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Economic Evidence for U.S. Asthma Self-Management Education and Home-Based Interventions

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Abstract

The health and economic burden of asthma in the United States is substantial. Asthma self-management education (AS-ME) and home-based interventions for asthma can improve asthma control and prevent asthma exacerbations, and interest in health care-public health collaboration regarding asthma is increasing. However, outpatient AS-ME and home-based asthma intervention programs are not widely available; economic sustainability is a common concern. Thus, we conducted a narrative review of existing literature regarding economic outcomes of outpatient AS-ME and home-based intervention programs for asthma in the United States. We identified 9 outpatient AS-ME programs and 17 home-based intervention programs with return on investment (ROI) data. Most programs were associated with a positive ROI; a few programs observed positive ROIs only among selected populations (e.g., higher health care utilization). Interpretation of existing data is limited by heterogeneous ROI calculations. Nevertheless, the literature suggests promise for sustainable opportunities to expand access to outpatient AS-ME and home-based asthma intervention programs in the United States. More definitive knowledge about how to maximize program benefit and sustainability could be gained through more controlled studies of specific populations and increased uniformity in economic assessments.

Keywords

asthma; education; home; control; cost; return on investment; community health worker

In the United States, asthma affects >22 million persons and costs approximately \$63 billion annually.^{1, 2} Uncontrolled asthma is common in this population, affecting 50% of adults and

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38% of children.³ Moreover, estimates indicate asthma-related emergency department (ED) visits and hospitalizations account for 30% of expenditures.² Together, these data suggest ample opportunity to improve asthma control and prevent asthma exacerbations, which could reduce the economic burden of asthma.

Certainly, uncontrolled asthma is multifactorial.³ Access and adherence to medical care consistent with the 2007 National Asthma Education and Prevention Program Guidelines for the Diagnosis and Management of Asthma (EPR-3) are fundamental.^{4, 5} In the EPR-3, complementary key components of asthma management include asthma self-management education (AS-ME) at multiple points of care, as well as control of environmental factors. Moreover, individually tailored, multi-faceted home-based interventions are recommended as a means to provide AS-ME and/or reduce environmental asthma triggers for specific populations.⁴

Despite the EPR-3 and growing emphasis on prevention and health care-public health collaboration in the United States^{4, 6–8}, there is limited availability of AS-ME outside of the traditional physician's office visit (hereafter referred to as "intensive AS-ME"⁴; examples include AS-ME provided through a group class or an individual visit dedicated to asthma education with an allied health professional) and home-based intervention programs (e.g., programs offering individually tailored education or assistance regarding environmental trigger reduction in the home).^{4, 7, 9–11} Economic sustainability is a common concern.^{10, 12} Improved understanding of these programs' economic implications could be useful to clinicians, health care administrators, public health officials, policy makers, investigators, and others considering such programs for the outpatient or home setting.

Thus, this review examines existing literature regarding economic outcomes reported for intensive outpatient AS-ME or home-based intervention programs for asthma in the United States.

Review Approach

For this narrative review, the following databases were searched in January 2016 for studies on asthma-related education or home-based intervention programs (heretofore referred to as "programs") with cost or economic data (see Table E1 in the Online Repository for a complete list of search terms and strategies): PubMed/Medline (1946–present), Embase (1947–present), Cochrane Library (1800–present), and CINAHL (1981–present). Other relevant articles were identified through manual searching of articles' reference lists. Similar search terms were used to conduct an online search of non-peer-reviewed materials (e.g., white papers, publicly available websites) and identify additional documents for reference list review. No data were obtained through personal communication.

Inclusion criteria were: (1) the program included provision of intensive outpatient AS-ME or 1 asthma-related home visit; (2) the program was provided to persons with asthma (i.e., tertiary prevention rather than primary or secondary prevention); (3) the program was conducted in the United States; and (4) asthma-specific data on return on investment (ROI) or calculated cost savings (positive or negative) were reported. Disease management

programs met the first inclusion criterion if intensive outpatient AS-ME or 1 asthma-related home visit was specifically mentioned as a program component.

Exclusion criteria were: (1) the program was restricted to an inpatient, ED, school, residential camp, or military setting; (2) the program description mentioned “asthma education” without specifying AS-ME; or (3) reported ROI or cost savings data did not include asthma-specific calculations.

Abstracted data included program participants, personnel, components, health care utilization outcomes (i.e., utilization of medical care for asthma), and economic outcomes (i.e., ROI or calculated cost savings [positive or negative]). Given this review’s focus, the program sample sizes presented herein are those used to calculate ROI or cost savings; these might have differed from the total number of persons who participated.

A descriptive analysis was performed using Microsoft Excel. Programs that offered both intensive outpatient AS-ME and 1 asthma-related home visit were classified as asthma-related home visit programs. Also, programs were stratified by whether a benefit-cost ratio (i.e., ROI) was explicitly reported, because it could not be ascertained if calculations of cost savings without accompanying ROI data consistently included program operating costs.

Intensive Outpatient AS-ME Programs

We identified 9 U.S. programs that provided intensive outpatient AS-ME and reported ROI (Table I).^{13–32} All but one were reported in peer-reviewed literature.¹⁵ An additional 18 U.S. programs providing intensive outpatient AS-ME reported cost savings without ROI data (Table E2).

All 4 U.S. Census regions were represented among the 9 programs with ROI data (Figure E1). Most programs (6/9) occurred in exclusively urban settings^{15–21, 23–25, 27–31}; 1 included both urban and suburban sites²², and information was not available for the remaining 2 programs.^{13, 14, 26}

Over half of programs with ROI data (5/9) only enrolled children^{15, 16, 18–20, 23–25, 29–31}, and 2 others included both children and adults.^{13, 14, 26} Only 2 were adult-specific.^{22, 27, 28} Beyond asthma, eligibility requirements for most programs (6/9) included some specification of asthma severity, control, or risk. Sample sizes used to determine ROI were available for 8/9 programs (median=220; range, 47–1,033).

Most programs (6/9) provided intensive outpatient AS-ME in 1 group session (maximum=8); 3 provided AS-ME to individuals or individual families (2 face-to-face^{15, 18–20}, 1 through regular phone calls^{13, 14}). Program personnel included nurses, respiratory therapists, social workers, and community health workers (CHWs). Also, programs varied widely in scope and type of additional interventions offered (e.g., case management, linkage to clinical or social services, supplies such as peak flow meters or bedding encasements).

The methodology used to evaluate program outcomes was primarily randomized controlled trial (RCT; 6/9); pre–post analysis was applied to 3 programs.^{13, 26–28} Length of participant follow-up (reported for 8/9 programs) ranged from 6 months–2 years. ROI calculations all incorporated ED visits and hospitalizations but varied substantially in other included considerations (e.g., discount rates and costs of medications, nebulizers, ambulances, or scheduled or unscheduled office visits). For all but one program^{27, 28}, reported ROIs excluded potential cost savings from reductions in work or school absenteeism.

Reductions in asthma-related ED visits or hospitalizations for program participants were reported for most (6/9) programs. In another program, decreased ED visits and hospitalizations occurred exclusively among program participants with 1 hospitalization in the past year.^{23–25} No effect on asthma-related health care utilization was reported for only 1 program.¹⁵

Eight out of 9 programs were associated with a positive ROI (i.e., >\$1 return per \$1 invested) for all or some participants (Table II); among these, 2 programs achieved positive ROIs only among participants with higher health care utilization for asthma (e.g., 1 hospitalization or 2 unscheduled visits within a certain timeframe prior to program participation).^{23–25, 29–31} Estimated time to achieve ROI ranged from 1–3 years.

Asthma-Related Home Visit Programs

We identified 17 U.S. programs that provided 1 asthma-related home visit and reported ROI (Table III).^{8, 21, 33–84} Approximately half (9/17) were identified in peer-reviewed literature.^{36, 46–48, 54, 60, 63, 64, 76, 77, 80, 81, 83, 84} An additional 25 U.S. programs providing 1 asthma-related home visit reported cost savings without ROI data (Table E3).

All 4 U.S. Census regions were represented among the 17 programs with ROI data, but programs were predominantly located in the Midwest (7/17) and Northeast (6/17). Most programs (12/17) operated in urban settings^{33–36, 42–44, 46–49, 60, 62, 65–67, 70, 71, 73–75, 80, 81, 83, 84}, and information was not available for the remaining 5 programs.^{37–41, 54, 59, 76–79, 85} Program descriptions indicated health insurance plans operated or served as partners in over one-third (6/17) of programs.^{33, 43, 54, 55, 59, 67, 70, 71, 78, 79}

All 17 programs enrolled children (13 exclusively, and 4 included both children and adults^{37–41, 54, 55, 57–59, 78, 79, 85}); none were adult-specific. Eligibility requirements varied across programs. Sample sizes used to determine ROI were available for 9 out of 17 programs (primarily in peer-reviewed literature). Median sample size for calculating ROI was 255 (range, 50–800).

Most (13/17) programs provided 1 home visit to all program participants. In 4 programs, home visits were a program component offered to selected individuals based on varied or unspecified criteria.^{37–44, 55, 73–75, 78, 79} Among 15 of the 17 programs, total number of home visits per individual ranged from 1–8; another program averaged 4 home visits per participant^{78, 79} and one provided a median of 5 home visits per person.^{83, 84} The time frame over which home visits occurred (when reported) varied from 2 weeks to 1 year.

Program personnel included nurses, respiratory therapists, certified asthma educators, social workers, environmental health specialists, health department or home health care staff, and CHWs (4/17 programs). Descriptions for 10/17 programs indicated participants received supplies, typically bedding encasements or cleaning supplies. Only 1 program gave spacers to participants.^{54, 59} Linkages to primary care providers were reported in 8 out of 17 programs; other linkages included school, child care, work, pest management, and other social services.

Pre–post evaluation was the most common method to measure program outcomes (9/17 programs). RCTs were conducted for 2 programs^{80, 81, 83, 84}, and a comparison group (non-randomized) was used to assess 4 additional programs.^{46–49, 75} Evaluation methodology was not available for 2 programs.^{43, 44, 54, 59} Length of participant follow-up (reported for 10/17 programs) ranged from 6 months–3 years.

Program descriptions varied widely in whether methodology to determine ROI was mentioned (typically but not universally present in peer-reviewed literature). When available, ROI calculations differed in which data were incorporated (e.g., discount rates, medications, office visits, or obtaining hospitalization costs from participants' insurance claims data versus estimating costs from hospital surveys). Program costs were reported for 12 out of 17 programs. Notably, ROI determination methods were largely uniform in excluding cost savings related to reduced work/school absenteeism, with the exception of 1 program.⁸⁵

Decreases in asthma-related ED visits or hospitalizations for program participants were reported for most (15/17) programs. A few program descriptions also included outcomes such as shorter hospitalization length-of-stay, fewer intensive care unit admissions, and reduced urgent care or unscheduled office visits.^{36, 54, 59, 60, 66, 80, 84, 85}

Most programs (14/17) were associated with a positive ROI. Two programs had negative ROIs^{75, 84}, and 1 program achieved a positive ROI only among selected participants (i.e., aged <6 years).⁷⁶ Median estimated time to achieve ROI was 3 years (range, 1–11 years).

Summary

In our literature review of economic outcomes for intensive outpatient AS-ME and home-based intervention programs for asthma in the United States, we found ROI data for 9 programs providing intensive outpatient AS-ME and 17 programs offering asthma-related home visits. Most programs were associated with a positive ROI; a few programs observed positive ROIs only among selected populations (e.g., higher urgent health care utilization for asthma or younger children). Methodology to calculate ROIs (when reported) varied across programs.

This review builds on prior work^{63, 86} by updating, comprehensively synthesizing, and examining current evidence regarding economic sustainability of intensive outpatient AS-ME and home-based intervention programs for asthma in the United States. These findings represent timely evidence for clinicians, health care administrators, public health officials, policy makers, investigators and others to consider expanding health care-public health

collaboration efforts to improve asthma control.^{7, 8, 87} This review's categorization of programs by state can facilitate local activities while providing a broader understanding of the current state of evidence. Additionally, provision of subtopic-specific materials in the Online Repository (i.e., Tables E4 and E5 on evidence for CHWs, Tables E6 and E7 on evidence for adult-focused programs, Tables E8 and E9 on evidence for programs involving health insurance plans) can inform ongoing discussions about how and when to implement programs with certain personnel or populations.

This review had several limitations. Publication bias might have caused positive findings to be overrepresented in the literature. For example, publication bias could be a reason why fewer ROIs were found for more recent (e.g., 2000–present) intensive outpatient AS-ME programs compared to older programs; other potential explanations include funding availability or views on the value or achievability of ROIs for such programs. Another limitation relevant to both intensive outpatient AS-ME and home-based asthma interventions was that studies without observed cost savings might have omitted cost data in their reports. Among studies with cost savings data, price years of dollar values were inconsistently reported, so we could not convert dollar values to a single price year for direct comparison. Similarly, heterogeneity in ROI calculation methodology could limit comparability of ROI across programs (e.g., effects of age, season, or time itself might not be fully addressed in a pre–post design compared to RCT). This review focused on cost-benefit analyses involving direct medical costs (e.g., ED visits, hospitalizations); program cost-effectiveness and effects on indirect costs (i.e., work or school absenteeism) were beyond the scope of this review. Lastly, these findings might not be generalizable to programs outside the United States or U.S. programs conducted in inpatient^{88, 89}, military^{90, 91}, school⁹², or residential camp settings.⁹³

Future Directions

This review highlights opportunities to improve understanding of economically sustainable programs offering intensive outpatient AS-ME and multifaceted home-based asthma interventions. No economic outcome data were available for programs in rural settings. Compared to children, evidence for adult-specific programs offering intensive outpatient AS-ME and home-based asthma interventions was relatively limited. Similarly, programs involving CHWs were less abundant than programs involving health professionals, despite increasing interest in this topic. The literature could be more conclusive if methodology to determine ROI was more consistent. For home-based intervention programs, a remaining question is the relative impact of AS-ME, environmental education, and supplies or services for environmental trigger reduction on health and economic outcomes (either immediately following or several years after program participation).

Conclusions

In conclusion, this review examines current economic evidence regarding intensive outpatient AS-ME and home-based intervention programs for asthma in the United States. Interpretation of existing data is constrained by heterogeneous ROI calculations and other limitations. Nevertheless, the literature suggests promise for sustainable opportunities to

strengthen health care-public health collaboration for improved asthma control, especially among populations at higher risk for adverse events. More definitive knowledge about how to maximize program benefit and sustainability could be gained through more controlled studies of specific populations and increased uniformity in economic assessments.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations used

AS-ME	asthma self-management education
CHW	community health worker
ED	emergency department
EPR-3	2007 National Asthma Education and Prevention Program Guidelines for the Diagnosis and Management of Asthma
RCT	randomized controlled trial
ROI	return on investment

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U.S. Programs With Return On Investment Data For Intensive Outpatient Asthma Self-Management Education (AS-ME), By State^a

Table 1

State; Program (Dates)	Reference	Participants (N ^b); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^c	Economic Outcome ^c	Study Design
Arkansas: Arkansas Foundation for Medical Care Quality Enhancing Intervention (2004–present)	<i>Peer-reviewed journal</i> , ¹³ <i>Other</i> , ¹⁴	Adults and children with asthma (aged 4–30 years) with 2 ED visits or hospitalizations (227); Medicaid	<ul style="list-style-type: none"> AS-ME: regular phone calls case management linkage to subspecialty care (if indicated); nurse; total of \$43,534 in baseline year, then \$63,958 in year 1, \$21,772 in year 2	↓ ED visits	ROI: \$6.35 per \$1 <i>Time to realize ROI:</i> 3 years	Pre–post
California: Asthma Tools and Training Advancing Community Knowledge (2008–2011)	<i>Peer-reviewed journal</i> ; N/A <i>Other</i> , ¹⁵	Children aged 1–18 years with asthma and ED visit (NR); Medicaid or MCO	<ul style="list-style-type: none"> AS-ME: individual session in clinic linkage to PCP medical exam in specialty clinic additional services or supplies (if indicated, e.g., education on spacer or nebulizer use, free asthma medication and spacer, referral to Asthma Start program for home visit [see Table III]); asthma educator, nurse, physician; total of \$32,000 in 3 years	No change in health care utilization (outpatient, ED, hospital, pharmacy)	ROI: <\$1 per \$1 <i>Time to realize ROI:</i> 3 years	RCT

State; Program (Dates)	Reference	Participants (N ^b); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^c	Economic Outcome ^c	Study Design
Illinois: Pediatric Asthma Intervention (1999–2002)	<i>Peer-reviewed Journal</i> : ¹⁶ <i>Other</i> : ¹⁷	Children aged 1–16 years with asthma (212); commercial insurance, Medicaid	Three AS-ME interventions: •Group 1 (G1): AS-ME in 1 group session (~20 minutes) + individual AAP •Group 2 (G2): G1 intervention + phone access to asthma educator •Group 3 (G3): G2 intervention + case management; CHW, nurse; \$94/child for G1, \$141–155/child for G2, \$389–663/child for G3	<i>Average among G1–G3</i> : ↓ ED visits by 64% ↓ hospitalizations by 81% ↓ outpatient visits by 58%	G1 ROI: \$43.64 per \$1 G2 ROI: \$27.66– \$30.46 per \$1 G3 ROI: \$7.79–\$13.29 per \$1 <i>Time to realize ROI: 2 years^d</i>	Pre–post
Massachusetts: Asthma Outreach Program (circa 1993)	<i>Peer-reviewed Journal</i> : ^{18–20} <i>Other</i> : ²¹	Children aged 1–15 years with asthma and ED visit, hospitalization, or physician referral (65 [control=32, intervention=33]); health maintenance organization	•AS-ME: 1 nurse visit for individual families •AAP •case management •education on trigger reduction •review of inhaler and peak flow meter technique •linkage to PCP or allergy consult (if indicated); nurse: \$190 PMPM	↓ ED visits by 57% ↓ hospitalizations by 75%	ROI: \$6.49 per \$1 <i>Time to realize ROI: ~3 years^d</i>	RCT

State: Program (Dates)	Reference	Participants (N ^b); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^c	Economic Outcome ^c	Study Design
Michigan: Self-Management Program for Adult Asthma (1986–1987)	<i>Peer-reviewed journal</i> ; ²² <i>Other</i> ; ²¹	Adults aged 18–70 years with asthma and ED visit (241 [control=122, intervention=119]); NR	<ul style="list-style-type: none"> AS-ME: 3 group sessions (6–10 persons each) education on asthma triggers and inhaler technique relaxation exercises; nurse; \$89/person 	↓ ED visits by 59%	ROI: \$22.50 per \$1 <i>Time to realize ROI:</i> 1 year	RCT
New York: Open Airways (circa 1986)	<i>Peer-reviewed journal</i> ; ^{23–25} <i>Other</i> ; ²¹	Children aged 4–17 years with asthma and 1 wheezing episode in the past 12 months (310 [control=103, intervention=207]); NR	<ul style="list-style-type: none"> AS-ME: 6 group sessions for families (10–15 families each) in clinic; health educator; \$1,558 per family 	<i>Among all participants:</i> No difference in ED visits or hospitalizations <i>Among children with / hospitalization in the past year</i> ↓ ED visits by 59% ↓ hospitalizations by 58%	ROI (among all participants): \$0.62 per \$1 ROI (if 1 hospitalization in the past year): \$11.22 per \$1 <i>Time to realize ROI:</i> 2 years ^d	RCT
North Carolina: Asthma Self-Management Program (1996)	<i>Peer-reviewed journal</i> ; ²⁶ <i>Other:</i> N/A	Persons aged 14 years with asthma (110); commercial insurance	<ul style="list-style-type: none"> AS-ME: 8 group sessions education on communication strategies with clinicians, inhaler use, and trigger reduction supplies (asthma journal, peak flow meter, relaxation tape); NR; ~\$450 per participant 	↓ ED visits ↓ urgent care visits	ROI \$2.54 per \$1 <i>Time to realize ROI:</i> 3 years ^d	Pre-post
Ohio: Self-Management Program for Adult Asthma	<i>Peer-reviewed journal</i> ; ^{27,28} <i>Other:</i> N/A	Adults aged 27–70 years with asthma 6 months (47); NR	<ul style="list-style-type: none"> AS-ME: 7 group sessions asthma diary education on 	↓ hospitalizations	ROI: \$2.28 per \$1 <i>Time to realize ROI:</i> 2 years ^d	Pre-post

State; Program (Dates)	Reference	Participants (N ^b); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^c	Economic Outcome ^c	Study Design
(circa 1990)			peak flow meter use; NR; \$208 per participant			
Multi-state: National Cooperative Inner-City Asthma Study ^e (circa 1997)	<i>Peer-reviewed journal</i> ²⁹⁻³¹ <i>Other</i> ³²	Low-income children aged 5-11 years with 2 asthma medications, 1 hospitalization or unscheduled visit, or uncontrolled symptoms (1,033 [control=518, intervention=515]); NR	<ul style="list-style-type: none"> AS-ME: 2 group sessions for caregivers and 2 group sessions for children linkage to community resources review of inhaler technique supplies (bedding encasements) physicians received spacer, peak flow meter, EPR-3, and blank AAP for each child; social worker ± exterminator^f; average \$337 per child 	↓ hospitalizations	ROI (all participants); <\$1 per \$1 ROI (if 1 hospitalization or 2 unscheduled visits in the past 2 months); >\$1 per \$1 <i>Time to realize ROI</i> : 2 years	RCT

AAP, asthma action plan; AS-ME, asthma self-management education; CHW, community health worker; ED, emergency department; MCO, managed care organization; PCP, primary care provider; PMPM, per member per month; N/A, not available; NR, not reported; RCT, randomized controlled trial.

^aExcludes programs that included home visits. Evidence supporting home visit programs is presented in Table III.

^bSample sizes reported herein are those used to determine economic outcomes.

^cQuantitative data are provided if these were available. These are not adjusted to today's dollars; they are reported in each program at the time of report or publication.

^dActual time to realize ROI might be shorter because this estimate included pre-intervention data (typically 1 year of pre-intervention data) used to calculate ROI.

^eParticipating states/districts: IL, MD, MI, MO, NY, OH, and Washington DC.

^fHomes of children who were found to be cockroach allergic on allergy testing received professional application of insecticide over 2 visits.

Table II

Distribution of Return on Investment (ROI) for Intensive Outpatient Asthma Self-Management Education (AS-ME) and Asthma-Related Home Visit Programs in the United States

Return on Investment	Number of U.S. Programs	
	AS-ME	Home Visit
Positive (>\$1 per \$1 invested)	6	14
Varied by population ^a	2	1
Negative (<\$1 per \$1 invested)	1	2

ROI, return on investment

^aPositive ROI reported for some program participants (e.g., younger age or higher health care utilization prior to program entry) but not others.

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Table III

U.S. Programs With Return On Investment Data For Asthma-Related Home Visits, By State

State; Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
California: Asthma Start (2001–present)	Peer-reviewed <i>Journal</i> ; N/A <i>Other</i> : ^{21,33-35}	Children aged 18 years with asthma referred through multiple mechanisms (NR); Medicaid MCO	<ul style="list-style-type: none"> •2–3 home visits •AS-ME •case management •supplies (bedding encasements, cleaning supplies, cockroach traps, HEPA vacuum) •linkage to PCP; social worker; NR 	<ul style="list-style-type: none"> ↓ ED visits by 90% ↓ hospitalizations by 90% 	ROI: \$5–7 per \$1 <i>Time to realize ROI</i> : NR	Pre-post
Illinois: Sinai Pediatric Asthma Initiative-2 (2004–2005)	Peer-reviewed <i>Journal</i> ; ³⁶ <i>Other</i> : N/A	Children aged 2–16 years with severe, poorly controlled asthma (50); Medicaid	<ul style="list-style-type: none"> •3–4 home visits •AAP (if indicated) •AS-ME •education on device or medication technique •linkage to PCP; CHW; NR 	<ul style="list-style-type: none"> ↓ urgent health care utilization (ED visits, hospitalizations, or urgent clinic visits) by 75% 	ROI: \$5.58 per \$1 <i>Time to realize ROI</i> : 2 years ^c	Pre-post
Indiana: Parkview ED Asthma Call Back Program (2009–present)	Peer-reviewed <i>Journal</i> ; N/A <i>Other</i> : ³⁷⁻⁴¹	Persons who visit ED for asthma (NR); NR	<ul style="list-style-type: none"> • 3 home visits (if indicated) with supplies (bedding encasements, cleaning supplies, HEPA vacuum) •AS-ME •linkage to PCP (if indicated) •medication assistance program; health 	<ul style="list-style-type: none"> ↓ ED visits 	ROI: \$20 per \$1 in the first year, \$23.75 per \$1 in 2012 <i>Time to realize ROI</i> : 1 year	Comparison group, not RCT

State: Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
Massachusetts: Cambridge Health Alliance (CHA) Partnership with Cambridge Public Health Department's Healthy Homes Program (2002–present)	<i>Peer-reviewed journal</i> : N/A <i>Other</i> : ^{21, 42–45}	Children aged 12 years with asthma eligible for home visits, but all children with asthma eligible for other CHA services (NR); Medicaid MCO	department staff, nurse, respiratory specialist; NR <ul style="list-style-type: none"> • 3+ home visits (if indicated) with supplies (bedding encasements, cleaning supplies, fire extinguisher, smoke detector) • AS-ME • asthma registry • clinician training • linkage to PCP and school; health department staff, nurse; NR 	↓ ED visits by 50% ↓ hospitalizations by 45%	ROI: \$4.29 per \$1 <i>Time to realize ROI: 7 years^d</i>	NR
Massachusetts: Community Asthma Initiative (2005–present)	<i>Peer-reviewed journal</i> : ^{46–48} <i>Other</i> : ^{8, 21, 49–53}	Children with asthma (2–18 years) with prior ED visit or hospitalization (661 [control]=559, intervention=102); Medicaid MCO, commercial insurance	<ul style="list-style-type: none"> • 1+ home visits • AS-ME • case management • linkage to social services • supplies (bedding encasements, HEPA vacuum, IPM materials); CHW, nurse; \$219 per child per month 	↓ ED visits by 68% ↓ hospitalizations by 85%	ROI: \$1.33 per \$1 <i>Time to realize ROI: 4 years^c</i>	Comparison group, not RCT
Michigan: Asthma Network of West Michigan MATCH program (1994–present)	<i>Peer-reviewed journal</i> : ⁵⁴ <i>Other</i> : ^{21, 55–59}	Adults and children with moderate to severe asthma or uncontrolled asthma (NR); commercial insurance, Medicaid MCO	<ul style="list-style-type: none"> • 3–6+ home visits • AAP • AS-ME • case management • linkage to PCP and (if indicated) school, daycare, work, or social services 	↓ ED visits by 60% ↓ hospitalizations by 64% ↓ hospital length-of-stay by 46%	ROI: \$2.10 per \$1 ^e <i>Time to realize ROI: NR</i> (but ED and hospital charges ↓ in the first year of the pilot)	Pre–post

State: Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
			<ul style="list-style-type: none"> • psychosocial interventions • spacer; • AE-C, social worker; NR 			
Michigan: Healthy Homes University in Lansing (2005–present)	<i>Peer-reviewed journal</i> ⁶⁰ <i>Other</i> ^{55, 61}	Children aged 18 years with asthma from low-moderate income households (243); commercial insurance, Medicaid	<ul style="list-style-type: none"> • 4 home visits • AS-ME • supplies (bedding encasements, cleaning supplies, HEPA vacuum, IPM materials); varied^f; • \$1,055 per household for administrative operating costs + \$230 per home visit for staff and travel + average of \$387 for supplies given to families^g 	<ul style="list-style-type: none"> ↓ ED visits by 53% ↓ hospitalizations by 68% ↓ unscheduled visits by 48% 	ROI: >\$1 per \$1 ^e <i>Time to realize ROI: 3 years</i>	Pre-post
Minnesota: Environmental Improvements for Children's Asthma (2005–2009)	<i>Peer-reviewed journal</i> ; N/A <i>Other</i> ⁶²	Low-income children with: (1) moderate or severe persistent asthma or (2) milder asthma but ED visit, hospitalization, or school absence (255); NR	<ul style="list-style-type: none"> • 2 home visits • supplies (allergen-reducing products); AE-C; • \$621 per home (\$321 for staff + \$301 for supplies) 	<ul style="list-style-type: none"> <i>Parent report from entire sample</i> ↓ ED visits ↓ hospitalizations <i>Subanalysis of health plan data (n=48)</i> ↓ ED visits by 44% ↓ hospitalizations by 68% 	ROI (total health care): \$2.19 per \$1 ROI (asthma-related health care): \$1.76 per \$1 <i>Time to realize ROI: 4 years</i>	Pre-post
Minnesota: Reducing Environmental Triggers of Asthma (2011–2013)	<i>Peer-reviewed journal</i> ^{63, 64} <i>Other</i> ^{8, 56, 65, 66}	Children with asthma living in low-income housing (118); NR	<ul style="list-style-type: none"> • 3–4 home visits • AS-ME • education on reducing environmental asthma triggers • supplies (bedding encasements, cleaning 	<ul style="list-style-type: none"> ↓ ED visits ↓ hospitalizations ↓ urgent care visits 	ROI: \$1.61 per \$1 <i>Time to realize ROI: 1 year</i>	Pre-post

State: Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
New York: The Bronx Improving Asthma Care for Children Project (2002–2005)	<i>Peer-reviewed journal</i> ; N/A <i>Other</i> : ^{67–69}	Children with: (1) moderate or severe asthma or (2) prior ED visit or hospitalization (NR); Medicaid MCO	supplies, HEPA filter, vacuum); nurse; average of \$424 per family (range, \$286–624) • 1 home visit • AS-ME • case management • clinician training; case manager, respiratory therapist, others; \$78 PMPY among pediatric asthma plan members; ^b	↓ ED visits by 75% ↓ hospitalizations by 66%	ROI: \$10 per \$1 among pediatric asthma members of the health plan; \$3 per \$1 across the entire health plan <i>Time to realize ROI</i> : 3 years	Comparison group, not RCT
New York: Monroe Plan for Medical Care's Improving Asthma Care for Children Initiative (2001–2004)	<i>Peer-reviewed journal</i> ; N/A <i>Other</i> : ^{21, 69–72}	Children with asthma (NR); Medicaid MCO, S-CHIP	• 1 home visit • AAP • allergy testing • AS-ME • case management • linkage to social services • supplies bedding encasements, HEPA filter) • spirometry; outreach worker; \$30 PMPM	↓ ED visits by 78% ↓ hospitalizations by 60%	ROI: \$1.48 per \$1 <i>Time to realize ROI</i> : 4 years ^c	Pre-post
Ohio: Home Health Asthma Pathway within the Cincinnati Children's Medical Center Asthma Improvement Collaborative (2008–2011)	<i>Peer-reviewed journal</i> ; N/A <i>Other</i> : ^{73–75}	Children with asthma and ED visit or hospitalization meeting additional criteria ^a (NR); Medicaid	• 3–5 home visits • AS-ME • case management • linkage to PCP and MCO • medication review; nurse; \$1.2 million total over 3 years	↓ acute utilization (ED visits and hospitalizations), but this did not differ from comparison group	ROI: <\$1 per \$1 <i>Time to realize ROI</i> : 3 years	Comparison group, not RCT

State: Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
Pennsylvania: National Jewish Medical and Research Center Disease Management Program for Asthma (western Pennsylvania) (circa 1999)	<i>Peer-reviewed journal</i> : ⁸⁵ <i>Other</i> : ²¹	Adults and children aged >12 years with moderate or severe asthma (317); Medicaid MCO	<ul style="list-style-type: none"> • 2 home visits • AS-ME • case management • physician education and helpline; home health care agency, nurse; \$303 per patient per 6 months 	<ul style="list-style-type: none"> ↓ ED visits by 76% ↓ hospital days by 37% ↓ ICU admissions by 66% 	ROI: \$4.64 per \$1 <i>Time to realize ROI: 1.5 years^c</i>	Pre-post
Rhode Island: Parents of Asthmatics Quit Smoking (2001–2004)	<i>Peer-reviewed journal</i> : ^{76, 77} <i>Other</i> : N/A	Children 17 years with asthma and with caregivers who smoked (224); Medicaid MCO	<ul style="list-style-type: none"> • 3 home visits • AS-ME • linkage to PCP • tobacco cessation counseling for caregiver; nurse; \$34,481 total (\$17,240 for children <6 years; \$15,851 for children with moderate or persistent asthma) 	<ul style="list-style-type: none"> ↓ hospitalizations ↓ outpatient visits 	ROI <\$1 per \$1 for entire program and children aged 6 years (n=112) ROI >\$1 per \$1 for children <6 years (n=112) <i>Time to realize ROI: 2 years^c</i>	Pre-post
Virginia: Optima Health Asthma Management Services (1994–present)	<i>Peer-reviewed journal</i> : N/A <i>Other</i> : ^{21, 78, 79}	Adults and children with asthma and ED visit; hospitalization, or physician referral (NR); commercial insurance, Medicaid	<ul style="list-style-type: none"> • home visits (average=4) • AAP • AS-ME • case management; case manager, nurse, respiratory therapist; \$425 PMPY 	<i>Medicaid:</i> <ul style="list-style-type: none"> ↓ ED visits by 33% ↓ hospitalizations by 32% <i>Commercial insurance:</i> <ul style="list-style-type: none"> ↓ ED visits by 18% ↓ hospitalizations by 54% 	ROI (combined Medicaid & commercial populations): \$4.40 per \$1 <i>Time to realize ROI: 5 years</i>	Pre-post
Washington: Seattle-King County Healthy Homes (1999–present)	<i>Peer-reviewed journal</i> : ^{80, 81} <i>Other</i> : ^{55, 82}	Children with uncontrolled asthma (373 [control]=191, intervention=182); Medicaid	<ul style="list-style-type: none"> • 2–4 home visits • AS-ME • case management • linkage to social services (bedding encasements, 	<ul style="list-style-type: none"> ↓ urgent health care utilization (ED visits, hospitalizations, or urgent clinic visits) 	ROI: \$1.90 per \$1 <i>Time to realize ROI: 2 years^c</i>	RCT

State: Program (Dates)	Reference	Participants (N ^a); Health Insurance Sector	Intervention(s); Personnel; Program Cost	Health Care Utilization Outcome ^b	Economic Outcome ^b	Study Design
Multi-state: Inner City Asthma Study ^f (1998-2000)	Peer-reviewed journal; ^{g,h} Other: N/A	Low-income children aged 5-11 years with asthma meeting multiple criteria ^k (800 [control=392, intervention=408]); commercial insurance, Medicaid, Medicaid MCO, uninsured	cleaning supplies, IPM materials [if indicated], vacuum); CHW: \$205 per home visit •home visits (median=5) •supplies (bedding encasements, cleaning supplies, HEPA vacuum, and [if indicated] HEPA air cleaner or vent filter) •pest control (if indicated); CHW with environmental counselor training; \$1,472 per family	No change in ED visits or hospitalizations ↓ unscheduled clinic visits by 19%	ROI: <\$1 per \$1 <i>Time to realize ROI: 2 years</i>	RCT

AAP, asthma action plan; AE-C, certified asthma educator; AS-ME, asthma self-management education; CHW, community health worker; ED, emergency department; ICU, intensive care unit; IPM, integrated pest management; MCO, managed care organization; N/A, not available; NR, not reported; PCP, primary care provider; PMPM, per member per month; PMPY, per member per year; RCT, randomized controlled trial; ROI, return on investment; S-CHIP, State Children's Health Insurance Program.

^aSample sizes reported herein are those used to determine economic outcomes.

^bQuantitative data are provided if these were available. These are not adjusted to today's dollars; they are reported in each program at the time of report or publication.

^cActual time to realize ROI might be shorter because this estimate included pre-intervention data (typically 1 year of pre-intervention data) used to calculate ROI.

^dROI calculations for shorter time intervals were not available, so the minimum time required to realize a positive ROI is unclear.

^eROI data obtained from non-peer-reviewed reference; ROI not reported in peer-reviewed source.

^fStaff had degrees in biology, medical technology, or environmental science, with prior experience in clinical research, low-income housing, and environmental contaminant investigation.

^gAlso, for the 12% of households required custom home remediation, the average cost of these services was \$2,647 per household.

^h\$3.37 PMPY health plan-wide; total program cost ~\$500,000 over 3 years.

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Children were eligible for home visits through the Home Health Asthma Pathway component if they met additional criteria such as medication nonadherence, unresolved home environmental triggers, or need for more AS-ME; children not meeting these criteria could receive other services (e.g., case management) from the overall program (i.e., the Cincinnati Children's Medical Center Asthma Improvement Collaborative).

Participating states: AZ, IL, MA, NY, TX, WA.

Additional inclusion criteria were: (1) allergy to 1 indoor allergen and (2) 1 hospitalization or 2 urgent visits for asthma in the past 6 months. Children had to meet all inclusion criteria to be eligible to participate.