Effectiveness of Home-Based, Multi-Trigger, Multicomponent Interventions with an Environmental Focus for Reducing Asthma Morbidity

A Community Guide Systematic Review

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Context: Asthma exacerbations are commonly triggered by exposure to allergens and irritants within the home. The purpose of this review was to evaluate evidence that interventions that target reducing these triggers through home visits may be beneficial in improving asthma outcomes. The interventions involve home visits by trained personnel to conduct two or more components that address asthma triggers in the home. Intervention components focus on reducing exposures to a range of asthma triggers (allergens and irritants) through environmental assessment, education, and remediation.

Evidence acquisition: Using methods previously developed for the *Guide to Community Preventive Services*, a systematic review was conducted to evaluate the evidence on effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus to improve asthma-related morbidity outcomes. The literature search identified over 10,800 citations. Of these, 23 studies met intervention and quality criteria for inclusion in the final analysis.

Evidence synthesis: In the 20 studies targeting children and adolescents, the number of days with asthma symptoms (symptom-days) was reduced by 0.8 days per 2 weeks, which is equivalent to 21.0 symptom-days per year (range of values: reduction of 0.6 to 2.3 days per year); school days missed were reduced by 12.3 days per year (range of values: reduction of 3.4 to 31.2 days per year); and the number of asthma acute care visits were reduced by 0.57 visits per year (interquartile interval: reduction of 0.33 to 1.71 visits per year). Only three studies reported outcomes among adults with asthma, finding inconsistent results.

Conclusions: Home-based, multi-trigger, multicomponent interventions with an environmental focus are effective in improving overall quality of life and productivity in children and adolescents with asthma. The effectiveness of these interventions in adults is inconclusive due to the small number of studies and inconsistent results. Additional studies are needed to (1) evaluate the effectiveness of these interventions in adults and (2) determine the individual contributions of the various intervention components.

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Context

Asthma is a common chronic respiratory disease and a major source of morbidity in the U.S. It affects more than 20 million Americans and can substantially reduce quality of life, and its prevalence has more than doubled since 1980.[1] Asthma is also a major cause of hospital use, resulting in approximately 500,000 hospitalizations, 1.8 million emergency department visits, and 12.3 million physician office visits annually.[1] Asthma further results in very high direct and indirect costs, with over $32.7 billion in healthcare costs spent annually when adjusted to 2007 U.S. dollars.[2] In 2001 asthma was ranked the 25th leading cause of disability-adjusted life-years (DALYs) lost worldwide, with an estimated 15 million DALYs lost.[3] Finally, asthma is a leading cause of school absences for U.S. children, with an estimated 12.8 million school days missed for the year 2003.[4]

Relationship Between the Home Environment and Asthma

The home environment is inextricably linked with the health of its occupants. This is especially true for diseases such as asthma. Numerous studies confirm that sensitization among genetically susceptible populations to certain indoor allergens such as house dust mite, animal dander, and cockroach is a risk for developing asthma in children.[5–11] Studies have shown that poor housing quality is strongly associated with poor asthma control even after controlling for potentially confounding factors such as income, smoking, overcrowding, and unemployment.[12] To treat asthma properly, conditions in the home environment must be addressed.[13–15]

Exposure to allergens and irritants within the home environment can trigger or exacerbate episodes of asthma.[5,6] Moisture from leaky plumbing, high humidity, and cracks in floors and walls can contribute to mold growth; provide water for cockroaches, mice, and dust mites; and provide avenues through which cockroaches and mice can enter the home.

Common Asthma Triggers and Strategies to Reduce Triggers

The most common asthma triggers within the home include allergens from house dust mites, pets, cockroaches, rodents, and mold as well as irritants such as environmental tobacco smoke (ETS) and indoor air pollutants.[6,7] Reducing these asthma triggers in the home can be accomplished through multiple strategies, such as environmental remediation to fix physical problems within the home and environmental education to address behaviors such as smoking and failing to seal food. Briefly, the existing evidence for individual strategies to reduce the most common asthma triggers is as follows:

Dust mites. The house dust mite is one of the most commonly implicated asthma triggers.[10,11,16,17] The link between house dust mites and asthma symptoms has been well established. Numerous well-designed studies have demonstrated that asthma symptoms, pulmonary function, and need for medication in dust mite–sensitive asthma patients correlate with the level of exposure to house dust mite.[9–11,16,17] There is conflicting evidence as to whether reducing exposure to house dust mite alone can improve asthma symptoms and reduce medication usage.[18–20] This asthma trigger can be removed by using allergen-impermeable pillow and mattress covers, washing bedding in hot water >130°F, removing old carpet, reducing home humidity to <60%, and washing stuffed animals weekly.[8,14,21,22]

Pets. Pet allergens, particularly dog and cat, are well-recognized asthma triggers in sensitized individuals.[23–25] A prospective controlled study of 554 HMO members with asthma found those with a dog in the home who were sensitized to dog allergen had a 49% increase in the risk of needing acute asthma care each year even after adjusting for other risk factors.[26] Removing pets from the home is the most effective method to reduce exposure to pet dander in sensitized patients.[27] Alternately, keeping pets out of bedrooms can reduce airborne pet dander allergen levels fivefold.[28]

Cockroaches. Cockroach allergen is a common cause of asthma exacerbations in urban environments. In the National Cooperative Inner-City Asthma Study (NCICAS), children sensitized and exposed to high levels of cockroach allergen showed increasing asthma severity as the level of cockroach allergen exposure increased.[29] Although hard to eliminate, cockroach allergen can be reduced using "integrated pest management" strategies. These include teaching residents to remove food and water sources, clean surfaces and floors, seal trash containers, store food carefully, use gel baits to exterminate roaches, and seal cracks and small holes in the residence to keep roaches out.[30]

Mice and rats. Mouse and rat allergen exposure is common in inner-city homes. In the NCICAS study, 95% of the 608 homes tested had detectable mouse allergen in at least one room of the home, with highest levels in the kitchen.[31] However, the link between mouse allergen exposure and asthma symptoms is not as clear.[32] Integrated pest management techniques can also help reduce mouse and rat allergen. These include filling holes, vacuuming, cleaning, using low-toxicity pesticide, placing traps, and storing food carefully.[33]

Mold. There is a strong link between asthma and mold. The IOM's "Report on Damp Indoor Spaces" found sufficient evidence of an association between mold and asthma symptoms in sensitized individuals.[34] A subsequent analysis estimated that exposure to dampness and mold account for 21% of current asthma in the U.S.[35] Mold-sensitive people can be protected by removing mold from hard, nonporous surfaces; discarding mold-contaminated materials (e.g., carpet, ceiling tiles); and addressing the source(s) of moisture responsible for mold growth.[34]

Environmental tobacco smoke. Environmental tobacco smoke (ETS) has been linked to increased risk of developing asthma[36,37] as well as increased severity and frequency of exacerbations in children with asthma.[38,39] Interventions to reduce ETS exposure focus on counseling/treatments to encourage smoking cessation, and air-filtration methods to reduce the presence of tobacco smoke in the air.[13] Smoking-cessation interventions directed toward parents of children with asthma have shown some success in reducing parental smoking and reducing the number of cigarettes smoked in the home.[40,41]

Current asthma guidelines emphasize smoking-cessation counseling as part of treatment for smokers with asthma, or smokers with children who have asthma.[14] Complete smoking bans in the home have been shown to have a small but noteworthy reduction in ETS exposure in caregivers who are unwilling to stop smoking.[42,43] Although studies have found that air filters and ventilation can reduce the indoor concentration of ETS particles in the air,[44] overall there is little research on the efficacy of air filters and ventilation in improving asthma outcomes.[13]

Indoor pollutants. Although often a trigger for asthma exacerbations, indoor pollutants are rarely the focus of home environmental interventions. Such pollutants include, but are not limited to nitrogen dioxide, particulate matter (resulting from biomass combustion products), and bacterial endotoxins.[45–47] Use of gas stoves and wood-burning appliances or fireplaces have been associated with increased wheezing in schoolchildren and asthma exacerbations.[48,49] However, data from a recent meta-analysis did not find any association between the use of solid biomass fuels and asthma in children or women.[50]

More comprehensive lists of indoor asthma triggers and recommendations to remove asthma triggers from the indoor environment are provided in the 2007 National Asthma Education and Prevention Program Expert Panel Report 3, Section 3[14] at www.nhlbi.nih.gov/guidelines/asthma/06_sec3_comp3.pdf (pdf p. 24, Figure 3-20) , and the Environmental Protection Agency (EPA) list of publications and resources.[44,51,52]

In summary, a variety of triggers in the home can worsen asthma symptoms. Although several studies document effectiveness of interventions aimed at single asthma triggers in reducing allergen levels,[33,53,54] other recent studies suggest that single-component interventions or those that address a single asthma trigger may not be as effective as interventions that address multiple triggers using multiple intervention components.[14,55,56]

Focus for This Review

For several reasons, the systematic review development team (see Methods), with the approval of the Task Force on Community Preventive Services (Task Force), decided to evaluate the effectiveness of home-based environmental interventions for improving asthma morbidity outcomes. The main research question was, "Do multi-trigger, multicomponent, home-based environmental interventions improve asthma morbidity?"

First, this review focused on approaches addressing multiple asthma triggers, which are more likely to be effective at a population level because more than half of individuals with asthma are sensitive to multiple allergens.[57–59] Second, there is evidence that using multiple approaches to address environmental triggers, specifically approaches that use both education and remediation, could be more effective than interventions that use either alone.[60,61] Third, because of limitations in transportation, money, and time, traditional asthma education programs set in clinic or school settings often have difficulty attracting and retaining participants.[62]

This review focused on environmental interventions conducted primarily in the home setting, which may address many of the limitations found in other settings. In these interventions, home visitors educate participants in a familiar setting that requires no travel or time away from work, which may increase participation and retention. In addition, after visually assessing home environmental conditions, a trained home visitor can provide a more accurate assessment of asthma triggers in the home than could a survey completed by home residents and administered in a clinic setting. Ideally and most importantly, home visitors attempt to build trusting relationships with clients, thereby enhancing the visitors' effectiveness in motivating behavioral changes.[62] These qualities suggest that home-based environmental interventions for asthma are distinct from and may be more effective than traditional clinic-based asthma programs.

Although environmental interventions for asthma have been evaluated in several publications, there has been no recent systematic review of the literature that focuses primarily on home-based environmental interventions for children and adults with asthma. Most of the literature on home-based, multi-trigger, multicomponent interventions with an environmental focus has been published in the last 4 years. Therefore, a comprehensive, up-to-date systematic review was needed to compile and summarize the evidence on effectiveness of these interventions in improving asthma morbidity.

Clinical Basis for This Review

The National Asthma Education and Prevention Program (NAEPP) Expert Panel Report 3, "Guidelines for the Diagnosis and Management of Asthma,"[14] forms the clinical basis for this systematic review. This report, the most widely used clinical practice guidelines for asthma in the U.S., outlines evidence-based guidelines for the treatment of asthma, including pharmaceutic management, educational activities, and environmental controls. This review examines interventions highlighted in the NAEPP guidelines that have been found to be effective in clinical practice at a population level.

Intervention Description

To be considered for inclusion in this review of home-based, multi-trigger, and multicomponent interventions with an environmental component (hereafter referred to as "home-based environmental interventions"), interventions had to: include at least one home visit; target more than one asthma trigger; and include more than one intervention component, at least one of which is an environmental component. Other accepted standard practices for asthma treatment identified in several of the included studies (e.g., general asthma education, self-management education, social services, or coordinated care) were not required components of the intervention. The intervention characteristics and components, along with definitions for each, are listed in Table 1.

Table 1. Intervention characteristics and components of home-based, multi-trigger, multicomponent interventions with an environmental focus to reduce asthma morbidity[a]

Intervention characteristics	Definition
Home visit	Some effort to change the home environment Assess Remediate Educate Conducted by someone with training or experience Community health workers Pest control professionals Clinicians or healthcare providers
Multi-trigger	Activities that reduce exposure to two or more environmental triggers that exacerbate asthma
Multicomponent	More than one of the seven identified intervention components, including at least one component directed toward home environment
Intervention components	
Environmental assessment	In-home written assessment of environmental triggers
Environmental remediation	Actions conducted or financed to reduce triggers in the home
Environmental education	Patient education regarding actions to reduce triggers in the home
Self-management education	Patient education on monitoring symptoms and taking action to modify treatment
Asthma education	General education on asthma without a self-management education component
Social services	Services to improve access to medical care or to advocate for environmental remediation
Coordinated care	Services to improve coordination of care between healthcare providers and home health workers

[a]At least one environmental component is necessary for each of these interventions. The three environmental components are environmental assessment (EA), and environmental remediation (ER), and environmental education (EE).

Composition of Multi-Trigger, Multicomponent, Home-Based Environmental Interventions

Home-based environmental interventions can vary considerably in cost, time, and effort. Some interventions provide more intense environmental remediation and have a smaller education component, whereas other interventions may provide less remediation and focus more on environmental and self-management education.

In the asthma field, the term "remediation" has typically been used to indicate structural changes in the home to reduce environmental triggers; in contrast, a variety of terms has been used to describe nonstructural changes. For the purposes of this review, any changes in the home—structural or nonstructural—designed to reduce asthma triggers were defined as remediation. Nonstructural changes to the home were classified as either minor or moderate remediation. Providing low-cost items, such as an allergen-impermeable cover, to reduce asthma triggers constituted minor remediation. The active involvement of a home visitor and the provision of multiple low- or moderate-cost materials to reduce triggers, such as in integrated pest management constituted moderate remediation. Any substantial structural changes to the home constituted major remediation. (Full definitions of major, moderate, and minor environmental remediation are provided in Appendix A.)

Education efforts varied in type and intensity. Some education-oriented interventions focused primarily on education to reduce environmental triggers (environmental education), whereas others placed more emphasis on asthma self-management education. The education component could also vary in intensity depending on the number of home visits, the amount and breadth of education given at each home visit, and the training of the home visitor. Some interventions used multiple detailed modules over several home visits to teach clients trigger-reduction and asthma-management behaviors, whereas other interventions provided less-detailed education over one or two home visits. The home visitors could be medical professionals, such as physicians, nurses, social workers, and respiratory therapists, or people from within the community where the intervention was conducted (community health workers [CHWs]). Most of the CHWs were not medical professionals but were given specialized training to conduct home environmental assessments and to provide environmental and self-management education.

One of the challenges of characterizing home-based environmental interventions is that various terminologies are used in the literature to describe the aspects of this intervention here termed "multi-trigger" and "multicomponent." These aspects are most often lumped under the terms "multifaceted" or "comprehensive," which are often not specifically defined.[14,57] The term "multifaceted" has been used to describe interventions directed toward more than one asthma trigger or interventions with more than one component. In this review, to highlight the importance of considering both multiple triggers and components, the choice was made to use the more-specific terms "multi-trigger" and "multicomponent." For additional information about terms and definitions used in this article, please refer to the Glossary (Appendix A).

Evidence Acquisition

The general methods used to conduct systematic reviews for the *Community Guide* are described in detail elsewhere.[63,64] The methods for conducting this specific review, including forming a systematic review development team (review team), creating a conceptual approach, developing a search strategy, selecting intervention criteria, conducting abstraction and evaluation of studies, making outcome determinations, and defining the intervention are presented below.

The Systematic Review Development Team

The review team included three subgroups:

- the coordination team, which drafted the analytic framework for reviews; managed the data collection and review process; and drafted evidence tables, summaries of evidence, and reports;
- the consultation team, which reviewed and commented on materials developed by the coordination team and set priorities for this review;
- the abstraction team, which collected and recorded data from studies for possible inclusion in the systematic review.

The names and affiliations of team members are presented in Appendix B.

Conceptual Approach

The analytic framework (Figure 1) shows the conceptual approach that guided the review process. This figure portrays the relationships among people with asthma, their households, and conditions in the physical environment, and shows the pathways along which an intervention is hypothesized to work to improve asthma outcomes. The framework indicates that home-based, multi-trigger, multicomponent interventions with an environmental focus are thought to reduce asthma morbidity through two different but intersecting pathways. One pathway runs through environmental assessment and remediation to change the physical environment (in this case the home). The second pathway runs through education intended to change behavior of people with asthma and their household members.

Along the environmental pathway, interventions that incorporate environmental assessment and remediation target characteristics of the physical environment and lead to reduced levels of asthma triggers in the home. Along the education pathway, interventions that incorporate environmental education, self-management education, or general asthma education, target all members of the household.

These efforts are intended to improve asthma knowledge, attitudes, and skills of household members, which should translate into improved asthma management behaviors. These asthma-management behaviors (AMBs) include more frequent use of asthma controller medications, better recognition of asthma symptoms, and use of peak flow meters.[14] AMBs could also include reducing asthma triggers by using integrated pest management to decrease both the number of insect and rodent pests[65] and by washing

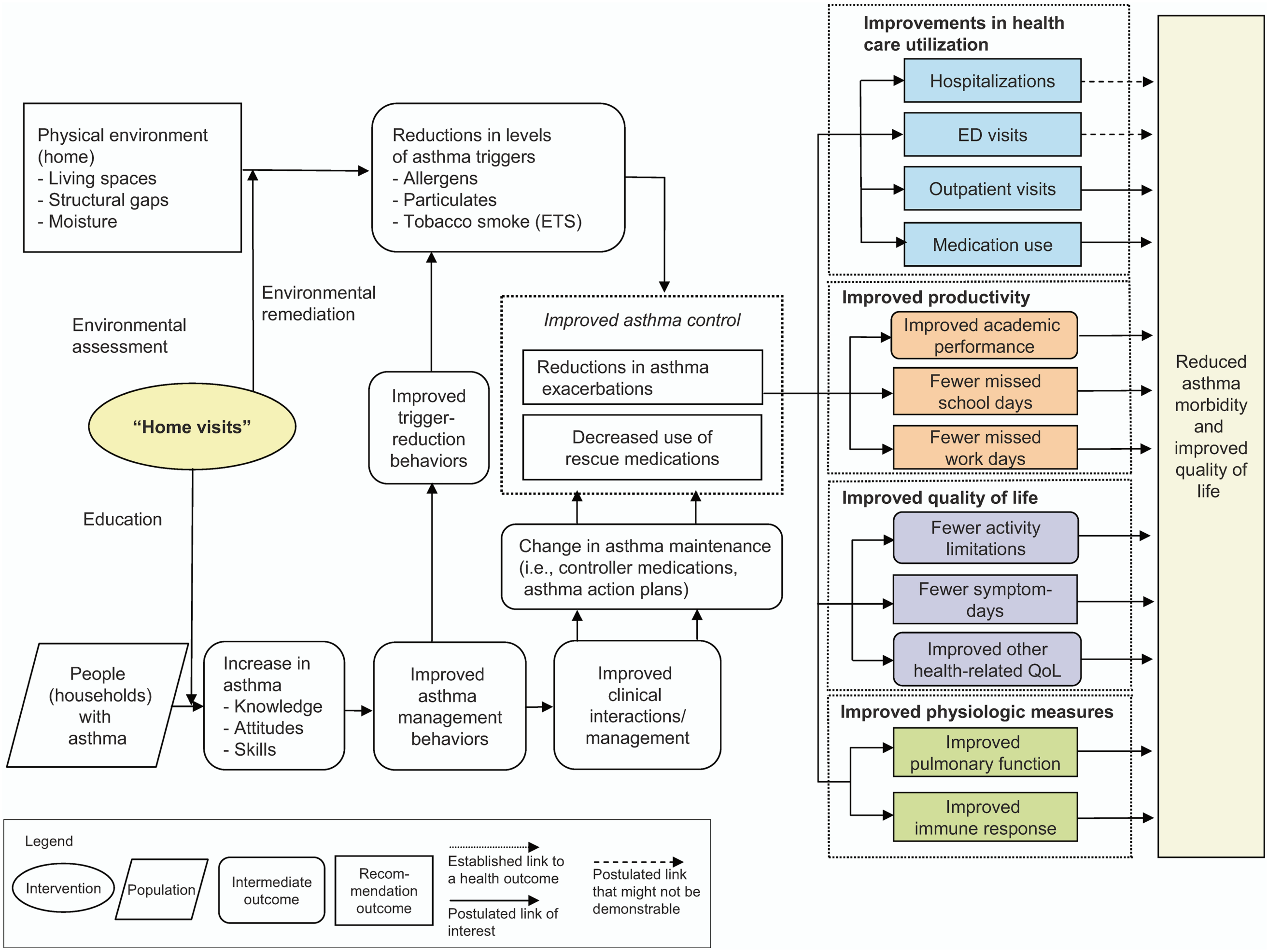

Figure 1. Analytic framework that guided the systematic review process
ED, emergency department; ETS, environmental tobacco smoke; QoL, quality of life

bedding in hot water to reduce dust mites. As depicted in Figure 1, the education pathway feeds back into the environmental pathway by educating about behaviors to reduce asthma triggers (trigger-reduction behaviors or TRBs).

Both of these pathways are thought to result in improved asthma control, as measured by outcomes including reduced use of rescue medications and reduced asthma exacerbations.[14] Improved asthma control has been shown ultimately to result in improvements in downstream outcomes of asthma morbidity such as decreased healthcare use (fewer hospitalizations, emergency department visits, and unscheduled office visits), improved productivity (fewer school or work days missed and improved academic performance or work productivity), improved quality of life (fewer symptom-days, fewer activity limitations, and improved quality-of-life [QOL] scores), and improved physiologic measures (better pulmonary function test scores and changes in immune response).

Search for Evidence

Study inclusion criteria. To be included in this review, a study had to meet the following criteria: (1) represent primary research published in a peer-reviewed journal, technical report, or government report, or unpublished research between January 1966 and February 2008; (2) meet *Community Guide* minimum research quality standards for study design and execution; (3) evaluate interventions with at least one home visit; (4) focus on reducing multiple environmental asthma triggers in the home; (5) include more than one intervention component; and (6) evaluate at least one health outcome. Studies that evaluated primary prevention of asthma or occupational asthma were excluded because those topics were beyond the scope of this review.

Search strategy. The literature search consisted of a systematic search of multiple databases, reviews of bibliographic reference lists, and consultations with experts in the field who were part of the review team (Appendix B).

The following electronic databases were searched: MEDLINE, EMBASE, ERIC, PsycINFO, Web of Science, Cochrane Library, Sociological Abstracts, and CINAHL. Only English language articles were included in the search. The initial literature search on the topic was conducted in July 2007, and a second search was conducted in February 2008.

Abstraction and Evaluation of Studies

Each study that met the inclusion criteria was evaluated for suitability of study design and study execution by two independent abstractors using the standardized *Community Guide* abstraction form.[63] Differences in ratings between the abstractors were resolved by consensus of the entire abstraction team. The suitability of each study design was rated as "greatest," "moderate," or "least," depending on the degree to which the design protected against threats to validity. The execution of each study was rated as "good," "fair," or "limited," based on several predetermined factors that could potentially limit a study's utility for assessing effectiveness. Only those studies in which quality of execution was rated as "good" or "fair" were included in the review. From the data in those included (or qualifying) studies, the team calculated effect sizes for study outcomes whenever sufficient information was available to do so. The team considered nonqualifying studies as sources of relevant background information to help conceptualize the review and to provide information on potential barriers to implementation and other benefits or harms. The nonqualifying studies, however, were not included in analyses.

Outcomes evaluated: primary outcomes. The primary outcomes evaluated in this review were quality of life (symptom-days, QOL scores); healthcare utilization (hospitalizations, emergency department visits, and unscheduled office visits); productivity (school or work days missed); and physiologic outcomes (changes in pulmonary function). All primary outcomes were analyzed for the client with asthma. The studies in this review measured these outcomes using a variety of effect measures for each outcome category. The team attempted to consolidate and compare outcomes when appropriate. The outcome categories and associated effect measures for each outcome are listed in Table 2.

Outcomes evaluated: additional outcomes. Besides the four primary outcomes noted above, many studies reported additional important outcomes, such as changes in indicators of asthma triggers (e.g., allergen levels, cotinine levels), behaviors to manage asthma (e.g., asthma self-management skills, use of preventive medication), TRBs (e.g., washing bedding, sealing food), and asthma control (e.g., reducing the number of asthma exacerbations, needing less rescue medication). Most of these additional outcomes listed above were reported using heterogeneous measures, which were not comparable; therefore, the effectiveness was reported by summarizing the number of studies in which intervention groups showed improvement compared to baseline and to the comparison group. The one exception is ETS exposure, which had enough comparable measures to allow quantitative summary.

Summary Effect Estimates

Community Guide systematic reviews consider data from all available studies of sufficient quality that compare outcomes in a group exposed to an intervention with outcomes in a group either concurrently or historically unexposed (or less exposed) to the intervention.[63,64] Consistent with the practices of many groups that focus on population-based or public health interventions,[66] this approach is broadly inclusive of a range of study designs. Studies with least-suitable study designs were included in the current analyses because they did provide useful information. The team recognized, however, that studies of least suitable study design could overestimate effects because of the lack of a comparison group, so differences in study design were considered when interpreting results across the body of evidence. A more detailed explanation of the methods used for this systematic review is presented in Appendix C.

The outcomes of interest in each study were generally ascertained from record reviews, client self-reports, or objective measures. Self-report data included dichotomous reports over a given time period or Likert-scale measures that reflected the frequency of the outcome. Intervention effectiveness was evaluated by assessing before–after changes in relevant outcomes in the intervention group and adjusting for concurrent changes in the comparison group when one was available. To facilitate comparison across studies, estimated intervention effects were expressed in common units that were appropriate to each outcome of interest.[63,64] Effect estimates for continuous data (e.g., symptom-free days, hospital visits) were expressed either as group mean differences or relative percentage changes (%), and those for dichotomous data (e.g., proportion of children with asthma symptoms) were expressed as absolute percentage point changes. Medians with interquartile intervals (IQI) were used as summary effect measures except when the sample size was less than 7 studies, in which case a range of values was provided. Studies with results that could not be converted to mean differences, percentage point changes, or relative percentage changes could not be included in the summary effect measures. These results were reported

Table 2. Systematic review outcomes and associated measures

Outcome of interest	Outcome categories	Effect measure
Quality of life	Symptom-days	Mean difference in number of symptom-days/year Absolute percentage change in children with >1 symptom-day per time period
	Quality-of-life or symptom score	Relative percentage change in quality-of-life or symptom score
Healthcare utilization	Hospitalizations (H)	Mean difference in number of visits
	Emergency department visits (ED)	Mean difference in number of visits
	Unscheduled office visits (UO)	Mean difference in number of visits
	Combined acute care visits	Mean difference in number of visits combined (H + ED + UO) Percentage of participants with >1 visit
Productivity	School days missed	Mean number of days Percentage of children with >1 school day missed per year
Physiologic outcomes	FEV1, FVC, FEV1/FVC, VC	% predicted FEV1 or FEV 0.5 Liters/minute FEV1 or FEV 0.5 % predicted peak flow Liters/minute peak flow
Asthma trigger indicators	Allergen levels, cotinine levels	Percentage change trigger level Mean change in trigger concentration
Asthma-management behaviors	Use of controller medications, use of asthma action plans	Percentage change in participants using controller medications Percentage change in participants using controller medications daily Mean number of days of controller use Mean dose of controller medication
TRBs	Washing sheets in hot water, eliminating or reducing smoking behaviors, use of integrated pest management strategies	Percentage change in people conducting TRBs Absolute number of people conducting TRBs OR of conducting more TRBs
Asthma control	Asthma exacerbations, use of rescue medications, use of oral corticosteroids	Percentage change in asthma exacerbations Absolute number of asthma exacerbations Mean amount of controller medication Absolute number of oral corticosteroid regimens Mean British Thoracic Society step score Percentage of participants in asthma severity categories

FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity; TRB, trigger-reduction behavior; VC, vital capacity

separately, however, to reflect the complete evidence base and to assess consistency across all studies.

Evidence Synthesis

The search identified 32 studies or study arms (hereafter collectively referred to as "studies")[30,57,67–96] evaluating the effectiveness of home-based, multi-trigger, multicomponent interventions. Twenty-three studies[57,68–72,74,75,78–82,85–94] met the quality criteria for inclusion in this review. The other nine studies were excluded due to limited quality of execution. Details of the 23 qualifying studies are provided on the *Community Guide* website at www.thecommunityguide.org/asthma/supportingmaterials/SET_multicomponent.pdf. Appendix D provides a summary of the characteristics of each study evaluated. Twenty-nine papers[12,97–124] provided additional information on the qualifying studies.

Study and Intervention Characteristics

The 23 qualifying studies that evaluated the home-based, multi-trigger, multicomponent interventions used a variety of research designs, of varying quality of execution (Table 3).

The number of participants in the studies ranged from 18 to 1033, with a median number of 104 participants (interquartile interval [IQI]: 64–274). Follow-up periods ranged from 1 month to 48 months, with a median follow-up period of 12 months (IQI: 12–18 months). Attrition (drop-out) rates were obtained for 21 of the 23 studies[57,68–72,75,78–82,85–88,90–94] and ranged from 0% to 78% at the follow-up time used for the current analysis (6–15 months). The study[85] with a 78% attrition rate is a least-suitability study and stated that the high attrition was due primarily to participants moving from the area. The overall median attrition rate was 18% (IQI: 6.5%–

Table 3. Design and quality of studies included in systematic review of home-based, multi-trigger, multicomponent interventions to reduce asthma morbidity

Quality of execution	Suitability of study design; N = 23 qualifying studies: Greatest; $n = 14$	Moderate	Least; $n = 9$
Good (0–1 limitations)	**Individual RCT** Morgan 2004[57]	—	—
Fair (2–4 limitations)	**Group RCT** Barton 2007[68] **Individual RCTs** Brown 2006,[69] Carter 2001,[70] Eggleston 2005,[71] Evans 1999,[72] Hughes 1991,[75] Kercsmar 2006,[78] Klinnert 2005,[79] Krieger 2005,[80] Krieger 2008,[81] Parker 2007,[88] Smith 2005[91] **Before-and-after, concurrent comparison group** Nishioka 2006[86]	—	**Before-and-after, no concurrent comparison** Levy 2006,[82] Nicholas 2005,[85] Primomo 2006,[89] Shelledy 2005,[90] Somerville 2000,[92] Stout 1998,[93] Thyne 2006,[94] Hasan 2003,[74] Oatman 2007[87]
Limited (≥5 limitations)	—	—	—

28%) for the 21 studies. Twelve studies[57,68–70,75,78,80,81,86,88,91,109] provided information on attrition rates for both intervention and comparison groups. The intervention group had a median attrition rate of 16% (IQI: 7%–19.8%), and the comparison group had an attrition rate of 14% (IQI: 9%–24%).

The content and components of the intervention varied considerably among the studies reviewed, and are listed in detail in Appendix D. In summary, 21 of the 23 studies (91%) conducted an environmental assessment; of these, 17 (74%) also included environmental remediation activities (minor [three studies; 18%], moderate [ten studies; 59%], or major [four studies; 23%]). Another 21 studies (91%) also included some form of education (six studies [29%] included education without remediation). Education focus ranged from primarily environmental education to primarily asthma self-management education, including monitoring asthma symptoms and the use of asthma management plans.

Most studies focused equally on both environmental and self-management education. Two studies (9%) focused only on remediation and did not have an educational component. Of the 23 studies, 14 were tailored based on exposure to asthma triggers in the home; of these, seven also included specific allergen sensitivities in tailoring the intervention. Number of home visits was one (three studies), two to seven (15 studies), and eight or more than eight (five studies). In the 23 studies, home visits were made exclusively by CHWs (six studies), nurses (five studies), respiratory therapists (two studies), physicians (two studies), social workers (one study), housing officers (one study), environmental educators (one study), and trained sanitarians (one study). In four of the studies, mixed teams of CHWs and nurses (two studies), social worker, nurse, and respiratory therapist (one study), and research assistant and pest control professional (one study) conducted the home visits. In 22 of the studies, information on asthma severity was included, and the results are indicated in Appendix D. Finally, 20 of the studies evaluated interventions targeting homes in which only children or adolescents had asthma; one study exclusively targeted adults; and two studies targeted children and adults (results of these last two studies were included both in the child and adult analyses).

Outcomes in Children and Adolescents

Outcomes related to quality of life. Sixteen studies[57,68,71,72,74,78–82,85,87–89,92,94] measured changes in quality of life among children or adolescents with asthma. These studies showed overall improvements in the number of asthma symptom-days, the proportion of children or adolescents with asthma symptoms, and in scores from symptom or QOL surveys. Six studies[57,72,78,80,81,94] evaluated changes in the number of symptom-days and showed an overall median reduction of 0.8 symptom-days/2-week period (range of values: 0.6 to 2.3 symptom-days/2-weeks reduction) or 21.0 fewer symptom-days/year (Figure 2). The median reduction in symptom-days/2-week period was 0.7 symptom-days in the subset of controlled trials and 2.3 symptom-days in the subset of uncontrolled studies.

Four studies[71,82,85,109] evaluated changes in the proportion of children or adolescents with any asthma symptoms on follow-up and found a median absolute reduction of 15.4 percentage points (range of values: 1.7 percentage point increase to 36.0 percentage point decrease). There was a median absolute reduction of 5.2 percentage points in the proportion of participants with asthma symptoms in the subset of controlled trials and a 27.4 percentage point median absolute reduction in the proportion of participants with asthma symptoms for uncontrolled trials (Figure 3).

There was a median relative improvement of 16.5% (IQI: 1.8% to 25% improvement) in symptom or QOL scores from the nine studies[68,71,79–82,87,89,92] that measured this outcome. The improvement in QOL scores was much smaller in the subset of controlled trials (3%) than in the subset of uncontrolled studies (25%) (Figure 4).

An examination was also made of the subset of studies that specifically used the Juniper Quality of Life Score (six studies: four controlled trials and two uncontrolled trials) to help determine clinical significance of improvements in quality of life. The Juniper Quality of Life (QOL) score is a validated questionnaire that measures symptoms, activity limitation, and emotional function on a 7-point scale and has been shown to correlate with clinical symptoms.[125] An increase of 0.5 pts or more is considered clinically significant. The overall median improvement in the Juniper QOL score using all of the studies was 0.4 pts (range of values: 0.02 pts to 1.41 pts), which is not considered clinically significant. The median improvement in the controlled studies was 0.13 pts (range of values: 0.02 pts to 0.6 pts) and 1.1 pts (range of values: 0.8 pts to 1.41 pts) in the uncontrolled studies (Figure 5).

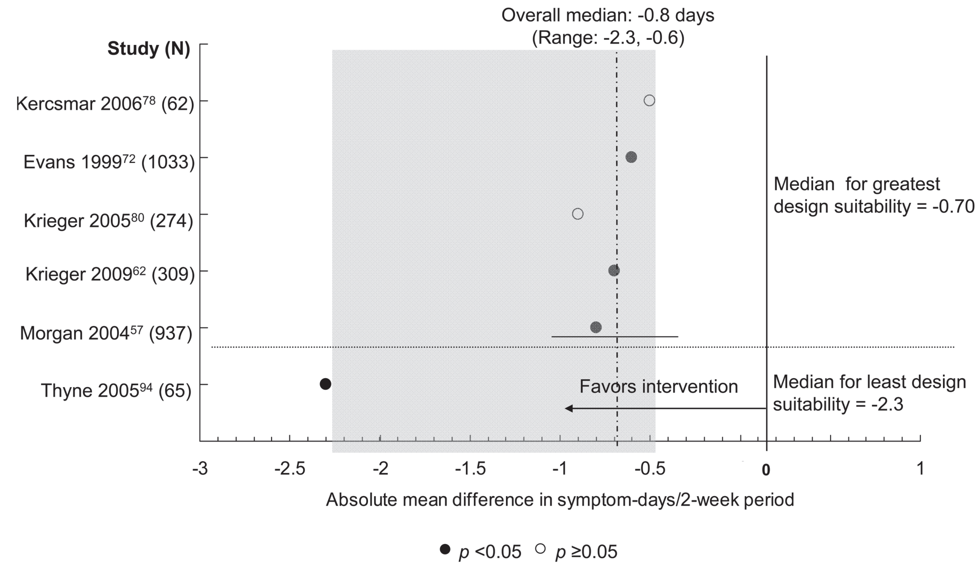

Figure 2. Quality of life: mean symptom-days
Note: Gray box represents interquartile interval or range; CIs were added to graph if reported in study or could be calculated.

Several studies measured QOL outcomes using measures different from those reported above and were thus analyzed separately. One study[88] measured individual instead of combined symptom scores and found improvement in two of six scores. Several studies measured quality of life using days of limitation on activity, with inconsistent results. One study[74] found a reduction of 22.0 percentage points in the proportion of children or adolescents with 8 or more days in which activity was limited per year ($p<0.001$). Another

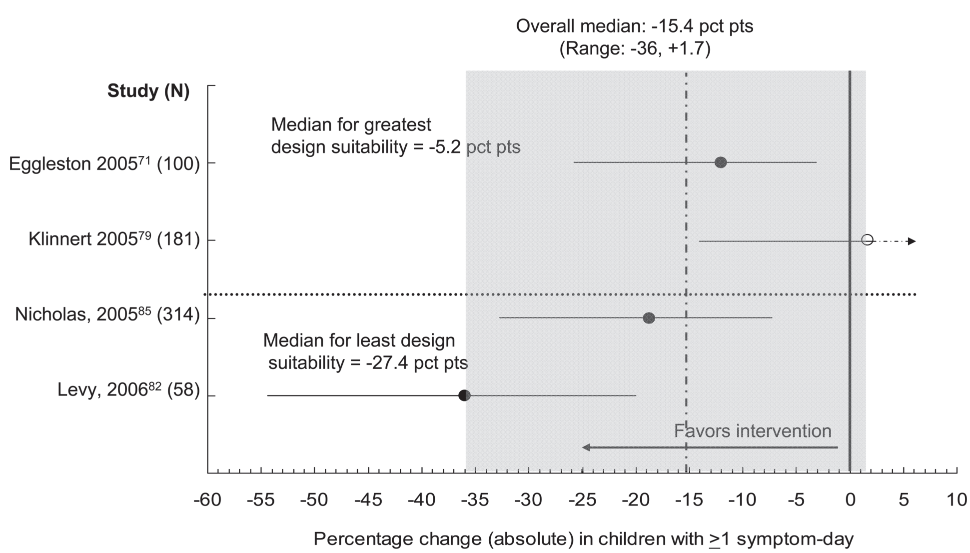

Figure 3. Quality of life: percentage of children with symptom-days
Note: Gray box represents interquartile interval or range; CIs were added to graph if reported in study or could be calculated.
pct pts, percentage points

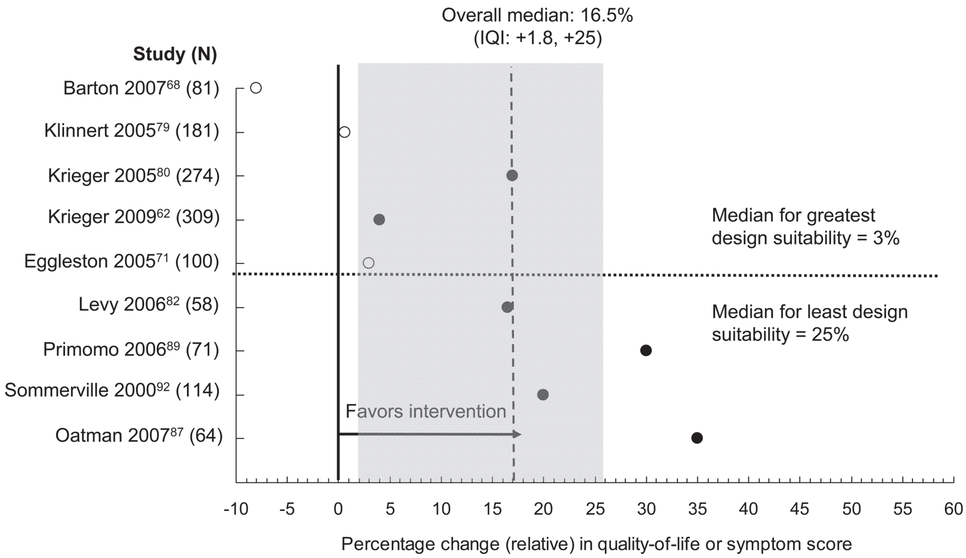

Figure 4. Quality of life: relative % change in symptom/quality-of-life score
Note: Gray box represents IQI or range; CIs were added to graph if reported in study or could be calculated.
IQI, interquartile interval

tion group but not between the intervention and the control group. Another study[57] reported a significant reduction in the number of days when the child had to slow down or stop play because of asthma in the intervention group compared to the control group, whereas a later study[85] found no improvement for this outcome. Another study[82] found a reduction of 38.0 percentage points in the proportion of children who had to slow down or stop activities because of asthma.

study[71] found a reduction of 7.7 percentage points in the proportion of children with 1 or more days of activity limitation between the intervention and control group, which was not significant.

A study by Krieger et al. in 2005[80] found a significant reduction in the number of days with activity limitation between the intervention and the control group. A later study by the same author[81] found a significant reduction in days of activity limitation from baseline in the interven-

Outcomes related to productivity. Ten studies[57,69,74,75,80,81,85,87,90,92] measured productivity outcomes in children or adolescents and showed a decrease in the number of school days missed. Six studies[74,75,80,81,85,92] specifically mentioned that school days missed were due to asthma. Four studies[57,69,87,90] did not say whether school days missed were due to asthma or other causes. Five studies[57,75,87,90,92] measured the mean number of school days missed (Figure 6) and showed a median absolute reduction of 12.3 school days missed per year (range of values: 3.4 to 31.2 reduction in school days missed). The median absolute reduction in school days missed was 6.5 days for controlled trials versus 18.2 days for uncontrolled trials. Three studies[80,81,85] measured changes in the proportion of children or adolescents who missed 1 or more days of school and observed a median absolute reduction of 10.8 percentage points (range of values: 1.2 to 16.2 percentage point reduction). The reduction in the proportion of children missing school was 6 percentage points for controlled trials and 16.2 percentage

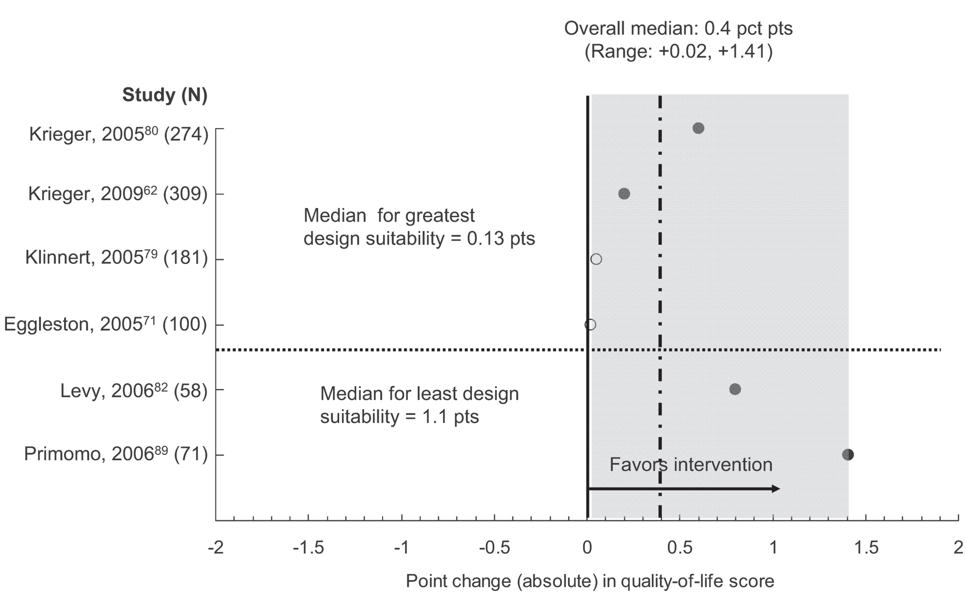

Figure 5. Quality of life: Juniper quality-of-life score
Note: Gray box represents interquartile interval or range; CIs were added to graph if reported in study or could be calculated.
pct pts, percentage points; pts, points

points for uncontrolled trials (Figure 7).

Two studies measured productivity outcomes different from those reported above and thus could not be included in the productivity analysis; these studies found inconsistent effects. One study[69] combined both work and school days missed as a measure of productivity and found a 3% increase in the number of children, adolescents, or adults missing at least 1 day of work or school per year but the increase was not significant (p=0.62). A second study[74] found a 23.0 percentage-point reduction in the proportion of children or adolescents missing 8 or more days of school per year (p<0.01).

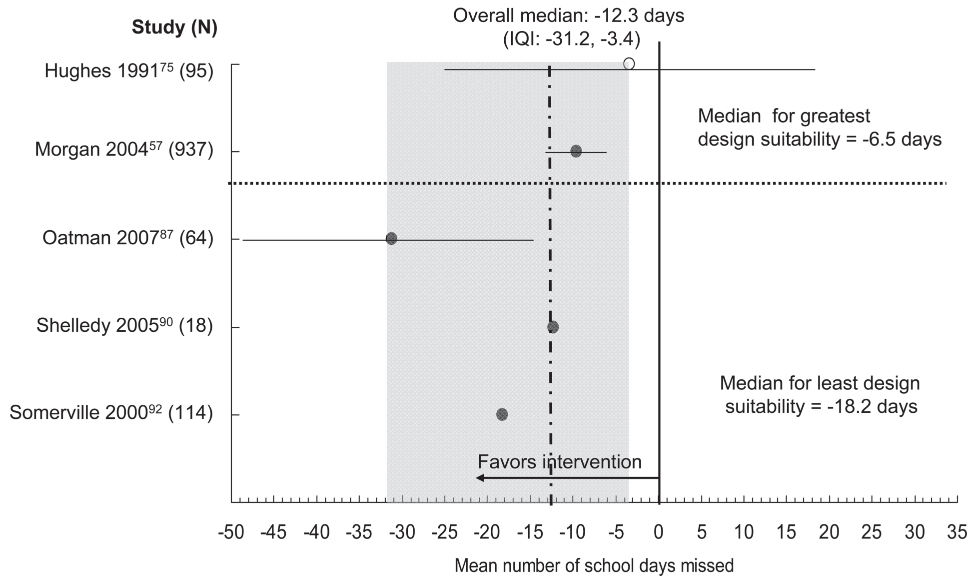

Figure 6. Productivity: school days missed, mean number/year
Note: Gray box represents IQI or range; CIs were added to graph if reported in study or could be calculated.
IQI, interquartile interval

Outcomes related to healthcare utilization. Eighteen studies[57,69–72,74,75,78–82,85,87–90,93] measured changes in one or more healthcare utilization outcomes. (Several studies used more than one measure for each outcome. Therefore, the number of studies for each outcome may not add up to total number reported here.) Overall improvements were small, with ten studies[57,70,72,74,75,78,79,87,90,93] showing a median reduction of 0.57 visits per year (IQI: 0.33 to 1.71 visit per year reduction) in the number of acute care visits for asthma (controlled trials: 0.37 acute care visits per year reduction; uncontrolled trials: 3.38 acute care visits per reduction) (Figure 8). The reduction in acute care visits included decreases of 0.40 hospitalizations per year (IQI: 0.10 to 1.45 hospitalizations per year reduction) from seven studies,[70,74,75,79,87,90,93] decrease of 0.2 emergency room visits per year (IQI: 0.11 to 0.5 visits per year reduction) from eight studies,[57,70,74,75,79,87,90,93] and decrease of 0.50 unscheduled office visits per year (range of values: 0.20 to 6.88 visits per reduction) from four studies.[57,70,87,93]

Eleven studies[57,69,71,72,75,78,80,81,85,88,89] observed a median absolute reduction of 5.4 percentage points (IQI: 1.6 percentage point increase to 19.2 percentage point decrease) in the proportion of children or adolescents with one or more acute care visits for asthma in the past year (controlled trials: 5.4 percentage point reduction; uncontrolled trials: 12.9 percentage point reduction) (Figure 9).

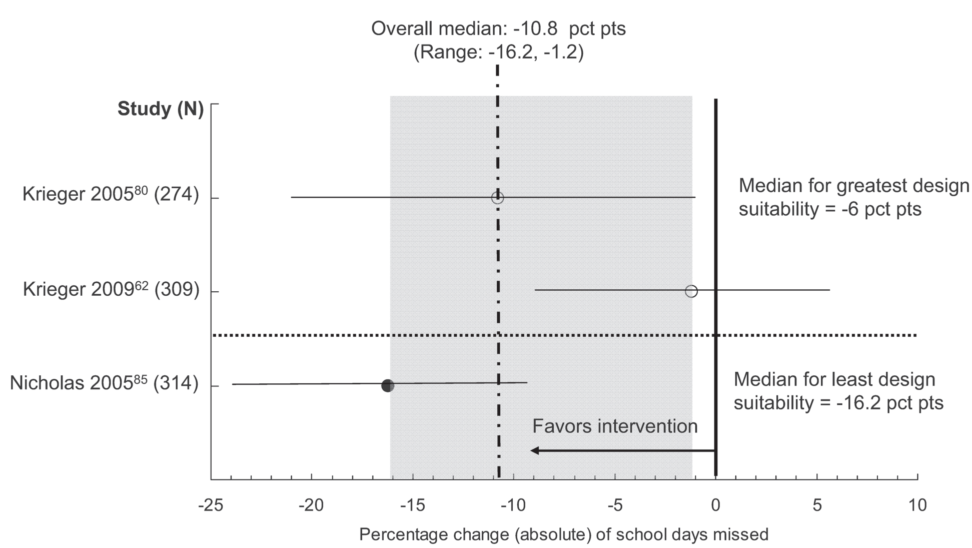

Figure 7. Productivity: school days missed, % population
Note: Gray box represents interquartile interval or range; CIs were added to graph if reported in study or could be calculated.
pct pts, percentage points

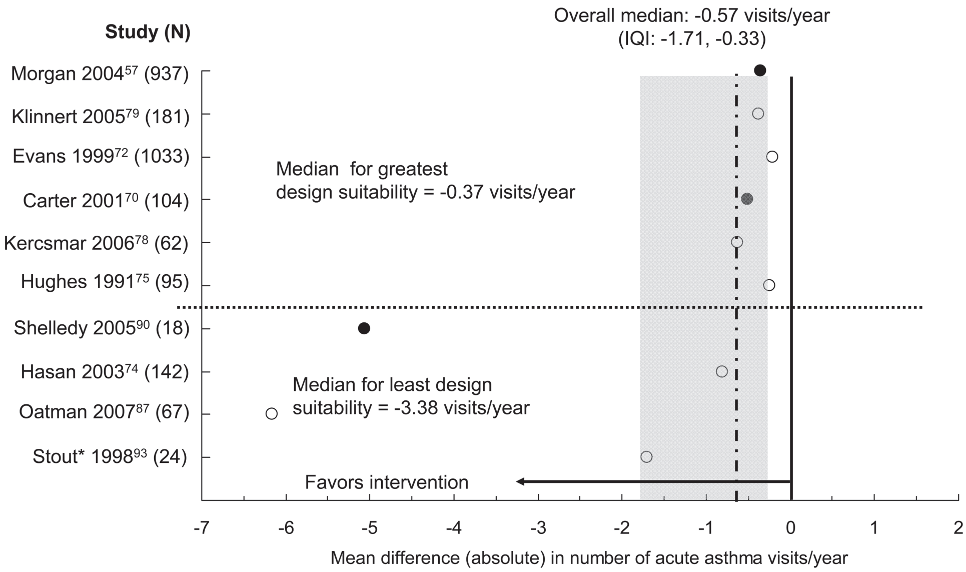

Figure 8. Healthcare utilization: combined measure of acute care visits/year
Note: Gray box represents IQI or range; CIs were added to graph if reported in study or could be calculated.
*Combined = sum of hospital, emergency department, and unscheduled office visits
IQI, interquartile interval

Six studies[57,68,71,75,88,109] were RCTs, and one[94] was an uncontrolled before-and-after study. The studies reported a variety of pulmonary function measures such as forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and peak flow. Two studies[75,88] showed significant improvement in pulmonary function testing. One paper[88] found a 10.0 percentage point absolute improvement in percentage predicted FEV1 and an 8.2 percentage point absolute improvement in percentage predicted peak flow compared to control. The second paper[75] showed an improvement in expiratory flow at 25% and 50% vital capacity at end of intervention but differences disappeared by 12-month follow-up. Five studies, however, found no overall improvement in pulmonary function measures.

One study[82] measured healthcare utilization outcomes using different measures than those reported above and thus could not be included in the analysis. This study found no improvement in hospitalizations but did not report specific data.

Outcomes related to physiologic pulmonary function. Seven studies[57,68,71,75,88,94,109] measured physiologic responses using pulmonary function testing.

Outcomes in Adults with Asthma

Three[68,69,91] of the 23 intervention studies included in this review included adult participants. All three studies were RCTs.

Quality of life. Two studies[68,91] measured a QOL outcome. One study[68] found a 13% relative improvement in quality-of-life or symptom scores (p=0.006). The other study found a nonsignificant improvement in quality-of-life or symptom scores of 5.3% (p=0.66).

Productivity. One study[69] measured productivity and found a 3% (p=0.62) nonsignificant increase in the proportion of people who missed more than 1 work or school day per year because of asthma.

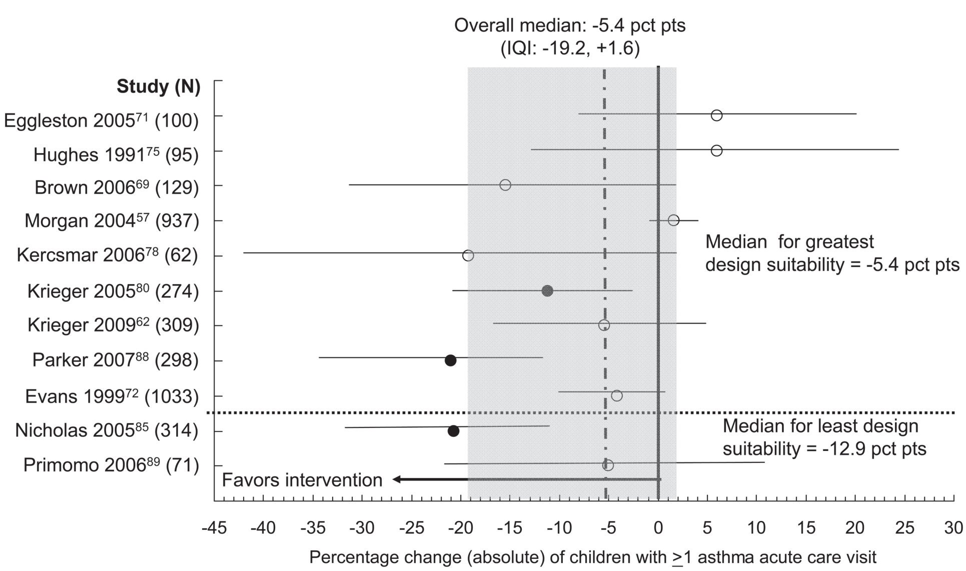

Figure 9. Healthcare utilization: percentage of children with acute care visits
Note: Gray box represents interquartile interval or range; CIs were added to graph if reported in study or could be calculated.
IQI, interquartile interval; pct pts, percentage points

Healthcare utilization. One study[69] measured healthcare utilization and found a nonsignificant 0.2 percentage point (p=0.85) decrease in the proportion of participants with one or more acute care visits for asthma symptoms.

Additional Outcomes in Studies with Children, Adolescents, and Adults

Outcomes related to trigger levels. Eleven studies[57,70,71,78–80,82,86,88,102,118] measured the levels of asthma triggers in the house before and after the intervention. Nine of those studies[57,68,70,71,78–80,86,88,118] compared trigger levels with a control group, and two studies[82,102] used a before-and-after design. The most common triggers measured were dust mite, cockroach, mold, mouse, cat, and dog allergens. Outcomes for irritants such as nitrogen dioxide and particulate matter were also reported in two studies.[71,82] Cotinine, a biological marker for ETS exposure, was measured in one study.[79] Trigger levels decreased in the intervention arm compared to baseline in ten of 11 studies (91%).[57,70,71,79,80,82,86,88,102,118] However, in two of those studies[82,102] the improvements in trigger levels were not sustained over time. Four of the nine controlled studies (44%)[57,71,86,118] had a significant decrease in at least one asthma trigger compared to the control group.

Outcomes related to trigger-reduction behaviors. Twelve studies[69,71,75,79–81,86,88,89,91,92,94] (nine controlled and three before-and-after studies) measured changes in TRBs. These are any behavior performed to reduce the level of asthma triggers in the home. The behaviors included washing bedding in hot water; using allergen-impermeable mattress and pillow covers; following pest-management strategies such as covering and sealing food; removing carpets; cleaning, vacuuming, washing, or freezing stuffed animals; fixing leaks and implementing other strategies for preventing or removing mold; and reducing exposure to ETS. All 12 studies showed an improvement in TRBs compared to before the intervention, and five[69,80,81,86,88] of the nine controlled studies showed improvement compared to the control group in at least one TRB. Use of bedding covers, ventilation, and household cleaning were the behaviors most often changed. Pet removal and smoking cessation were the behaviors least often changed.

Twenty-one of the 23 studies included in this review provided some form of information related to smoking or ETS. Of these, 18[57,68,71,72,75,78–82,85–88,91–94] supplied information on the percentage of households with at least one smoker at baseline. A median of 45% of homes in the intervention arm of these studies contained a smoker (IQI: 38.2% to 60.3%). Thirteen studies[57,71,72,75,79–81,86,88–90,93,115] explicitly indicated that smoking-cessation information, ETS counseling, or service referrals were provided as part of the intervention. Seven studies[75,80,86,88,91,92,94] reported the percentage of caregivers that smoked or participants exposed to ETS before and after the intervention and found a median reduction of 7% (IQI: 5% to 13% reduction) for this outcome. Five of these studies[75,80,86,88,91] were controlled studies of which four[75,80,86,88] saw a decrease in the percentage of caregivers smoking over the control group (range of values: 1% to 6.5% decrease) but none of the decreases were significant. Four[71,80,86,89] of five studies[71,80,81,86,89] that measured changes in smoking behavior indicated that parents or caregivers changed their smoking behaviors post-intervention by smoking outside the house, by reinforcing that no smoking was permitted inside, or by providing a smokefree room in the house. Two studies[71,79] reported objective measures of ETS exposure before and after the intervention.

One study[79] measured urine cotinine levels before and after the intervention and found that the mean cotinine level was reduced from 48.16 nanograms (ng)/mg creatnine to 35.43 ng/mg creatnine in the intervention group and from 70.74 ng/mg creatnine to 53.82 ng/mg creatnine in the control group. The reduction in mean cotinine levels was not significant between two groups (p=0.10) in the unadjusted regression model, but in the adjusted model the intervention group had a significantly greater reduction in mean cotinine levels from baseline (p=0.02). Another study[71] found that home ambient air particulate levels, which have been associated with ETS exposure, decreased significantly after the intervention.

Five studies[71,80,86,91,92] reported the number of parents and caregivers of asthma sufferers who stopped smoking. Four of these studies[71,80,86,91] specifically mentioned delivery of ETS education during the home visit, and one tailored intervention[86] provided extensive counseling on allergen avoidance. This same study,[86] which reported a decrease in asthma exacerbations, speculated that the decrease was related to ETS avoidance because no other allergen decrease was reported.

Outcomes related to asthma management behaviors. Ten studies[69,75,79–82,85,88,89,94] (six RCT and four before-and-after) measured and reported outcomes for AMBs. These are any behaviors aimed at monitoring and controlling asthma. The most common AMBs reported were: using an asthma controller medication, having an asthma management plan, using a peak flow meter, regularly visiting a primary care physician, being prescribed controller medications by a physician, and using a spacer with an asthma inhaler. Nine of ten studies[69,75,79,81,82,85,88,89,94] reported improvements in asthma management behaviors compared to baseline values. The one study[80] that did not show an improvement did not include self-management training as part of the intervention. Four of six controlled studies[75,79,81,88] (67%) showed a significant improvement in at least one AMB compared to the control group. Having an asthma management plan, being prescribed controller medications, and increasing use of controller medication were more commonly improved behaviors. Increased use of a peak flow meter was less commonly improved.

Outcomes related to asthma control. Seven studies,[68,79–81,86,87,89] five of them controlled trials, reported on asthma control outcomes. These outcomes included frequency of rescue-medication use, frequency of asthma exacerbations, asthma control or severity scores, and frequency of oral steroid use. Five of seven studies[79–81,86,87] showed improvement compared to baseline values in at least one asthma-control outcome. However, compared to the control group, only one[81] of five controlled studies showed a significant improvement in at least one asthma-control outcome.

Subgroup Analyses

Number of home visits. A comparison was made of the studies with four or more home visits and the studies with less than four home visits in outcomes with at least one study in each category. Controlled studies with more than four home visits showed slightly greater improvement in QOL, healthcare utilization, and productivity outcomes than controlled studies with less than four visits. For the uncontrolled studies, studies with four or more home visits did not show any greater improvement over studies with less than four visits in most of the outcomes that could be measured (percentage of children with more than 1 symptom-days, quality-of-life scores, mean number of acute care visits per year, and school days missed). However the number of studies within each category is too small (one to two studies) to draw any overall conclusions.

Type of remediation. Also compared were the type of environmental remediation (major, moderate, or minor) in outcomes with at least one study in each category. In terms of quality of life, the controlled studies with moderate remediation showed a greater reduction in symptom-days and quality-of-life score improvements compared with major and minor remediation studies. In terms of healthcare utilization, there was a greater reduction in acute care visits per year as remediation intensity increased, although this difference was very small. In the uncontrolled studies, the results showed a similar pattern for the quality-of-life and healthcare utilization outcomes. There were not enough studies in the productivity outcomes to make any direct comparisons.

Summary of Outcomes

Of 23 studies, 22 included children or adolescents and three included adults. In studies including children and adolescents, QOL outcomes demonstrated clinically meaningful improvement and consistent effects across the body of evidence, except for QOL scores, which showed improvement that was not clinically meaningful. In healthcare utilization studies including children and adolescents, the team found a borderline reduction in acute visits that was consistent across the evidence. Productivity outcomes in children or adolescents showed consistent meaningful improvements across the body of evidence. Most of the studies reporting physiologic outcomes in children and adolescents showed no significant improvements. In studies including adults, although there were borderline improvements in QOL outcomes, not enough studies showed improvements to draw any definitive conclusions on the effectiveness of these interventions. Most studies measuring the additional outcomes (trigger levels, TRBs, AMBs, and asthma control) demonstrated substantial improvements compared to baseline.

Applicability

Eighteen of 23 studies[57,69–72,74,78–82,85,87–90,93,94] were conducted in the U.S., three[68,91,92] in the United Kingdom, one[75] in Canada, and one[86] in Japan. The U.S. studies all took place in urban, inner-city locations in 15 different states. Two studies[57,72] were multiple-site studies, each in seven cities across the U.S. (NY, Chicago, Boston, Seattle, Dallas, Tucson, and Boston). Two studies[68,92] were conducted in rural areas, both in the United Kingdom.

Minority groups were well represented in this body of evidence. In eight studies[70–72,74,78,80,88,93] African Americans represented the largest percentage of participants; in six studies[57,79,81,82,90,115] Hispanics represented the largest percentage of participants; in two studies[69,89] whites represented the largest group; one study[94] reported equal numbers of African-American and Hispanic participants; one study[87] reported 80% minority populations; and one study[86] included only Asian participants. The remaining four studies[68,75,91,92] did not report on race or ethnicity.

Eighteen studies[57,68,70–72,74,78–82,85,88,90–94] were conducted in low-income populations. The other five studies[69,75,86,87,89] did not provide income information. The interventions were conducted by trained personnel in a wide range of organizations including academic institutions, healthcare clinics or systems, state and local health departments, and community-based organizations. Trained personnel most commonly were CHWs[80–82,85,88,89,93,94] but nurses,[68,69,75,79,91] respiratory therapists,[87,90] social workers,[72] and physicians[70,86] also implemented these interventions. The majority of studies were directed toward urban, inner-city minority child and adolescent populations with low SES—a population considered more at risk for poor asthma control. However, given the diversity of study and participant characteristics in this body of evidence, the review team concluded that these interventions should be applicable across a broad range of settings and asthma populations.

Other Positive or Negative Effects

Multiple studies[68,69,79–82,88,89,115] identified improved caregiver support and improved quality of life as an additional benefit of these interventions. Other benefits mentioned included improved family relationships,[68] improved energy efficiency,[68] greater communication between caregivers and physicians,[88] and improved relationships between healthcare providers and the community.[82] Additional benefits postulated by the team were the health benefits of smoking cessation for the caregiver, the health benefits of reducing triggers in the home for parents and siblings of children in the study, and identification of additional health concerns, such as lead paint, as part of the home assessment.

Potential harms of these interventions postulated by the team included the expense of remediation, particularly major remediation, to the participant (if not paid by the study). Additionally, the team hypothesized that remodeling may increase triggers such as dust and volatile organic compounds and worsen asthma and allergies. However, neither of these issues was reported in any of the reviewed studies. Another potential harm postulated by the team was the danger to healthcare workers of going into the home. However, this has not been the case in the field. One study[80] reported that only two of 1400 homes had incidents requiring withdrawal of services because of safety concerns (Dr. Jim Krieger, oral communication, February 2008). In another study,[69] the mean physical safety rating by the nurses conducting the study was 3.6, which fell between somewhat safe (3) and very safe (4).

Economic Efficiency

An economic analysis[126] of home-based, multi-trigger, multicomponent interventions with an environmental focus was conducted after the initial effectiveness review and appears in this issue.[126] The economic findings, based on the results of 12 studies described in 13 papers,[57,68,71,77,78,80,83,87,89,90,92,106,121] all of which were also included in the assessment of effectiveness, are briefly summarized here. All numbers were converted to 2007 U.S. dollars. Study cost per participant ranged from $231–$14,858 (12 studies). Interventions with major environmental remediation had significantly higher study costs (range: $3796–$14,858; three studies) compared to interventions with minor or moderate remediation (range: $231–$1720; nine studies).

Six studies (all minor or moderate remediation studies with an educational component) provided full economic summary measures. Three provided cost–benefit estimates, and three provided cost-effectiveness estimates. The three cost–benefit ratios ranged from $5.3–$14.0, which suggests that these interventions provide substantial returns on each dollar invested. The three cost-effectiveness studies reported costs ranging from $12–$57 per additional asthma symptom-free day. This range is lower than the standard cut-off used in the cost-effectiveness literature and indicates good value for money invested.[127]

Barriers to Intervention Implementation

Several barriers to implementation of this intervention were mentioned in the body of evidence, including reluctance of families to accept home visits,[94,96] inability to maintain follow-up due to a transient population,[96,115] difficulty scheduling appointments,[69,85,114] and poor compliance with recommendations.[69,93] The team postulated other potential barriers such as cost of the intervention (particularly major remediation) and whether intervention benefits are maintained over time. Although some studies[72,82] found that benefits (particularly reductions in allergen levels) decreased over time, other studies found intervention behaviors and health effects were sustained. One study[87] found that intervention materials provided by the study were still in use in the homes 1 year after the study ended. Two other studies[57,72] found that reductions in symptom-days and hospital visits were still sustained 1 year after the intervention ended. Another potential barrier postulated by the team was the ability of interventions to obtain enough funding (i.e., insurance reimbursement) to sustain the intervention over time. However, a recent report by the U.S. Environmental Protection Agency (EPA) found that several home environmental interventions have been successful in obtaining reimbursement from insurance companies.[128]

Research Issues

Effectiveness. Findings of this review indicate that home-based, multi-trigger, multicomponent interventions are effective in reducing asthma symptom-days and school days missed by children. Important questions still remain regarding the intervention composition and intensity as well as effectiveness in different settings and populations. Some of these questions include:

- What are the independent contributions of particular intervention components to overall intervention effectiveness? Which components are the most important for inclusion in this intervention?
- What is the required intensity (number of home visits, intensity of remediation, intensity of education) needed for an effective home environmental intervention?
- What impact does ETS have on the effects of this intervention? Should smoking-cessation counseling be a necessary component of all home-based environmental interventions for asthma?

Applicability. This intervention has been studied mostly in low-income, urban minority populations but is most likely effective in most settings and populations. The following questions remain about the applicability of this intervention in various settings and populations.

- How effective is this intervention in adult populations?
- Are there differences in intervention effectiveness between children and adolescents?
- How effective is this intervention in rural populations?
- Is this intervention more effective in participants with more severe asthma symptoms?
- How does the type of dwelling (apartment, duplex, single-family home) affect the effectiveness of the intervention?

Implementation. This intervention has been implemented in a variety of ways. However, questions still remain as to what is the most effective and cost-effective way to implement this intervention in a "real-world setting." These questions include:

- How should these interventions be integrated in the healthcare system to ensure appropriate access and sustainability?
- Which asthma patients should these interventions target?
- Who are the most effective intervention implementers (e.g., CHWs, nurses, respiratory therapists) and does this change depending on intervention setting?
- Which intervention components are most important to include?
- Would a scaled-back version of these interventions be as effective?

Conclusion

The systematic review described in this article provided the evidence on which the Task Force based its findings on the effectiveness of multi-trigger, multicomponent, home-based environmental interventions for reducing asthma. The review found that home-based environmental interventions that target more than one asthma trigger and employ more than one intervention component might successfully reduce asthma symptom-days and school days missed by children. These results are consistent with those from previous reviews and advisory panels that have examined similar interventions.[14,56,129,130]

Home-based, multi-trigger, multicomponent interventions with an environmental focus provide an effective way to target two of the four components considered essential to effective asthma management, according to the NAEPP Expert Panel Report *Guidelines for the Diagnosis and Management of Asthma* (EPR-3):[14] (1) provision of self-management education for a partnership in asthma care; and (2) reduced exposure to indoor environmental triggers.[14] Further, the guidelines put forth by NAEPP support the results found in this systematic review, that "effective allergen avoidance requires a multifaceted, comprehensive approach" and "individual steps alone are generally ineffective." Other organizations, such as the Center for Managing Chronic Disease with the Asthma Health Outcomes Project (AHOP), the Global Initiative for Asthma with the GINA report, and the National Center for Healthy Housing with the Housing Interventions and Health review have recently published guidelines stating that multifaceted home-based environmental interventions are effective and ready for implementation.[14,56,129,130]

The median attrition rate for these interventions at 12 months was relatively low at 18%, indicating a low drop-out rate for most studies. The differential attrition rate between intervention and control groups was small, indicating that the intervention probably did not affect study attrition. Most of the RCTs did not provide a comparison of the severity of asthma, even at baseline, among dropouts in the study groups. Most of the attrition was due to loss at follow-up, and although small, it could have affected results.

The body of literature in this review suggests that the home visit, without any other components, may be an intervention in itself. Home visits provide a source of social support for people with asthma and their caretakers. The beneficial effect of home visits may also be due in part to the Hawthorne effect, whereby subjects improve or modify aspects of their behavior in response to being studied or measured. This may explain why, in several studies in the current review, both the intervention and comparison groups improved significantly.

One study in the review by Carter and others[43] randomized participants into three groups: an intervention group that received the full home visit, environmental education, and remediation; a placebo group that received a home visit and ineffective environmental education and remediation; and a control group that received no home visits or other types of interventions. Both the intervention and the placebo group that received home visits had a significant decrease in acute healthcare use compared to the control group that did not receive home visits. The fact that there were similar results for the intervention and placebo group could be because participants who received home visits were more likely to clean their homes prior to the visit, which reduced asthma triggers, or could be a placebo effect from the sham environmental education and remediation. These effects illustrate how studies could underestimate the benefits of home-based environmental interventions if both the intervention and comparison group receive home visits. Although the home visit is not identified here as an intervention component, it clearly confers some benefit.

This model has the potential for more comprehensive health benefits. Even though all home visits in this review focused primarily on asthma, several home-based environmental interventions in the community may combine asthma-related interventions with other health interventions, such as teaching lead-poisoning prevention and offering vaccinations during the home visit.[56] However, there was some concern that taking the focus of the intervention away from asthma could make the primary intervention objective less effective. More evidence is needed on the effectiveness of comprehensive home-based interventions that combine asthma interventions with other public health interventions.

Many of the studies in this review used CHWs to perform the intervention. The literature indicates that it is beneficial to hire and train CHWs to implement this intervention for the purpose of reaching out to primarily low-income, ethnic minority populations. CHWs play an essential role in the implementation of interventions, bridging the gaps between underserved populations and researchers.[131–133] Because they are usually from the same community, CHWs can connect culturally with local populations and build trusting relationships with clients and their families. This trust often allows clients to disclose more health needs to CHWs.[131]

One study in this review mentioned the initial reluctance of families of children with asthma to accept home visits and how this barrier was overcome by using CHWs to gain the trust of the community.[94] Brief home visits enable CHWs to establish a comfortable, ongoing interaction with community members who participate in the intervention. This relationship allows them to become a valuable source of asthma education for these population groups and at the same time an important resource for the evaluation of the home environment.[134,135] Several studies in the review discussed the importance and benefits of using CHWs in the implementation of asthma interventions. One study[80] found that CHWs played a crucial role in providing education and support to study participants, resulting in a significant reduction in asthma morbidity and decrease in healthcare services used. In addition, the outcomes of several other studies[81,88,89,93,94] have similarly suggested that CHWs or asthma outreach workers contribute to an increased effectiveness of asthma interventions and provide substantial help for the families of asthma patients. CHWs may also be more economical than other trained personnel such as nurses or respiratory therapists. However, nurses and other healthcare professionals may be able to address health needs in more detail and greater depth. All these factors should be considered when choosing what type of healthcare worker will implement the intervention.

Environmental tobacco smoke is a key asthma trigger and was reported in a high percentage of homes in this review, yet only 13 studies included an ETS component as part of the intervention.[57,71,72,75,79–81,86,88–90,93,115] These components came in the form of education on avoiding ETS, behavioral education to decrease exposure, smoking-cessation counseling, or referral to cessation programs. Addressing numerous other home environmental triggers without addressing ETS could blunt the effects of these interventions. Studies that addressed ETS were more successful at changing smoking behaviors than at attaining smoking cessation in the targeted population, although some studies did report successful smoking cessation as a result of the intervention.[71,80,86]

Few studies specifically reported results on smoking behavior, which makes it difficult to assess the success of the intervention at reducing ETS exposure. Most studies that did evaluate smoking behaviors used surveys before and after the intervention. The use of more objective measures of ETS such as cotinine testing may also be useful because subjective measures such as before-and-after surveys may not accurately reflect changes in smoking practices. The literature strongly suggests that ETS be considered at the same level of importance as other asthma triggers and be an integral part of the standard environmental assessment, education, and evaluation components in home-based environmental interventions.

Very few studies in this body of literature evaluate interventions conducting major remediation, which makes it difficult to compare major, moderate, and minor remediation studies in terms of effectiveness. Studies of major remediation efforts showed effectiveness in several outcomes, but they did not clearly show a greater effect than interventions conducting moderate and minor remediation. In fact, in most of the quality-of-life outcomes studies with moderate remediation showed the greatest effect sizes. Implementers must weigh the potential benefits of increased remediation intensity against the added cost. The review team is aware of and awaits the results of several ongoing major remediation studies.

Despite strong evidence of effectiveness in quality-of-life and productivity outcomes, the team found no significant improvement in physiologic measures (only two of seven studies showed any significant improvement in pulmonary function testing). Pulmonary function testing is used in clinical practice and is recommended by the NAEPP guidelines to guide asthma diagnosis and treatment decisions for individuals. Fuhlbrigge and colleagues[136] demonstrated that a low absolute value of %FEV1 in pediatric patients does predict the occurrence of ED visits and hospitalizations for asthma in the 4-month period following spirometry. However, several studies have shown very little correlation between changes in pulmonary function testing on a population level and any of the other measures of asthma status.[137,138] Therefore, the absolute values in FEV1 may be more predictive than changes in FEV1 at a population level in predicting clinical outcomes. In addition, most children in these studies had a percentage predicted FEV1 that was relatively normal at baseline, which is often the case in asymptomatic children with mild or moderate persistent asthma. When FEV1 is normal or shows only mild obstruction at baseline, the amount of improvement will be smaller, thus, making it more difficult to reach significance.

Most interventions in this review were tailored to client exposure to asthma triggers in the home, the client's allergen sensitivities by skin testing or specific immunoglobin E (IgE) levels, or both. Interventions tailored to exposure or sensitivity may be more costly and time-consuming initially, due to the additional efforts needed to assess the client's trigger exposure and allergen sensitivity, but may ultimately be less costly and time-consuming because clients are given only necessary education and remediation. Not enough studies within each outcome were identified in this review to make any definitive conclusions or recommendations about how tailoring home environmental interventions to client exposure or allergen sensitivity affects outcomes. Implementers should consider these benefits with other factors, such as cost and time, when deciding if tailoring is worthwhile.

Five studies evaluating interventions targeted at indoor asthma triggers and with similar components to the ones used in the 23 studies included in this review were published after the literature search period ended.[139–143] The findings reported in these five studies agree in size and direction with the findings of this review. A recently published systematic review on home-based interventions for children with asthma reports findings consistent with those of the current review.[144] That review focused solely on interventions conducted by CHWs, whereas this review includes interventions conducted by several types of trained personnel. In addition, that review included only interventions targeting children or adolescents, whereas this review includes interventions targeting children or adolescents and adults. Four of seven studies included in that review are also included in this systematic review. Three studies included in that review were excluded from this review for several reasons: one was published after the search dates; one was excluded because it did not include health outcomes; and one was excluded because it did not meet *Community Guide* quality-of-execution criteria.

This review has some limitations. The home-based, multi-trigger, multicomponent, environmental interventions in this review were extremely heterogeneous. The outcomes and effect measures varied among studies. Some outcome measures, such as emergency room visits, hospitalizations, and unscheduled outpatient visits were similar enough to combine. Other outcomes, however (e.g., symptom-days, QOL scores), were too disparate to combine. Additionally, effect measures differed among studies: some studies reported in percentages and others in mean numbers, and these measures could not be combined. Because the data were too heterogeneous, the team opted to summarize data using descriptive statistics rather than meta-analysis.

Another challenge to evaluating multicomponent interventions is the difficulty in isolating the effect of one component from those of other components. Further, the studies included various combinations of components and targeted various types of asthma triggers, which adds to the difficulty when using these findings to implement interventions. In this review, the team was largely unable to assess the specific benefit of each component in the intervention because not enough studies with similar components measured comparable outcomes. Most of the studies in this review did not blind participants or implementers to group assignment because the nature of the intervention made blinding difficult. Four studies[57,70,71,79] were able to conduct some form of blinding. The lack of blinding in most studies could produce biased results. Finally, systematic reviews are prone to publication bias. The team attempted to minimize this bias by considering unpublished studies, such as government reports and unpublished manuscripts, in addition to published data sources. One study included in the final review[87] is an unpublished government report. Another study[81] in the review had not been published at the time of inclusion but was published later in 2009.[62]

Based on *Community Guide* methods,[64] this review identified evidence that multi-trigger, multicomponent, home-based environmental interventions were effective in reducing the number of symptom-days and school days missed because of asthma among children and adolescents. These interventions also resulted in a modest reduction in asthma-related healthcare utilization. The review team found insufficient evidence to determine the effectiveness of this intervention in adults because of the small number of and inconsistent results from qualifying studies. Additional research is needed on the use and impact of these interventions for adults with asthma. The effectiveness of these interventions may vary for different asthma populations. Implementers will need to adapt these interventions to meet their available resources and the individual needs of their community.

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Points of view are those of the Task Force on Community Preventive Services and do not necessarily reflect those of the CDC.

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Appendix A: Glossary and Abbreviations

Allergen An antigen that causes allergic disease[1]

Asthma control The degree to which the manifestations of asthma (symptoms, functional impairments, and risks of untoward events) are minimized and the goals of therapy are met[14]

Asthma education General education on asthma without a self-management component

Asthma-management behaviors (AMB) Use of asthma controller medications, use of asthma action plans, use of peak flow meters and additional behaviors aimed at monitoring and controlling asthma

Asthma triggers Allergens and irritants that induce asthma symptoms

Component A primary element of an intervention delivered to produce a desired outcome; for example, environmental education to reduce asthma morbidity

Community Health Worker (CHW) Members of the community who, by performing preventive medical services, monitoring the community's health, and identifying patients at particular risk, act as liaisons between the community and the health system, interpret the social climate, provide basic curative services, and enhance the outreach and effectiveness of health services to underserved populations with the specific mission of reducing the impact of a single illness[2,3]

Coordinated care Services to improve coordination of care between healthcare providers and home health workers

Environmental education Patient education regarding actions to reduce triggers in the home

Environmental remediation Actions conducted or financed to reduce triggers in the home

Environmental remediation, major Major structural improvements to the home, which may include some combination of carpet removal, replacement of ventilation systems, or extensive repairs to restore structural integrity (e.g., to roof, walls, floors)

Environmental remediation, moderate Providing multiple low-cost materials with the active involvement of the trained home visitor(s); activities in this category may include providing and fitting mattress and pillows with allergen-impermeable covers, installing small air filters and dehumidifiers, integrated pest management, professional cleaning services or equipment, and minor repairs of structural integrity (e.g., patching holes)

Environmental remediation, minor Minor changes to the home, which at a minimum include providing advice on recommended environmental changes to be performed by the members of the household and may include providing low-cost items such as mattress and pillow allergen-impermeable covers

Environmental assessment In-home written assessment of environmental triggers

Environmental tobacco smoke (ETS) Smoke from other people's tobacco products that may be involuntarily inhaled

Home visit Visit to the home by a trained or experienced person or people with the purpose of changing the home environment to reduce asthma triggers

Major environmental remediation *See Environmental remediation, major*

Moderate environmental remediation *See Environmental remediation, moderate*

Minor environmental remediation *See Environmental remediation, minor*

Multifaceted intervention Comprehensive intervention that, in this systematic review, focuses on more than one asthma trigger

Multi-trigger Activities that reduce exposure to two or more environmental triggers that exacerbate asthma

Multicomponent intervention Intervention that includes more than one component

Self-management education (SM) Teaches problem-solving skills that allow patients to identify their health problems, and provides techniques to help them make decisions, take appropriate actions, and modify these actions as needed as they encounter changes in circumstances or disease[4]

Social services Services to improve access to medical care or to advocate for environmental remediation

Tailored environmental intervention Intervention with education and remediation efforts that accommodates the client's specific allergen sensitivities and environmental exposures

Trigger-reduction behaviors (TRB) application of behavioral strategies for preventing and/or reducing asthma triggers in the home (e.g., washing bedding in hot water, using allergen-impermeable mattress and pillow covers, counseling for smoking cessation)

Abbreviations

AA	African American
AC	Asthma control
AE	Asthma education
AMB	Asthma-management behaviors
CC	Coordinated care
CHW	Community health worker
EA	Environmental assessment
EE	Environmental education
ER	Environmental remediation
ETS	Environmental tobacco smoke (also called "secondhand smoke")
HCU	Healthcare utilization
IQI	Interquartile interval
NR	Not reported
PHYS	Physiologic outcomes
PRO	Productivity
QOL	Quality of life
SM	Self-management
SS	Social services
TRIG	Asthma trigger indicators
TRB	Trigger-reduction behaviors
VOC	Volatile organic compounds

References for Appendix A

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Appendix B: Systematic Review Development Team

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Appendix C: Methods

Results of each study were represented as change in quality of life, healthcare utilization, productivity, and physiologic measures attributable to the intervention and presented separately for children and adults; where possible, percentage point (i.e., absolute) change from baseline or comparison value in children or adults or both was used as the measure of effect. Percentage point changes and baseline rates were calculated as follows:

For studies with before-and-after measurements and concurrent comparison groups:

$(I_{post} - I_{pre}) - (C_{post} - C_{pre})$; baseline: I_{pre}

For studies with post-only measurements and concurrent comparison groups:

$(I_{post} - C_{post})$; baseline: C_{post}

For studies with before-and-after measurements and no concurrent comparison groups:

$(I_{post} - I_{pre})$; baseline: I_{pre}

Where:

I_{post} Last reported percentage of intervention group after intervention;

I_{pre} Reported percentage of intervention group, immediately before intervention;

C_{post} Last reported percentage of comparison group after intervention;

C_{pre} Reported percentage of comparison group, immediately before intervention; and

Baseline Estimated study population in the absence of or prior to intervention.

When the effect was reported as an OR or a percentage (i.e., relative) change from baseline or comparison value, the team sought to convert the estimate to percentage point change. If this was not possible, the outcome was excluded from the summary effect measure but reported separately to reflect the complete evidence base and to assess consistency across all studies.

Studies with multiple effect estimates were handled in one of two ways. First, when there was more than one estimate for a single outcome in a single study arm, consistent rules were applied to choose the most appropriate estimate. For example, estimates adjusted for confounding were selected over crude estimates; when estimates were taken at multiple follow-up points, the estimate at longest follow-up was selected over those measured earlier. Second, when estimates within a study differed in terms of population and intervention and therefore provided relatively independent information on effectiveness, they were treated as separate data points in the analyses. This approach was used when more than one form of the intervention of interest was evaluated in separate study groups or when the same intervention was evaluated in distinct geographic areas or subpopulations. These estimates were used separately because they enhanced our ability to assess for effect heterogeneity by intervention characteristics or by setting context. As a result, the number of effect estimates reported in the reviews was often greater than the number of studies.

Summarizing Effectiveness Evidence and Translating into Recommendations

For each review, effect estimates across all related studies were summarized using the median as the descriptive statistic. When seven or more effect measures were available, interquartile intervals were used as the measure of variability; otherwise, a range of values is presented.

The *Community Guide* characterizes evidence for determining intervention effectiveness as insufficient, sufficient, or strong on the basis of the number of available studies, the suitability of study design for evaluating effectiveness, the quality of execution, the overall consistency of results, and the magnitude of effect. Evidence is considered sufficient or strong when the body of evidence is of sufficient size and quality to support conclusions, when reported effects are consistent and in the favorable direction, and when the magnitude of effect is, in the judgment of the Task Force, large enough to be of public health importance. If these conditions are not met, evidence is considered insufficient to determine effectiveness. Insufficient evidence should not be interpreted as evidence of ineffectiveness but rather as an indication that additional research is needed.

Task Force recommendations link directly to the strength of evidence on effectiveness, as described elsewhere.[1] In brief, a finding of strong or sufficient evidence of intervention effectiveness leads to a Task Force recommendation favoring use of the intervention. Insufficient evidence leads to a recommendation for additional research.

References for Appendix C

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Appendix D: Summary of evaluated studies: demographics and characteristics

Study	Study design	Study location	N	Age range	Race/ethnicity	SES	Tailored	Asthma severity[a]	Intervention components	Type of environmental remediation	Educational component	Home visits	Type of home visitor
Barton 2007[68]	gRCT	Watcombe (in Torquay UK)	126	0–65+ yrs	NR	Low SES	No	Mild	EA, ER	Major	NR	1	Nurse
Brown 2006[69]	iRCT	Grand Rapids MI	239	57% <18 yrs; 43% >18 yrs	56% white; 30% AA	NR	No	All severity types	AE, EA, EE, SM	None	EE, SM	1	Nurse
Carter 2001[70]	iRCT	Atlanta GA	104	5–16 yrs	92% AA	Low SES	No	NR	EA, EE, ER	Moderate	NR	4	Physician
Eggleston 2005[71]	iRCT	Baltimore MD	100	6–11.9 yrs	98% AA	NR	Yes: exposure and sensitivity	Mild	EA, EE, ER	Moderate	EE, SM	3	Environmental educator
Evans 1999[72]	iRCT	Multisite (8 U.S. cities)	1033	5–11 yrs	76% AA; 17% Hispanic	Low SES	Yes: exposure and sensitivity	Moderate to severe	EA, EE, ER, SM, SS	Minor	NR	NR; 1 pest-control visit	Social worker
Hasan 2003[74]	Before-and-after	Flint MI	142	2–10 yrs	54% AA; 43% white	Low SES	No	Moderate to severe	CC, EE, SM	None	EE, SM	4 (and one school visit; follow-up phone calls)	Social worker, nurse, respiratory therapist
Hughes 1991[75]	iRCT	Nova Scotia Canada	95	6–10 and 11–16 yrs	NR	NR	Yes: exposure and sensitivity	All severity types	EA, EE, SM	None	EE, SM	2	Nurse
Kercsmar 2006[78]	iRCT	Cleveland OH	62	2–17 yrs	82% AA; 17% white	Low SES	No	Mild persistent	EA, ER, EE, SM	Major	EE, SM	4	Trained sanitarians
Klinnert 2005[79]	iRCT	Denver CO	181	9 mos to 4 yrs	55% Hispanic; 33% AA; 23% white	Low SES	Yes: exposure	Wheezing no asthma diagnosis	EA, EE, ER, SM, SS	Moderate	EE, SM	15 visits (avg)	Nurse
Krieger 2005[80]	iRCT	Seattle WA	274	4–12 yrs	31% AA; 25% Vietnamese; 17% Hispanic; 12% white	Low SES	Yes: exposure	Persistent	EA, EE, ER, SS	Moderate	EE	5–9	CHW
Krieger 2008[81]	iRCT	Seattle WA	309	3–13 yrs	49% Hispanic; 14% AA; 13% Vietnamese; 9% white	Low SES	Yes: exposure and sensitivity	Persistent	CC, EA, EE, ER, SM, SS	Moderate	NR	1–5 home; 4 clinic	CHW and nurse

(continued on next page)

Appendix D: Summary of evaluated studies: demographics and characteristics *(continued)*

Study	Study design	Study location	N	Age range	Race/ ethnicity	SES	Tailored	Asthma severity[a]	Intervention components	Type of environmental remediation	Educational component	Home visits	Type of home visitor
Levy 2006[82]	Before-and-after	Boston MA	58	4–17 yrs	70% Hispanic; 28% AA	Low SES	No	Moderate persistent	EA, EE, ER, SM, SS	Major	EE, SM	2–6	CHW and nurse
Morgan 2004[57]	iRCT	Multisite (7 U.S. cities)	937	5–11 yrs	40% Hispanic; 37% AA	Low SES	Yes: exposure and sensitivity	Moderate to severe	EA, EE, ER	Moderate	EE	5–7	Research assistant and pest control professional
Nicholas 2005[85]	Before-and-after	Harlem (New York City) NY	314	0–12 yrs	43% white Latino; 39% black/Latino; 28% AA	Low SES	Yes: exposure	All severity types	EA, EE, ER, SM, SS	Moderate	EE, SM	6	CHW
Nishioka 2006[86]	CT	Japan	36	2–7 yrs	Japanese	NR	No	Mild to moderate	EA EE, ER	Moderate or minor	EE	12	Physician
Oatman 2007[87]	Before-and-after	Minneapolis MN	64	<18 yrs	80% minority	Low SES	Yes: exposure and sensitivity	Moderate persistent	AE, EA, EE, ER	Moderate	EE, SM	3	Respiratory therapist
Parker 2007[88]	iRCT	Detroit MI	298	7–11 yrs	83% AA; 11% Hispanic	Low SES	Yes: exposure and sensitivity	Moderate to severe persistent	AE, EA, EE, ER, SS	Moderate	EE	9	CHW
Primomo 2006[89]	Before-and-after	Tacoma WA	71	<18 yrs	68% white; 19% AA	NR	Yes: exposure	All severity types	EA, EE, ER, SM	Minor	EE, SM	2	CHW
Shelledy 2005[90]	Before-and-after	Little Rock AR	18	3–18 yrs	50% Hispanic; 27% white	Low SES	Yes: exposure	Moderate to severe	CC, EA, EE, ER, SM	Minor	EE, SM	8	Respiratory therapist
Smith 2005[91]	iRCT	Norfolk and Suffolk UK	92	Adults	NR	Low SES	No	Severe	AE, EE, SM, SS	None	EE (minor), SM	4	Nurse
Somerville 2000[92]	Before-and-after	Cornwall UK	114	<3 to <16 yrs	NR	Low SES	Yes: exposure	Moderate to severe	EA, ER	Major	NR	2	Housing officer
Stout 1998[93]	Before-and-after	Seattle WA	23	1–9 yrs	87% AA	Low SES	Yes: exposure	Moderate to severe	CC, EA, EE, SM, SS	None	EE, SM (with AE)	8+	CHW
Thyne 2006[94]	Before-and-after	San Francisco CA	65	0–12+ yrs	43% Hispanic; 43% AA; 11% Asian	Low SES	No	Persistent	CC, EA, EE, SM, SS	None	EE, SM	2–3	CHW

[a]Asthma severity is based on a majority of asthma clients in that category as reported in the article

AA, African American; AE, asthma education; avg, average; CC, coordinated care; CHW, community healthcare worker; CT, controlled trial; EA, environmental assessment; EE, environmental education; ER, environmental remediation; gRCT, group RCT; iRCT, individual RCT; mos, months; NR, not reported; SM, self-management; SS, social services; UK, United Kingdom; yrs, years