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Race and “Hotspots” of Preventable Hospitalizations

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ABSTRACT

Preventable hospitalizations (PHs) are those for ambulatory care-sensitive conditions that indicate insufficiencies in local primary healthcare. PH rates tend to be higher among African Americans, in urban centers, rural areas and areas with more African American residents. The objective of this study is to determine geographic clusters of high PH rates (“spatial clusters”) by race. Data from Maryland hospitals were utilized to determine the rates of PHs in zip code tabulation areas (ZCTAs) by race in 2010. Geographic clusters of ZCTAs with higher than expected PH rates were identified using Scan Statistic and Anselin’s Local Moran’s I. 10 PH spatial clusters were observed among the total population with an average PH rate of 3,046.6 per 100,000 population. Among whites, the average PH rate was 3,339.9 per 100,000 in 11 PH spatial clusters. Only five PH spatial clusters were observed among African Americans with a higher average PH rate (3,710.8 per 100,000). The locations and other characteristics of PH spatial clusters differed by race. These results can be used to target resources to areas with high PH rates. Because PH spatial clusters are observed in differing locations for African Americans, approaches that include cultural tailoring may need to be specifically targeted.

Keywords: Preventable Hospitalizations, Hotspots, GIS

INTRODUCTION

A preventable hospitalization (PH) is a hospital admission for an ambulatory care-sensitive condition (ACSC) (Billings, Anderson, & Newman, 1996; A. B. Bindman et al., 1995; Frey, 1995; U.S. Department of Health and Human Services, 2012). ACSCs can be treated in the primary care system, therefore, PHs could have potentially been avoided if treatment in the primary care system had occurred in a timely manner. Because of this, PHs are also considered a proxy for deficiencies in the local healthcare system (Ansari, Laditka, & Laditka, 2006; Baker, 1995; A.B. Bindman, Chattopadhyay, Osmond, Huen, & Bacchetti, 2005; Frey, 1995). PHs account for one out of 10 hospitalizations in the United States (U.S.) (Stranges & Stocks, 2010) at a rate of 1,434 PHs per 100,000 population (Fingar et al., 2015). Moreover, it is estimated that

PHs cost close to $30 billion annually (Jiang et al., 2009; U.S. Department of Health and Human Services, 2012).

Race is consistently associated with higher rates of PHs. While the magnitude of disparities varies by certain characteristics like age and insurance, studies estimate that the rate of PHs is three times greater among African Americans than whites, and is not eliminated after controlling for insurance (Chang et al., 2008; Derose, 2008; Gaskin & Hoffman, 2000; Laditka et al., 2003; O'Neil et al., 2010). Race disparities have been demonstrated among Medicare beneficiaries as well as among patients with private insurance (Chang et al., 2008; Gaskin & Hoffman, 2000).

Another consistent predictor of PHs is area-level characteristics such as rurality (Delia, 2003; Laditka et al., 2009; Rust et al., 2009; Schreiber & Zielinski, 1997), racial composition (Billings et al., 1996; Blustein et al., 1998; Derose, 2008; Pappas et al., 1997), poverty (Basu, Thumula, & Mobley, 2012; Blustein, Hanson, & Shea, 1998; Derose, 2008; Pappas, Hadden, Kozak, & Fisher, 1997) and access to healthcare resources (Epstein, 2001; Rosano et al., 2013; Rothkopf, Brookler, Wadhwa, & Sajovetz, 2011). Ecological studies that examine associations between area-level characteristics and PHs through regression analyses highlight the potential importance of considering place of residence and demonstrate the need for spatial analyses of PHs. Few studies have applied spatial analyses to PHs (Fishman, 2015; Mobley et al., 2006). Spatial analyses of PHs have found that there are indeed geographic clusters (or “spatial clusters”) of PHs in a national sample of Medicare beneficiaries (Mobley et al., 2006) and in Chicago, IL (Fishman, 2015).

Spatial analyses of PHs are needed because these techniques can be used to directly target specific areas with high PH rates instead of addressing PHs through generalized characteristics such as high poverty or high numbers of minority residents. An analysis of the presence of spatial clusters by race is warranted because of high PH rates among African Americans. Moreover, African Americans and whites tend to live in different places that vary in terms of the area-level characteristics associated with PHs (White, Haas, & Williams, 2012; Williams & Collins, 2001).

The overall aim of this study is to assess the presence of spatial clusters of PHs in the State of Maryland, and to determine whether the locations of these PH spatial clusters vary in the white population compared to the African American population in Maryland. This study was conducted in Maryland given the relatively large minority population (30.3% African American) and the variety in the demographic profile of African Americans in Maryland such as a substantial rural population, as well as, urban/poor and suburban/affluent populations (U.S. Census Bureau, 2016). Moreover, policymakers in Maryland have developed a unique, geographically based approach to addressing racial health disparities (Hussein, et al., 2014). This study may complement this type of work. A previous study found racial disparities in preventable hospitalizations among Maryland Medicare beneficiaries (O’Neil et al., 2010), so this study will add to the literature on PHs in Maryland. Spatial analyses can used by researchers and policymakers to specifically target resources to these areas. We hypothesized that there will be geographic clusters of PHs in Maryland, and that the location of these clusters will differ among the white population compared to the African American population.

METHODS

<u>Data Sources</u>

Preventable hospitalizations (PHs) were measured using data obtained from the Maryland Health Services Cost Review Commission (HSCRC). The HSCRC is an independent agency in the State of Maryland that is responsible for setting rates for services provided in Maryland hospitals, and collects cost and patient-level data on all patients (Health Services Cost Review Commission, 2012). Maryland hospitals treat about 800,000 inpatient cases annually (HSCRC, 2012). These records include patient demographic information such as sex, age, race/ethnicity, marital status, primary diagnosis, primary payer, and the zip code of residence (HSCRC, 2012). The dataset contained records for 746,967 hospitalizations from 2010. Hospitalizations for patients of all ages were included in these analyses.

Inpatient visits of Maryland residents hospitalized in the following bordering states were obtained: the District of Columbia, Pennsylvania and Virginia. Inpatient hospitalizations of Maryland residents in the District of Columbia were obtained from the Maryland Health Care Commission (MHCC). This dataset included 46,589 inpatient hospitalization records. Data from Virginia was obtained from Virginia Health Information (VHI) and data from Pennsylvania were obtained from the Pennsylvania Health Care Cost Containment Council (PH4C). These datasets included 6,065 and 3,820 inpatient hospitalizations, respectively.

Population-based data were collected from the U.S. Census Bureau. To calculate rates of preventable hospitalizations, the overall, non-Hispanic black and non-Hispanic white population was collected for each zip code tabulation area (ZCTA) in Maryland. Data from the 2010 Census Summary File 1 was used to obtain the population by race/ethnicity for every Maryland ZCTA from the file entitled "Race Alone or in Combination and Hispanic or Latino: 2010 (QT-P6)". The number of people in each ZCTA was recorded. Rurality was obtained from 2010 Census Summary File 1 and median income was obtained from the 2008-2012 American Community Survey 5-Year Estimates.

Data on primary healthcare resources were obtained from several sources. The zip code in which every hospital in Maryland is located was obtained from the Maryland Department of Health and Mental Hygiene. The number of federally qualified health centers (FQHCs) in each Maryland zip code was obtained from the Health Resources and Services Administration (HRSA). HRSA maintains a data warehouse that includes the name and location of every FQHC and look-alike site by state and county. Data on physician supply were obtained from SK&A, a company that maintains datasets of practicing healthcare professionals in the U.S. SK&A obtains data from sources such as company and corporate directories, websites, state licensing information, mergers and acquisitions announcements, trade publications, White and Yellow Pages directories, professional associations, and government agencies. The data is verified by SK&A staff through phone calls every six months. SK&A estimates that their data includes up to 97% of all office-based doctors in the U.S. Data on the number of family practitioners practicing in Maryland zip codes in 2010 were obtained for this study.

Variables

Individual-Level Variables

PHs are defined as an inpatient visit where the primary diagnosis was for one of the following conditions: angina, asthma, cellulitis, chronic obstructive pulmonary disease, congestive heart failure, convulsions, dehydration, dental conditions, diabetes, ear, nose and throat infection, gastroenteritis, hypertension, hypoglycemia, kidney infection, nutritional deficiencies, pelvic inflammatory disease, pneumonia, tuberculosis, and urinary tract infection (Billings et al., 1996). A dichotomous variable was created where "1" represented a hospitalization that was considered preventable, and "0" represented all other hospitalizations.

This set of conditions was chosen because they have frequently been used to define PHs in the literature (Basu, 2014; Basu, Mobley, & Thumula, 2014; Moy, Chang, & Barrett, 2013; White, Ellis, & Simpson, 2014). A report on hospitalizations for ACSCs among Medicare fee-for-service beneficiaries included a list of ICD-9 codes used in the literature for each of the conditions for which hospitalizations are considered preventable (McCall, Brody, Mobley, & Subramanian, 2004). The ICD-9 codes used to indicate a condition for which the hospitalization was preventable were garnered from the lists in this report.

A dichotomous variable to represent patient race/ethnicity was calculated. A value of “0” was given to hospitalization records where the patient’s ethnicity was non-Hispanic and the race was white. A value of “1” was given to hospitalizations were the patient’s ethnicity was not Hispanic and the race was black or African American.

A categorical variable was created to indicate the patient’s ZCTA of residence. An algorithm was created to match the patient’s reported zip code of residence with the corresponding ZCTA (American Academy of Family Physicians, 2015). A zip code is a product of the United States Postal Service and does not necessarily directly correspond to a U.S. Census Bureau ZCTA (U.S. Census Bureau, 2012). The algorithm matches zip codes to ZCTAs and assigns post office boxes and unique zip codes (i.e. those that belong to entities such as large companies, rather than a geographic place) to ZCTAs (American Academy of Family Physicians, 2015).

ZCTA-Level Variables

Using data on primary diagnosis, patient race and ZCTA of residence, a dataset was created with the number of PHs in each Maryland ZCTA in 2010. The number of PHs among non-Hispanic whites and blacks (hereafter, referred to as white and African American) in each Maryland ZCTA was also included. The dataset also included the total population, and the number of white and African American residents in each ZCTA.

The racial composition of each ZCTA was assessed in Maryland. The percentage of residents who were African American in each ZCTA was calculated by dividing the number of African American residents by the total population. Racial composition was measured continuously. The rurality of each ZCTA was calculated as the percentage of ZCTA residents who did not live in an urban cluster or urbanized area. Rurality was measured continuously as well. The median income of the ZCTAs was categorized into quartiles (<\$56,143, \$56,143 to \$72,840, \$72,841 to \$95,586, and >\$95,587). Dichotomous variables were created to represent whether a hospital or FQHC was located in a ZCTA. Physician supply was measured continuously as the number of family practitioners practicing in a ZCTA per 10,000 population.

Statistical Analyses

First, the overall PH rate for the total, white and African American population was calculated (see Equation 1). Racial differences in the percentage of hospitalizations that were preventable were assessed using chi-square tests. Descriptive statistics of ZCTA demographics and primary healthcare were reported.

$$\frac{Preventable\ hospitals\ among\ ZCTA\ residents}{ZCTA\ Population} \times 100{,}000 \qquad \text{Equation 1}$$

Second, exploratory spatial analyses were conducted by creating choropleth maps to display PH rates by ZCTA in the total, white and African American population. The PH rate for each Maryland ZCTA was calculated for the total population using Equation 1. The white PH rate and the African American PH rate were calculated for each ZCTA using race-specific population. Maps to display the white and African American PH rates in Maryland ZCTAs were created. Empirical Bayes Smoothed (EBS) PH rates were calculated that accounted for PH rates in neighboring ZCTAs using a 1^{st} order Rook contiguity weight. EBS PH rates were displayed in choropleth maps for the total, white and African American populations.

Third, regression analyses were performed to assess the association between area-level characteristics and PH rates. Racial composition, rurality, median income, hospitals, FQHCs, and physician supply were regressed on PH rates using negative binomial regressions. Three regressions were performed where the dependent variable was PHs among the total population, white PHs and African American PHs. An exposure of the total population, white population and African American population was included in the three regressions, respectively.

Fourth, a series of spatial clustering analyses were conducted. Spatial clusters of ZCTAs with high PH rates were assessed for the total population, the white population and the African American population using the Scan Statistic as well as Anselin's Local Moran's I. These analyses are described in depth in the Appendix.

Lastly, area-level characteristics of ZCTAs included in PH spatial clusters were compared to those not included in PH spatial clusters. Dichotomous variables were created to indicate whether a ZCTA was included in a PH spatial cluster for the total, white or African American population. Analysis of Covariance (ANCOVA) analyses were used to detect differences in ZCTA-level variables between non-spatial cluster and spatial cluster ZCTAs.

<u>Software</u>

Analyses to report descriptive statistics of Maryland ZCTAs and regression analyses were performed using Stata Version 14 (StataCorp LP, College Station, TX). ArcGIS Version 10.3 (Esri, Redlands, CA) was used to create choropleth maps of raw and EBS PH rates. ArcGIS was also used to display spatial clusters.

SatScan Version 9.1.1 (SatScan™, New York, NY) is the statistical software package used to detect PH spatial clusters with the spatial scan statistic. SatScan uses three types of data to calculated PH spatial clusters. A file including the Location ID (here, the ZCTA) and the number of cases (here, the number of PHs) is used as the Case File. A Case File was created for by race/ethnicity. A file containing the Location ID (ZCTA), population and time (here, year 2010) is used as the Population File. A Population File for the total population, the NH white population and the NH black population was created, resulting in 3 Population Files for analyses. A Coordinates File is used that contains the Location ID (ZCTA), the latitude and longitude of each ZCTA. GeoDa Version 1.8 (was used to calculated EBS PH rates, and spatial clusters using Anselin's Local Moran's I statistics.

RESULTS

Table 1 displays preventable hospitalizations (PHs) in the State of Maryland. The overall rate of PHs in Maryland in 2010 as 1,942.3 per 100,000 population. The rate was higher among African Americans. The African American PH rate was 2,513.9 per 100,000 population and the white PH rate was 1,778.3 per 100,000 population. Among African Americans, 16.8% of hospitalizations were preventable, while 14.8% were preventable among whites ($p<0.001$). There were race differences in all types of PHs with the exceptions of angina, gastroenteritis and kidney infections.

Table 1: Preventable hospitalizations in Maryland, 2010

	Total Population	White Population	African American Population	p-value
PH rate (per 100,000 population)	1,924.3	1,778.3	2,513.9	
Hospitalizations by type, %				
Preventable	14.8	14.8	16.8	<0.001
Angina	0.2	0.2	0.2	0.119
Asthma	1.3	0.9	2.2	<0.001
Cellulitis	1.7	2.0	1.4	<0.001
Chronic obstructive pulmonary disease	1.9	2.3	1.5	<0.001
Congestive heart failure	2.7	2.6	3.4	<0.001
Convulsions	0.2	0.2	0.2	0.002
Dehydration	0.5	0.6	0.5	<0.001
Dental conditions	0.1	0.1	0.1	0.003
Diabetes	1.6	1.2	2.5	<0.001
Ear/nose/throat infection	0.1	0.1	0.1	<0.001
Gastroenteritis	0.3	0.3	0.3	0.913
Hypertension	0.4	0.2	0.7	<0.001
Hypoglycemia	0.0	0.0	0.0	0.001
Kidney infections	0.3	0.3	0.3	0.905
Nutrition	0.3	0.2	0.4	<0.001
Pelvic inflammatory disease	0.1	0.1	0.1	<0.001
Pneumonia	2.1	2.2	2.0	<0.001
Tuberculosis	0.0	0.0	0.0	<0.001
Urinary tract infection	1.1	1.3	0.9	<0.001

Area-level characteristics of Maryland zip code tabulation areas (ZCTAs) are displayed in Table 2. The racial composition of the average Maryland ZCTA was 31.5% African American. The average Maryland ZCTA was 45.1% rural. Hospitals are located in about nine percent (9.1%) of Maryland ZCTAs, and 13.3% of Maryland ZCTAs have a federally qualified health center (FQHC) located in it. The mean number of family physicians practicing in Maryland ZCTAs was 12.0 per 10,000 population.

Table 2: Descriptive characteristics of Maryland zip code tabulation areas (ZCTAs), 2010	
*Racial composition, %	31.5
**Rural, %	45.9
Median income, %	
Quartile 1	24.8
Quartile 2	25.1
Quartile 3	25.1
Quartile 4	25.1
Hospital, %	9.6
Federally qualified health center, %	13.3
Physician supply (per 10,000 population), mean ± S.E.	12.0 ± 15.0

*Percentage of ZCTA residents who are African American.
**Percentage of ZCTA residents who do not live in an urbanized area or urban cluster.

The associations between area-level characteristics and PH rates are displayed in Table 3. For PHs among the total population, racial composition, rurality and hospitals were positively associated with PH rates. ZCTA median income and physician supply were negatively associated. With every 1-percentage increase in the number of African American residents, the PH rate increased by 53% (IRR=1.53, 95% CI=1.27-1.84). The PH rate increased by 27% with every 1-percentage increase in the number of rural residents living in a ZCTA (IRR=1.27, 95% CI=1.15-1.40). The PH rate in ZCTAs with median incomes in the highest quartile is 48% lower than in ZCTAs with the lowest median incomes (IRR=0.52, 95% CI=0.47-0.58). ZCTAs with a hospital located in it had 22% higher PH rates than ZCTAs without a hospital (IRR=1.22, 95% CI=1.08-1.38). The PH rate decreased by 2% as the number of family physicians per 10,000 population increased (IRR=0.98, 95% CI=0.97-0.99). There were racial differences in the associations between area-level characteristics and PH rates. PHs among both whites (IRR=0.55, 95% CI=0.49-0.62) and African Americans (IRR=0.60, 95% CI=0.50-0.70) were negatively associated with increasing median income. PH rates among whites were positively associated with racial composition (IRR=2.11, 95% CI=1.73-2.59), while the African American PH rate was positively associated with rurality (IRR=1.64, 95% CI=1.41-1.91), hospitals (IRR=1.23, 95% CI=1.05-1.45) and FQHCs (IRR=1.18, 95% CI=1.02-1.37).

Table 3: Association between area-level characteristics and preventable hospitalization rates in Maryland Zip Code Tabulation Areas (ZCTAs), 2010

	Total Population	White Population	African American Population
	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)
Racial Composition	1.53 (1.27-1.84)	2.11 (1.73-2.59)	1.20 (0.93-1.55)
Rurality	1.27 (1.15-1.40)	1.10 (0.99-1.22)	1.64 (1.41-1.91)
Median Income			
Quartile 1	1.00	1.00	1.00
Quartile 2	0.80 (0.72-0.88)	0.86 (0.77-0.96)	0.84 (0.72-0.98)
Quartile 3	0.71 (0.64-0.79)	0.73 (0.65-0.82)	0.81 (0.69-0.96)
Quartile 4	0.52 (0.47-0.58)	0.55 (0.49-0.62)	0.60 (0.50-0.70)
Hospital	1.22 (1.08-1.38)	1.13 (0.99-1.30)	1.23 (1.05-1.45)
FQHC*	1.09 (0.98-1.21)	1.02 (0.91-1.15)	1.18 (1.02-1.37)
Physician supply**	0.98 (0.97-0.99)	0.98 (0.97-1.00)	0.99 (0.97-1.01)

*FQHC=federally qualified health center
**Family practitioners per 10,000 population

Figure 1 displays PH rates among the total, white and African American populations in Maryland ZCTAs. Figure 2 shows Empirical Bayes Smoothed PH rates. Figure 3 displays spatial clusters of PHs for the total, white and African American population detected using the Scan Statistic. For the total population, there were 10 distinct PH spatial clusters that span the state. Among whites, there were 11 PH spatial clusters that were in the central, Southern and Western parts of the state. There were five PH clusters among African Americans in the central, Southern and Eastern Maryland. The locations of the clusters varied by race except for that in Baltimore.

Figure 4 displays spatial clusters derived from Anselin’s local Moran’s I statistic. Several clusters of ZCTAs with high PH rates neighboring other ZCTAs with high PH rates (“high-high”) were detected and were located across the state. There were also “low-low” PH clusters located in the central part of the state signifying ZCTAs with low PH rates neighboring other ZCTAs with low PH rates. “High-high” and “low-low” PH clusters were detected among whites and African Americans, however, their locations differed. Among African Americans, more “high-high” clusters were in Eastern Maryland, while more “low-low” clusters were located in Western Maryland. Among whites, “low-low” clusters were in central Maryland.

Table 4 displays information about each PH spatial cluster detected in Maryland using the Scan Statistic. For the total population, the principal (or largest) city of the primary spatial cluster is Baltimore. The PH clusters ranged in size from a single ZCTA to a group of ZCTAs with a radius of 14.1 miles. The PH rate of spatial clusters ranged from 3,287.6 (Baltimore) to 2,282.7 per 100,000 population (Clinton). The principal city of the primary spatial cluster among both whites and African Americans was Baltimore. The white PH rate in the Baltimore cluster was 3,043.5 per 100,000 population, while the African American PH rate was 4,157.9 per 100,000 population. The locations and characteristics of PH clusters varied by race other than the primary cluster. The size of PH clusters varied among whites from three clusters consisting of one ZCTA (Silver Spring, Solomons, and Brunswick) to one cluster with a radius of 11.0 miles (Cumberland). Among African Americans, there was one cluster consisting of one ZCTA (Capitol Heights) and one with a radius of 33.4 miles (Cambridge). White PH rates ranged from 3,043.5 (Baltimore) to 2,839.1 per 100,000 population (Brunswick) among spatial clusters. PH rates among African American clusters ranged from 4,157.9 (Baltimore) to 3,738.4 per 100,000 population (LaPlata).

Figure 1: Preventable Hospitalization Rates by Race in Maryland, 2010

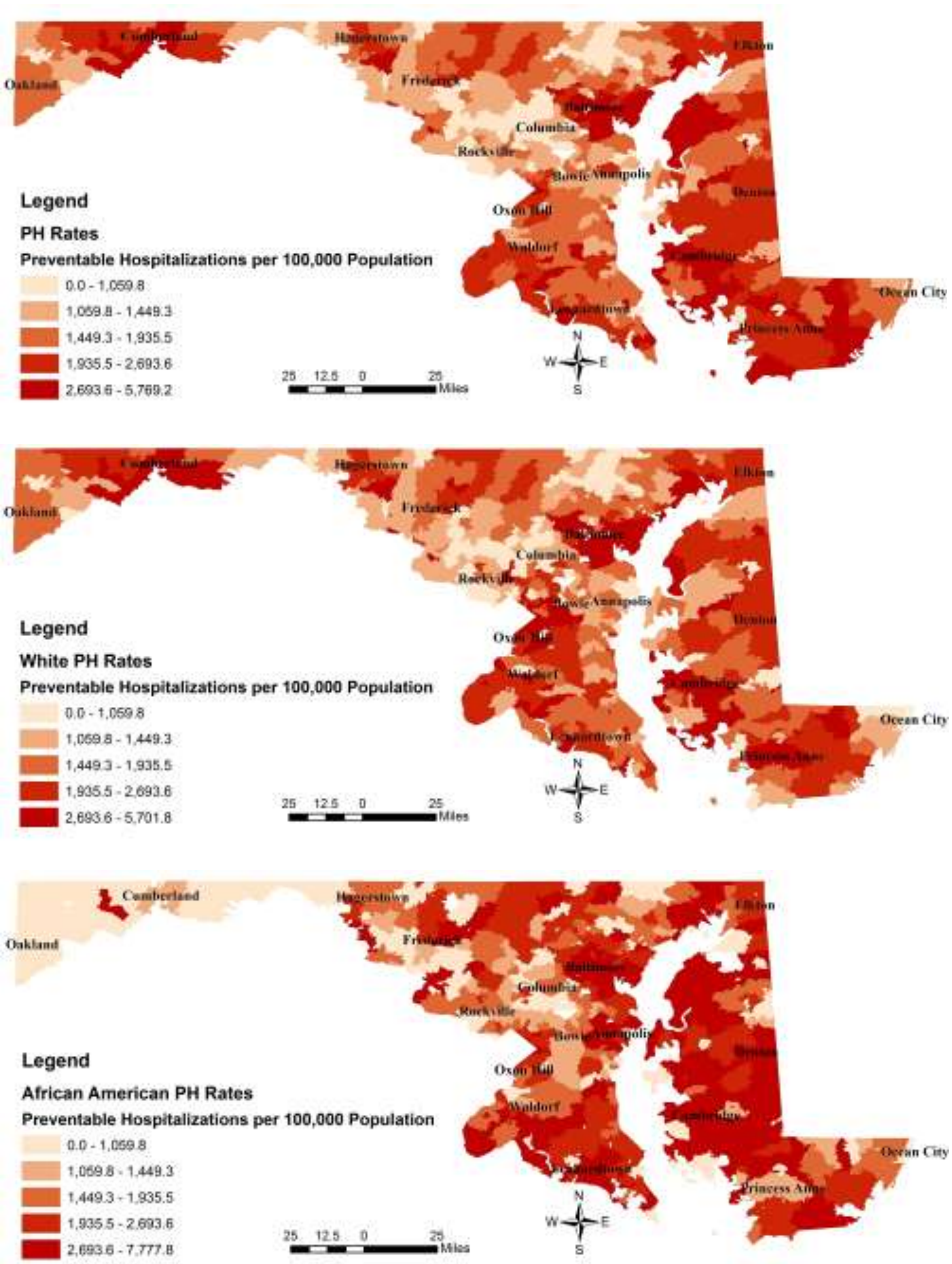

Figure 2: Empirical Bayes Smoothed Preventable Hospitalization Rates by Race in Maryland, 2010

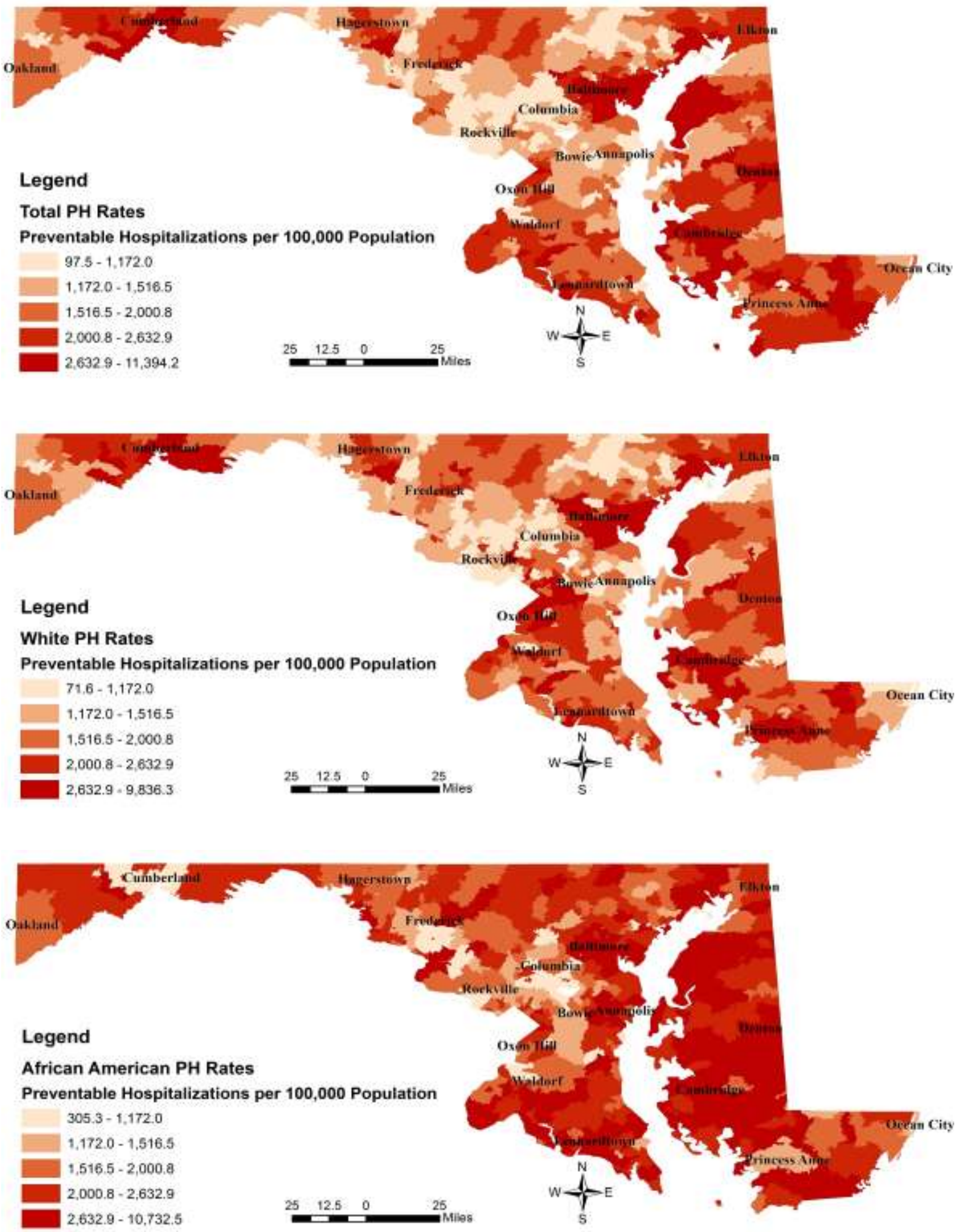

Figure 3: Preventable Hospitalizations Clusters (Scan Statistic) by Race in Maryland, 2010

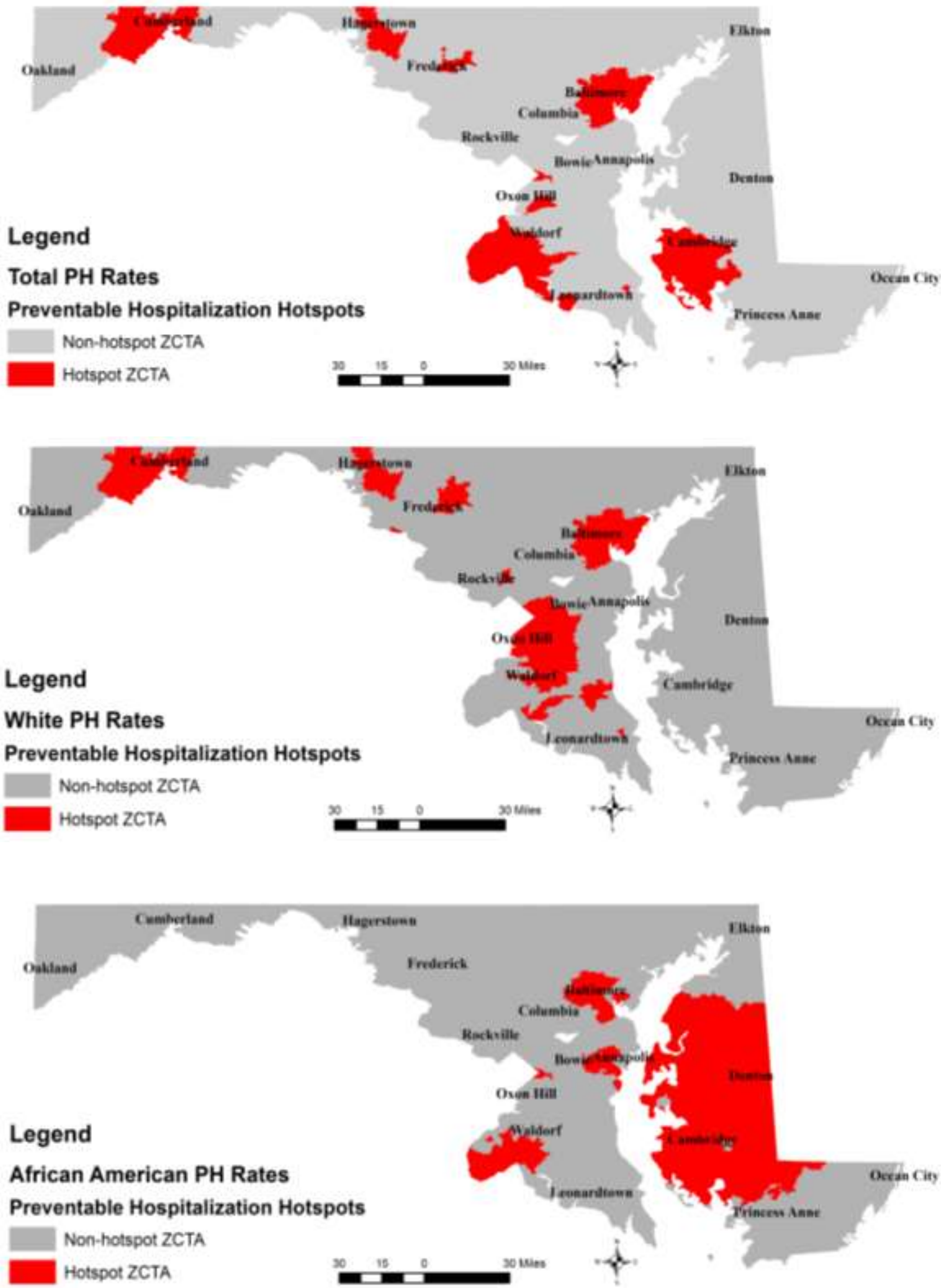

Figure 4: Preventable Hospitalization Clusters (Anselin’s Local Moran’s I) by Race in Maryland, 2010

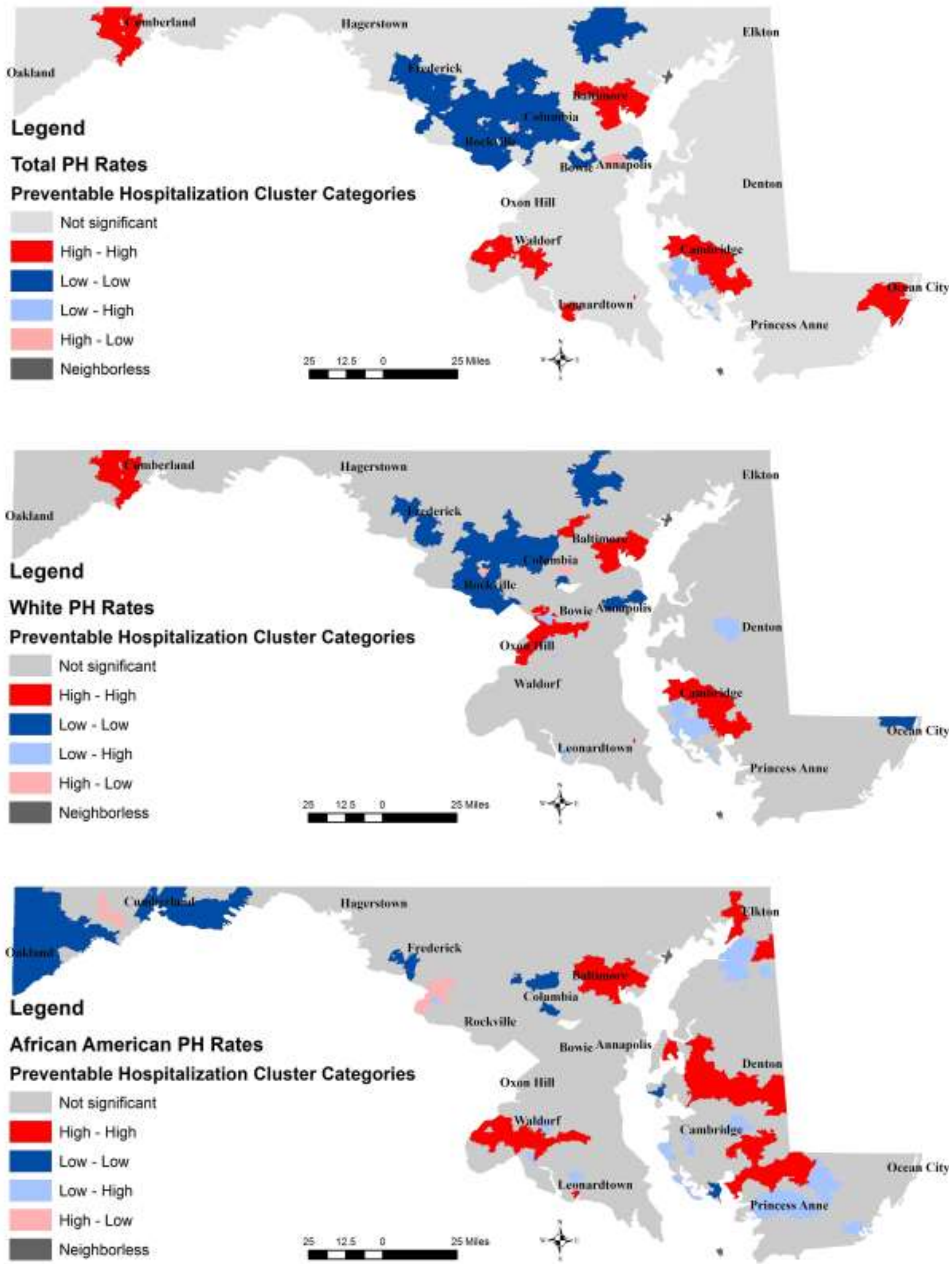

Table 4: Preventable Hospitalizations Spatial Clusters† Characteristics in Maryland, 2010

Total Population					White Population					African American Population				
Spatial cluster*	Radius (miles)	Rate per 100,000 population	LLR**	p-value	Spatial cluster*	Radius (miles)	Rate per 100,000 population	LLR**	p-value	Spatial cluster*	Radius (miles)	Rate per 100,000 population	LLR**	p-value
Baltimore	9.7	3,287.6	5,499.8	<0.001	Baltimore	9.7	3,043.5	1,799.8	<0.001	Baltimore	7.4	4,157.9	2,900.1	<0.001
Cumberland	11.0	3,125.6	226.5	<0.001	Cumberland	11.0	3,457.6	329.6	<0.001	Cambridge	33.4	3,858.4	115.1	<0.001
Capitol Heights	0.0	3,069.7	113.5	<0.001	Bowie	8.4	2,871.9	93.3	<0.001	Capitol Heights	0.0	3,134.7	22.5	<0.001
Cambridge	14.1	3,508.7	106.7	<0.001	Hagersto wn	5.7	2,581.6	68.3	<0.001	Annapolis	3.2	3,664.8	17.0	<0.001
Solomons	0.9	4,603.2	31.8	<0.001	Silver Spring	0.0	3,040.1	62.1	<0.001	LaPlata	7.9	3,738.4	14.3	0.001
Hagerstown	5.7	2,302.9	27.5	<0.001	Solomons	0.0	5,479.1	36.5	<0.001					
LaPlata	18.4	2,314.0	23.2	<0.001	Frederick	5.3	2,325.0	18.1	<0.001					
Frederick	0.0	2,380.8	18.3	<0.001	Waldorf	6.6	2,344.1	13.5	<0.001					
Bushwood	3.4	3,588.0	14.6	<0.001	Prince Frederick	4.4	2,576.7	9.2	0.026					
Clinton	3.8	2,282.7	12.5	0.002	Charlotte Hall	4.9	2,839.9	8.9	0.038					
					Brunswick	0.0	2,839.1	8.8	0.044					

†Spatial clusters identified using the Scan Statistic
*Identified by principal city included in the spatial cluster
**LLR=log likelihood ratio

In Table 5, ZCTAs included in spatial clusters are compared to those that are not. For the total population, ZCTAs included in PH clusters were less likely to be in the highest median income quartile (p<0.001). ZCTAs in PH clusters were more likely to have a hospital (p=0.037), more likely to have an FQHC (p=0.014), and had a lower physician supply (p=0.007). ZCTAs within white PH clusters had more African American residents (37.8%) compared to those ZCTAs not included in PH clusters (12.8%, p<0.001). A similar association was observed among African American PH clusters where ZCTAs within PH clusters had more African American residents (23.5%) compared to those not included (15.8%, p=0.003). White PH clusters had fewer rural residents (16.8% versus 53.4%, p<0.001), but African American PH clusters had more rural residents (57.8% versus 43.8%, p<0.001). Fewer PH cluster ZCTAs were in the highest median income quartile among whites (9.6% versus 28.6%, p<0.001) and among African Americans (8.2% versus 29.7%, p<0.001). ZCTAs in African American PH clusters were more likely to have an FQHC (28.0% versus 9.2%, p<0.001). No healthcare-related variables were associated with PH clusters among whites.

Table 5: Association between area-level characteristics and preventable hospitalization clusters† in Maryland Zip Code Tabulation Areas (ZCTAs), 2010

	Total Population			White Population			African American Population		
	Non-cluster ZCTA	Cluster ZCTA	p-value	Non-cluster ZCTA	Cluster ZCTA	p-value	Non-cluster ZCTA	Cluster ZCTA	p-value
Racial Composition, %	15.3	26.7	0.101	12.8	37.4	<0.001	15.8	23.5	0.003
Rurality, %	49.0	36.5	0.129	53.4	16.8	<0.001	43.8	57.8	<0.001
Median Income, %									
Quartile 1	19.7	48.1		20.3	44.6		19.7	43.3	
Quartile 2	25.7	22.2	<0.001	23.9	30.1	0.006	22.9	33.0	0.181
Quartile 3	26.8	17.3	<0.001	27.2	15.7	<0.001	27.8	15.5	0.001
Quartile 4	27.9	12.3	<0.001	28.6	9.6	<0.001	29.7	8.2	<0.001
Hospital, %	7.3	19.5	0.037	6.6	23.0	0.200	8.2	15.0	0.532
FQHC*, %	10.2	26.4	0.014	10.5	25.3	0.952	9.2	28.0	<0.001
Physician supply**, mean ± S.E.	14.5 ± 13.2	1.0 ± 0.2	0.007	14.4 ± 13.2	1.6 ± 0.3	0.467	14.9 ± 13.6	1.2 ± 0.3	0.424

†Spatial clusters identified using the Scan Statistic
*FQHC=federally qualified health center
**Family practitioners per 10,000 population

DISCUSSION

This study assessed the presence of spatial clusters of preventable hospitalizations (PHs) in the State of Maryland during the year 2010 by race. There were indeed several PH clusters throughout the State of Maryland. With the exception of the PH spatial cluster located in Baltimore, the location of PH clusters varied by race/ethnicity. This study demonstrates that PHs are spatially dependent, and knowledge of clusters can be used by public health practitioners to more directly target resources and interventions, potentially including culturally-appropriate ones.

Two previous studies have assessed geographic clusters of PHs. Mobley (2006) performed spatial analyses of PHs among Medicare beneficiaries in the U.S. and found that there are clusters of primary care service areas (PCSAs) that have higher than average rates of PHs (Mobley et al., 2006). The results of the current study agree that PHs are indeed spatially dependent in that PH spatial clusters were detected in Maryland. However, the Mobley study did not assess possible differences in geographic clustering by patient race. An study of PH clustering in Chicago, IL did not stratify by race either (Fishman, 2015).

Ecological studies of area-level characteristics and PH rates find that PH rates increase as the number of African American residents increase (Billings et al., 1996; Blustein et al., 1998; Derose, 2008; Pappas et al., 1997), are higher in rural areas (Delia, 2003; Laditka et al., 2009; Rust et al., 2009; Schreiber & Zielinski, 1997) and in high poverty areas (Blustein et al., 1998; Derose, 2008; Pappas et al., 1997). Studies have also shown that more local primary healthcare is associated with lower PH rates (Epstein, 2001; Rosano et al., 2013; Rothkopf et al., 2011). The results of the current study agree with previous studies on area-level characteristics to a degree. As the literature suggests, the total PH rate in the current study was positively associated with racial composition and rurality, and negatively associated with median income and physician supply. Contrary to the literature, PH rates were higher in ZCTAs with a federally qualified health center (FQHC). FQHCs are in medically underserved, poorer areas. These analyses were not restricted to low-income areas and accounted for median income, therefore, the associations between FQHCs and PHs could differ from previous literature.

Numerous PH spatial clusters were detected using both the Scan Statistics and Anselin's Local Moran's I, which suggests that PHs are spatially dependent. This is potentially due in part to clustering of various area-level characteristics that are associated with PHs. PH clusters among the total population were associated with lower median income, hospitals, FQHCs and less physician supply. Race-specific clusters were associated with racial composition and rurality. These results suggest that these demographic and primary healthcare characteristics may predict PH spatial clusters.

There were racial differences in the locations and characteristics of PH clusters. White PH clusters could be located in different areas than African American PH clusters because of racial segregation, or the fact that whites tend to live in different areas than African Americans (Williams & Collins, 2001). Many white PH clusters were located where there is a preponderance of white residents (for example, Cumberland, Hagerstown, Solomons, and Brunswick). However, several white PH clusters were located in areas that have a substantial African American population such as Bowie and Waldorf. Moreover, PH clusters were associated with a higher percentage of African Americans living in a ZCTA for both whites and African Americans, and more strongly so among whites. There were racial differences in some area-level characteristics that are associated with PH clusters. ZCTAs in white PH clusters had fewer rural residents, while ZCTAs in African American PH clusters had more rural residents. This could account for racial differences in the locations of PH clusters. More rural African Americans live in poverty than rural whites (United States Department of Agriculture, 2016), therefore, the preponderance of African American PH clusters in rural areas could be due to higher poverty rates among rural African Americans. The current study accounted for overall median income, not race-specific income.

FQHCs were positively associated with PH clusters among African Americans, but not among whites. Because FQHCs are targeted toward poorer and medically underserved areas, populations in these areas may have more chronic conditions that could lead to more PHs. They may also be less likely to have health insurance which could lead to more PHs despite the presence of an FQHC. African Americans in Maryland living near FQHCs may have more chronic conditions and be less likely to have health insurance. These two predisposing conditions to PHs have been considered in the literature around Andersen's Behavioral Model for Healthcare Utilization (Andersen 1995).

This study adds to the literature on PHs and use of this spatial analysis technique. Knowledge of PH spatial clusters is important to public health practitioners of all kinds. When members of the public health infrastructure are aware of the locations of PH spatial clusters, they are able to better target interventions and address them more directly. Moreover, knowledge of race-specific PH spatial clusters can allow for culturally targeted interventions if necessary. The results of this study do indeed suggest the need to target PHs in Baltimore City, but areas in western and southern Maryland, and to the east of the District of Columbia among the white population. Among African Americans, in addition to Baltimore City, PHs should be targeted in on Maryland's Eastern Shore, Annapolis and an area in southern Maryland. Knowledge of PH clusters allows for direct targeting of resources and policies for these areas. The observation that certain area-level characteristics such as racial composition, median income, rurality and hospitals (for African American PH clusters specifically) can be accounted for in policymakers' efforts to address PH clusters. The methods and results from this study can be easily shared with policymakers and resulting action can be performed based on these results.

The finding that African American PH rates and spatial clusters are positively associated with hospitals has important implications. Areas with a hospital may have higher PH rates simply because of the ease with which residents can access hospitals due to proximity. Patients may wait until ACSCs are so severe to seek care, and may opt to go to a hospital because of the severity of the condition and the proximity of the hospitals. African Americans may avoid seeking primary healthcare before an ACSC is so severe that a hospitalization is needed because of potential discrimination in primary healthcare. Studies have shown that African Americans report discrimination in healthcare (Williams & Mohammed, 2009). This could also help to explain the positive association between FQHCs and African American PH rates and clusters. Policymakers may need to account for these particular associations when addressing African American PHs, particularly in areas with hospitals and FQHCs.

There are strengths to this study. The detection of race-specific PH spatial clusters is novel and the results are useful to public health practitioners in Maryland. The data for this study includes patients of all ages, and also includes data on Maryland residents who were hospitalized in surrounding states (i.e. District of Columbia, Pennsylvania, and Virginia). There are some limitations to the study. First, the study was performed only in the State of Maryland, and the results may not be generalizable to other states or the nation as a whole. Maryland is a relatively affluent state, and the associations between median income and PHs, though in line with other studies, may not be generalizable. Second, the dataset represents inpatient hospitalizations, not patients. It is possible that numerous hospitalizations could have been made by the same patient or a small number of patients, especially in small ZCTAs. The HSCRC dataset does contain a variable that shows whether a patient has been admitted in the last 30 days. This variable does not include the primary diagnosis of the previous hospitalization. Because of this, there is an over-calculation of PHs. However, these data are extensively used in Maryland, and similar data are utilized nationally. Even with this limitation, the data are comparable with other datasets which partly addresses this feature of the data. An additional limitation is the inability to examine emergency department visits. Data from HSCRC only includes emergency department visits of treated in Maryland. A substantial percentage of patients are treated in out-of-state hospitals. It would have been useful to analyze preventable emergency department use as well. Lastly, in regression analyses, a race-specific exposure variable was included. For African Americans, this variable was African American population which was also represented by the racial composition variable included in the regression. Because of this, it is possible that the association between racial composition and African American PH rates was not detected. However, it should be noted that racial composition was positively associated with PH clusters.

CONCLUSION

This study examined spatial clusters of PHs by race and associations with area-level characteristics. Racial composition, rurality, and hospitals were positively associated with PH rates. Median income and physician supply were negatively associated with PH rates, and these associations varied by race. PH spatial clusters were detected and differed by race in terms of locations and characteristics. These types of studies can be utilized for a number of health outcomes. Given this, public health practitioners in Maryland can look to the results of this study for targeting PHs and replicate the analysis for other similarly structured data. Policymakers in Maryland can utilize these results to better target resources and inform decisions on provision of healthcare access. Policies to address African American PH rates and clusters can partner with hospitals and FQHCs since PH rates are higher in areas with these characteristics. These analyses can be replicated in other states for similar purposes. Future studies should seek to more fully understand why PH spatial clusters differ by race. Possible explanations could include differential access and utilization of healthcare resources. Future studies should also seek to address the potential for cultural tailoring of interventions by determining potential racial differences in healthcare-seeking norms and attitudes.

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APPENDIX

Spatial clusters of zip code tabulation areas (ZCTAs) with higher than expected PH rates were assessed using two methods. First, spatial clusters of areas with higher than expected PH rates were assessed using the spatial Scan Statistic. This method of assessing spatial clusters is described in depth elsewhere (Kulldorff, 1997), but a simple description is included here. To assess the presence of a PH spatial cluster, circles of varying sizes are placed on the map of PHs. Each circle has the potential to be a cluster. A cluster was defined as a contiguous set of ZCTAs that have greater than the expected number of PHs. Using a Poisson model, many Monte Carlo simulations were replicated to determine whether each cluster supports or rejects the null hypothesis that PH rates are spatially random. Once a cluster was identified, the simulations are repeated to determine if adjacent ZCTAs should be included. The most likely cluster was identified and the log likelihood ratio (LLR) of this spatial cluster existing compared to the null hypothesis was reported. These steps were repeated to identify secondary clusters, and the LLR of all subsequent PH spatial clusters was reported. Race-specific spatial clusters were determined using race-specific ZCTA population data. PH spatial clusters were not reported where the number of PHs in the ZCTA or group of ZCTAs was less than 20. Moreover, there were some ZCTAs that are represent post office (P.O.) boxes, but residents were assigned to these ZCTAs. PH spatial clusters that were found to include only these P.O. box ZCTAs with residents were not reported. PH spatial clusters were identified by the largest (or principal) city located in the cluster, and the radius, PH rate per 100,000 population, and log likelihood ratio were reported.

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1 j \neq 1}^{n} w_{i,j}(x_j - \bar{X}) \qquad \text{Equation 2}$$

$$S_i = \frac{\sum_{j=1 j \neq 1}^{n} (x_j - \bar{X})^2}{n-1} - \bar{X}^2 \qquad \text{Equation 3}$$

Spatial clustering was also assessed using Anselin's Local Moran's I statistic (Anselin & Getis, 1992). This measure determines local spatial autocorrelation, or the degree to which neighboring ZCTAs have similar PH rates. Anselin's Local Moran's I is calculated using Equations 2 and 3 such that x_i and x_j were PH rates of $ZCTA_i$ and $ZCTA_j$, $\bar{X}$ was the mean PH rate, and w_{ij} was the spatial weight. Spatial weights with a 1st order Rook contiguity were used for these analyses. Spatial clusters can be categorized as "high-high" (where neighboring ZCTAs have similarly high PH rates) and "low-low" (where neighboring ZCTAs have similarly low PH rates). ZCTAs can also be categorized as "high-low" (where the reference ZCTA has a relatively high PH rate and is neighbored by ZCTAs with low PH rates) or "low-high" (where the reference ZCTA has a relatively low PH rate and is neighbored by ZCTAs with high PH rates). Spatial cluster significance was determined using Z-scores and p-values. This approach is described in more detail elsewhere (Anselin & Getis, 1992).