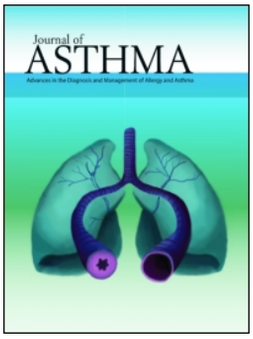

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Characterizing environmental asthma triggers and healthcare use patterns in Puerto Rico

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ABSTRACT

Objective: Asthma carries a high burden of disease for residents of Puerto Rico. We conducted this study to better understand asthma-related healthcare use and to examine potential asthma triggers.

Methods: We characterized asthma-related healthcare use in 2013 by demographics, region, and date using outpatient, hospital, and emergency department (ED) insurance claims with a primary diagnostic ICD-9-CM code of 493.XX. We examined environmental asthma triggers, including outdoor allergens (i.e., mold and pollen), particulate pollution, and influenza-like illness. Analyses included descriptive statistics and Poisson time-series regression.

Results: During 2013, there were 550,655 medical asthma claims reported to the Puerto Rico Healthcare Utilization database, representing 148 asthma claims/1,000 persons; 71% of asthma claims were outpatient visits, 19% were hospitalizations, and 10% were ED visits. Females (63%), children aged $\leq$9 years (77% among children), and adults aged $\geq$45 years (80% among adults) had the majority of asthma claims. Among health regions, Caguas had the highest asthma claim-rate at 142/1,000 persons (overall health region claim-rate = 108). Environmental exposures varied across the year and demonstrated seasonal patterns. Metro health region regression models showed positive associations between increases in mold and particulate matter <10 microns in diameter (PM_{10}) and outpatient asthma claims.

Conclusions: This study provides information about patterns of asthma-related healthcare use across Puerto Rico. Increases in mold and PM_{10} were associated with increases in asthma claims. Targeting educational interventions on exposure awareness and reduction techniques, especially to persons with higher asthma-related healthcare use, can support asthma control activities in public health and clinical settings.

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Introduction

Asthma carries a high burden of disease for residents of Puerto Rico. For both children and adults, the prevalence of asthma is higher in Puerto Rico than in the rest of the United States (1,2). Although one in 13 people in the United States has a current diagnosis of asthma, two in 13 people in Puerto Rico currently have asthma (1,2). In addition, one in three people in Puerto Rico with current asthma reports visiting an emergency department (ED) in the past 12 months for urgent treatment of worsening asthma symptoms (3).

Identification and avoidance of asthma triggers are essential components of asthma management (4). Puerto Rico is a tropical territory with a diverse

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landscape. The types of environmental exposures that trigger asthma in Puerto Rico may vary from other regions of the United States. For example, exposures in Puerto Rico include molds and pollens from the tropical rain forest and particulate matter (PM) from African dust storms (5,6) that travel across the island. Viral respiratory illnesses, such as respiratory syncytial virus and influenza, are also of special interest as asthma triggers because their infectious seasons are often longer in Puerto Rico than in other regions of the United States (7,8).

Studies examining asthma-related healthcare use in Puerto Rico are limited in scope and number (9–14). Improving our understanding of the reasons for higher asthma morbidity is important for addressing asthma disparities. We conducted this study to better understand asthma morbidity in Puerto Rico by examining environmental asthma triggers and characterizing asthma-related healthcare use via examination of insurance claims. Similar to other public health, environmental, and air pollution studies (15–20), we used an ecological study design, linking health and environmental data, coupled with a time-series statistical regression approach to gain insights into causal associations.

This study was developed in conjunction with a 2016 Epi-Aid request from the Puerto Rico Department of Health to the Centers for Disease Control and Prevention (CDC). The aim of the Epi-Aid was to establish a recent baseline assessment of asthma and its triggers in Puerto Rico. Data sources and study objectives were identified in collaboration with partners from the Puerto Rico Department of Health, the University of Puerto Rico, and CDC. As many factors may impact asthma morbidity and asthma disparities including outdoor pollutants, allergens, respiratory illness, healthcare access and delivery, socioeconomic status, and sociocultural factors, multiple data sources relevant to characterizing asthma burden were identified for analysis in this study.

Methods

Study area and demographics

Insurance claims and environmental exposures occurring in Puerto Rico were examined. Study demographics included sex, age (classified as children aged 0–19 years, adults aged 20 years and older, and six age groups: 0–4, 5–9, 10–14, 15–19, 20–44, 45–64, and ≥65 years), and location of residence (classified as health region, outside of Puerto Rico, and unknown). To conform to predetermined census groupings for population estimates, the age category for children includes persons aged 19 years. The territory is divided into 78 municipalities, which are categorized into eight health regions: Aguadilla, Arecibo, Bayamón, Metro, Fajardo, Caguas, Ponce, and Mayagüez. The Metro health region includes the capital city of San Juan and the six Puerto Rican municipalities of Canóvanas, Carolina, Guaynabo, Loíza, San Juan, and Trujillo Alto.

Asthma-related healthcare use

We examined asthma-related healthcare use patterns using insurance claims from the 2013 Puerto Rico Healthcare Utilization database. This database is managed by the Auxiliary Secretariat of Planning and Development at the Puerto Rico Department of Health. For 2013, it contained claims for 75% of Puerto Rico's insured population (2,524,069 insurance subscribers) and included the major insurance carriers for Puerto Rican residents. We defined asthma claims as any insurance claim with a primary diagnostic ICD-9-CM code including 493.XX. We categorized claims by healthcare setting (i.e., outpatient visits, hospitalizations, and ED visits). Outpatient visits included physician offices and urgent care facilities. In cases where the municipality of residence was known for a subscriber (i.e., insured person), asthma claims were categorized into one of the eight health regions of Puerto Rico.

In 2013, there were 715,694 asthma claims. Duplicate claims were defined as multiple visits in the same healthcare setting on the same day by a unique subscriber. After removal of duplicate claims and the exclusion of a single dental claim, 550,655 claims, including 449 claims from Puerto Rican insurance subscribers residing outside of the territory, remained. Figure 1 shows inclusion and exclusion criteria for asthma claims used in our final analysis. Maps were constructed for the 73% of claims ($n = 402{,}425/550{,}655$) for which health region was known.

Environmental exposures

Particle air pollution: dust storms

Puerto Rico's local air quality monitoring stations measure air pollutants such as carbon monoxide, ozone, and particle pollution. Measurements of PM less than 10 microns in diameter (PM_{10}) and less than 2.5 micron in diameter ($PM_{2.5}$) were obtained from two air quality monitors in the Metro health region (21). Figure 2 shows the municipalities of the health region and the monitor locations, which are approximately 1 mile apart. At air quality monitoring Site A,

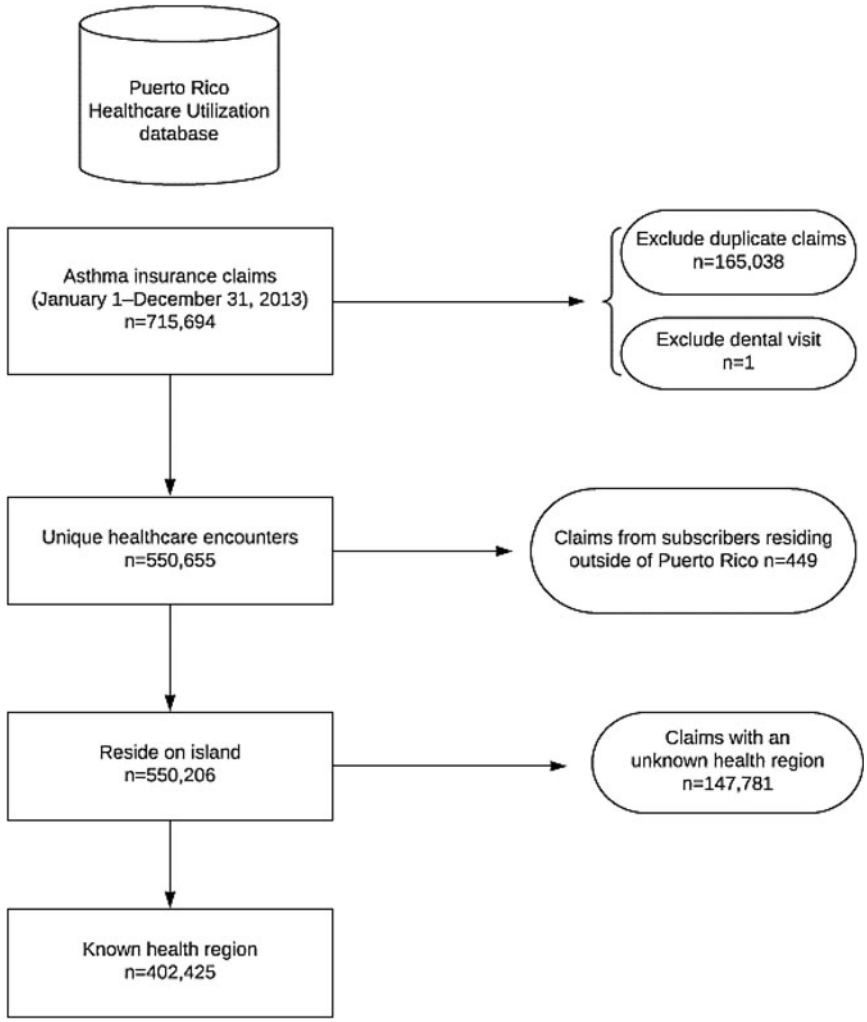

Figure 1. Inclusion criteria flowchart for asthma-related healthcare use.

PM_{10} and $PM_{2.5}$ measurements were taken approximately every 3 days. At Site B, PM_{10} measurements were recorded daily. PM_{10} and $PM_{2.5}$ are measured in units of micrograms per cubic meter ($\mu g/m^3$). Mean PM_{10} was calculated for days when measurements were collected at both monitors.

Outdoor allergens: mold and pollen

Outdoor allergen monitoring occurs in the Metro health region at the American Academy of Allergy, Asthma, and Immunology National Allergy Bureau (AAAAI-NAB) San Juan station at the University of Puerto Rico (Figure 2). We obtained daily mold and pollen counts from the AAAAI-NAB San Juan station. A Burkard volumetric air sampler was used to collect daily samples. Mold (fungal spores per cubic meter) and pollen (grains per cubic meter) were measured and categorized. Although tree pollen is routinely identified at the San Juan NAB station, weed and grass pollens are less common and rarely recovered. Hence, this study only includes tree pollen concentrations. The AAAAI-NAB San Juan station provides publicly available updates on its website (22).

Syndromic surveillance: influenza-like illness

Counts of influenza-like illness (ILI) were obtained from hospitals and EDs in each municipality in Puerto Rico. Weekly counts of suspected and confirmed ILI were submitted to the Office of Epidemiology and Investigation at the Puerto Rico Department of Health using a case investigation form. In this local syndromic surveillance system (Sistema de Vigilancia de Influenza de Puerto Rico), the case definition for suspected ILI is characterized as a fever $\geq$37.8 °C with cough and one or more of the following symptoms: difficulty breathing, diarrhea, chills, vomiting or nausea, sore throat, stuffy nose, muscle pain, headache, or fatigue. For our study, pooled weekly counts of cases by municipality were provided for analysis.

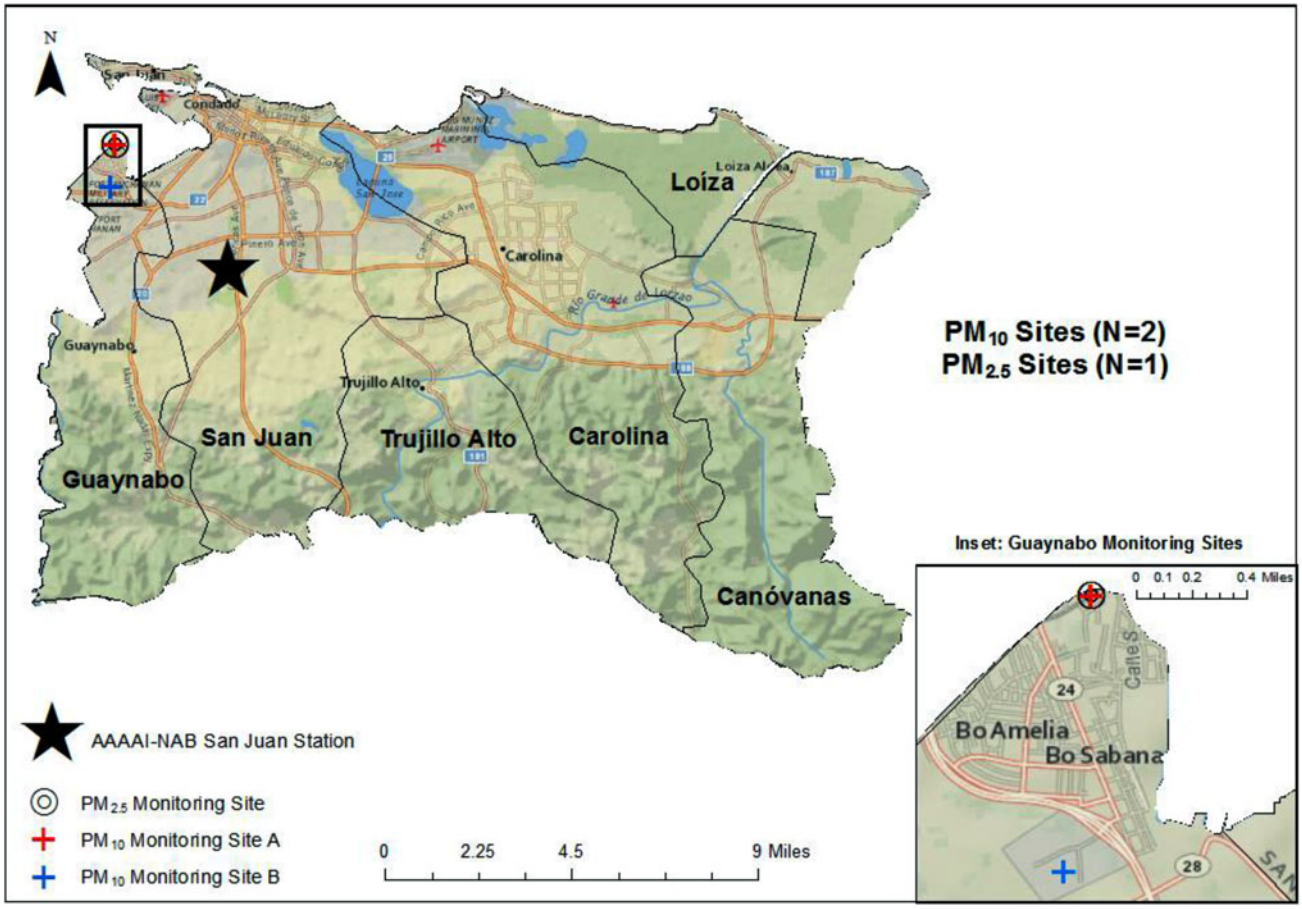

Figure 2. Environmental monitoring stations and the municipalities of the Metro Health Region, Puerto Rico, 2013. Abbreviations: AAAAI-NAB = American Academy of Allergy, Asthma, and Immunology National Allergen Bureau; PM = Particulate Matter.

Statistical analyses

Based on the 2010 Puerto Rico census (population = 3,725,789), we calculated rates of asthma claims (i.e., claim-rate) and ILI counts per 1,000 persons (23). By healthcare setting, claims-rates (# of claims per 1,000 persons) and percentages (based on total claims within the database) were generated. We also mapped rates of asthma claims by health region (based on regional census estimates). For ILI-counts, we calculated and mapped rates of ILI counts per 1000 persons by health region (based on regional census estimates). All rate denominators for demographic categories (i.e., age, sex, region) were derived from 2010 census populations. We created an asthma claims composite variable that was the sum of the daily count of ED and outpatient visits. We calculated means with ranges of PM_{10}, $PM_{2.5}$, mold, pollen, and ILI. Because environmental data were limited to specific monitors, we restricted regression analyses to claims from the Metro health region.

We conducted statistical analyses using SAS®, version 9.3 (SAS Institute Inc., Cary, NC, USA). Risk ratios (RRs) and 95% confidence intervals (CIs) were calculated using Poisson regression models for the daily counts of asthma claims, with cubic splines for time, and adjusted for daily mean temperature, daily relative humidity, calendar quarter, and holidays. As ILI and $PM_{2.5}$ were not measured daily, these variables were excluded from the time-series analyses. Daily outpatient and ED claims were analyzed separately in these models. Hospital claims were excluded from temporal analyses (i.e., descriptive and time-series) as the date of service for claims were unable to be identified as admission or discharge dates.

The following variables were included as cubic splines with two knots at the 25th and 75th percentiles: mean temperature (range = 75.5 °F–88.0 °F; knots: 79.5 °F, 83.0 °F) and mean relative humidity (range = 52.7–91.6%; knots: 71.8%, 78.6%). Calendar quarters were defined as January 1–March 31, April 1–June 30, July 1–September 30, and October 1–December 31 (*referent category*). National and local holidays during which schools and businesses are typically closed (24) were included in the model. We allowed for an AR(1) error structure to account for potential autocorrelation

Table 1. Demographic characteristics and incidence rates by health encounter type for insurance claims with a primary diagnosis of asthma, 2013.

	Population No.	Total		Health encounter type: Outpatient visit		Hospitalization		ED visit	
		No. claims (%)[a]	Rate[b]	No. claims (%)[a]	Rate[b]	No. claims (%)[a]	Rate[b]	No. claims (%)[a]	Rate[b]
Total (all claims)	3,725,789	550,655 (100)	147.8	389,273 (71)[c]	104.5	104,668 (19)[c]	28.1	56,714 (10)[c]	15.2
Sex									
Male	1,785,171	204,508 (37)	114.6	140,371 (36)	78.6	41,555 (40)	23.3	22,582 (40)	12.6
Female	1,940,618	346,147 (63)	178.4	248,902 (64)	128.3	63,113 (60)	32.5	34,132 (60)	17.6
Age (years)									
Children (0–19)	1,017,590	136,569 (25)	134.2	71,553 (18)	70.3	46,600 (45)	45.8	18,416 (32)	18.1
Adults (≥20)	2,708,199	414,086 (75)	152.9	317,720 (82)	117.3	58,068 (55)	21.4	38,298 (68)	14.1
Age group (years)									
0–4	224,756	57,289 (10)	254.9	30,087 (8)	133.9	19,855 (19)	88.3	7,347 (13)	32.7
5–9	240,004	44,993 (8)	187.5	23,776 (6)	99.1	15,394 (15)	64.1	5,823 (10)	24.3
10–14	268,571	21,705 (4)	80.8	11,378 (3)	42.4	7,302 (7)	27.2	3,025 (5)	11.3
15–19	284,259	12,582 (2)	44.3	6,312 (2)	22.2	4,049 (4)	14.2	2,221 (4)	7.8
20–44	1,236,710	80,151 (15)	64.8	45,722 (12)	37.0	20,623 (20)	16.7	13,806 (24)	11.2
45–64	929,491	153,603 (28)	165.3	113,141 (29)	121.7	25,677 (25)	27.6	14,785 (26)	15.9
≥65	541,998	180,332 (33)	332.7	158,857 (41)	293.1	11,768 (11)	21.7	9,707 (17)	17.9
Health region									
Aguadilla	231,078	28,122 (5)	121.7	25,011 (6)	108.2	2,014 (2)	8.7	1,097 (2)	4.7
Arecibo	456,036	54,483 (10)	119.5	49,149 (13)	107.8	2,939 (3)	6.4	2,395 (4)	5.3
Bayamón	620,110	76,690 (14)	123.7	68,148 (18)	109.9	5,138 (5)	8.3	3,404 (6)	5.5
Caguas	589,795	83,774 (15)	142.0	71,394 (18)	121.0	6,952 (7)	11.8	5,428 (10)	9.2
Fajardo	136,115	12,279 (2)	90.2	10,742 (3)	78.9	895 (1)	6.6	642 (1)	4.7
Mayagüez	304,410	30,872 (6)	101.4	26,181 (7)	86.0	2,646 (3)	8.7	2,045 (4)	6.7
Metro	822,562	75,552 (14)	91.8	66,671 (17)	81.1	5,918 (6)	7.2	2,963 (5)	3.6
Ponce	565,683	40,653 (7)	71.9	33,055 (8)	58.4	3,826 (4)	6.8	3,772 (7)	6.7
Total (known region)	3,725,789	402,425	108.0	350,351	94.0	30,328	8.1	21,746	5.8
Outside of Puerto Rico[d]	–	449 (0.08)	–	398 (0.1)	–	47 (0.04)	–	4 (0.01)	–
Unknown[d]	–	147,781 (26.8)	–	38,524 (10)	–	74,293 (71)	–	34,964 (62)	–

Note.
[a]Column %, unless otherwise specified.
[b]Number of claims per 1,000 persons.
[c]Row %.
[d]Claim-rate calculations omitted (–) when population estimates are unavailable.

and model-based standard errors. That is, because the dependent and independent variables at any one particular time, t, are related to the measurement of the variables at time t–1, an autocorrelation is possible. Hence, we specified the time-series models with an autoregressive error structure, AR(1), to account for potential dependency between errors. Sensitivity analyses using seven-knot, time-splines were also performed.

Results

Asthma-related healthcare use: territory-wide

Of the 715,694 asthma-related insurance claims for 2013 included in the Puerto Rico Healthcare Utilization database, 550,655 (77%) claims were included in our study. Table 1 shows number, percentage, and claim-rate of asthma-related healthcare use by healthcare setting and demographic characteristics. There were 389,273 (71%) outpatient visits, 104,668 (19%) hospitalizations, and 56,714 (10%) ED visits. Across all healthcare settings, the highest percentages of asthma claims occurred among females (63%) and adults aged ≥20 years (75%).

The 2010 Puerto Rico Census populations used to calculate rates for sex, age, and health region are shown in Table 1. The overall claim-rate was 147.8 asthma claims per 1,000 persons. By healthcare setting, the claim-rates were 104.5, 28.1, and 15.2 claims per 1,000 persons for outpatient, hospital, and ED visits, respectively. The claim-rate for outpatient visits was highest for adults at 117 asthma claims per 1,000 persons. The asthma claim-rates for hospitalizations and ED visits were highest for children at 46 and 18 claims per 1,000 persons, respectively.

Among children aged 0–19 years, across all healthcare settings, children aged ≤9 years had the highest rates of asthma claims per 1,000 persons (220.1 claims/1000 persons). Among adults, persons aged 45–64 years had the highest hospitalization claim-rate at 27.6 claims per 1,000 persons. Adults ≥ 65 years had the highest asthma claim-rates for ED and outpatient visits at 17.9 and 293.1 claims per 1,000 persons, respectively.

Figure 3 shows regional differences in asthma claim-rates. Asthma-related outpatient visits rates ranged from 58 in Ponce to 121 per 1,000 persons in Caguas. Asthma-related hospitalization rates ranged

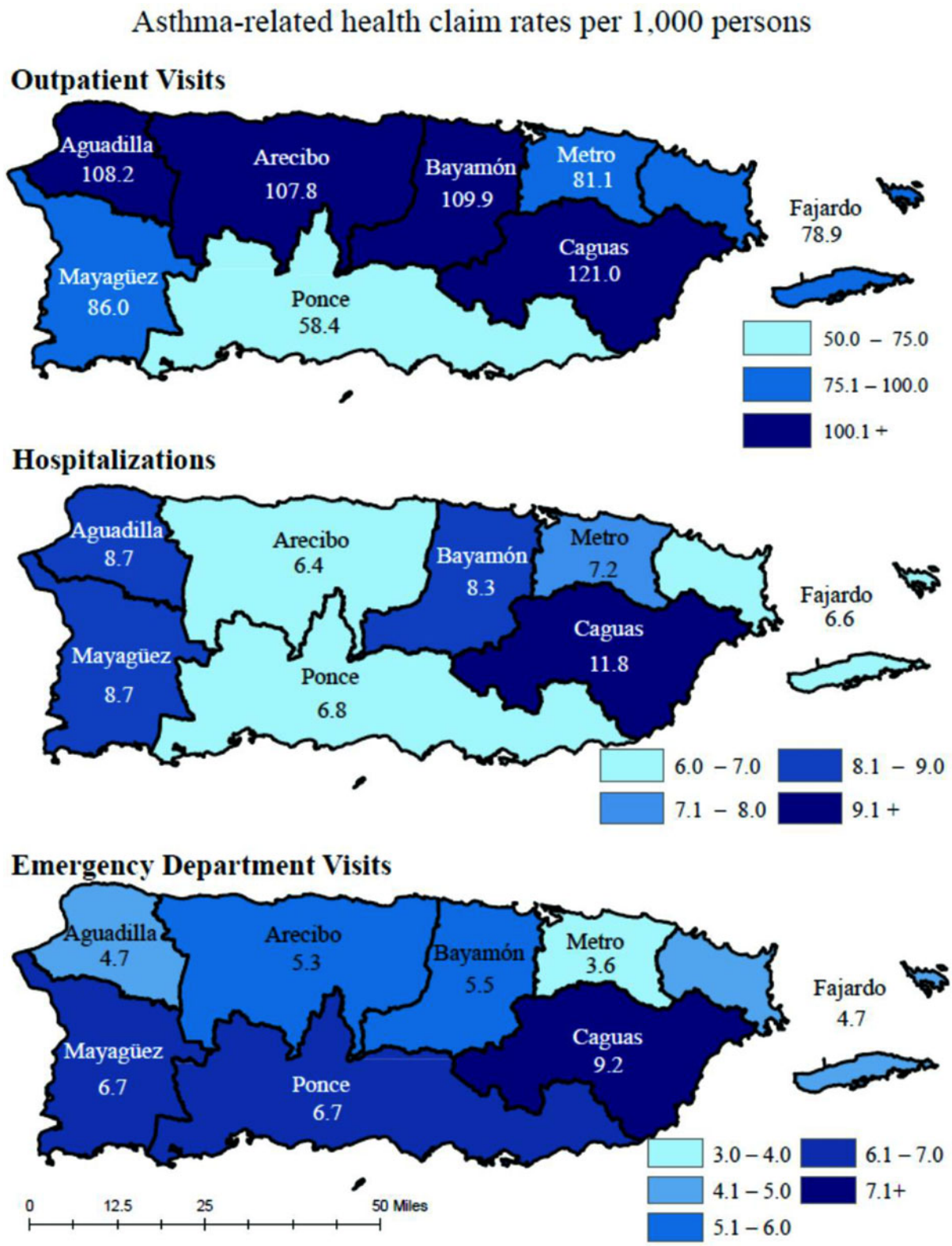

Figure 3. Regional variations in asthma claim-rates by healthcare setting, Puerto Rico, 2013.

from 6.4 per 1,000 persons in Arecibo to 11.8 per 1,000 persons in Caguas and asthma-related ED rates ranged from 3.6 per 1,000 persons in Metro to 9.2 per 1,000 persons in Caguas. Asthma claims were lower during the months of June–July.

Influenza-like illness: territory-wide

Figure 4 shows rates of ILI counts per 1,000 persons by health region. Rates ranged from 30 counts per 1,000 persons in Fajardo to 192 counts per 1,000

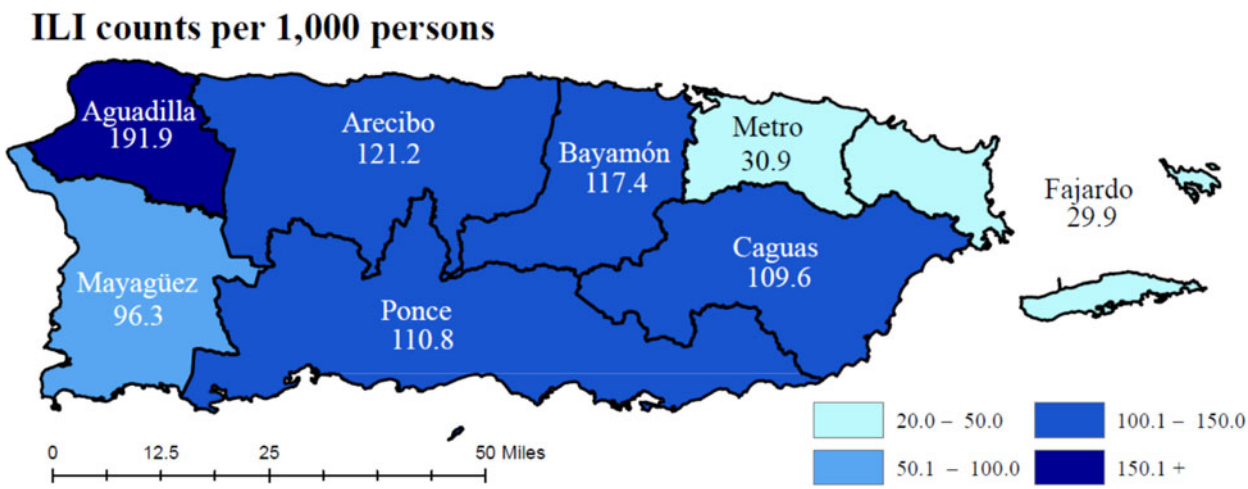

Figure 4. Influenza-like illness rates by Health Region, Puerto Rico, 2013.

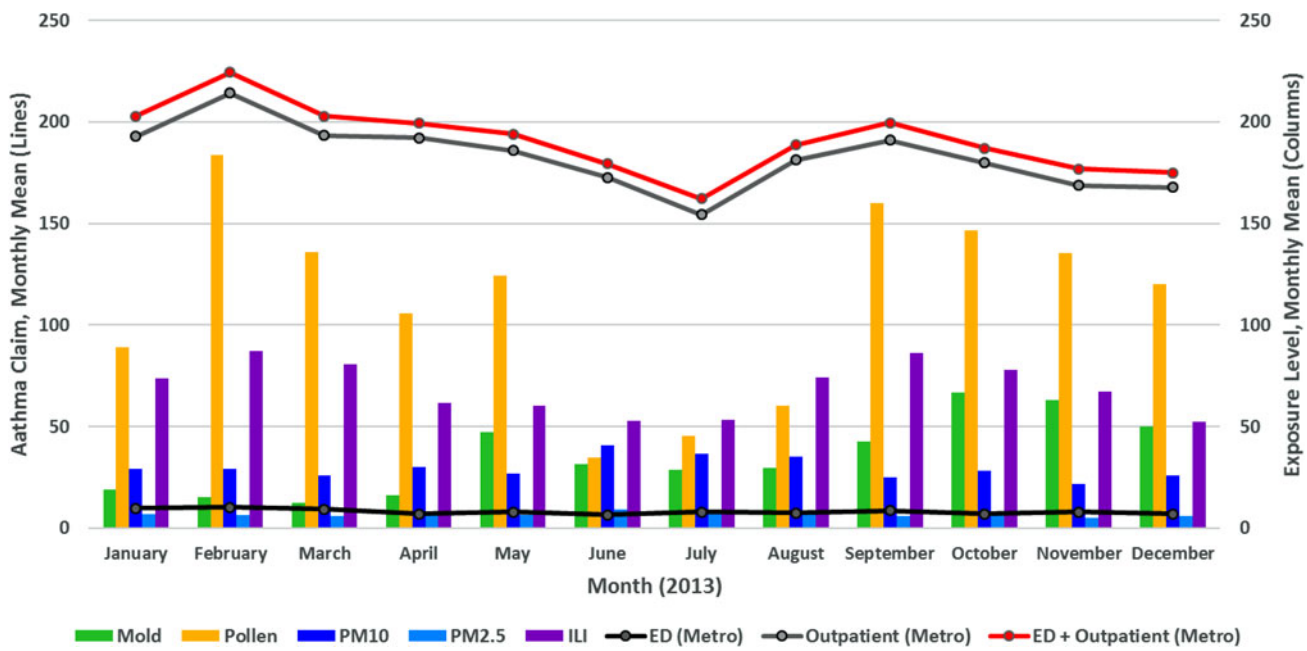

Figure 5. Environmental exposures and asthma claims by healthcare setting, Puerto Rico, 2013*.
Abbreviations: PM = Particulate Matter; ED = Emergency Department.
*Mold levels are represented in thousands, ILI counts are represented in hundred.

persons in Aguadilla. In 2013, ILI counts decreased in April, reached a nadir in July, and began to increase in August.

Environmental exposures: metro health region

In 2013, mold levels ranged from 1,016 to 148,281 fungal spores/m^3. Mold levels rose in May and during the months of September–December. Tree pollen levels ranged from 0 to 616 grains/m^3 and were lower during the summer months of June–August. The highest levels of PM_{10} occurred from June to August. Mirroring PM_{10} elevations, 2013 dust storms were most frequent during the months of June–August (not shown, dust storm event dates confirmed by triangulated satellite, visual, and aerosol data reported by the Puerto Rico Environmental Quality Board). For $PM_{2.5}$, the mean particle count was 7 μg/m^3 (range = 2–18 μg/m^3) over the approximately 3-day sampling period.

Monthly means: metro health region

Figure 5 shows monthly means of asthma claims overlaid on monthly means of environmental exposures and ILI counts in the Metro health region. Peaks in claims, pollen, and ILI counts occurred in February. The lowest levels in numbers of claims, pollen levels, and ILI counts occurred during the summer months.

Table 2. Associations between environmental exposures and asthma claims by healthcare setting — Metro health region, Puerto Rico, 2013.

	Environmental exposures		
Healthcare setting	Mold RR (95% CI)	Pollen RR (95% CI)	PM_{10} RR (95% CI)
ED	1.0012 (0.9991–1.0034)	1.0001 (0.9997–1.0005)	1.0013 (0.9975–1.0051)
Outpatient	**1.0028 (1.0002–1.0053)**	0.9998 (0.9993–1.0004)	**1.014 (1.0095–1.0185)**
ED + Outpatient	**1.0027 (1.0003–1.0052)**	0.9998 (0.9993–1.0003)	**1.0135 (1.0092–1.0178)**

Note. ED: emergency department; PM: particulate matter; RR: risk ratio; CI: confidence interval.
Model adjusted for temperature, relative humidity, calendar quarters, and Puerto Rican holidays.

Poisson regression

Adjusting for temperature, relative humidity, calendar quarters, and Puerto Rican holidays, we found a positive association between mold and PM_{10} levels with asthma claims in the outpatient healthcare setting (Table 2). Every 1,000-unit increase in fungal spores/m^3 was associated with a 0.28% increase in asthma-related outpatient claims (RR = 1.0028; 95% CI: 1.0002–1.0053). Every 1 $\mu g/m^3$ increase in PM_{10} was associated with a 1.4% increase in asthma-related outpatient claims (RR = 1.0140; 95% CI: 1.0095–1.0185). For the composite total (ED + outpatient visits), every 1,000-unit increase in mold (fungal spores/m^3) was associated with a 0.27% increase in asthma claims (RR = 1.0027; 95% CI: 1.0003–1.0052). Similarly, every 1 $\mu g/m^3$ increase in PM_{10} was associated with a 1.35% increase in the asthma-related claims composite (RR = 1.0135; 95% CI: 1.0092–1.0178). Sensitivity analyses showed similar results.

Discussion

Our study highlights asthma-related healthcare use in Puerto Rico by demographics, region, and date during 2013. Environmental exposures (i.e., mold and PM) were positively associated with increases in asthma claims. Implications of our study findings are broad and reflect an array of opportunities for clinical and public health practitioners.

In 2013, females, children aged $\leq$9 years, and adults aged $\geq$45 years had the highest asthma-related healthcare use. This pattern is consistent with age-specific patterns of healthcare use in other regions of the United States (25,26). National studies found that asthma-related healthcare use tends to be comparable between the sexes (25–27). Similar to our findings, a territory-specific study found higher asthma-related healthcare use among females (28). Additionally, studies have commonly reported higher rates of healthcare use (non-asthma-related) among women than men (29,30).

Regionally, across all healthcare settings, the highest rates of asthma-related healthcare use occurred in the Caguas health region. As claim-rate calculations are based upon the number of claims in a specific population, as Caguas has the highest number of claims (of known regions), yet has the third highest population of those regions, it results in a proportionately higher claim-rate. The city of Caguas is approximately 20 miles from the city of San Juan, and the health region of Caguas is located in the largest valley in the Puerto Rican territory. The populations of Caguas and San Juan are similar in distribution of sex, age, and socioeconomic status (i.e., median household income, % educational attainment, % of persons below poverty level) (17). Although the cause for high asthma prevalence and asthma-related healthcare use in the Caguas health region is unknown, environmental exposures related to geography may contribute. Caguas is located in a valley, sits in the path of dust storms, and is downwind of the El Yunque rainforest's dissemination of tropical molds and pollens. Air sampling case studies in Caguas identified the presence of asthma-related airborne fungi in the area (31). If Caguas's location affects the type, frequency, and concentration of environmental exposures in the area, the elevated rates of asthma-related healthcare use observed in Caguas would not be unexpected.

Across the year, our study showed changes in concentrations of mold, pollen, and PM in the Metro health region. Specifically, mold counts were higher in May and September–December, and tree pollen counts were lower in June–August. The pattern of mold elevation mirrors peaks in the Puerto Rico rainy season (32). Conversely, the pollen counts decreased during the rainy season (32). The 2013 mold and pollen seasons mirror patterns in the allergen seasons observed in 2014 and 2015 at the San Juan station. Data on seasonal changes of outdoor allergens can be used to reduce asthma exacerbations by reducing exposure to seasonal triggers.

Mold levels are high throughout the year in San Juan, Puerto Rico compared to other regions of the United States (33). At the San Juan station, the most commonly observed types of fungi were Basidiospores (60%) and Ascospores (34%) (1,6), typically dispersed

from the El Yunque rainforest. Prior studies investigating the impacts of common fungal species in Puerto Rico have suggested possible roles for these species in exacerbating respiratory conditions and increasing sensitization to allergies (34,35). Diagnostic panels are not routinely available for these commonly observed allergens, though studies in Puerto Rico have shown high serological reactivity to these fungal spores (36). Clinical assessment and management of both allergies and asthma could be enhanced by the availability of relevant, standardized tropical fungal antigens on diagnostic allergen panels, specifically for tropical settings such as Puerto Rico. Additional information about the role that fungal species in Puerto Rico play on asthma exacerbations and management could be used to support identification of susceptible persons and to target educational interventions around exposure reduction. Additionally, as the San Juan station is currently the only AAAAI-certified pollen and mold counting station on the island, the establishment of allergen counting stations at other locations in Puerto Rico would allow further characterization of outdoor environmental allergen exposures across the territory. Such counting stations could drive identification and quantification of other relevant outdoor environmental allergen species to include on tropical allergen panels.

We also observed patterns in timing of exposures. Periods with lower levels of pollen and mold coincided with periods during which asthma claims were lower. Across the year, elevations and reductions in pollen and ILI levels mirrored elevations and reductions in outpatient asthma claims. The study observations and findings factor into the theories that pollen and mold allergens as well as PM and ILI, and perhaps interactions between them, might act as potential drivers of asthma-related healthcare use. For example, investigators in Japan reported an association between ambient desert dust levels and increased risk of allergic symptoms in pollen-sensitive pregnant women (37). In Puerto Rico, bacterial, endotoxin-induced bronchial inflammation is increased by African dust events (ADE), and there is likely synergism between ADE-associated PM_{10} and non-ADE PM_{10} exposures, triggering adverse respiratory responses (38,39). Additionally, there is some evidence that allergens and respiratory viral infections contribute synergistically to asthma exacerbations (40). Although such interactions were not investigated in this study, further examination of patterns and interactions between exposures would be helpful in characterizing the relationship between asthma and environmental exposures in the territory.

Overall, in our study, we found increases in mold and PM exposures were associated with increases in asthma claims. In outpatient settings, daily asthma claims increased by 0.28% when mold levels increased; daily claims increased by 1.4% when PM_{10} levels increased. At the population level, these small percentage changes may reflect substantial numbers of claims in terms of asthma-related healthcare use. For instance, if 1.4% of the approximately 400,000 persons with current asthma in Puerto Rico sought care, it would correspond to 5,600 asthma claims (or 5,600 instances of asthma-related healthcare use). Other studies have shown similar findings for African dust or particulate pollution on asthma-related healthcare use (5,20,41).

In both clinical and public health settings, targeting asthma control interventions and messaging towards demographic subgroups with higher morbidity benefits those persons with the highest burden of asthma (4,42). To address demographic groups with higher asthma prevalence and asthma-related healthcare use, the Puerto Rico Asthma Program began several interventions in the community, including a home visit program for families with children aged 4–17 years who have uncontrolled asthma and the development and distribution of school-based asthma education materials targeting students and educators. The Puerto Rico Asthma Program also provides educational seminars and trainings to students, teachers, health educators, and healthcare professionals. Colleagues at the University of Puerto Rico and the AAAAI-NAB San Juan station have also sought to educate communities on environmental allergens. The San Juan station has its own Facebook page (43) entitled "Alergia a Hongos [Allergy to Fungi]" where visitors can find information on the most recent pollen and mold counts in San Juan and learn about how allergens impact asthma. They also work with local news stations to include mold and pollen levels in daily weather reports. Additionally, students in Puerto Rico are developing a mobile application to share warnings of red alert levels for outdoor molds and PM.

Preventive measures that minimize environmental exposures, such as self-management educational techniques that support awareness, avoidance, and mitigation of asthma triggers, could optimize asthma control, reduce asthma attacks, and, ultimately, decrease asthma morbidity and asthma-related healthcare use. In conjunction with medical and environmental assessments, education on simple interventions

such as watching the forecast for high-risk exposure days and then limiting outdoor activities, keeping windows closed, using an air conditioner (when possible), and/or wearing a mask to reduce exposures can be helpful.

Strengths of this study are the substantial coverage of the territory's population in the health insurance claims database and the daily measurements of mold and pollen at the San Juan Allergen station. This study provides information about numerous environmental exposures in the Metro health region that may serve as asthma triggers in Puerto Rico. It also provides previously unavailable analysis on asthma healthcare use in multiple settings across all health regions of the territory during 2013.

Our study also has limitations. First, as the study is limited to a 1-year period, we are unable to examine multi-year trend patterns in asthma-related healthcare use. Second, as it was not possible to identify whether the dates of hospital claims reported were admission or discharge dates or to separate claims for outpatient visits into urgent care settings and routine visits, analyses specifically examining urgent healthcare use were limited. Additionally, while the 2013 rates are generated from census data available at the time of the study, the 2010 census counts may not precisely mirror the demographic make-up of the 2013 population. This may limit the accuracy of the descriptive rates.

In the wake of multiple public health emergencies including the Zika epidemic and 2017 hurricanes (instances where potential asthma triggers may be newly introduced), examination of urgent healthcare use (i.e. urgent care visits, ED visits, and hospital stays) would be helpful for future preparedness efforts. Additionally, identifying ways to rapidly obtain urgent healthcare use data would be useful for surveillance and preparedness in such emergencies. While our study is a recent assessment of asthma healthcare use in Puerto Rico, it is limited as the data were collected in 2013, prior to the 2015 Zika epidemic and the 2017 hurricane season. In the wake of natural disasters and public health emergencies, such data might help guide response and recovery efforts.

Conclusions

This study provides a recent assessment of asthma-related healthcare use patterns in outpatient, hospital, and ED settings across the island of Puerto Rico. We provide descriptive information on diverse environmental asthma triggers including outdoor molds, pollens, PM (including dust storms), and respiratory illness. We identified positive associations between increases in outdoor mold and PM exposures and outpatient asthma-related healthcare use. Comprehensive efforts to optimize asthma control through education on environmental exposures and avoidance of asthma triggers remain central to asthma management in clinical and public health settings (4,42). Interventions targeting persons with higher asthma-related healthcare use with education on exposure reduction can support asthma control activities and may be integrated into acute and long-term emergency preparedness planning.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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