Published in final edited form as:

Disaster Med Public Health Prep. 2022 April ; 16(2): 777–782. doi:10.1017/dmp.2020.424.

Impact of Hurricanes on Children with Asthma: A Systematic Literature Review

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Abstract

Following hurricanes there can be increases in exacerbations of chronic diseases, such as asthma. Asthma is common among children, and many asthma exacerbations can be prevented. This systematic literature review assessed literature describing the impact of hurricanes on children with asthma in the United States. Medline, Embase, Global Health, PubMed, and Scopus databases were searched for peer-reviewed, English-language articles published January 1990–June 2019 that described the effect of a hurricane on children with asthma. This search identified 212 articles; 8 met inclusion criteria. All 8 were related to Hurricane Katrina, but research questions and study design varied. Articles included information on asthma after hurricanes from cross-sectional surveys, retrospective chart review, and objective clinical testing. Four articles described discontinuity in health insurance, asthma-related health care, or asthma medication use; and three articles examined the relationship between mold exposure and asthma symptoms and reported varying results. The eighth study quantified the burden of asthma among people visiting mobile medical units but did not describe factors associated with asthma symptoms. These results highlight opportunities for future research (e.g., on more recent hurricanes) and disaster preparedness planning (e.g., strategies to prevent health care discontinuity among children with asthma).

Keywords

hurricanes; asthma; children

Introduction:

Growing evidence suggests that natural disasters are being reported more frequently.[1, 2] Some modeling suggests that natural disasters including tropical cyclones and hurricanes could become even more common.[3–5] When preparing for a hurricane many planning measures need to be considered such as infrastructure improvements, evacuation routes and

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plans, temporary shelters, and hazard removal. While the risk for communicable diseases following hurricanes is known to be high,[6] recent hurricanes have demonstrated that such events can exacerbate chronic illnesses.[7–11]

Asthma is one of the most common chronic illnesses in children, affecting approximately 6 million children in the United States.[12] It disproportionately affects low-income communities, which are also disproportionately affected by hurricanes.[13, 14] Asthma exacerbations are common and can be fatal or life-threatening, requiring emergency care.[15] Over half of U.S. children with asthma had one or more asthma exacerbations in the past year.[13] Each year in the United States, asthma results in more than 500,000 emergency department visits and more than 80,000 hospitalizations among children.[13] Often, asthma exacerbations can be prevented by actions to control asthma, including taking asthma medication as prescribed and reducing exposure to asthma triggers (e.g., mold, viral infections, smoke, airborne chemicals).[15]

Some literature has described asthma exacerbations and worsened asthma after hurricanes.[16, 17] Children are more vulnerable than adults in emergency situations including after hurricanes;[18] however, less is known about specific after-event factors that might predispose children to asthma exacerbations. The objective of this systematic literature review was to identify and summarize research that has been conducted to answer the research question, “what are the effects of hurricanes on children with asthma?” by identifying factors associated with increases in asthma-related outcomes, defined as self-reported symptoms or emergency department visits for asthma following hurricanes. The synthesis of this information will aid in developing disaster preparedness planning that reduces the burden of asthma in children following hurricanes.

Methods:

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[19], a systematic literature review was conducted to assess existing literature on the impact of hurricanes on children with asthma in the United States. In collaboration with librarians at the Stephen B. Thacker CDC Library, the authors developed key terms: “asthma,” “asthma attacks,” “hurricanes,” “disaster,” “chronic disease,” “post-disaster,” “asthma morbidity,” “asthma burden,” “environmental health,” “mold,” “allergens,” and “stress-induced asthma.” Medline, Embase, Global Health, PubMed, and Scopus databases were searched for articles published in English between January 1990 and June 2019 using the search terms found in Supplemental Table S1. The final search of the databases was completed on July 1, 2019. Title and abstract were reviewed for all abstracts returned using the initial search terms. Articles were included if they were published in a peer-reviewed journal and included data on children with asthma after a hurricane. After reading abstracts, articles were excluded if they were systematic reviews, focused exclusively on adults, or focused on worker or responder health (usually less generalizable to children). Because of the limitations of conducting field studies with vulnerable populations in the wake of a disaster, there were no study design or quality inclusion criteria. For these reasons, and due to limited study types that can be rapidly conducted in a post-disaster setting, a formal quality assessment was not completed. Three authors (KC, JH, AP) abstracted

data on hurricane, study population, study design, exposure, outcome(s), data source, and asthma-related health data (i.e., presence of asthma, asthma symptoms, asthma medication use, or asthma-related healthcare use). Data on environmental exposures were abstracted only if they were analyzed in relationship to asthma-related health outcomes. In lieu of a formal quality assessment, two reviewers individually reviewed articles to assess quality, abstract studying findings, and note research limitations.

Results:

The search terms returned 212 abstracts (Figure 1). Twenty-two of the abstracts were removed because of type (i.e., a methods paper that did not report results, a systematic review, or an abstract for a presentation or meeting). After review of the full-length articles, 182 were excluded, for three reasons: did not relate to a hurricane, did not include children, or did not report results related to asthma.

A total of eight articles met the criteria. Because of heterogeneity in these articles, a meta-analysis was not performed. All eight articles were related to Hurricane Katrina. Almost half (3/8) of the articles focused solely on children; the remainder included both children and adults. Most articles (6/8) involved people living in Louisiana after Hurricane Katrina. Two articles described people who lived in Louisiana before Hurricane Katrina but were displaced to other states (Texas, Mississippi) after the disaster. Only one article included comparison to other groups (i.e., non-displaced populations and non-disaster affected populations).[20]

Three articles focused on asthma and involved children; one also included young adults (aged 18–20 years) with asthma (Table 1). The largest and most recently published article in this group examined Medicaid claims data to assess the effect of a Medicaid Emergency Waiver program (“TexKat”) in Texas, which mostly served former Louisiana residents displaced by Hurricane Katrina.[20] People with asthma (aged 0–20 years) in the TexKat program appeared to have greater decreases in healthcare use (office and emergency department visits) and asthma medication refills (controller and rescue medications) than in three comparison groups of non-displaced populations.

The two other articles that focused exclusively on asthma were related to the Head-off Environmental Asthma in Louisiana (HEAL) study. This program provided home environmental assessments and asthma counseling sessions for 182 children (aged 4–12 years) with moderate to severe asthma in the greater New Orleans area after Hurricane Katrina.[21, 22] Both articles were pre-post analyses among the same population. The first of these articles, by Grimsley and colleagues, examined relationships between environmental allergen levels, allergy skin test sensitivity, and asthma symptoms but did not observe any consistent relationships.[22] The authors found that lower indoor levels of airborne mold were significantly associated with asthma symptoms in their baseline data, but observed no significant associations between mold levels and asthma symptoms at 6-month and 12-month follow-up. These results led the study authors to question the usefulness of one set of exposure measurements from 18 months after Hurricane Katrina (i.e., their baseline measurements taken in 2007).[22] The more recent article by Thornton and colleagues found

that medication adherence among program participants significantly improved over the 12-month study period.[21]

Most of the articles (5/8) in this review included but were not limited to participants with asthma (Table 2). Three reported the percentage of people with asthma in the study populations (10–18% [23–25]); two did not report these data.[26, 27] Only one article, by Rabito and colleagues, focused exclusively on children (aged 7–14 years), of which 10% had asthma or bronchitis.[24] Three articles included participants aged ≤24 years. In the 2011 Rath et al. article, 72% of participants were 10 years old or younger. [23] In the 2007 Rath et al. article, 80% of participants were younger than 13 years old.[25] In the 2008 Madrid et al. article, ages were not reported.[26] In the remaining article (Krol et al.), 29% of patient encounters were for individuals aged 0–21 years, but the percentage of encounters for individuals aged 0–17 years old was not reported. [27]

The only article in Table 2 focused exclusively on children was a repeated measures follow-up study that assessed respiratory symptoms and spirometry over a 2-month period in 2006, the year after Hurricane Katrina.[24] The authors reported that lower respiratory tract symptoms decreased significantly over the 2-month study period among 73 children aged 7–14 years (of which 10% had asthma or bronchitis). They found no significant associations between air sampling measurements of mold levels (indoor and outdoor) and respiratory symptoms or medication use. They also observed no differences in spirometry results between the two time periods.

Of the remaining four articles in Table 2, two were cross-sectional surveys,[23, 25] one was a case study,[26] and one was a retrospective chart review.[27] One cross-sectional survey, the Health Survey for Children and Adolescents After Katrina (HSCAAK), found that lower respiratory symptoms (including shortness of breath, asthma attack, and/or difficulty breathing) increased after Hurricane Katrina.[23] Also, mold growth in the home was associated with lower respiratory tract symptoms (adjusted odds ratio=1.47, 95% CI 1.02–2.12) and of the 81 children who evacuated and ran out of medications, 24% ran out of asthma medications or feared they would run out of asthma medications. The other cross-sectional survey in this group (Rath et al., 2007[25]) compared people aged ≤24 years with and without chronic condition(s) prior to Hurricane Katrina. In this survey, 18% of participants reported asthma or another chronic lung disease. Among these individuals, 78% reported needing more asthma medication during the first 3 months after Hurricane Katrina than before the hurricane.[25]

Two articles of individuals with and without asthma reported observations from mobile medical units, which served people displaced by Hurricane Katrina and living in Federal Emergency Management Agency transitional housing. One of these articles was a retrospective chart review of patient encounters at two mobile medical units in Mississippi. This study found that asthma was the most common chronic illness associated with patient encounters in individuals aged 0–21 years old.[27] The other article was a case study which described multiple challenges faced by people aged ≤24 years with asthma who received care from a mobile medical unit in Louisiana.[26] These challenges included expired controller medication prescriptions, inability to afford medications, lost Medicaid insurance

cards, and loss of health insurance because of being dropped from Medicaid enrollment.[26] Assessment of pre-hurricane asthma morbidity was not available for either of these articles.

Discussion:

This systematic literature review identified eight articles involving children with asthma after hurricanes, all conducted after Hurricane Katrina gathering data related to the research question "What are the effects of hurricanes on children with asthma?" The articles addressed a wide range of research questions, such as the effect of a Medicaid Emergency Waiver program for people displaced by a hurricane and the result of post-hurricane environmental exposures on asthma symptoms. Many articles reported discontinuity in health insurance, asthma-related health care use, or asthma medication use following a hurricane. Also, a few articles examined the relationship between post-hurricane mold exposure and asthma symptoms, reporting varying results.

This review adds to the literature by synthesizing existing research involving children with asthma after hurricanes. Strengths of this project include its systematic search and review process, as well as having three individuals review articles and abstract data. Also, broad criteria were used to include articles of many types, capturing many perspectives on post-hurricane research. This paper highlights opportunities for disaster preparedness planning to reduce asthma burden among children by identifying frequently reported issues among children with asthma post-hurricane: discontinuity in health insurance, asthma-related health care use, or asthma medication use.

Characterizing the scope of existing literature on this topic makes research gaps more evident. For example, all included articles were related to Hurricane Katrina; we did not find any articles pertaining to more recent major hurricanes, such as Hurricane Harvey, Irma, or Maria in 2017. Also, this review did not find publications describing mental health among children with asthma, despite related research on adults with asthma, mental health after hurricanes, and known associations between mental health and asthma morbidity among children.[17, 28–33] The majority of included articles (n=5) relied on self-reported measures for exposure, outcome, or both, and only one article included comparison groups.[20] Future research on this topic would benefit from different study designs and objective measures. Finally, work to determine the population attributable fraction of post-hurricane asthma burden related to factors such as discontinuity in health care or indoor mold exposure could facilitate efficient allocation of resources after a hurricane. Based on our high-level perspective we have identified that cohort studies that objectively measure exposures and asthma symptoms or outcomes pre- and post-hurricane would be valuable.

Because a wealth of evidence documents a relationship between indoor mold exposure and asthma symptoms, it was surprising that results varied from included articles examining the relationship between post-hurricane mold exposure and asthma symptoms.[34, 35] The largest included article to address this relationship, a survey of 1,243 people, found current mold growth was significantly associated with current lower respiratory symptoms.[23] In contrast, included articles that did not report consistent relationships between mold exposure and asthma measures (i.e., asthma symptoms, "breathing medication use") had much smaller

sample sizes (N=182 and N=73).[22, 24] Differences in sample size among these three articles might have accounted for variation in their results.

Although no formal quality assessment was conducted because of the heterogeneity of the study types included, the authors carefully reviewed the limitations of post-disaster research. One identified limitation is that the majority of articles on this topic following Hurricane Katrina were cross-sectional. Hurricanes can be difficult to predict, and they are predicted usually only a few days before they occur, at a time where safety needs to be prioritized over research. This short warning time makes other study designs less feasible in this context. One limitation of this systematic literature review is that it included articles only in the United States, so its findings cannot be generalized to other nations, particularly those with different types of healthcare systems. Also, these results cannot necessarily be generalized to adults or to children of socioeconomic backgrounds not addressed in the included articles. Additionally, only peer-reviewed articles were included, so it's possible that some research in this area was missed. This systematic literature review abstracted environmental exposure data only if they were analyzed in relationship to asthma-related health outcomes, so it is not intended to fully describe environmental exposures among children with asthma after hurricanes.

Currently, CDC recommends that if a tropical storm or hurricane is coming to an area, people with asthma should make sure to have at least a 3-day supply of asthma medication, copies of medical documents such as asthma action plans, health insurance cards, and immunization records.[36] Also, CDC recommends that children and people with asthma or with weakened immune systems do not spend time in areas with mold or participate in clean-up.[37] Specific messaging targeted to those with asthma regarding continuing medication use, coping with disasters, and staying away from mold in homes could be useful in reducing exacerbations in asthma following hurricanes.

Conclusions:

This systematic literature review identified and summarized research conducted on the effects of hurricanes on children with asthma. Eight articles were included, all conducted after Hurricane Katrina. Many articles reported discontinuity in health insurance, asthma-related health care use, or asthma medication use following a hurricane. Also, a few examined the relationship between post-hurricane mold exposure and asthma symptoms and reported varying results, indicating that further research on mold growth in the homes of children with asthma may be useful. These findings can be used to inform hurricane preparedness planning, public health hurricane response, and future investigations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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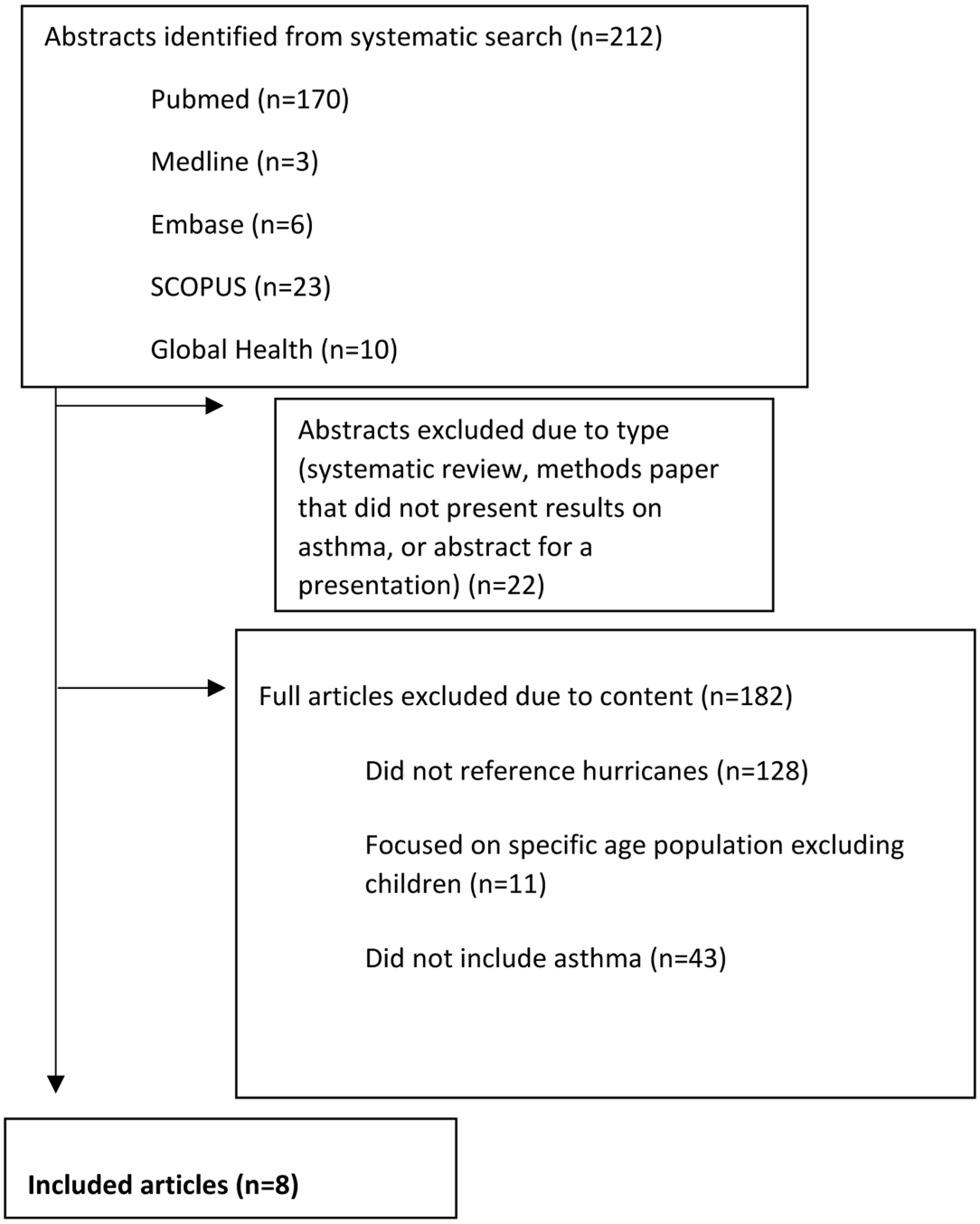

Figure 1.
Summary of Articles Identified from Literature Search

Table 1.

Summary of Included Articles that Focused Solely on Asthma and Involved Children

Author (Year)	Study Population; Event	Study Design	Exposure(s)	Outcome(s) and Data Source	Asthma-related Results
Quast, T. (2018) [20]	210,030[a] people with asthma (aged 0–20 years) continuously enrolled in Medicaid 2004–2006; Hurricane Katrina (2005)	Pre-post (2 year period) with 3 control groups	TexKat Medicaid Emergency Waiver program in Texas (97% of program participants were from Louisiana)	•Prescriptions for asthma medication refills •Medical encounters with an asthma diagnosis Source: 2004 and 2006 Medicaid claims data from Louisiana and Texas	•Refills for asthma controller medications decreased after Hurricane Katrina in the TexKat group, unlike the 3 control groups. •Refills for asthma quick-relief medications decreased more in the TexKat group than in the 2 control groups of Louisiana residents, but did not differ from the control group of Texas residents. •Office and ED visits for asthma decreased more in the TexKat group than in the 3 control groups ($p<0.001$).
Thornton, E. et al. (2016) [21]	182 children with moderate-to-severe asthma (aged 4–12 years) in the greater New Orleans area; Hurricane Katrina (2005)	Pre-post (12-month period within 2007–2009[b])	Home environmental assessments and asthma counseling sessions through the HEAL program	•Asthma symptoms •Medication adherence Sources: In-person questionnaire, phone interview, records from asthma counseling sessions	•Asthma symptoms improved over time ($p=0.059$). •Multiple medication adherence measures improved: inhaled corticosteroid adherence increased ($p=0.003$), running out of medications decreased ($p=0.009$), being worried about medication side effects decreased ($p=0.01$), reports of problems obtaining medications decreased ($p=0.005$).
Grimsley, L.F., et al. (2012) [22]	182 children with moderate-to-severe asthma (aged 4–12 years) in the greater New Orleans area; Hurricane Katrina (2005)	Pre-post (12-month period within 2007–2009[b])	Environmental allergen concentrations from outdoor air samples and indoor air and dust samples collected as part of the HEAL program	•Allergy skin test sensitivity •Asthma symptoms Sources: Allergy skin tests for 10 allergens, survey of asthma symptoms	•No consistent relationship between environmental allergen levels, allergy skin test sensitivity, and asthma symptoms, including no significant relationship between airborne mold levels (indoor or outdoor) and mold skin test results. •Surprisingly, increased asthma symptoms were observed in children with lower indoor mold levels at baseline, but this association was not observed at follow-up.

ED, emergency department; HEAL, Head-off Environmental Asthma in Louisiana.

[a]Of the 210,030 study participants, 1,151 were enrolled in the TexKat program and 208,879 were in the control groups (Louisiana residents who lived in a disaster-declared area prior to Hurricane Katrina but did not relocate to Texas [n=62,317]; Louisiana residents who did not live in a disaster-declared area [n=45,982]; and Texas residents enrolled in Medicaid not through TexKat [n=100,580]).

[b]Baseline evaluations began March 2007 through July 2008, between 19 and 35 months after Hurricane Katrina. [38]

Table 2.

Summary of Included Articles that Involved Children with Asthma or Other Health Conditions

Author (Year)	Study Population; Event	Study Design	Exposure(s)	Outcome(s) and Data Source	Asthma-related Results
Rath, B. et al. (2011) [23]	1,243 people (aged ≤24 years) in New Orleans, of which 17% reported preexisting asthma; Hurricane Katrina (2005)	Cross-sectional survey (HSCAAK[a]) administered October 2005–February 2006	Environmental exposures (self-reported)	•Upper respiratory symptoms[b] •Lower respiratory symptoms[c] Source: Survey (HSCAAK[a])	•Upper and lower respiratory symptoms post-Katrina were significantly higher than pre-Katrina symptoms (p<0.0001). •Age was inversely associated with upper and lower respiratory symptoms post-Katrina. •Mold growth in the home was associated with lower respiratory symptoms[c] (adjusted odds ratio=1.47, 95% CI 1.02–2.12). •24% of children (19/81) who evacuated and ran out of medications ran out of asthma medications or feared running out of asthma medications.
Rabito, F.A., et al. (2008) [24]	73 children (aged 7–14 years) from 55 households in New Orleans, of which 10% had asthma or bronchitis; Hurricane Katrina (2005)	Pre-post (before Katrina, 2 observations between February and May 2006)	Mold levels, from indoor (bedroom) and outdoor air samples	•Respiratory symptoms •Spirometry Sources: Questionnaire, spirometry	•Lower respiratory tract symptoms decreased significantly (p<0.05) from baseline to follow up. No significant association between mold levels and respiratory tract symptoms (upper or lower). •No significant association between mold levels and reported use of "any breathing medication". •No spirometry decrements were observed when results were stratified by asthma/bronchitis or flooding.
Madrid, P.A. et al. (2008) [26]	People (aged ≤24 years) who received care in the Baton Rouge Children's Health Project[d], of which the number of children with asthma was not reported; Hurricane Katrina (2005)	Case study	None (based on study design)	•None (this article reported authors' experiences) Source: Authors' experiences	•"The treatment and management of children with chronic medical conditions such as asthma was challenging. Most children were under-medicated." •"… children with moderate or severe asthma commonly lacked controller medication due to expired prescriptions, being dropped from Medicaid enrollment, inability to afford medications, or having lost their Medicaid cards."
Rath, B., et al. (2007) [25]	531 people (aged ≤24 years) in metropolitan New Orleans, of which 18% reported asthma or another chronic lung disease; Hurricane Katrina (2005)	Cross-sectional survey administered October–December 2005	Chronic condition(s) prior to Hurricane Katrina	•Symptoms related to physical and mental health Source: Survey	•78% of children with asthma (80/102) reported needing more asthma medication or inhalers in the three months after the hurricane than before the hurricane. •30 children reported worse asthma symptoms since the month after the hurricane. •3% of children (12/379) who previously did not use asthma medication started new asthma medication after the hurricane
Krol, D.M., et al. (2007) [27]	1,205 patient encounters[e] from 2 mobile medical units in the Gulfport/Biloxi, Mississippi area; Hurricane Katrina (2005)	Retrospective chart review	None (based on study design)	•Diagnoses associated with patient encounters Source: medical records	•In the 0–21 age group, the most common chronic illness associated with patient encounters was asthma (16.5%).

FEMA, Federal Emergency Management Agency; HSCAAK, Health Survey for Children and Adolescents After Katrina.

[a]The Health Survey for Children and Adolescents After Katrina (HSCAAK) was administered to individuals aged ≤24 years in New Orleans health clinics between October 2005 and February 2006.

[b]Upper respiratory symptoms included runny nose, stuffy nose, sore throat, flu-like illness, ear infection, new-onset cough, new-onset headache, red eye, and eye drainage.

[c]Lower respiratory symptoms included shortness of breath, pneumonia, bronchitis, asthma attack, cough >2 weeks, and difficulty breathing.

[d]The Baton Rouge Children's Health Project included a mobile medical unit to deliver primary care to people in a FEMA transitional housing site that housed approximately 1,600 Katrina evacuees (including about 600 children) near Baton Rouge, Louisiana.

[e]296 of these 1,205 patient encounters were for patients aged 0–21 years. For this age group, 31 patient encounters were associated with a diagnosis of asthma.