (9.93 to 12.57) vs C: 10.61 (9.43 to 11.78), p =NS	No significant difference between control and intervention. **Illustrated as no effect**
		Urgent healthcare services Not reported	
Bartholomew, 2006[18] cRCT FU: 12m USA, Urban minority, 60 schools: 946 children, Age: 6-10yrs (Grade 1-4)	**Intervention characteristics** Social cognitive theory Based on NAEPP Tailored to language, health literacy **Outer setting** Parents mailed action plans, video	**School absenteeism** *Missed school in days*' Overall rates of absenteeism declined but here were no between-group differences in the frequency of absences over time'	No between-group data provided: Authors state no significant between-group difference **Illustrated as no effect**
		Asthma control *Validated Usherwood Symptom Questionnaire*. 'Symptoms declined	No between-group data provided: Authors state no significant

Intervention: Partners in School Asthma Management program RoB: Unclear	Tailored letters and video to HCP **Inner setting** School action committee **Individual characteristics** Self-efficacy assessed **Process** Interactive computer program	significantly over time, but there were no between-group differences on symptom level or rate of decline'	between-group difference **Illustrated as no effect**
		Urgent use of healthcare services *Hospitalisations/ED.* "Increasing over time but there was no between-group difference in the level or rate of increase of hospitalisations at post-test by group."	No data provided: Authors state no significant between-group difference **Illustrated as no effect**
Clark, 2010[23] cRCT, FU: 12m USA. Urban, minority 19 schools: 1292 children, Age: 10-13 (mean: 11.6) Intervention: tailored Open Airway for School (OAS) and tailored OAS + peer component (OAS+) RoB: Unclear	**Intervention characteristics** OAS+: Children involvement Adapted to minority in urban setting **Outer setting** Take home assignments and material for parents **Inner setting** [X] School staff delivered/received intervention Delivered during school hours **Individual characteristics** Asthma self-regulation and management scale **Process** OAS+: Games, role-play, artistic activities	**School absenteeism** Not reported	
		***Asthma control** *Symptoms score* No significant differences between either group and control in mean frequency of day symptoms. • Odds of a fall in day-time symptoms OAS: OR = 1.1 (p> 0.5) OAS+: OR = 1.3 (p=0.3). No data provided for control group	No significant difference between intervention A and B with control groups for symptoms. **Illustrated as no effect**
		Urgent healthcare services Not reported	
Gerald, 2006[24] cRCT FU:12m USA, Urban minority 54 schools: 736 children, Age: 6-10 yrs Intervention: tailored Open Airway for School + educational programme for school community RoB: Unclear	**Intervention characteristics** Included written personalised asthma action plan Tailored asthma plan individually to each child **Outer setting** Parent attended session at school All children received asthma medication Coordination care with school nurse and HCP **Inner setting** Session for school faculty and staff Delivered during physical education period **Individual characteristics** Knowledge score **Process** [X]Fidelity: program shortened, not as planned	***School absenteeism** *Number of all-cause absences.* No significant between-group difference Number of absences Mean (SD) I: 3.88 (3.5) vs C: 3.21 (3.2), p=NS	No significant effect of intervention on school absenteeism **Illustrated as no effect**
		Asthma control Not reported	
		Urgent healthcare services *Number of ED and hospital events. No significant between group difference:* • ER visits Median (SD): I: 0.09 (0.28) vs C: 0.10 (0.31), NS • Hospitalisations (median (SD): I: 0.04 (0.19) vs C: 0.02 (0.14), NS	No significant effect of intervention on ER visit and hospitalization. **Illustrated as consistently no effect**
Horner, 2016[25] cRCT, FU:12m	**Intervention characteristics** Bruhn's theoretical Model	**School absenteeism** Not reported	

USA, Rural minority 33 schools: 168 children, Age: 7-11 yrs Intervention: Asthma Plan for Kids [Only the school-based group extracted for this review] RoB: unclear	Based on US guideline Parents involved in development Tailored to families in rural areas **Outer setting** Group presentation and booklets for parents 92% of children were insured [X] Coordination care with HCP **Inner setting** [X] school involvement Delivered during lunch time **Individual characteristics** Asthma management score **Process** Fidelity: measured Vignettes + problem solving	**Asthma control** (School-based intervention only) *Asthma symptoms* No significant-between group difference: • Severity of chronic asthma scale Mean (SD) : I: 3.38 (0.69) vs C: 3.79 (1.34), NS	No significant effect of intervention on asthma control **Illustrated as no effect**
		***Urgent healthcare services** (School-based intervention only) *Urgent asthma events.* No significant between-group difference in: • *Office visits/12m Mean (SD) I: 0.49 (1.02) vs C: 0.69 (1.3), NS • *Hospitalisation/12m Mean (SD) I: 0.01 (0.11), vs C: 0.02 (0.22), NS • *ED visits/12m Mean (SD): I: 0.04 (0.19) vs C: 0.04 (SD 0.19), NS	No significant effect of intervention on offices visits, hospitalisation and ED visits **Illustrated as no effect**
McCann, 2006[26] cRCT FU : 12 m UK 24 schools: 219 children, Age: 7-9 yrs Intervention: Nurse-led RoB: Unclear	**Intervention characteristics** Based on UK guideline Developed with school staff Tailored to local evidence **Outer setting [None]** **Inner setting** Session for teachers **Individual characteristics** Asthma knowledge + self-confidence + self-esteem **Process** Role play	***School absenteeism** *School days missed.* 'After adjusting for social deprivation, no effect of the intervention was found.' • Within intervention group: Mean days/yr (SD) Pre: 7.0 (7.4) vs post 6.8 (6.1) [No control group data provided]	No data provided: authors state no significant effect of intervention on school absenteeism **Illustrated as no effect**
		Asthma control *Asthma symptoms reporting*. 'Resolution of symptoms for all children (Chi-squared 21.8; p=0.0005), but no effect of the intervention was found.'	No data provided: authors state no significant effect of intervention on asthma control **Illustrated as no effect**
		Urgent healthcare services Not reported	
McGhan, 2003[19] cRCT FU: Canada, Majority 18 schools: 162 children, Age: 5-13 Intervention: Roaring Adventures of Puff RoB: Unclear	**Intervention characteristics** Social cognitive theory Based on Canadian guideline **Outer setting** Parents attended session at school Letter + communication with HCP **Inner setting** Session for teachers **Individual characteristics** Self-efficacy and management behaviour	**School absenteeism** *School absences.* No significant between-group difference in: % (n) with ≥1 absence/12m: I: 39% vs C: 47% (p=0.07)	No significant effect of intervention on missed school days **Illustrated as no effect**
		Asthma control Reported symptoms. Mixed findings: Only one significant between-group difference in proportion of children in last 2w with: • Waking with symptoms: I: 45 % vs C: 39% (p>0.1) • Coughing (mod/severe: I: 25% vs C: 28% (p>0.1) • Tight chest (mod/severe): I: 11% vs C: 11% (p>0.1) • Wheezing (mod/severe): I: 15% vs C: 14% (p>0.1)	No significant difference of intervention for all measurement on asthma control except for limitation in kind of play. **Illustrated as no effect but hatched to indicate inconsistent**

	Process Puppetry, games, role-play, model building etc	• Shortness of breath (mod/severe): I: 15% vs C: 11% (p>0.1) • Limited kind of play: I: 29% vs C: 31% (p<0.01) • Limited amount of play: I: 59% vs C: 58% (p>0.1)	
		Urgent healthcare services Urgent events: No significant between group difference in: • % with ≥1 ED visit/12m: I:12%, vs C: 10% (p > 0.1) • % with ≥1 unscheduled visit/12m: I: 34% vs C: 37% (p >0.1)	No significant effect of intervention in ED visits and unscheduled visits. **Illustrated as consistently no effect**
Perry, 2018[31] cRCT FU: 6 m USA, Rural minority 19 schools: 363 children, Age: 7-14 (mean:9.6) Intervention: Telemedicine asthma education RoB: Unclear	**Intervention characteristics** Based on NAEPP guideline Tailored to individual and rural population **Outer setting** Parents attended session Letter to HCP 3 monthly **Inner setting** Educational session for school nurse [X] Delivered outside of school hours **Individual characteristics** Asthma knowledge and self-efficacy **Process** Fidelity: Implemented as planned	**School absenteeism** Not reported	
		***Asthma control** *Symptom free days.* No significant between-group difference in Symptom free days in last 2w Mean (SD): I: 8.8 (5.1) vs C: 9.4 (5.1), p=0.55	No significant effect of intervention on asthma control **Illustrated as no effect**
		Urgent healthcare services Not reported	
Persaud, 1996[27] RCT FU: 20wks USA, Urban minority 10 schools: 36 children Age: 8-12 Intervention: Asthma Self-Management RoB: High	**Intervention characteristics** Based on US guideline School nurses involved in development Tailored to urban disadvantaged population **Outer setting** [X] parental involvement Practice accepted insured and non-insured Letter to HCP **Inner setting** Feedback and interview with school staff Delivered during school hours **Individual characteristics** Asthma knowledge and children asthma attitude **Process** Role-play	**School absenteeism** *School days missed.* No significant between group difference in: Days absent/20w mean (SD) I:6.4 (4.6) vs C: 7.6 (5.3), p= NS	No significant effect of intervention on school absenteeism **Illustrated as no effect**
		Asthma control Not reported	
		Urgent healthcare services *ED visits.* No significant between-group difference in: • ED visits/20w. Adj mean (SD): I: 0.27 (0.57) vs C: 1.0 (1.2), p=NS Significant between-group difference in proportion of children with ED visits I: 22% vs C: 50%, p<0.05	Adjusted mean was prioritised over proportion in measurement for the outcome. No effect of intervention on ED visits **Illustrated as no effect**

Velsor-Friedrich, 2005[28] Non-randomised study FU: 12 m USA, Urban, minority 4 schools: 52 children Age: 8-13 (Mean:10.8) Intervention: Open Airway for School RoB: High	**Intervention characteristics** Orem's Self-Care deficit theory Based on US guideline Individually tailored by school nurse **Outer setting** [X] parental involvement Coordination with school-based clinic physician **Inner setting** Delivered during school hours **Individual characteristics** Measured care abilities and self-care practices **Process** Group discussion, stories, games, role-play	**School absenteeism** *School days missed.* No significant between group difference in: Days absent/yr mean (SD): I: 9.0 vs C: 14.4, p=NS	No significant effect of intervention on missed school days **Illustrated as no effect**
		Asthma control *Days with symptoms*. No significant between-group difference in: • % with ≥1 day of symptoms in past 2w: I: 50% vs C: 54%, p=NS	No significant effect of intervention on asthma control **Illustrated as no effect**
		Urgent healthcare services *Urgent doctor visits.* No significant between-group difference in: % with ≥1 day of symptoms in past 2w: I: 14% vs C: post:20% , p=NS	No significant effect of intervention on urgent care visits **Illustrated as no effect**

* indicates primary outcome of the study

Abbreviations: adjOR=adjusted Odds Ratio, adjRR=adjusted Risk Ratio, ACT= Asthma Control Test, ACQ= Asthma Control Questionnaire, C= Control, CAN= *Control Asma en Niños* CHSA =Children's Health Survey for Asthma (parent version) and CHSA-C (child version). cRCT = cluster Randomised Controlled Trial, CI= Confidence Interval, ED= Emergency Department, FU= Follow up, HCP= HealthCare Professional, RCT = Randomised Controlled Trial, I=Intervention, RoB = Risk of Bias, RR=Risk Ratio, MCID: Minimal Clinically Importance Difference, NAEPP= National Asthma Education and Prevention Programme, NS=Not Significant, SABA= Short Acting Beta Antagonist, SE= Standard Error, SD= Standard Deviation, m=month, PE= Physical Education, PBL=Problem Based Learning, vs=versus, UK = United Kingdom, USA/US =United States of America, w= week, yr=year

Table 3: Summary matrix comparing 12 sub-domains of CFIR in overall positive or no effect studies

Studies with overall positive effect															
CFIR domains and subdomains		Cicutto 2005	Cicutto 2013	Clark 2004	Clark, 2005	Isik 2020	Levy 2006	Magzamen 2008	Marsland 2019		Simoneau, 2020	Spencer 2000	Suwannaree 2016	Szetler 2019	Total with this domain
									ICC	OAS					
Intervention characteristics	Theory-driven	✓	✓		✓	✓			✓						5
	Evidence-based	✓	✓		✓	✓	✓			✓			✓	✓	8
	Stakeholder involvement	✓	✓			✓		✓	✓		✓			✓	7
	Tailored	✓	✓	✓	✓	✓		✓					✓	✓	8
Outer setting	Substantial parental involvement	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓	10
	Minimal parental involvement					✓		✓		✓					3
	Access to asthma care	✓	✓				✓						✓	✓	5
	Coordination with child's health provider	✓	✓				✓				✓		✓	✓	6
Inner setting	School participation		✓	✓	✓		✓		✓		✓		✓	✓	8
	Done during school hours	✓	✓			✓		✓	✓				✓	✓	7
Individual characteristics	Measurement of knowledge, skill or practice	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	12
Process	Fidelity	✓	✓			✓			✓					✓	5
	Child satisfaction	✓	✓		✓	✓		✓	✓	✓				✓	8
Total sub-domains met in individual study (range is in final column)		11	12	4	7	9	6	6	8	6	5	2	8	11	2-12

Studies with overall no effect														
CFIR domains and subdomains		Bartholomew 2006	Clark 2010		Gerald 2006	Horner 2016	McCann 2000	McGhan 2003	McGhan 2010	Praena-Crespo 2016	Perry 2018	Persaud 1996	Velsor-Friedrich 2005	Total with this domain
			OAS	OAS plus										
Intervention characteristics	Theory-based	✓				✓		✓	✓				✓	5
	Evidence-based	✓			✓	✓	✓	✓	✓		✓	✓	✓	9
	Stakeholder involvement			✓		✓	✓			✓		✓		5
	Tailored	✓	✓		✓	✓	✓			✓	✓	✓	✓	9
Outer setting	Substantial parental involvement				✓	✓		✓	✓		✓			5
	Minimal parental involvement	✓	✓											2
	Access to asthma care				✓	✓				✓		✓		4
	Coordination with child's health provider	✓			✓			✓	✓	✓	✓	✓	✓	8
Inner setting	School participation	✓			✓		✓	✓	✓	✓	✓	✓		8
	Done during school hours		✓		✓	✓				✓		✓	✓	6
Individual characteristics	Measurement of knowledge/skills/behaviour	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	11
Process	Fidelity					✓				✓	✓			3
	Child satisfaction	✓		✓		✓	✓	✓	✓	✓		✓	✓	9
Total sub-domains met in individual study (range is in final column)		8	4	6	8	10	6	7	7	9	7	9	7	4-11

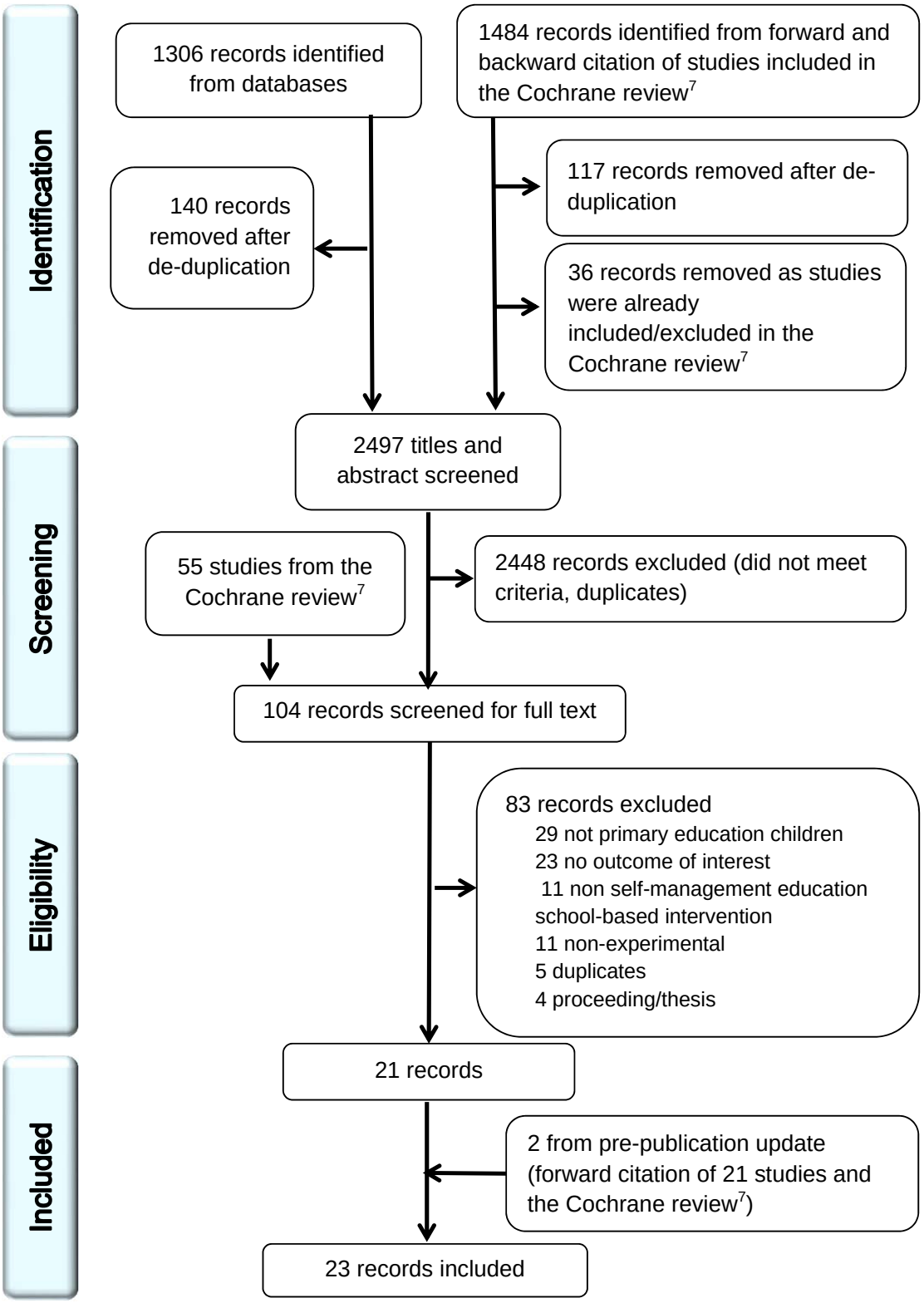

Figure 1: PRISMA diagram of selection process

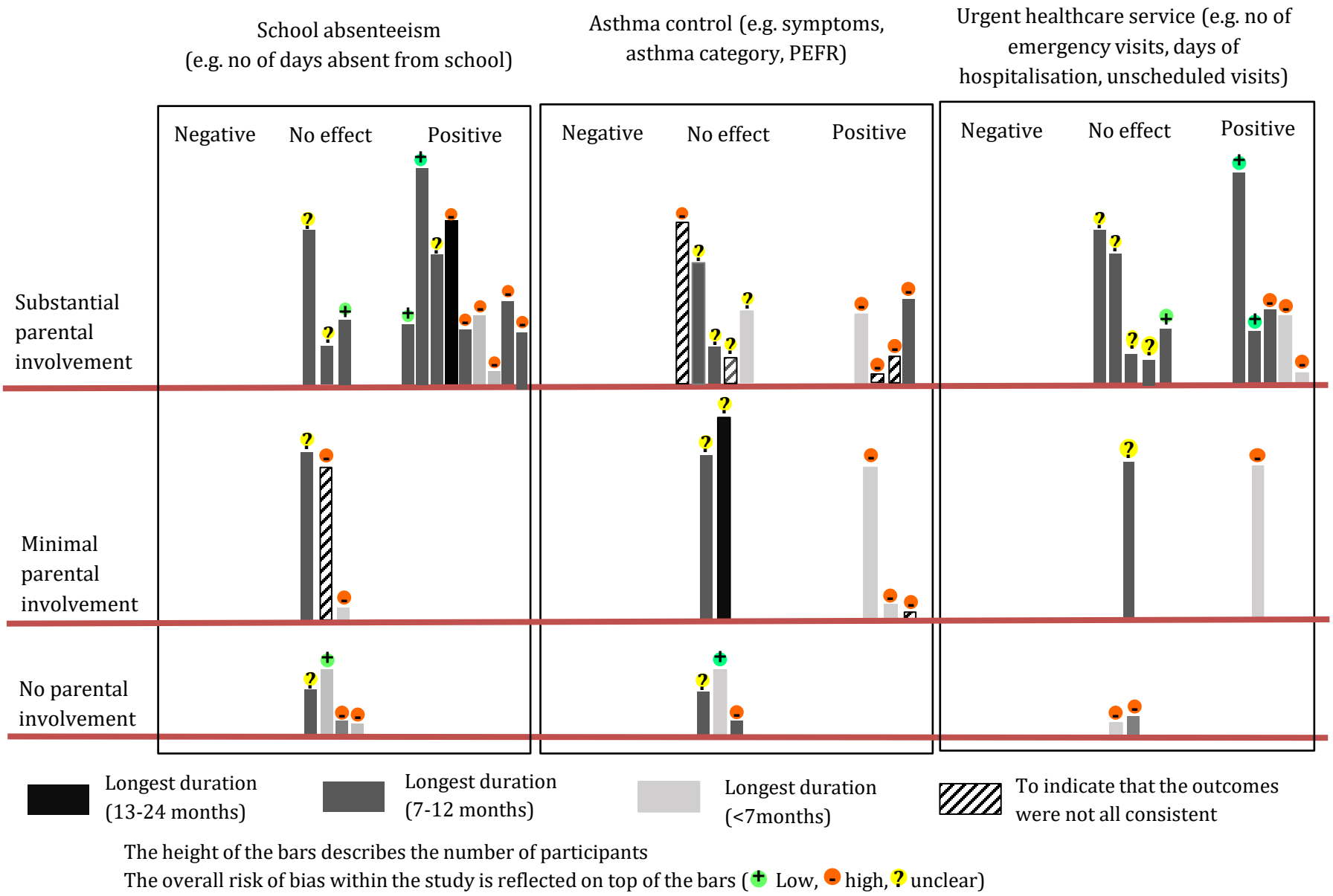

Figure 2: Harvest plot illustrating the effectiveness on school absenteeism, asthma control and urgent healthcare services across parental involvement for school-based self-management asthma educational intervention