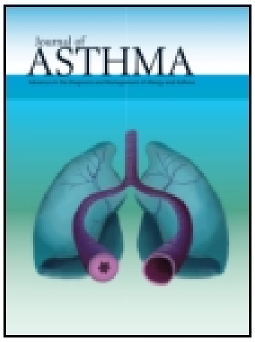

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ORIGINAL ARTICLE

Community Health Workers and Environmental Interventions for Children with Asthma: A Systematic Review

Julie Postma, Ph.D.,[1,*] Catherine Karr,[2] and Gail Kieckhefer[1]

[1]*University of Washington School of Nursing, Family and Child Nursing, Seattle*
[2]*Pediatrics, Environmental & Occupational Health Sciences, University of Washington, Seattle*

Community health worker (CHW)–delivered, home-based environmental interventions for pediatric asthma were systematically reviewed. Seven PubMed/MEDLINE listed randomized controlled trials that encompassed the following intervention criteria were identified: (1) home-based; (2) delivered by a CHW; (3) delivered to families with children with asthma; and (4) addressed multiple environmental triggers for asthma. Details of research design, intervention type, and setting, interventionist, population served, and the evaluated outcomes were abstracted.

Outcome assessment was broad and non-uniform. Categories included direct mediators of improved health outcomes, such as trigger-related knowledge, trigger reduction behaviors and allergen or exposure levels, and asthma-related health outcomes: change in lung function, medication use, asthma symptoms, activity limitations, and health care utilization. Indirect mediators of health outcomes, or psychosocial influences on health, were measured in few studies.

Overall, the studies consistently identified positive outcomes associated with CHW-delivered interventions, including decreased asthma symptoms, daytime activity limitations, and emergency and urgent care use. However, improvements in trigger reduction behaviors and allergen levels, hypothesized mediators of these outcomes, were inconsistent. Trigger reduction behaviors appeared to be tied to study-based resource provision.

To better understand the mechanism through which CHW-led environmental interventions cause a change in asthma-related health outcomes, information on the theoretical concepts that mediate behavior change in trigger control (self-efficacy, social support) is needed. In addition, evaluating the influence of CHWs as clinic liaisons that enhance access to health professionals, complement clinic-based teaching, and improve appropriate use of asthma medications should be considered, alongside their effect on environmental management. A conceptual model identifying pathways for future investigation is presented.

Keywords asthma, allergens, patient education, community health aides, review

Introduction

Pediatric asthma is a significant public health problem. In the United States, approximately 6.5 million children (younger than 18 years of age) have asthma, with rates disproportionately affecting low-income and minority populations (1). Based on evidence that controlling exposure to indoor environmental triggers reduces asthma symptoms and exacerbations, the National Heart, Lung and Blood Institute (NHLBI) guidelines highlight control of environmental factors among the four core components of comprehensive pediatric asthma management (2). While the majority of asthma management education occurs in the clinical setting, increasingly, multifaceted environmental interventions are delivered in the home setting. Home visitation offers an opportunity to assess and address indoor environmental triggers while reinforcing clinical education.

The NHLBI's guidelines cite several randomized controlled trials (RCTs) of interventions using clinical specialists (e.g., medical doctors, registered nurses) or community health workers (CHWs) to deliver the interventions (3–8). CHWs are members of the communities they serve and are well-positioned to establish rapport with families and provide culturally appropriate services (9). Previous studies support the effectiveness of CHWs in improving diabetes knowledge, management of hypertension, and appropriate health care utilization (10–12). Here we provide a systematic review of the effectiveness of CHW-delivered environmental interventions for pediatric asthma and include a conceptual model to guide future research in this area.

*Corresponding author: Julie Marie Postma, Ph.D., Washington State University College of Nursing, PO Box 1495, Spokane, WA 99210; E-mail: Jpostma@wsu.edu

Methods

We identified RCTs that encompassed the following intervention criteria: (1) home-based; (2) delivered by a CHW; (3) delivered to families with children with asthma; and (4) addressed multiple environmental triggers for asthma. CHWs were defined as interventionists who were specifically trained to deliver the intervention but had no formal professional or paraprofessional training in healthcare (13).

Studies were identified in a four-step PubMed/MEDLINE search using the terms: (1) asthma (major); (2) air pollution OR environmental exposure OR allergens OR environmental trigger OR environmental pollution; (3) patient education OR intervention OR skills OR remediation OR health education OR education; and (4) community health aides OR community health worker OR lay educator OR community health services. Searches were then combined with the following limits: Humans, Clinical Trial, Meta-Analysis, Randomized Controlled Trial, English. This yielded 40 publications. No other publications were identified in a five-step CINAHL search using the search terms: (1) asthma (major concept); (2) environmental pollution OR antigens; (3) community health workers OR health educators OR allied health personnel; (4) education OR health services; (5) clinical trials. All CINAHL search terms were exploded and used as exact subject headings or key words. Unpublished data were not considered.

An abstraction form was used to document research design, population served, intervention type and setting, and interventionist. Eight publications met the criteria, one of which reports allergen and exposure results from a subset of homes in the study by Krieger et al. Exclusions included (in a hierarchical order) interventions that were not RCTs (12), focused on adults (2), addressed a single trigger (9), delivered in a non-home setting (3) (e.g., school or emergency room), and/or were delivered by non-CHWs (6). (One publication included in the review focused on outcomes related to cockroaches, although the intervention addressed multiple triggers. Related outcomes will be presented in future publications.) In addition to the primary publications, five companion papers and a project website were used to gather additional detail about the studies (14–19).

We systematically evaluated the state of the evidence for the practice of CHWs in environmental management of childhood asthma. Given the heterogeneity of the outcome measures, statistical methods were not used to combine the results. Thus, results are qualitatively synthesized and presented in a table format (20).

Results

Study Characteristics

All of the studies were published within the last 5 years and conducted in urban settings in the U.S. (Table 1). One study was conducted at numerous sites (6). Sample sizes ranged from 100 (7) to 937 participants (6) and included children with current asthma 2 to 16 years of age (21). With the exception of one study whose participants were screened for asthma using a questionnaire (22), eligibility requirements included either a physician diagnosis of asthma or a recent visit to a clinic, emergency room, or hospital for asthma. Two studies also required at least one positive skin test to an allergen (6, 8).

Recruitment occurred through self- and physician referrals (21), school-based programs (7, 8, 22), community and public health clinics, local hospital and emergency rooms (5, 23), and community agencies and residents (5). One study did not report recruitment methods (6).

Selection of control groups and the type of "usual care" they received varied. Four studies used parallel control and intervention groups (5, 7, 8, 23) with provision of the intervention in total or in a condensed form at the end of the study. One study had three arms: (1) an observation-only or "attention control" group, (2) a treatment group, (3) and a case-matched control group in which asthma hospitalizations and emergency department visits were recorded (21). A two-by-two factorial design to evaluate environmental and physician-feedback interventions in the same study population was used in one study with a traditional non-treated control group (6). A staggered design, such that the groups that served as controls in "Wave 1" received the full intervention in "Wave 2" was used in one study (19). Community Based Participatory Research (CBPR) principles were cited in four studies (5, 7, 22, 23) as providing the basis for using either a low-intensity control group versus a usual care group and/or providing intervention materials to the control group at the end of the study (15, 16, 22). Length of follow-up ranged from 4 months (8) to 2 years (6), with five studies following participants for 1 year after the start of the intervention (5, 7, 21–23). There was no blinding in five studies, only the data collectors were blinded in the one study (7) and blinding was not reported in another study (22). In three studies, the interventionists were also the data collectors (8, 21, 23).

In general, study subjects were between the ages of 5 and 9 years, low-income, and ethnic minorities (Table 2). In particular, subjects were all or primarily African American in three studies (7, 21, 23) and almost all Hispanic in another study (8). African Americans and Hispanics made up the majority of participants in two studies (6, 22). Krieger et al. enrolled the most ethnically diverse sample with subjects reporting being African American, Hispanic, Vietnamese, and white.

Five studies reported the atopic status of their participants at baseline. Between 28.2% of participants in one study (18) and 65% and 75% of the control and treatment group participants in another study, respectively, had more than one positive skin test for an allergen at baseline (7).

Characteristics, Training, and Supervision of Community Health Workers

The CHWs came from, lived, or worked in the same community as study subjects, with the exception of one study (23) (Table 3). One study reported that the CHWs either had asthma or had close family members with asthma (16). Only one author reported the minimum educational background required to be a CHW (22).

Three studies quantified training requirements for the CHWs (16, 18, 22) and three others discussed training programs in which the CHWs had participated (8, 15, 23). In terms of quality control, the use of standardized protocols was reported in three studies and materials posted on another study's website suggest the same. Supervision was only reported in one study, whereby CHWs met with the primary investigator every other week and with the project's steering committee quarterly (16).

Interventions

Social cognitive theory (SCT) and its precursor social learning theory was cited most frequently as guiding the intervention approach, with five of seven studies incorporating components of SCT into their intervention delivery (Table 4). For example, to improve caregivers' *self efficacy* (confidence) to reduce exposures to triggers, CHWs promoted *behavioral capability* (the knowledge and skills to perform a behavior), via role modeling (7, 16, 18, 19, 21).

The health belief model was used extensively by Parker et al. to guide their intervention, from the educational messages developed to the resources and referrals provided. Organizational and community level theories were also synthesized in their comprehensive "ecological stress model," which was presented, but not tested, in their published study. Social networks and social support concepts were cited by two authors to validate the use of CHWs as appropriate interventionists (16, 19). In one study, the transtheoretical stages of change guided the collection of data on caregivers' smoking status and the delivery of a stage-specific intervention approach (16).

TABLE 1.—Study characteristics.

Primary author (year), study design	Study Characteristics: Study, n	Setting	Eligibility requirements	Recruitment	Control group study protocol	Assessment/total length of follow-up in months
Bryant-Stephens (2008) 3 arm RCT	Total: 396	Philadelphia	• 2–16 years of age • Live in West Philadelphia zip code • Receive care at Children's Hospital of Philadelphia • At least one asthma-related hospitalization or two asthma-related emergency department visits, in year before enrollment	Self- & physician referrals	Observation-only group (OBS): visited every month to collect symptom diaries, given information about asthma self-management classes in the community. Case-matched controls (CMC): no care	Every month, outcomes reported at 6, 12 mo /12 mo
Eggleston (2005) 2 arm RCT	100	Baltimore	• 6–12 years of age • Current asthma symptoms • Physician-diagnosed asthma • No other chronic lung disease	School-based asthma education program	Control group received intervention at the end of the study.	6, 12 mo/12 mo
Krieger (2005) 2 arm RCT	274	Seattle/Tacoma	• 4–12 years of age • Persistent asthma diagnosis • Income below 200% of 1996 FPL or child enrolled in Medicaid • Caregiver verbally proficient in English, Spanish, or Vietnamese • Child spent at least 50% nights in the house • House was in King County	Community & public health clinics (65%), local hospital & emergency rooms (27%), community agencies & residents (8%)	Low-intensity control group received a single CHW visit, which included a home environmental assessment, an action plan, limited education, & pillow & mattress encasements. At the end of the study, this group received all resources & additional education.	12 mo/12 mo 18 mo for high- intensity group only
McConnell. (2005) 2 arm RCT	150	Los Angeles	• 6–14 years of age • At least 3 visits to mobile clinic or clinic • Positive skin test to mixed cockroach allergen • Persistent asthma diagnosis	School-based mobile asthma clinic or allergy clinic at university medical center	Control group received condensed version of the intervention at the end of the study.	4 mo/4 mo
Morgan (2004) 2 × 2 Factorial RCT	937	Boston, Chicago, Dallas, New York, Seattle/Tacoma, Tucson	• 5–11 years of age • Residents of census tracts where at least 20% of households had incomes below the FPL • Physician diagnosis of asthma • At least one asthma-related hospitalization or two unscheduled, asthma-related visits to the clinic or emergency department during the previous 6 months • Positive skin test in response to at least one allergen	NR	Control group received visits only for evaluation of health outcomes at 6-month intervals throughout the study. (Physician feedback intervention included bimonthly reports of the children's asthma symptoms & use of health care services to their primary care physicians.)	6, 12, 18, 24 mo/24 mo
Parker (2007) Staggered, 2 arm RCT	298	Detroit	• 7–11 years of age • Resided in Southwest or Eastside Detroit • Reported persistent symptoms	School-based programs	Control group received a booklet of basic information on asthma. Control group received intervention at the end of the study.	12 mo/12 mo
Williams (2006) 2 arm RCT	161	Atlanta	• 5–12 year of age • English speaking • Resided within the zip code of the Atlanta Empowerment Zone • Previous presentation to the emergency department of the local major public children's hospital	Emergency department at local children's hospital	Control group received intervention at the end of the study.	4, 8, 12 mo/12 mo

Abbreviations: CMC = case-matched control group; FPL = Federal Poverty Level; Mo = months; NR = not reported; OBS = observation group; RCT = randomized clinical trial; T = treatment group.

TABLE 2.—Characteristics of study population.

Primary author (year)	Age, years (mean) [SD] C/T	Gender (% female) C/T	Race/ethnicity (%) C/T	Household Income (%) C/T	Atopic status (% positive) at baseline C/T
	Characteristics of study population				
Bryant-Stephens (2008)	T: 6.1 [3.9] OBS: 5.6 [3.5] CMC: 5.3 [NR]	T: 40 OBS: 34 CMC: 43	T: AA 99 OBS: AA 100 CMC: AA 100	NR	NR
Eggleston (2005)	8.3 [1.4]/8.5 [1.5]	60/48	98 AA/100 AA	$<10,000/yr: 33/45 $10,000–20,000: 42/34 >$20,000: 25/21	DM: 36/23 CR: 44/40 Mouse: 8/10 Cat: 26/19 ≥ 1+ : 65/75
Krieger (2005)	7.3 [NR]/ 7.4 [NR]	38.2/44.2	Non–Hispanic White 21.3/12.3 AA 27.9/31.9 Vietnamese 22.1/25.4 Other Asian 5.2/9.4 Hispanic 17.7/17.4 Other 5.9/3.6	<100% FPL: 60.9/51.9 100–149% FPL: 24.1/33.3 150–200% FPL: 15/14.8	NR
McConnell (2005)	NR	33/34	Hispanic 92/94 Other 8/6	<$15,000/yr: 38/40 $15,000–24,999: 33/31 ≥ 25, 000 : 29/29	CR: 40/61
Morgan (2004)	7.7 [SE 0.09]/7.6 [SE 0.09]	37.8/36.9	AA 41.5/40.3 Hispanic 40/40.3 Other 18.5/22	% with Income<$15,000/yr: 60.9/59.8	DM: 63.3/62.8 CR: 70.3/67.8 Cat: 47.8/40.8 Dog: 22.6/21.4 Rodent: 33.6/33.3 Mold: 48.1/51.8
Parker (2007)	8.8 [1.41]/9.01 [1.50]	41/43	AA 79/83 Hispanic 10/11 Caucasian 5/4 Other 6/3	% with Income < $10,000/yr: 46/37	DM: 35/41 CR: 16/25 Cat: 25/21 Dog: 5/11 Grasses: 30/29 Ragweed: 23/24 Mouse: 13/12 Rat: 10/10 Mold: 18/22
Williams (2006)	8 [NR]/8 [NR]	34/48	AA 100/99	<$500/mo: 39/33 $500–1200: 33/36 $1201–1600: 13/15 >$1601: 8/6 Did not answer: 7/10	DM: 60/57 CR: 38/35 Cat: 17/19 Dog: 14/16 Grasses: 51/47 Trees: 31/23 Mold: 13/15

AA = African American; C = control group; CMC = case-matched control group; CR = cockroach; DM = dust mite; FPL = Federal poverty level; NR = not reported; OBS = observation group; SE = standard error; SD = standard deviation; T = treatment group; Yr = year.

Education related to the relationship between triggers and asthma and ways to decrease or avoid triggers was delivered in all seven studies. Most studies focused solely on environmental triggers for asthma, but three studies included general information about asthma (5, 21, 22). One study also included education around medication use and devices (21).

All of the RCTs' interventions included providing pillow and mattress encasements for dust mite avoidance. Other resources given to some or all participants (depending on the assessment and their need) included cockroach bait, pest remediation, rodent traps, boric acid and caulk, vacuum bags, vacuums with HEPA filters, HEPA air filters/purifiers, cleaning kits, shower curtains, and commercial quality door mats. Referrals varied among studies but encompassed smoking cessation, professional house cleaning and extermination, skin testing, weatherization program assistance, and social service agencies.

All but one study provided individually tailored interventions, either in terms of (1) incorporating the caregivers' preferences in determining problems and solutions (8); (2) responding to individual subjects' allergic sensitivity (skin prick testing); and/or (3) responding to triggers identified during the home assessment (23). Three studies combined all three of these approaches (5, 15, 19). Morgan et al. tailored the selection and intensity of the intervention modules to each child's allergic profile and their home assessments, but not caregiver preference for particular problems or solutions.

The length of the intervention period varied from three to nine home visits, although one study's authors reported that some participants actually received 17 home visits (22). Visits were generally 60 minutes each but sometimes ran as long as 150 minutes (8). In addition to content covered at the home visits, 2 of the studies also included follow-up telephone calls (6, 7). The intervention period ranged from 6 weeks to 1 year.

Four studies described the cost of intervention per child. Costs ranged from $492, which included encasements, the room HEPA air filter, pest control visits, and CHW visits (7) to $1500–2000/child (not itemized in publication) (6).

Study Findings

Outcome categories among the studies were broad and non-uniform. Categories included mediators of improved health outcomes, such as trigger-related knowledge, trigger

TABLE 3.—Characteristics, training, & supervision of community health workers.

Primary author (year)	Social congruence with study participants	Training	Quality control
Bryant-Stephens (2008)	• From target community	NR	Use of protocols
Eggleston (2005) Swartz (2004)	• All lived, had lived, or had worked in target community • All African American	Previously trained, but training not described	NR
Krieger (2005) Krieger (2002)	• All lived in target community • 54% shared ethnic background of study participants • Most communicated in primary language of participants • All either had asthma or had close family members with asthma	40 hours, 10–20 hours of continuing education/yr	Met with the primary investigator every other week; met with the project's steering committee quarterly, use of protocols
McConnell (2005)	• From target community	Participation in training program in urban health education, included content specific to asthma	Use of protocols
Morgan (2004) Crain (2002)	• "Culturally sensitive" • Bilingual	2 centralized training sessions	Use of protocols
Parker (2007)	• "Culturally similar" • Half were bilingual	4 weeks of "intensive training" & "ongoing" training	NR
Williams (2006)	NR	Participation in CHW Training Program via local university	NR

NR = not reported; Yr = year.

reduction behaviors and allergen or exposure levels, as well as asthma-related health outcomes, such as a change in lung function, medication use, asthma symptoms, functional limitations, and health care utilization (Table 5). Psychosocial influences on health, including measures of quality of life, social support, and depression, were measured in few studies.

Caregiver's depressive symptoms significantly decreased in the intervention group (p value not reported) but increased in the control group ($p = 0.028$), whereas two measures of social support, instrumental and emotional, did not improve in the one study that measured these outcomes (22). Child quality of life did not improve in the one study that measured it (7), while caregiver quality of life did significantly improve within the low- and high-intensity groups and across-groups (0.58 points, 95% CI: 0.18-0.99, $p = 0.005$) in the one study that measured it (5).

Knowledge was measured in two studies and results were non-significant, although in the direction predicted. In one study, knowledge significantly increased in both the low- and high-intensity groups but was greater in the high-intensity group (17). In another study, a summary score of knowledge increased in the intervention group but was not significant across-groups (8).

Behavior change was measured in four studies and results were mixed, with most behavioral improvements tied to resource provision (Figure 1). For example, in one study, two out of four improved behaviors were related to the use of pillow and mattress encasements (21). In a second study, self-reported behavior change significantly increased in both the low- and high-intensity groups but was greater in the high-intensity group. Again, the across-group effect was insignificant when measured as a summary score. The five behaviors that did significantly improve across the groups included vacuuming the child's bedroom at least twice over the past 2 weeks, vacuuming or removing cloth covered furniture at least twice over the past 2 weeks, using doormats

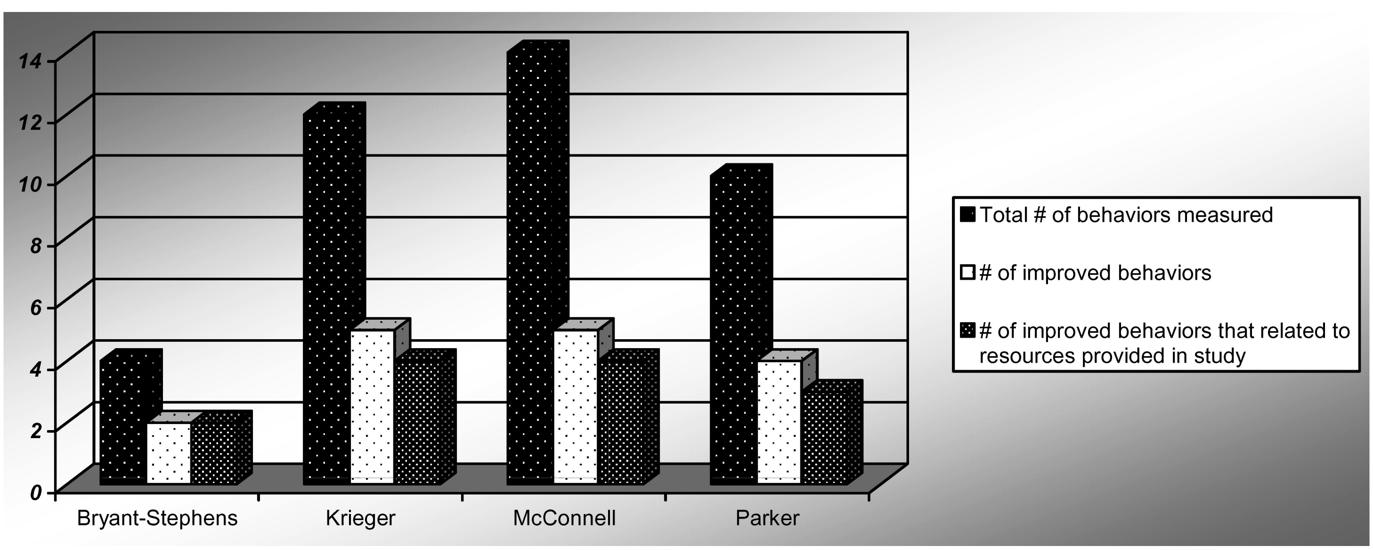

FIGURE 1.—Behavior improvement & resource provision.

TABLE 4.—Intervention characteristics.

Primary author (year)	Intervention characteristics: Theoretical framework	Content	Resources/referrals	Mode	Dose/ frequency	Length of HV	Cost/child
Bryant-Stephens (2008)	NR	HV1: No education given HV2: Asthma as a disease, signs & symptoms of an asthma attack, medication review, pest control HV3: Indoor triggers, avoidance techniques, use of encasements HV4: Review of asthma medications & devices, cockroach & pet dander, avoidance techniques HV5: Medication action plan HV6: Review of medications & devices, question & answer session	Pillow & mattress encasements, bait, cleaning supplies, vacuum & trash bags, referrals to contractors	HV	6 HV within $1^1/_2$ mo	NR	Intervention & CHW salary: $675
Eggleston (2005) Swartz (2004)	Social cognitive theory	HV1: Sources of indoor air pollutants, ways to reduce indoor air pollutants, avoiding exposure to second h& smoke, smoking cessation HV2: Indoor allergen & irritant control, creation of personalized care plan HV3: Reinforce allergen & air pollution information	Pillow & mattress encasements, CR & rodent extermination if child was allergic, HEPA air filter, smoking cessation, visual aids, materials	HV & Phone calls	3 HV within 5 mo	60 min	Intervention & CHW salary: $492
Krieger (2005) Krieger (2002)	Social cognitive theory Social networks, social support Transtheoretical stages of change	HV1: Asthma basics, DMs, roaches HV2: Discuss household action plan, DMs, moisture, tobacco, CR HV3: Discuss household action plan, DM, household cleaning, household toxins, moisture, pets, rodents, outdoor air HV4: Discuss household action plan, asthma basics, household cleaning, CRs HV5: Discuss household action plan, DMs, household cleaning, household toxins HV6: Discuss household action plan	Pillow & mattress encasements, bait/traps, pest remediation, vacuum, shower curtain, door mat, cleaning kit, weatherization programs, social service referrals, skin testing	HV	5 HV, 4 more optional, within 12 mo Mean: 7 HV	60 min	Intervention & CHW salary, indirect costs: $1124
McConnell (2005)	NR	(NR per HV) (LA CASA website, 2008) Effect of CR on lungs, lifecycle of CR, CR control, strategies to reduce infestations (e.g. sealing cracks, cleaning, traps)	Pillow & mattress encasements, boric acid, caulk, written materials, coloring book	HV	2 HV within 4 mo	60–150 min	NR
Morgan (2004) Crain (2002)	Social learning theory/ Social cognitive theory	Module 1: Role of allergens & irritants in asthma, strategies to minimize DMs & create a safe sleeping zone Module 2. Review of HV1, strategies to decrease exposure to ETS Module 3.Review of HV1, cockroach behavior, strategies to decrease exposure to cockroaches (e.g. cleaning, IPM) Module 4. Review of HV1, pet allergens & asthma, strategies to avoid pets, pet dander Module 5. Review of HV1, rodent behavior, strategies to prevent rodents (e.g. copper mesh at entry points) Module 6. Review of HV1, sources of mold/moisture, Strategies to prevent & clean mold	Pillow & mattress encasements, vacuum, HEPA air purifier, pest remediation, if needed	HV & Phone calls	5 HV within 12 mo Mean: 4.7 HV+/− SD 1.09	<120 min Mean: 73.6 +/− SD 27.59	$1500–2000
Parker (2007)	Social cognitive theory Health belief model Organizational & community level theories	HV1: General asthma information & the role of environmental triggers HV2: Action plan developed based on prioritized list of triggers HV 3–9: Methods to reduce triggers (DM, ETS, CR, pets, rodents, mold)	Pillow & mattress encasements, vacuum, cleaning supplies, IPM, clinic, & social service referrals, if needed	HV	9 HV within 12 mo Range: 1–17 Mean: 9.24	NR	NR
Williams (2006)	Self efficacy	(NR per HV) Care of encasements, washing sheets & upholstery Use of CR bait, food handling practices Impact of ETS on asthma Other topics as needed: controlling moisture & humidity, cleaning mold, pets	Pillow & mattress encasements, one time professional housecleaning, roach bait	HV	3 HV within 12 mo	NR	NR

CR = cockroaches; DM = dust mites; ETS = environmental tobacco smoke; HEPA = High-efficiency particulate air; HV = home visit; IPM = integrated pest management; Min = minutes; Mo = months; NR = not reported.

TABLE 5.—Findings.

	Mediators of improved health-related outcomes		Health-related outcomes			
Primary author (year)	Trigger reduction behaviors	Environment (allergen/exposures)	Asthma symptoms	Activity limitations	Medication use	Urgent care use
Bryant-Stephens (2008)	S↑in use of pillow ($p < 0.001$) & mattress encasements ($p < 0.001$) NS change in reducing carpet & presence of ETS	NS change in CR & rodent problems	NR	NR	*Need for daily use of:* *Rescue med* NS (NR) *Controller med* NS (NR)	T & OBS: NS difference on 3/3 measures (Hosp. $p < 0.95$, ED $p < 0.99$, Clinic $p < 0.26$) T & CMC: S↓across 3/3 measures (Hosp. 0.31, $p < 0.05$, ED 0.97, $p < 0.01$, Clinic 0.48 $p < 0.05$
Eggleston (2005)	T: 27% had pillow/mattress encasements in place at 12 mo	S 39%↓ in PM 10 in T vs. 5% ↑ in C ($p < 0.001$), S ↓ in PM 2.5 ($p < 0.001$) NS change in CR ($p = 0.08$), NO, cat, DM, Mouse (NR)	S ↓ in daytime symptoms/2 wks ($p < 0.05$) NS change in other categories	NR	NR	NS ↓ in clinic, ER visits & hospitalizations (NR)
Krieger (2005) Allergen & exposure analysis is from a subgroup of 60 homes (Takaro, 2004)	NS ($p = 0.141$)	*Exposures* T: S ↓ in presence of CR ($p = 0.003$), Condensation ($p = 0.000$), Moisture ($p = 0.003$), Dust weight ($p = 0.008$), Composite trigger score ($p = 0.005$) C: NS A: Condensation ($p = 0.013$), dust weight ($p = 0.042$) *Antigen surface loading* T: S ↓ in DM ($p = 0.025$), dog ($p = 0.034$), fraction of antigens ≥ cutoff point ($p = 0.006$) C: S ↓ in cat ($p = 0.020$) A: NR *Antigen concentration in dust* All groups: NS	*# days with symptoms/2 wks* NS ($p = 0.138$)	*# days with activity limitations/2wks* S ($p = 0.029$) *# days child missed school/2 wks* NS ($p = 0.105$) *# days caregiver missed work/2 wks* NS ($p = 0.890$)	*# days using a rescue med/2 wks* NS ($p = 0.781$) *# days using a controller med/2 wks* NS ($p = 0.250$)	*# visits to urgent care/2 mo* S ($p = 0.026$) T: Gains in behaviors & health outcomes at exit persisted @18 mo follow up, with a tendency for further improvement across all outcomes (data not shown in original paper)
McConnell (2005)	*Reported practices* S ↑ in use of sticky traps ($p < 0.05$), boric acid ($p < 0.01$), caulking ($p < 0.05$) NS change in 3 behaviors (NR) *Observed practices* S ↑ in use of encasements ($p < 0.01$), boric acid ($p < 0.01$) NS change in 3 CR practices & 4 food behaviors	S ↓ CR load in bedding ($p < 0.05$), NS change in CR concentration in bedding, & CR load, concentration in kitchen, S ↑ in # CR trapped ($p < 0.05$) NS ↓ in evidence observed, problem reported, presence on traps	NR	NR	NR	NR
Morgan (2004)	NR	@ 12 mo *Bed allergens* S ↓ DM1 ($p < 0.001$), DM2 ($p = 0.007$), cat ($p < 0.001$) NS changes in CR ($p = 0.13$) & dog ($p = 0.29$) *Floor allergens* S ↓ CR ($p < 0.001$), DM1 ($p = 0.004$), S ↑ cat ($p = 0.02$) NS changes in DM2 ($p = 0.28$) & dog ($p = 0.56$) @ 24 mo *Bed allergens* S ↓ DM1 ($p = 0.004$) *Floor allergens* S ↓ CR ($p < 0.003$)	*# of days with symptoms/2 wks* @ 12 mo S ↓ by 0.82 ($p < 0.001$) @ 24 mo S ↓ by 0.60 ($p < 0.01$)	@ 12 mo *# of nights caretaker woke/2 wks* S ↓ by 0.61 ($p < 0.001$) *# days caretaker changed plans/2 wks* S ↓ by 0.31 ($p < 0.001$) *# school days missed/2 wks* S ↓ by 0.17 ($p < 0.003$) @ 24 mo 2/3 activity improvements were sustained	NR	@ 12 mo *# of unsched. visits /yr* ED ↓ by 0.35 ($p = 0.04$), Hosp NS ($p = 0.56$) @ 24 mo *# of unsched. visits/yr* ER ↓ by 0.26 ($p = 0.07$), Hosp NS ($p = 0.19$)

(Continued on next page)

TABLE 5.—Findings. *(Continued)*

	Mediators of improved health-related outcomes		Health-related outcomes			
Primary author (year)	Trigger reduction behaviors	Environment (allergen/exposures)	Asthma symptoms	Activity limitations	Medication use	Urgent care use
Parker (2007)	S ↑ in changing sheets weekly ($p = 0.004$), vacuuming ($p < 0.0001$), use of pillow ($p = 0.0006$) & mattress encasements ($p < 0.0001$) NS change in dusting, washing bed covers, removing mold, & 3 ETS measures	S ↓ in dog ($p < 0.001$) NS change in CR, DM, cat	S ↓ in 2/8 symptoms: Persistent cough ($p = 0.034$), Cough with exercise ($p = 0.017$) NS change in 6/8 symptoms	NR	*Not on a corticosteroid* NS↓ ($p = 0.073$) *Not on any controller* S ↓ ($p = 0.004$)	S ↓ in need for unsched. Medical care ($p = 0.004$)
Williams (2006)	NR	S↓in DM ($p < 0.05$), CR ($p < 0.05$)	25%↓in FSS ($p < 0.01$)	25%↓in FSS ($p < 0.01$)	NS (NR)	NS (NR)

Abbreviations: A = across group; C = control group; CMC = case-matched controls; CR = cockroaches; DM = dust mites; ED = emergency department; ETS = environmental tobacco smoke; FSS = Functional severity score; Hosp = hospital; NR = not reported; NS = not significant; OBS = observation group; S = significant; T = treatment group; Unsched = unscheduled.

or removing shoes, using allergy control devices on mattress and pillows, and having and using a working kitchen exhaust fan (5). Four of five of these behaviors were facilitated by resources (e.g., vacuums, pillow and mattress encasements, door mats) provided in the study. Behaviors that did not significantly change included dusting the child's bedroom twice a week, washing sheets in hot water weekly, removing pets from the child's bedroom and/or home, having and using a working bathroom exhaust fan, smoking in the home, and smoking by the caregiver (5).

In a third study, 5 of 14 reported and observed behaviors significantly improved across-groups, with 4 of 5 related to resources provided in the study (e.g., mattress/pillow encasements, caulk, boric acid [use of boric acid counted as both a reported and observed behavioral outcome]) (8). A fourth study reported similar findings. Of 10 behaviors, 4 significantly improved, 3 of which were related to resource provision (e.g., vacuums, pillow and mattress encasements) (22).

A variety of allergens and exposures were measured in the studies. Results were mixed in terms of which allergens or exposures significantly decreased over time and how or where they were measured. One study found no significant across-group difference in reducing cockroach or rodent problems (21). Another study found no significant reduction in the levels of cockroach allergen, dust mite allergens, cat allergen, or nitric oxide concentration but did find significant reductions in particulate matter 2.5 and particulate matter 10 at 1 year (7).

Exposure levels for a subgroup of 60 randomly selected homes from the Seattle-based Healthy Homes Project were reported in a separate publication (17). Overall, the high-intensity intervention group had significant reductions from baseline-to-exit in the surface loading of dust mite and dog antigens and the fraction of cat, dog, dust mite, and roach antigens that exceeded an a priori ($\geq 5\ \mu g/m^2$) cutoff point. The surface loading of cat allergen was the only significant improvement in the low-intensity group and the intervention effect across-groups was not reported. Presence of roaches, condensation and moisture score, dust weight, and composite trigger scores also significantly decreased in the high-intensity group, whereas there were no significant improvements in the low-intensity group, and only condensation and dust weight were significant across-groups. No significant changes were demonstrated within or across-groups in terms of antigen concentration in dust (17).

McConnell et al. also demonstrated mixed results in terms of cockroach allergen; there was little difference across-groups in the proportion of homes at a 4- month follow-up with trapped cockroaches, although there was a significant difference in the geometric mean cockroach count (killed by means other than traps) at the follow-up visit. There was also a significant across-group reduction in the level of cockroach allergen in bedding, likely due to the mattress and pillow encasements, but not in the allergen samples obtained from the kitchen.

Morgan et al. found that at 1 year, the intervention was effective in decreasing levels of dust mite and cat allergen in bed samples and cockroach, dust mite, and cat allergen obtained from floor samples across-groups. There were no significant differences in the levels of cockroach or dog allergens sampled from the bed or dog allergens sampled from the floor. At 2 years, dust mite and cat allergen obtained from bed samples and cockroach and cat allergen in floor samples remained significantly lower in the intervention group when compared to control subjects. Across-group differences in dog and cockroach allergens sampled from the bed remained insignificant as did dog allergen sampled from the floor. The decrease in cat allergen was not sustained at 2 years.

Parker et al. reported a significant intervention effect only in the reduction of concentration of dog allergen per gram of bedroom dust, but no effect in terms of cockroach, dust mite, or cat allergen concentration. Williams et al. found that the difference in the median pooled dust mite antigen levels between the intervention group and the delayed intervention group was significantly different in the direction predicted; however, they found no difference across-groups in cockroach antigen.

The lack of a consistent allergen reduction effect in two of the studies may be explained by limited statistical power to detect a difference (17) and differences in sampling and analytic strategy (8). Nonetheless, Takaro et al. demonstrated correlations between frequent vacuuming and antigen levels found in dust. This supports the assumption that interventions directed at the sources of these exposures, as well as vacuuming itself, can reduce the surface loading of antigens. One study also demonstrated a dose-response relationship between reduction in bedroom dust mite and cockroach allergen levels with decreases in the maximal number of days with symptoms, the number of hospitalizations, and the number of unscheduled visits for asthma in both years of the study (6).

Asthma-related health outcomes were reported in six out of seven studies, including asthma symptoms, activity limitations, medication use, lung function, and urgent care use. Symptoms were defined similarly across three studies and included caregiver report of the child's daytime symptoms, nighttime symptoms, and symptoms that interfered with their child's activity or exercise over the past 2 weeks (5–7). Bryant-Stephens et al. collected information from caregivers on the frequency of nighttime wheezing, nighttime coughing, daytime wheezing, and daytime coughing over the past 2 weeks. Parker et al. asked caregivers to recall similar symptoms over the past year. Williams et al. asked caregivers to recall wheeze frequency, nighttime awakening symptoms, occurrence of a severe asthma attack, and limited home and sports activities, every 4 months. This information was included as the "functional severity" component of a total asthma severity score that also included a medication and urgent care component. For the purposes of this review, these subcomponents will be considered separately.

There was a consistent and significant decrease in caregiver-reported asthma symptoms among intervention subjects compared with control subjects, and, in one study, this decrease persisted for 1 year after the intervention was completed. Eggleston et al. reported a significant decrease in all categories of asthma symptoms across-groups at 6 months, but only daytime symptoms remained significantly different in the intervention group at 1 year (7). Others reported significantly fewer asthma symptoms during the intervention and follow-up year on all measures (6, 23). (Note: Williams et al. report this decrease in symptoms as part of the functional severity score [FSS]).

Two studies had insignificant findings across-groups, but one found a trend toward significance (21) and the other demonstrated a reduction in symptoms in both the high and low-intensity groups, thereby attenuating the difference across-groups (5). Parker et al. reported that although the intervention group reported a decrease in eight symptoms, the control group reported a decrease in six of eight symptoms. Thus, only two of the eight symptoms (persistent cough and cough with exercise) significantly differed across groups.

In addition to a decrease in symptoms, there was a significant decrease in caregiver reports of activity limitations among intervention subjects compared to control subjects. Again, in one study, this decrease persisted for one year after the intervention was completed. Morgan et al. found significant across-group effects on all three measures (the number of nights a caretaker woke up or changed plans because of child's asthma and the number of school days missed due to child's asthma), two of which remained significant at the 2-year follow-up (number of nights caretaker wore up, school days missed) (6). Another study found that the number of days with activity limitations significantly decreased in both the high- and low-intensity groups, and the difference across groups was significant. However, missed work days did not improve in either group, and missed school days improved only in the high-intensity group (5). Williams et al. reported that in ad hoc analyses and as a subcomponent of the FSS, caregiver-reported limitations in the child's home and sports activities contributed to the significant across-group differences in the FSS.

Four studies measured a change in medication use, and the effect of the interventions on use of "rescue" and "controller" medications was mixed. One study reported that individuals in both the low and high-intensity groups significantly decreased their use of beta-2 agonist "rescue" medications, but the difference across-groups was insignificant. In addition, the "need for asthma controller medications" decreased in the high-intensity group only, although it is not clear that a self-reported decrease in use of controller medication is an indication of improved asthma management (5). For example, another study reported a significant and positive intervention effect in "reducing under treatment for active symptoms in the category of children who should be on a controller but are not," or increasing participants' access to controller medications (22). Two studies found no significant across-group differences in terms of medication use (21, 23).

Four studies assessed changes in lung function. Results were mixed and complicated by poor technique and compliance (21, 22). One study demonstrated, in a subgroup of participants, significant improvement in daily nadir PF and FEV_1, but no significant change in intraday variability in the same measures (22). Neither of the other two studies demonstrated a significant across-group effect as measured by spirometry or peak-flow monitoring (6, 7).

Six studies measured unscheduled asthma-related clinical utilization. Results were, for the most part, statistically significant, with fewer unscheduled asthma-related visits associated with the intervention group. Three studies demonstrated reduced urgent health care use across groups, including urgent care visits, emergency room visits, and hospitalizations (5, 21, 22). One study demonstrated a reduction in asthma-related visits to the emergency department or clinic, but no reduction in asthma-related hospitalizations during the intervention year, although this study was not powered to detect a difference in this infrequent outcome. In the follow-up year, significant differences across-groups for urgent health care use disappeared (6). Notably, Bryant-Stephens et al. found that there was no significant difference in urgent health care use across the intervention and observation groups, but there were differences between case-matched controls and the intervention group. That said, the observation-only group in this study was given information on asthma self-management classes available in the community. (Use of those services by the participants was not reported.) Another study found that both intervention and control groups made fewer visits to the emergency department and had fewer hospitalizations, but these reductions were not statistically significant (7). Finally, when measured as part of the asthma severity score, urgent health care use was not significantly reduced in the study by Williams et al.

Discussion

Notable similarities among the seven RCTs of CHW-delivered environmental interventions include their focus on minorities with low-income and urban residence. Most used research designs that eventually provided education and resources to all subjects, including "controls." The majority of studies used social cognitive theory (SCT) to guide intervention delivery, using role modeling and tailoring to deliver educational messages and build caregivers' skills in avoiding allergens and other asthma triggers.

Assessment of intervention effectiveness differed among the studies. Only two measured indirect mediators, or psychosocial aspects, such as a change in depression, social support, and (emotional aspects of) quality of life. Direct mediators, including trigger-related knowledge acquisition, behaviors to reduce triggers, and allergen levels were available for two, four, and six studies, respectively. Direct measures of asthma status using lung function, symptoms, activity limitations, and/or urgent health care use were reported by at least three studies.

Overall, the studies support the effectiveness of CHW-delivered interventions, demonstrating decreased asthma symptoms, lessened daytime activity limitations, and lessened emergency and urgent care use, as indicated by the solid line in Figure 2. The studies with higher intensity and higher frequency ("higher dose") interventions reported the most positive health outcomes. However, evidence of trigger reduction behaviors and improvements in allergen levels, hypothesized mediators of these interventions, were mixed, as indicated by the dashed lines in Figure 2. Nonetheless, one study demonstrated that trigger reduction behavior correlated with a reduction in antigens, and another study demonstrated a dose-response relationship between reductions in bedroom antigen levels with improvements in asthma-related health outcomes. Trigger reduction behaviors that did improve appeared to be tied to resource provision.

Sources of potential bias in these studies include baseline differences among intervention and control subjects, differential drop out, nonblinding, and the Hawthorne effect. Overall, there was little evidence for baseline differences in the reviewed studies. Two studies reported a higher dropout rate

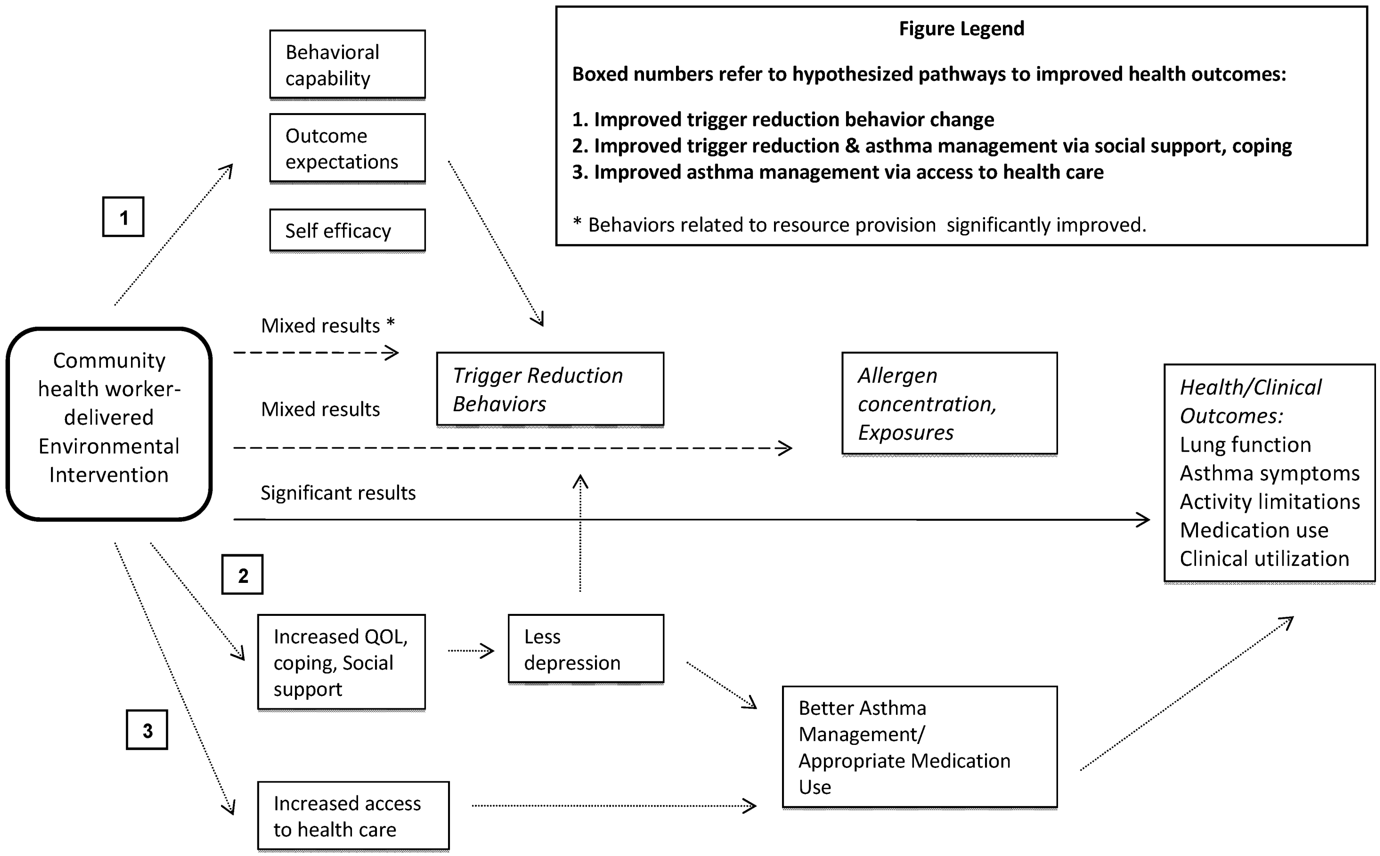

FIGURE 2.—Conceptual Model of Community Health Worker-Delivered Environmental Interventions

among the intervention group, with Williams et al. noting that persons lost to follow-up differed on residential, staff, and logistic factors (8, 23). One study found the opposite effect, that 5% of the intervention group and 9% of the control group dropped out by one year (6). Another reported their overall attrition rate of 3% but did not report the rate per group (7). Parker et al. reported similar dropout rates across-groups; however, subjects that completed the study were more likely to be male children and living in a home that their family owned (22). Likewise, one study had similar dropout rates but those who completed the study were more likely to be Asian and less likely to have pets (5). The greatest source of bias was likely related to the lack of blinding in most of the studies. Nonblinding may have inflated the intervention effect. In addition, questions asked about environmental triggers by a home visitor to control subjects may have motivated caregivers to pay attention to triggers, minimizing the effect of the intervention (Hawthorne effect).

Three pathways need to be explored in future studies to better determine the mechanism through which CHW-delivered interventions cause a change in asthma-related clinical outcomes, as indicated by the dotted lines and numbers in Figure 2. First, although most interventions were based on SCT, few studies operationalized theoretical concepts that serve to mediate behavior change, thereby limiting assessment of the influence of this component of the causal pathway. No study measured participants' "self-efficacy" in reducing environmental triggers via, for example, making and using a weak bleach solution on mold, placing a vapor barrier to prevent moisture buildup, and applying principles of integrated pest management. In addition, although two studies measured "knowledge," in keeping with SCT, "knowledge" includes elements of "behavioral capability," the knowledge and skills needed to perform a behavior, and "outcome expectations," the anticipatory outcomes of a behavior. Without these intermediate variables, it is difficult to understand what aspects of the intervention promoted behavioral change and delineate the pathways through which trigger reduction behavior occurs (22, 24).

A second pathway in need of further understanding relates to the therapeutic processes of the CHWs. Qualitative studies suggest that CHWs are instrumental in providing social and emotional support (12). In this review, social support was measured in only one study, and the change was insignificant (22). These authors did, however, find a significant decrease in levels of depressive symptoms among caregivers in intervention families, which suggests that CHWs facilitated coping mechanisms among caregivers "through the information, assistance, and referrals given to them" by the CHWs (22). Notably, one study found that 74% of the enrolled caregivers had symptoms of depression, 44% of whom were severely depressed per the CES-D scale (7). No subanalyses were reported in these studies testing for a moderator effect, although it could be hypothesized that a depressed caregiver would lack the motivation to make behavior changes that would consequently lead to allergen reduction.

Other researchers have hypothesized that increased caregiver quality of life is related to an increase in self-efficacy and coping (4). Nine of 13 items on the Pediatric Asthma Caregiver's Quality of Life Questionnaire (QOL) concern emotional function and likely tap into the related construct (25). In this review, caregiver quality of life significantly increased in one study (5), a finding that is consistent with a quasi-experimental CHW-delivered asthma intervention study using the same QOL tool (26) as well as a nurse-delivered environmental health intervention in an RCT (27). Better coping could lead to a decrease in depression and an improvement in asthma management (including trigger reduction behaviors), which would likely contribute to better clinical outcomes.

Finally, none of the studies assessed the role of the CHW as a liaison to health care providers, which may have led to a decrease in urgent care visits due to appropriate medication use and better asthma management. Previous literature supports CHWs in this role (9, 11, 12, 28–31). Alternative pathways to improved clinical outcomes are supported by findings that demonstrated a reduction in urgent care use by both the environmental intervention *and* observation-only (e.g., attention control) groups, with no significant difference found across these groups (21). In another study, those subjects that had a prolonged relationship with a CHW demonstrated improvements in caregiver quality-of-life score, child's asthma symptoms, and reductions in urgent health services use, relative to households receiving a single visit from a CHW and no resources other than bedding encasements. Those receiving the low-intensity intervention showed smaller improvements that reached statistical significance for quality-of-life and symptoms (5).

While evidence suggests that CHW-delivered interventions cause a change in asthma-related health outcomes, understanding the mechanisms through which this improvement occurs is critical to developing and evaluating asthma intervention programs. Evidence from this review suggests that social, behavioral, and environmental dimensions of asthma management are necessary to consider when designing and evaluating asthma intervention programs.

Conclusion

Identification and management of environmental asthma triggers is a well-established cornerstone of optimal asthma care. Preliminary evidence for the effectiveness of CHW-led interventions supports ongoing development of this CHW role, which may be more cost effective and readily accepted by at-risk communities. Overall, the studies consistently identified positive outcomes associated with CHW-delivered interventions, including decreased asthma symptoms, daytime activity limitations, and emergency and urgent care use. However, improvements in trigger reduction behaviors and allergen levels, hypothesized mediators of these outcomes, were inconsistent. Trigger reduction behaviors appeared to be tied to study-based resource provision. Knowledge gaps regarding the impact of CHW interventions on self-efficacy and other mediating factors such as depression and community and individual stress, need to be addressed to better understand the critical factors that link these interventions to improved outcomes.

Future work in this area should include developing, testing, and/or incorporating measures that link the theory underlying the intervention to relevant outcomes, and measures that capture complimentary social pathways through which CHWs are effecting change in asthma morbidity, such as through increased access to health professionals and improvements in general asthma management skills through coping and social support and access to health care.

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