

Asthma-Related Emergency Department Visits in North Carolina, 2010–2014

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BACKGROUND The purpose of this study was to compare asthma-related emergency department (ED) visit rates across North Carolina. Results from this study can inform health planning while helping public health and health care professionals in identifying geographical areas and targeting age groups to reduce the asthma burden in North Carolina.

METHODS This was a retrospective data analysis between 2010 and 2014 among North Carolina patients presenting to an ED with a first or second listed diagnosis code related to asthma (ICD-9-CM, 493.xx). Data was obtained from the North Carolina Disease Event Tracking and Epidemiology Collection Tool. Annual, age-adjusted rates were standardized to the 2000 US standard population using the direct method. Repeated measures ANOVA was conducted to compare differences between mean values of asthma-related ED visit rates in regions, urbanicity, and age groups across years.

RESULTS Asthma ED rates were consistently higher in the east (85.1 per 10,000) compared with other regions. While most age group ED rates fluctuated over the study period, univariate test results indicated statistical increases in ED asthma visits among the groups aged 5 to 9 years ($P < .01$), and 65 and over ($P < .03$).

CONCLUSION Public health officials should recognize the disproportionate burden of asthma-related ED visits, particularly among rural and impoverished counties in the eastern portion of North Carolina when prioritizing health concerns across North Carolina.

Asthma is a serious public health problem that affects an estimated 25 million, or 7.6% of adults and 8.4% of children in the United States [1, 2]. Asthma disproportionately affects low-income minorities, with the highest prevalence rates among black, non-Hispanic (13.4%) and Hispanic-Puerto Rican (13.7%) children (less than 18 years) [2]. As a chronic inflammatory, respiratory disease, asthma can lead to breathing difficulties that can interfere with regular activities, often requiring prompt medical treatment [3, 4]. According to the Centers for Disease Control and Prevention (2015), nearly 47% of all persons in the United States with asthma reported having at least 1 or more asthma attack within the past year; 14.1% resulted in an overnight hospital visit. In 2015, 1.6 million asthma-related emergency department (ED) visits occurred [2, 5, 6], including an estimated 87,000 asthma ED visits in North Carolina [7].

Asthma is the leading chronic condition among children in the United States [8]. While North Carolina adults report similar asthma prevalence (7.8%) [2], an estimated 10.5% or approximately 2% more of North Carolina children reported having higher asthma compared to children at the national average. In 2014–2015, black, non-Hispanic children in North Carolina had significantly higher asthma prevalence (21.5%) compared to children reporting at the national level as either black, non-Hispanic (10.3%), white (7.4%), Mexican/Mexican American (6.0%), or Hispanic-Puerto Rican (13.7%). Additionally, among North Carolina children with asthma, nearly 30% ($N = 111$) reported having a hospital ED or urgent care clinic visit in 2015 [9].

Previous North Carolina statewide surveillance reports and studies have evaluated asthma-related ED visit rates

using population-based survey methods [2] or prevalence estimates, using the total number of asthma patients presenting to the ED (numerator) divided by the total number of ED visits (denominator) [7, 10]. In this study, we evaluate asthma ED visits using first-listed or second-listed *International Classification of Diseases, Ninth Revision, Clinical Modification*, 493.xx (ICD-9-CM, 493.xx) diagnosis codes as a measure to estimate rates by region, urbanicity, and county tier designation status. To our knowledge, there have not been any recent published studies that have evaluated age-specific ED visit rates using mid-year population estimates in North Carolina. Results presented in this project may be useful for evaluating regional trends of asthma ED visits, informing policy, and assisting with asthma educational programs to target the asthma burden among age-specific groups.

Methods

This was a retrospective analysis that evaluated the prevalence of asthma-related ED visits using data obtained from the North Carolina Disease Event Tracking and Epidemiology Collection Tool (NC DETECT). NC DETECT is a statewide, syndromic surveillance system that provides early event detection by collecting data from hospital ED visits, pre-hospital events, poison center calls, and veterinary laboratories

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in North Carolina. An estimated 120 participating hospitals were reporting data to NC DETECT during the study period [11].

Inclusion criteria for this project included data for ED visits between January 1, 2010 and December 31, 2014, inclusive with either a first-listed or second-listed ICD-9-CM, 493.xx diagnosis code. ED visits by patients who were not North Carolina residents were not included. A formal data use agreement between the North Carolina Division of Public Health and East Carolina University (ECU) was executed and approved by the Institutional Review Board at ECU (#15-000104) prior to any data analysis.

Study Regions, Classifications, and Designations

Eastern, Piedmont, and Western regions. The study area included all North Carolina counties (N = 100). The state was divided into 3 broad sections that make up its geographical regions: Coastal plains (Eastern), Piedmont (Central), and Mountains (Western).

Urban, suburban, and rural county classifications. North Carolina counties were classified as either urban, regional/suburban, or rural using definition parameters set by the North Carolina Rural Center [12]. More specifically, rural counties (N = 80) were classified as having an average population density of 250 persons per square mile or less; suburban counties (N = 14) between 250 and 750 persons per square mile; and urban counties (N = 6) a population density of 750 people or greater per square mile [12].

County Tier designations. County Tier levels (Tier 1, Tier 2, and Tier 3) are ranked designations established for each of the 100 counties in North Carolina as a representative indicator of economic distress and well-being [13]. County Tier designations can be found on the North Carolina Department of Commerce website (<http://www.nccommerce.com/>). As defined, Tier 1 counties (N = 40) are the most economically distressed, Tier 2 counties (N = 40) are the next distressed, and Tier 3 counties (N = 20) are the least distressed. Each county Tier ranking designation is established based on a combination of 4 factors: average unemployment rate, population growth, adjusted property tax base per capita, and median household income [13]. Any change in county Tier designation status (eg, from Tier 1 to Tier 2) that may have occurred during the study interval was noted in the final results.

Procedures

Variables used in the analysis included ED visit date, age-specific groups (0-4, 5-9, 10-14, 15-17, 18-24, 25-44, 45-64, and 65 and over), sex (male/female), and patient county residence. A total of 45 cases were excluded for incomplete or missing data.

Data Analysis

Annual, age-adjusted rates (per 10,000 persons per year) were calculated for each year and then averaged

across the 5-year study period for each county (N = 100), regional area (Eastern, Western, or Piedmont), and county type (rural, regional/suburban, or urban). Age-specific rates were calculated as the number of ED asthma-related visits in a specified age group (mentioned above) in a given year as the numerator, divided by the mid-year, annual estimated population [14] for that age-specific group. Age-adjusted rates were standardized to the 2000 US standard population [15] using the direct method. Mean values were calculated by averaging the individual rates for each region, county, and age-specific group. Repeated measures ANOVA was conducted to compare differences between means of asthma-related ED visit rates in regions, urbanicity, and age groups across years. It was assumed that the characteristics of the population for each county were similar from 2010 to 2014. Therefore, the asthma-related ED visit rates for each year were correlated. Data analyses were conducted using SPSS Inc. (v. 22.0). GIS (Geographic Information Systems) software (ESRI, v. 10.4) was used to map the spatial distribution of asthma-related ED visit rates across North Carolina counties.

Results

During the study period, there were a total of 329,119 asthma-related (ICD-9-493.xx) ED visits reported for North Carolina that met the inclusion criteria. Overall, the state-wide age-adjusted, asthma-related ED visit rate during the study period (2010-2014) was 66.2 per 10,000 persons (see Table 1). The Eastern region consistently had the highest ED visits each year, with an overall mean annual asthma ED rate of 85.1 asthma-related ED visits (per 10,000 persons/year) over the study period. When evaluating annual trends, age-adjusted asthma ED rates declined from 40.1 (per 10,000 persons/year) in 2010 to 31.4 (per 10,000 persons/year) in 2014 in the Western region. Similarly, the Piedmont region showed a decline in age-adjusted asthma ED rates from 68.3 (per 10,000 persons/year) in 2010 to 64.2 (per 10,000 persons/year) in 2014. In contrast, age-adjusted asthma ED rates in Eastern North Carolina increased from 76.3 (per 10,000 persons/year) in 2010 to 93.5 (per 10,000 persons/year) in 2014.

Overwhelmingly, the majority of asthma-related ED visits were from rural counties (91.2%); 5.6% were from the Piedmont and 3.2% were from regional/suburban counties. The mean, age-adjusted, asthma-related ED visit rates over the study period were highest among suburban counties (69.0 per 10,000 persons/year), while lower rates were found among urban counties (65.1 per 10,000 persons/year) and rural counties (65.8 per 10,000 persons/year).

Among age groups, the 45 to 64 years group had the highest percentage of total asthma ED visits (22.6%). However, the highest age-specific age group was the 0-4 years group, with an average rate of 196.0 (per 10,000 persons/year). In other age groups, most age-specific rates were consistently stable throughout the study

TABLE 1.
Age-Adjusted, Asthma-Related Emergency Department (ED) Visits by Region, Urbanicity, and Age Group (per 10,000 persons per year)

	Total patients (%) (2010-2014)	2010	2011	2012	2013	2014	Mean (SD)
(N = 329,119)	100.0	64.7	63.4	66.7	67.4	68.8	66.2 (2.2)
Region							
Western	6.6	40.1	37.1	31.9	32.0	31.4	34.5 (3.9)
Piedmont	58.7	68.3	63.7	65.6	63.8	64.2	65.1 (1.9)
Eastern	34.6	76.3	78.5	87.0	90.2	93.5	85.1 (7.4)
Urbanicity							
Rural (N = 80)	91.2	62.8	63.0	65.8	67.4	70.0	65.8 (3.0)
Suburban (N = 14)	3.2	76.6	64.1	69.0	71.1	64.4	69.0 (5.2)
Urban (N = 6)	5.6	62.6	66.4	73.4	60.0	63.0	65.1 (5.2)
Age group							
0-4	22.1	198.6	189.5	199.5	194.6	197.6	196.0 (4.1)
5-9	6.8	50.6	52.6	56.1	60.1	64.0	56.7 (5.5)
10-14	3.6	29.1	28.6	32.2	30.0	31.7	30.3 (1.6)
15-17	2.0	30.4	30.5	30.2	26.6	29.1	29.4 (1.6)
18-24	5.9	44.4	44.2	40.5	42.0	43.9	43.0 (1.7)
25-44	17.6	44.5	44.1	47.2	46.5	46.7	45.8 (1.4)
45-64	22.6	57.7	57.7	61.4	62.0	61.9	60.1 (2.2)
65 and over	19.4	107.2	102.0	107.5	115.9	119.3	110.4 (7.0)

Note. SD, standard deviation.

Asthma-related ED rates were calculated using the number of asthma-related ED visits (with primary or secondary ICD-9-CM, 493.00-493.92 diagnosis code) as the numerator, divided by the US Census mid-year population for each year for each age-group as the denominator. Age-adjusted rates were calculated for region, urbanicity and age-groups using the direct method, standardized to the 2000 US Standard Population.

period. However, the group aged 5-9 years saw nearly a 14% increase from 2010 to 2014; the group aged 65 years and over increased approximately 3.0% and had the second-highest mean rate of all age-groups at 110.4 visits (per 10,000 persons/year).

As shown in Figure 1, the average age-adjusted, asthma related ED visit rates varied across individual counties, ranging from 14.7 to 208.8 (per 10,000 persons/year). Lower rates were found in the Western region, while the highest ED rates were identified among several rural, northeastern counties. Among those counties with the highest rates (81.0-208.8), 12 out of 13 counties in the Eastern region of the state had Tier 1 designation. The repeated measures ANOVA indicated statistically significant interaction effects of regions and year ($P = .02$), and urbanicity classification and year ($P = .03$), in asthma-related ED visits over time (see Table 2).

As shown in Figure 2, asthma-related ED rates generally trended upward in the Eastern region while rates in the Western and Piedmont regions either trended downward or remained stable. ED rates were significantly different over time for the Eastern region ($P = .01$), with highest rate in 2014 and lowest ED rate in 2010. No significant differences in asthma-related ED rates were found over time for the other 2 regions.

As shown in Figure 3, rates gradually went up in rural counties, but fluctuated in urban and suburban counties. However, within each county type, there were no different asthma-related ED rates over time ($P < .05$). Within each region, rate changes for the Eastern region were statistically

significant ($P = .01$). The omnibus test indicated statistically significant changes of asthma-related ED visit rates over years by age ($P = .02$). While most age group rates fluctuated over the study period, univariate test results indicated statistically significant increases among the groups aged 5 to 9 years ($P = .01$), and 65 ($P = .03$) and over.

Discussion

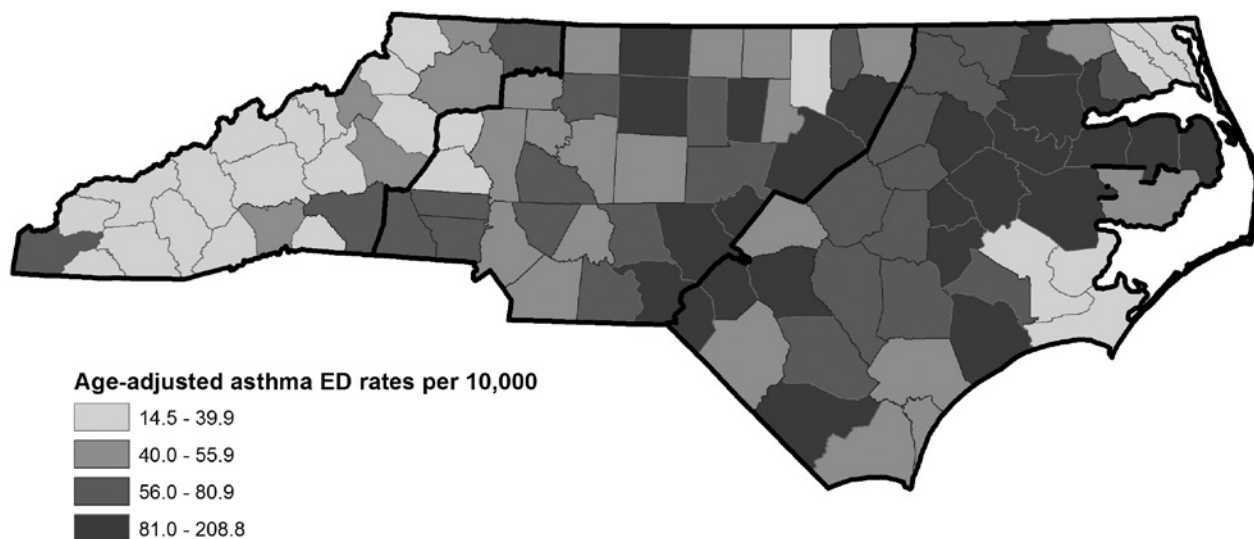
Overwhelmingly, rural counties in North Carolina had an exceedingly higher percent of asthma-related ED visits than suburban and urban counties, with the Eastern region consistently having the highest rates among Tier 1 counties in the northeastern part of the state. Using this method, the results presented here reflect trends in ED visits across North Carolina that may support enhanced surveillance for state asthma reports. For example, we identified that children aged 5-9 years experienced the largest percentage increase of asthma-related ED visits among all age-groups across the study period. This corresponds with recent statewide survey (CHAMPS) data that indicates children aged 5-10 years had the highest asthma rates (11.0%) in the state [9], suggesting that this group may be an ideal age group to target for asthma education and intervention efforts.

The high rates of asthma ED visits in eastern North Carolina warrants increased public health concern. Although data on race and ethnicity were not available, Eastern counties with the highest asthma rates were also located in the poorest counties with the highest percent black, non-Hispanic population. Further investigation is needed to examine

this issue. However, these results are reflective of national reports and the published literature that low-income, and uninsured, high-risk minorities often rely on the ED as a safety net for asthma-related care [16, 17]. Although we did not factor costs into our project, the fact that asthma rates were increasingly higher in rural counties leads us to conclude that hospitals in eastern North Carolina are disproportionately absorbing excessive asthma-related ED costs, and that asthma education and/or medication compliance in counties are simply not adequate.

Given eastern North Carolina's continued disproportionate chronic health disparities and health conditions in the state, it is not surprising to see asthma listed as yet another health burden. A large percent of the population in eastern

FIGURE 1.
Age-Adjusted, Asthma-Related ED Rates (per 10,000 persons) Averaged Over 2010-2014 by County Name, Region, and Urbanicity Classification



Age-Adjusted asthma ED rates (per 10,000)							
14.7-40.2		40.3-57.0		57.1-80.9		81.0-208.8	
Alexander	P(R)	Alleghany*	W(R)	Alamance	P (S)	Beaufort*	E(R)
Ashe*	W(R)	Avery	W(R)	Anson*	P(R)	Bertie*	E(R)
Buncombe	W(S)	Brunswick	E(R)	Bladen*	E(R)	Chowan†	E(R)
Caldwell*	W(R)	Burke	W(R)	Cabarrus	P(S)	Columbus*	E(R)
Camden*	E(R)	Caswell*	P(R)	Chatham	P(R)	Cumberland	E (S)
Carteret	E(R)	Davidson	P (S)	Cherokee	W(R)	Dare	E(R)
Catawba	P(S)	Davie	P(R)	Cleveland	P(R)	Edgecombe*	E(R)
Clay*	W(R)	Durham	P(U)	Duplin	E(R)	Franklin	P(R)
Craven	E(R)	Gates*	E(R)	Forsyth	P(U)	Greene*	E(R)
Currituck	E(R)	Harnett	E(R)	Gaston	P (S)	Guilford	P(U)
Graham*	W(R)	Henderson	W(S)	Halifax*	E(R)	Hertford*	E(R)
Granville	P(R)	Hyde*	E(R)	Johnston	E(R)	Hoke	E(R)
Haywood	W(R)	Iredell	P (S)	Jones*	E(R)	Lee	P(R)
Jackson*	W(R)	Mecklenburg	P (U)	Lincoln	P (S)	Lenoir*	E(R)
Macon*	W(R)	New Hanover	E (U)	Montgomery*	P(R)	Martin*	E(R)
Madison	W(R)	Pender	E(R)	Nash*	E(R)	Moore	P(R)
McDowell*	W(R)	Person	P(R)	Northampton*	E(R)	Onslow	E(R)
Mitchell	W(R)	Randolph	P(R)	Perquimans*	E(R)	Orange	P (S)
Pamlico	E(R)	Robeson*	E(R)	Rowan	P (S)	Pitt	E (S)
Pasquotank*	E(R)	Stanly	P(R)	Rutherford*	W(R)	Richmond*	P(R)
Polk	W(R)	Stokes	P(R)	Sampson	E(R)	Rockingham	P(R)
Swain*	W(R)	Union	P(S)	Surry	W(R)	Scotland*	E(R)
Transylvania	W(R)	Warren*	P(R)	Vance*	P(R)	Tyrrell*	E(R)
Watauga	W(R)	Wilkes	W(R)	Wayne	E(R)	Wake	P(U)
Yancey*	W(R)	Yadkin	P(R)	Wilson	E(R)	Washington*	E(R)

Note. W, Western; P, Piedmont; E, Eastern; U, urban; S, suburban; R, rural.

*Counties designated as a Tier 1 County throughout the 2010-2014 study period.

†Chowan County was designated a Tier 1 County in 2010, 2012, 2013, 2014 and a Tier 2 County in 2011.

TABLE 2.
Summary of Repeated Measures ANOVA for Asthma-Related Emergency Department Rates (2010–2014)

	2010		2011		2012		2013		2014			
Variable	M	SE	M	SE	M	SE	M	SE	M	SE	P	Partial η^2
Region (no. of counties)	F (8, 188) = 2.33, p = .02, partial η^2 = .09											
Western (N = 24)	40.1	7.8	37.1	7.4	31.9	8.2	32.0	8.4	31.4	8.1	.48	.15
Piedmont (N = 35)	68.3	6.5	63.7	6.1	65.6	6.8	63.8	7.0	64.2	6.7	.28	.15
Eastern (N = 41)	76.3	6.0	78.5	5.6	87.0	6.2	90.2	6.4	93.5	6.2	.01	.37
Urbanicity (no. of counties)	F (8, 188) = 2.20, p = .03, partial η^2 = .09											
Rural (N = 80)	62.8	4.6	63.0	4.4	65.8	5.1	67.4	5.3	70.0	5.2	.39	.05
Suburban (N = 14)	76.6	10.9	64.1	10.6	69.0	12.2	71.1	12.7	64.4	12.5	.10	.51
Urban (N = 6)	62.6	16.6	66.4	16.2	73.4	18.6	60.0	19.3	63.0	19.1	.38	.79
Age-Group	F (32, 68) = 2.20, p = .02, partial η^2 = .47											
0-4	198.6	10.3	189.5	10.7	199.5	12.4	194.6	11.2	197.6	11.0	.64	.01
5-9	50.5	4.3	52.6	4.4	56.1	4.7	60.1	4.9	64.0	4.8	.01	.05
10-14	29.1	3.0	28.6	2.7	32.2	3.0	30.0	2.4	31.7	2.7	.48	.01
15-17	30.4	3.3	30.5	2.6	30.2	2.7	26.6	2.4	29.1	2.6	.58	.01
18-24	44.4	3.6	44.2	3.4	40.5	3.2	42.0	3.6	43.8	3.2	.63	.01
25-44	44.5	2.9	44.1	2.9	47.2	3.4	46.5	3.6	46.6	3.4	.57	.01
45-64	57.7	4.0	57.7	4.2	61.4	4.9	62.0	5.2	61.9	4.9	.28	.01
65 and over	107.1	9.4	102.0	8.2	107.4	9.2	115.9	11.0	119.3	10.3	.03	.04

Note. M, mean; SE, standard error.

North Carolina continue to have low access to health care, combined with a shortage of health care providers in the region. The social determinants of health also pose additional challenges and risk factors for those with asthma [18]. For example, eastern North Carolina continues to have some of the worst substandard housing conditions in the state [19]. Poor housing conditions are presumably likely to contain numerous asthma allergen triggers (eg, mold from leaking roofs) that can pose unfortunate exposure opportunities for someone with allergic asthma [17, 20–23]. Other contributory risk factors, such as exposure to first-hand and/or second-hand smoke, are also a consideration. In 2016, North Carolina Behavioral Risk Factor Surveillance System data reported that Eastern North Carolina had the highest percentage of current smokers (19.4%) compared to Western and Piedmont regions [24].

Limitations

As a secondary data analysis, these results should be interpreted with caution. For example, data variables for race/ethnicity, occupation, and behavior (eg, smoking) were not available for analysis and not included in the evaluation. Furthermore, although NC DETECT captures 99% of all ED visits, the data does not include federal facilities, which are not required under mandate to report data. Data also does not include residents who visited hospitals outside of North Carolina, primary care physicians, or ambulatory facilities. When calculating age-adjusted rates, we included ED visits of patients with either first and/or second diagnoses of asthma with an ICD-0 493.xx, which is consistent with the methodology in the literature, but may result in higher rates [7, 10]. Because of data confidentiality requirements, we were unable to control for duplicate ED visits. Other limit-

ing factors that may have contributed to either increases or decreases included: affected residents that traveled outside of North Carolina for asthma ED care; whether the patient was presenting with an acute asthma exacerbation or routine asthma; and exposure to environmental pollutants from natural sources (eg, forest fires) and/or anthropogenic sources (eg, pulp mills), which can pose respiratory concerns that can trigger asthma attacks [25].

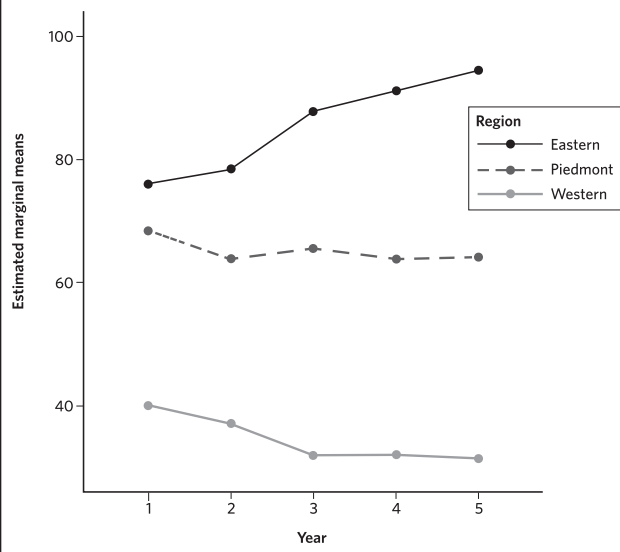
Conclusion

Asthma remains a serious chronic health condition in North Carolina. With the recent loss of federal asthma funding to the North Carolina Division of Public Health, county health departments have less state-level support for asthma education efforts to raise awareness in their communities. Concentrated efforts by programs such as Mission Children's Hospital [26], Community Care of North Carolina-Wake/Johnston Counties [27], and the Eastern Carolina Asthma Prevention Program [28] have shown tremendous benefit to those with asthma through home-based education and intervention efforts. Programs like these represent good models to follow to lower the asthma burden throughout North Carolina communities, but more funding and resources are needed to keep these programs in motion.

Without appropriate leadership and guidance to address the asthma burden in North Carolina, the disproportionate burden of asthma remains challenging particularly for those at the highest risk [29]. Collaborative efforts among health care providers and policymakers are needed to prioritize this issue to reduce asthma among high-risk populations and excessive asthma-related ED visits in North Carolina. Medical care providers are on the front-line of patient care and are in ideal positions to provide enhanced care and edu-

FIGURE 2.

The Interaction Effect of Region and Year on Asthma-Related ED Rates Showing Increased Asthma-Related ED Visit Rates in the Eastern Region and Decreasing and Stabilizing Rates in Piedmont and Western Regions



cation for asthma control [30, 31] and inform public policy to raise awareness in settings such as school environments [32, 33]. NCMJ

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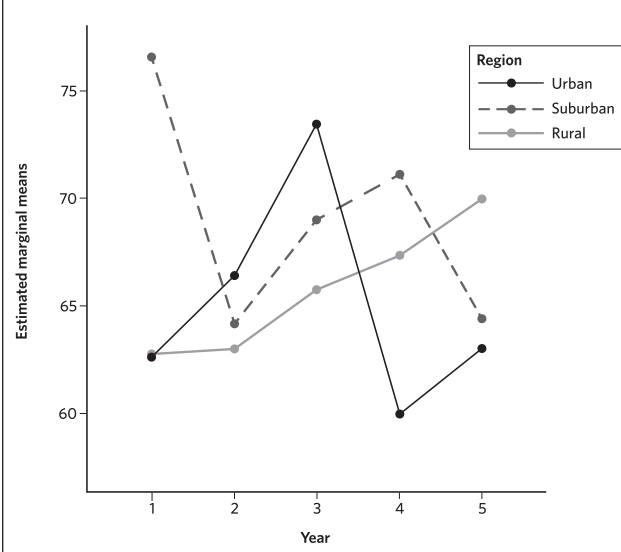
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FIGURE 3.

The Interaction Effect of Urbanicity and Year on Asthma-Related ED Rates Showing Increased Rates in Rural Counties (N = 80) and Fluctuating Rates in Urban (N = 6) and Suburban Counties (N = 4)



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