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Individual and county level predictors of asthma related emergency department visits among children on Medicaid: A multilevel approach

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Abstract

Objective: Disparities in asthma outcomes are well documented in the United States. Interventions to promote equity in asthma outcomes could target factors at the individual and community levels. The objective of this analysis was to understand the effect of individual (race, gender, age, and preventive inhaler use) and county-level factors (demographic, socioeconomic, health care, air-quality) on asthma emergency department (ED) visits among Medicaid-enrolled children. This was a retrospective cohort study of Medicaid-enrolled children with asthma in 29 states in 2009. Multilevel regression models of asthma ED visits were constructed utilizing individual-level variables (race, gender, age, and preventive inhaler use) from the Medicaid enrollment file and county-level variables reflecting population and health system characteristics from the Area Resource File (ARF). County-level measures of air quality were obtained from Environmental Protection Agency (EPA) data.

Results: The primary modifiable risk factor at the individual level was found to be the ratio of long-term controller medications to total asthma medications. County-level factors accounted for roughly 6% of the variance in the asthma ED visit risk. Increasing county-level racial segregation (OR=1.04, 95% CI=1.01-1.08) was associated with increasing risk of asthma ED visits. Greater supply of pulmonary physicians at the county level (OR=0.81, 95% CI=0.68-0.97) was associated with a reduction in risk of asthma ED visits.

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Declaration of interest
The authors report no potential conflicts of interest.

Conclusions: At the patient care level, proper use of controller medications is the factor most amenable to intervention. There is also a societal imperative to address negative social determinants, such as residential segregation.

Keywords

Asthma; emergency department visits; Medicaid; children; poverty; race; segregation; multilevel; health care system; long-term controller medication; counties

Introduction

Asthma affects approximately 6.8 million children in the United States [1]. Minority and economically disadvantaged children are disproportionately affected, and it is the most common chronic medical condition among Medicaid-enrolled children [2,3]. Children with new-onset asthma, acute exacerbations, and severe symptoms unabated with rescue medications are more likely to present to urgent and emergent care facilities. As a result, asthma morbidity can be measured in part by the frequency of emergency department (ED) visits and hospitalizations as sentinel events.

There are significant racial-ethnic differences in asthma prevalence and severity of illness [3–5]. According to Smith et al., genetic susceptibility in combination with psychosocial factors, socioeconomic status, environmental exposures, and access to medical care all play contributing roles [6]. Racial disparities also exist in utilization, specifically for asthma ED visits [7–9]. Black and Hispanic children are more likely to receive urgent care for initial treatment and to underutilize preventive care when compared to White, non-Hispanic children [7,8,10–12]. A higher proportion of Medicaid-enrolled children suffering from asthma may use the ED as a first-line of care, perhaps because of challenges in timely access to primary care practices accepting Medicaid [13].

Along with racial-ethnic differences, asthma prevalence and ED visit use have also been shown to vary by geographic location [14] even among Medicaid enrolled children, who by definition have similar levels of low-income and similar health insurance coverage. One analysis found substantial regional variation in asthma ED visits among Medicaid-enrolled children in Michigan [15]. A previous analysis by our group found variation in asthma prevalence and asthma ED utilization based on county of residence for both White and Black pediatric Medicaid enrollees in 14 Southern states [16]. In their comprehensive review of the individual and ecologic causes of asthma health disparities, Gold and Wright detail the complexities related to ecologic drivers of the geographic disparities, and the residential segregation that have been observed [17].

These include the influence of income inequality on higher asthma hospitalizations [18] and the relationship between environmental stress caused by neighborhood disadvantage, poverty, violence, and other factors on asthma outcomes [19]. Although striking racial-ethnic and geographic disparities exist among children with asthma in the United States, no work has characterized how both individual and ecologic or neighborhood level variables contribute to these disparities in the pediatric Medicaid population. In their 2007 article in

CHEST, Wright and Subramanian call for a multilevel approach to better discern the complex social and environmental factors at play in asthma health disparities [20].

We undertook this study to determine how individual and county-level risk factors contribute to risk of asthma ED visits among Medicaid-enrolled children with asthma by constructing a multilevel model that includes individual and county level variables. We measured the extent to which county level factors were independent of individual-level factors that also affect children's risk of having an asthma ED visit. Finally, we examined the relationship between county-level factors and each individual-level association observed, with a focus on racial differences in asthma ED utilization.

Methods

Data sources

This study used an observational/ecologic design to analyze asthma ED visits among pediatric patients with a diagnosis of asthma. We obtained individual level information from the Centers for Medicare and Medicaid Services' 2009 Medicaid Analytic Extract (MAX) file [21]. County level rural/urban status, demographic, socioeconomic status, and healthcare information were acquired from the 2009–2010 Area Resource File (ARF) [22]. The Environmental Protection Agency (EPA) 2009 provided county level air quality measurements (specifically the percentage of days in the year with poor air quality) [23]. We merged ARF and EPA data with MAX data by matching county Federal Information Processing Standard (FIPS) codes [24].

Study population

Eligible patients for the study were Medicaid enrollees aged 5 to 12 years from 28 states (Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington) plus the District of Columbia (Washington, DC). These jurisdictions account for 80% of all Medicaid enrollees in the United States and 90% of Black or African American Medicaid enrollees. Patients were identified as having asthma if they had one or more billed claim from the inpatient (IP) file or at least two billed claims from the outpatient/other (OT) file with a diagnosis of asthma (International Classification of Disease 9 (ICD-9) diagnostic codes 493.xx, excluding 493.2 (Chronic Obstructive Asthma related to COPD or Chronic Bronchitis) [25]. Applying these criteria resulted in 615,432 unique subjects.

Outcome variable

The outcome in this study is an asthma ED visit. ED visits were identified by the following criteria: 1) a place of service code of 23 (Emergency Room – Hospital), 2) revenue codes 450–459 (450 = Emergency room-general classification; 451 = Emergency room-Emergency Medical Treatment & Labor Act (EMTALA) emergency medical screening services; 452 = Emergency room-ER beyond EMTALA screening; 456 = Emergency room-urgent care; 459 = Emergency room-other), or 3) procedure codes 99281–99285 (Emergency room visit for the evaluation and management of a patient ranging from minor 99281 to life threatening 99285 severity). ED visits from both inpatient and outpatient files which were assigned a primary diagnosis code of asthma were defined as an 'asthma ED visit'. Asthma ED visits for each child were classified into a yes/no binary variable (one or more ED visits versus no ED visits). ED visits for non-asthma diagnoses were not included in the analysis.

Individual-level predictors

Individual level predictors and covariates in our study included demographic characteristics (age, gender, race/ethnicity), and medication use as defined by the ratio of long-term asthma controller medication use compared to use of all asthma medications (controller + rescue medications) [20]. This controller-to-total asthma medication ratio has been previously shown to be associated with patient-centered as well as utilization outcomes [26]. Race/ ethnicity was classified into five groups (White, Black, Hispanic, Asian, and other).

Using the prescription drug claims (RX) file, we calculated the asthma drug ratio by dividing the number of times a long-term controller medication prescription was filled by total amount of all asthma medications prescriptions filled. Because a substantial portion of subjects did not have any asthma prescriptions, we created three groups for drug ratio (no asthma prescription, ratio less than 0.5 [less asthma controller medication use compared to rescue medication use], and ratio greater than or equal to 0.5 [more asthma controller medication use compared to rescue medication use]). A ratio greater than or equal to 0.5 has been associated with more favorable utilization outcomes [26].

County-level predictors

County was the smallest geographic unit common to the datasets used in this analysis. We included rural/urban status, demographic characteristics, socioeconomic measures, healthcare indicators, and air quality indicators. The county level ratio of total (all-cause) ED visits to all-cause doctor's office visits was controlled for as an indicator of ED visit utilization or potential ED overuse unrelated to asthma. Based on 2012–2013 Rural/Urban Continuum Codes from Department of Agriculture's Economic Research Services (ERS), counties were classified as big metropolitan (population > I million), small metropolitan (population between 250,000 and 1 million), and rural (population < 250,000) [27].

We used the percentage of Black, Asian, and Hispanic population to represent county demographics. County socioeconomic variables included racial segregation (measured by the Isolation Index for Whites [28,29], e.g., the percentage of Whites that live in a census tract for the average White person in the county), wealth of Black population, wealth of White population, income inequality as measured by the Gini Coefficient, unemployment rate, percentage of children living in poverty, and percentage of owned occupied units. County healthcare access indicators were obtained from the ARF and included primary care providers (general pediatricians, general practitioners, family physicians, and general internists) and pulmonary physicians per 10,000 total population, pediatricians per 10,000 children ≤19 years old, and hospital beds per 1,000 total population. The two indicators of air quality were percentage of days with bad air quality and median air quality index.

Statistical analysis

We conducted descriptive statistics to characterize our sample by both individual and county level predictors. Traditional (Model 0) and multilevel multivariate logistic regression (Model 1) models were used to evaluate and mutually adjust to the associations between asthma ED visit risk and individual level measures. We then estimated a multilevel model that included the individual-level variables and the county-level covariates of metro area and ED visit ratio (Model 2).

Then, we performed separate multilevel regression models by keeping all variables from model 2 and one single county level indicator at a time to test the relationship with individual asthma ED visit risk and to determine whether they modified the effect of individual level predictors (Model 3). Note: Model 3 is actually a set of models for each individual county-level variable. We then selected county-level indicators which were significantly associated ($p<.05$) with asthma ED visits from Model 3 into the final multilevel model (Model 4). We checked for interaction effects (marginal fixed effects) between each statistically significant county level variable with the metro/rural status variable (the only categorical county-level variable); no significant interaction term was observed.

Sociodemographic and air quality variables were rescaled as per 10 percent change to make the odds ratios easier to interpret. The significance level was set at p-value ≤ 0.05 and all analyses were accomplished using SAS 9.3 (SAS Institute, Cary, NC). Intra-class correlations coefficient (ICC) indicated how much of the total variation in the probability of having an ED visit is accounted for at the county level. ICC for each model was calculated using 3.29 as the level-1 error variance [29]. This research was conducted with the approval of the institutional review board at Morehouse School of Medicine, which also waived the requirement for individual informed consent.

Results

Table 1 describes individual and/or county level characteristics of the study population. The majority of pediatric asthma patients were male (60%), Black (32%), residents of large metro areas (54%), with an average age of 8.0 years (SD 2.3). 49% of these children received long-term asthma controller medicines as less than half of their total asthma prescription medication claims filled. Because all county level factors were attached to the personal summary file by county FIPS, the average of these variables were essentially weighted on asthma population of each county. At the county level, one asthma ED visit was observed for every three doctors' office visits. The average proportion of Hispanic, Black, and Asian population were 21%, 17%, and 4% among the total. There was a mean of 14 primary care providers, five pulmonary physicians, 293 hospital beds per 100,000 of the total county population, and 82 pediatricians per 100,000 children aged 19 years and younger.

Based on ICC of the multilevel models, county-level factors accounted between 6% and 7% of the variance in the ED visit risk. Table 2 summarizes associations between asthma ED visits and individual and county-level factors. Age, race, and long-term controller medication ratio were all found to be significant predictors of asthma ED visits in the individual level traditional logistic model (Model 0). The odds ratios for each individual level factor only changed slightly when using a multilevel model excluding county covariates (Model 1). Both metro area and ED visit ratio were found to be significant when added to the model, however their inclusion led to small or no changes in the estimates of the individual factors (Model 2).

Black and Asian population percentage, segregation, % unemployed, % children living in poverty, primary care and pulmonary care physicians per 10,000 population, hospital beds per 1,000 population, and % poor air quality days were all found to be significant predictors of asthma ED visits when added individually to the model (Model 3), and thus were included in Model 4. In the final model (Model 4), male gender (OR= 1.14, 95% CI = 1.12–1.15) was a significant predictor for ED visits. Blacks (OR = 1.88, 95% CI = 1.84–1.92) and Hispanics (OR = 1.06, 95% CI = 1.03–1.09) were more likely to have asthma ED visits compared to Whites, while Asians (OR = 0.60, 95% CI = 0.56–0.64) tended to have fewer. Asthma patients with lower asthma controller medication use were almost two times (OR = 2.18, 95% CI = 2.15–2.21) more likely to have an asthma ED visit compared to those who had no asthma medication, while those with more robust controller medication use were only 25% more likely to have an asthma-related ED visit when compared to those with no asthma medication.

No county demographic characteristics in terms of population proportion were associated with an increased risk of an asthma ED visit. Increasing county-level segregation (OR = 1.04, 95% CI = 1.01–1.08) was associated with increasing risk of asthma ED visits, while the association between unemployment rate and proportion of children living in poverty with risk of an asthma ED visit did not remain after controlling for other county level predictors. Increasing county-level supply of primary care providers (OR = 1.07, 95% CI = 1.02–1.12 per 10,000) and hospital beds (OR = 1.05, 95% CI = 1.02–1.07 per 1,000) were associated with a mildly increased odds of an asthma ED visit (7% and 5%, respectively), while a more robust supply of pulmonary physicians at the county level (OR = 0.81, 95% CI = 0.68–0.97) was associated with a reduction in risk of asthma ED visits. No significant association was detected between air quality factors and asthma ED visits in the final model.

Discussion

Our findings suggest that both individual and county-level characteristics contribute to disparities in asthma ED visits. Specific socioeconomic, demographic, health system factors, and county-level factors influence the risk of asthma ED visits among children on Medicaid. The individual-level factors of age, gender, and race/ethnicity were all associated with increased odds of an asthma ED visit. At the individual level, the ratio of asthma controller medication use to total asthma medications was also predictive of ED visits, but only for those children receiving at least one long-term asthma controller prescription medication. Children using controller medications were more likely to have an ED visit compared to children who were not prescribed controller medications.

This is consistent with previous findings among Medicaid-enrolled children with asthma, and is explained by the severity profile of the asthmatic child most likely to be prescribed a long-term controller medication [30,31]. In other words, children with more clinically severe manifestations of asthma are more likely to be prescribed controller medication, and also are at higher risk for an asthma ED visits.

On the other hand, those who use their preventive controller medication in an advantageous way were less likely to have an asthma ED visit than those who did not. In our data, children whose asthma medication regimens consisted of more long-term controller than rescue medications (e.g., controller to total asthma medication ratio > 0.5) were about 80% less likely to have an asthma ED visit than those whose controller use comprised less than half of their regimen. This reinforces the known efficacy and importance of compliance with controller medications for patients with asthma [32]. None of the effects of the individual level variables were explained by the county level variables.

For some factors the direction of the association with asthma ED visits was not as predicted. Air quality, which has been implicated as a risk factor for asthma exacerbations, was not a significant predictor of asthma ED visits in our study [33,34]. Unfortunately, we could not measure air quality in real time during the day or week of the asthma ED visit. Although living in a small metro area was associated with a minimally lower risk of an asthma ED visit than living in a large metro area before adjusting for other county level-factors (95% confidence interval 0.87–1.00), there was no significant difference between living in a large metro or rural area. Given that the level of geographic analysis was the county, more meaningful conclusions about rural urban differences might be made at a smaller unit of geographic analysis, such as zip code tabulation areas or census tracts, in future studies.

Although the conventional wisdom is that living in a poor area is associated with higher rates of asthma exacerbations [35], no county-level socioeconomic variables were associated with an increased risk of asthma ED visits after controlling for other county level factors with the exception of county-level segregation. A recent study examined the complex relationship between neighborhood socioeconomic status and asthma outcomes, which found that living in a poor county was not independently associated with asthma prevalence [3].

One potential explanation for this finding may be that children on Medicaid with asthma had better access to primary care providers who accept Medicaid as opposed to counties with lower poverty, because in poorer counties there is a critical mass needed to support high-quality healthcare services targeting the low-income population. Although research has shown greater barriers to primary care in the Medicaid population versus privately insured patients after adjusting for confounders, there has been no documentation of variation in barriers to accessibility of primary care within the Medicaid population [36].

Further work should be done to determine if health system resources or primary care alternatives to ED use may be unequally distributed in counties with greater racial segregation. Landrine and Corral reviewed evidence on the residential segregation which have resulted from poorer healthcare facilities and built environments and higher environmental exposures in Black neighborhoods, compared to predominantly White ones [37]. Areas where lack of access to a ‘primary medical home’ for children creates an environment whereby the residential segregation maybe more apparent. Living in ‘disadvantaged’ neighborhoods where there is lack of access to quality healthcare, adversely affects health outcomes, independent of individual indicators of SES (education, income, occupational status and a broad range of biomedical and behavioral risk factors) [38].

The supply of pulmonary care physicians in a county (e.g., number of pulmonary care physicians per 10,000 population in the county) significantly lowered the risk of having an asthma ED visit. This finding is consistent with a previous study that found visits to pulmonary specialists were associated with lower risk of an asthma ED visit [39]. On the other hand, we found a small but significant positive association with county-level primary care and pediatrician supply and risk of an asthma ED visit.

However, it is important to note that these variables, both the primary care physician variable and the pediatrician variable, account for all physicians in these specialties practicing in a county. All of these physicians are not necessarily accessible to children with Medicaid and their families. Additionally, the primary care physician supply includes general internists, who do not care for children. The primary care physician variable in the Area Resource File includes general internists, which is a limitation of the data source. What maybe more indicative of actual access to primary care for individuals with Medicaid in a county is the ED visit to outpatient visit ratio variable, which has a positive association with the odds of an asthma ED visit.

Individual factors associated with increased odds of having an asthma ED visit included male gender, younger age, race (Black and other), and Hispanic ethnicity, these findings are consistent with the existing literature on asthma health disparities [40,41]. Although these maybe considered unmodifiable characteristics at the individual level, the nearly twofold rate of asthma-related ED visits of Black vs White children is especially disconcerting, given that all the children in this sample were similarly poor (e.g., met similar income and asset criteria for Medicaid eligibility) and had similar insurance coverage and pharmacy benefits. Inequality of outcomes may be considered a target or quality indicator for state Medicaid programs to address, just as they have been able to eliminate racial disparities in initiation of anti-retroviral therapy for Medicaid-enrollees with HIV [42]. Racial-ethnic subgroups may also require culturally-relevant or community-specific interventions in order to reach equality of outcomes. For example, Flores et al. demonstrated the effectiveness of parents as peer counselors for Hispanic and Latino children with asthma [43]. while the Harlem Children’s Zone initiative has reduced asthma ED visits among predominantly Black children in low-income neighborhoods by 77% (absolute reduction from 35% to 8%) [44,45].

Limitations

The primary limitation of this study is our lack of geographic granularity. Counties maybe too large of an area to effectively measure some of exposures or risks that operate at the neighborhood level [46]. For example, measures of average socioeconomic status in a county may not give an accurate picture of the very different socioeconomic realities of a child living in a poor inner city versus a child living in an affluent suburb. This was suggested by our findings with regard to housing segregation.

Similar limitations exist with regard to measures of air quality, which may depend on the precise location of the air quality monitoring sites within a county. In addition, we did not have the temporal granularity to measure the precise air quality in the days preceding a child's asthma ED visit, although our air quality measures did include not only the annual median air quality index, but also the percentage of days with poor air quality. Thus the number of days in which poor air quality spiked in a given community would be expected to be associated with its influence on the odds of childhood asthma ED visits averaged over time.

Due to the observational/ecological nature of the study design and limited availability of variables in available datasets, we are unable to assess causation for the observed associations. For instance, we do not have information on the length of time children lived in a county. Information on seasonality which may influence asthma attacks was lost since the outcome was collapsed to whether they had one or more attack regardless of the time of year that attacks occurred. We also do not have information on other causal or confounding variables such as whether the children had a flu vaccine, or whether they were exposed to environmental tobacco smoke.

We also did not measure *de facto* access to primary care clinicians or specifically to pediatricians with practices open to children with Medicaid as their source of health insurance, but only county-level physician supply. Additionally, county level primary care physicians included internal medicine physicians, who do not see children. County-level access to pulmonary physicians also likely includes pulmonary providers who do not see children. Finally, we did not have access to medical record data, and therefore could not control for asthma staging or severity, nor could we distinguish between whether physicians did not prescribe controller medication versus whether patients adhered to controller medications.

Conclusions

We found that disparities in childhood asthma ED utilization among Medicaid enrollees are indeed multilevel. Individual characteristics, access to care, and racial segregation all played independent roles that contributed to pediatric asthma health disparities. The primary modifiable risk factor at the individual level was found to be the prescribed controller medication to total asthma prescribed medication ratio. This suggests that the primary intervention points for eliminating disparities in uncontrolled asthma leading to ED visits might include culturally-relevant interventions as well as community-specific interventions. Based on these results, we propose patient-focused interventions to improve compliance with prescribed controller medications and provider-focused interventions to assure appropriate prescribing. In addition to clinically-focused interventions, broader efforts to eliminate the effects of residential segregation will be necessary to achieve optimal and equitable health outcomes for children with asthma.

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Table 1.

Individual and county level characteristics of Medicaid enrollees, age 5 to 12 years, with an asthma diagnosis, 2009.

Characteristic		***N***	**%**
Sex			
Female		248,151	40%
Male		367,281	60%
Race			
White		179,180	29%
Black		196,675	32%
Hispanic		149,365	24%
Asian		10,683	2%
Other		79,529	13%
Metro			
Big metro		331,688	54%
Small metro		184,212	30%
Rural		97,941	16%
Long-term controller asthma medication ratio			
No medication		277,621	45%
< 0.5		302,255	49%
≥ 0.5		35,556	6%
		Mean	SD
Age (years)		8.0	2.3
ED visit ratio		0.33	0.41
County demographic	Black population percentage	16.9%	15.3%
	Asian population percentage	4.3%	4.7%
	Hispanic population percentage	20.8%	20.4%
County socioeconomic	Residential segregation *	0.72	0.16
	Wealth of Black population	0.02	0.05
	Wealth of White population	0.07	0.18
	Gini coefficient	0.46	0.05
	Unemployment rate	6.1%	1.8%
	Children living in poverty	21.3%	7.7%
	Owner occupied units percentage	88.8%	5.5%
County healthcare	Primary care physician per 100,000	14.3	18.9
	Pulmonary physician per 100,000	4.9	4.3
	Hospital beds per 100,000	293.4	184.9
	Pediatrician per 100,000	81.7	70.9
County air quality	Bad air quality days percentage	38.2	23.0
	Air quality index median	45.5	12.0

Note.

* Isolation index for Whites.

Table 2.

Results of multilevel logistic regression models, odds ratios and 95% confidence intervals for risk of having an asthma related ED visit for Medicaid enrollees, age 5 to 12 years, with an asthma diagnosis, 2009.

Characteristic		Model 0: Individual logistic regression		Model 1: Multilevel model with no county variable		Model 2: Model 1 + county covariates		Model 3: Model 1 + single county variable		Model 4: Model 2 + significant county variables	
Category	Variable	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age		0.99*	0.99–0.99	0.99*	0.98–0.99	0.99*	0.98–0.99	N/A	N/A	0.99*	0.98–0.99
Sex											
Female		1.00	N/A	1.00	N/A	1.00	N/A	N/A	N/A	1.00	N/A
Male		1.14*	1.12–1.15	1.14*	1.12–1.15	1.14*	1.12–1.15	N/A	N/A	1.14*	1.12–1.15
Race											
White		1.00	N/A	1.00	N/A	1.00	N/A	N/A	N/A	1.00	N/A
Black		1.97*	1.93–2.00	1.82*	1.79–1.86	1.83*	1.80–1.87	N/A	N/A	1.88*	1.84–1.92
Hispanic		1.05*	1.03–1.08	1.05*	1.02–1.07	1.04*	1.02–1.07	N/A	N/A	1.06*	1.03–1.09
Asian		0.73*	0.68–0.78	0.60*	0.56–0.64	0.60*	0.56–0.64	N/A	N/A	0.60*	0.56–0.64
Other		1.42*	1.39–1.45	1.25*	1.21–1.28	1.25*	1.22–1.28	N/A	N/A	1.28*	1.24–1.31
Long-term controller											
Medication ratio											
No medication		1.00	N/A	1.00	N/A	1.00	N/A	N/A	N/A	1.00	N/A
<0.5		2.05*	2.02–2.08	2.12*	2.09–2.15	2.14*	2.11–2.17	N/A	N/A	2.18*	2.15–2.21
≥ 0.5		1.20*	1.16–1.24	1.25*	1.21–1.29	1.26*	1.22–1.30	N/A	N/A	1.25*	1.21–1.30
County-level variables											
Metro area											
Big metro		N/A	N/A	N/A	N/A	1.00	N/A	1.00	N/A	1.00	N/A
Small metro		N/A	N/A	N/A	N/A	0.95	0.88–1.02	0.93	0.86–1.01	0.93	0.84–1.03
Rural		N/A	N/A	N/A	N/A	0.93*	0.87–0.99	0.93*	0.87–1.00	0.90	0.78–1.03
ED visit ratio		N/A	N/A	N/A	N/A	1.30*	1.23–1.37	1.30*	1.23–1.37	1.21*	1.13–1.30
County demographics											
	Black pop percentage per 10%	N/A	N/A	N/A	N/A	N/A	N/A	0.98*	0.97–1.00	0.98	0.95–1.01

Characteristic		Model 0: Individual logistic regression		Model 1: Multilevel model with no county variable		Model 2: Model 1 + county covariates		Model 3: Model 1 + single county variable		Model 4: Model 2 + significant county variables	
Category	Variable	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	Asian pop percentage per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.18*	1.07–1.30	1.12	0.97–1.29
	Hispanic pop percentage per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.01	0.99–1.03		
County socioeconomics											
	Segregation per 0.1*	N/A	N/A	N/A	N/A	N/A	N/A	1.02*	1.00–1.03	1.04*	1.01–1.08
	Wealth of Black Pop per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.03	0.97–1.11		
	Wealth of White Pop per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.05	0.98–1.11		
	Gini Index per 0.1	N/A	N/A	N/A	N/A	N/A	N/A	0.99	0.92–1.06		
	Unemployment rate per 10%	N/A	N/A	N/A	N/A	N/A	N/A	0.80*	0.71–0.92	1.14	0.90–1.43
	Kids in poverty per 10%	N/A	N/A	N/A	N/A	N/A	N/A	0.95*	0.92–0.98	0.97	0.89–1.05
	Owned occupied units per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.03	1.00–1.06		
County healthcare workforce											
	Primary care physician per 10K total population	N/A	N/A	N/A	N/A	N/A	N/A	1.04*	1.02–1.06	1.07*	1.02–1.12
	Pulmonary physician per 10K total population	N/A	N/A	N/A	N/A	N/A	N/A	1.11*	1.03–1.21	0.81*	0.68–0.97
	Hospital beds per 1K total population	N/A	N/A	N/A	N/A	N/A	N/A	1.02*	1.01–1.03	1.05*	1.02–1.07
	Pediatrician per 10K population under the age of 19	N/A	N/A	N/A	N/A	N/A	N/A	1.00	0.99–1.01		
County air quality											
	Bad air quality per 10%	N/A	N/A	N/A	N/A	N/A	N/A	1.04*	1.01–1.06	1.02	0.98–1.06
	Air quality index per unit	N/A	N/A	N/A	N/A	N/A	N/A	1.00*	1.00–1.01	1.00	0.99–1.01
Intra-class correlations coefficient (ICC)		N/A		7.2%		6.8%		N/A		6.5%	

Note.

*Isolation index for Whites.